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11 August 2020

Online at <https://mpra.ub.uni-muenchen.de/102873/>
MPRA Paper No. 102873, posted 15 Sep 2020 17:33 UTC

Life Expectancy in West African Countries: Evidence of Convergence and Catching Up with the North

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ABSTRACT

We investigate the possibility of convergence and catching up of life expectancy values of West African countries with those of North African countries. Following the theory of time series convergence documented in Bernard and Durlauf (1996) and Greasley and Oxley (1997), we apply more robust unit root tests, based on Fourier nonlinearity and instantaneous breaks, proposed in Furuoka (2017) in investigating the convergence of each pair, that is, a West African country with that of a particular North Africa country. As no unit root in the differences of the pair implies convergence, the results obtained by the new statistical approach quite outperform those of classical unit root tests. The results show general evidence of convergence of life expectancy values of those in West Africa to those of the North.

Keywords: Africa; Convergence; Fourier function; Life expectancy ratio; Nonlinearity; Unit root

1.0 Introduction

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Life expectancy is a statistical measure of the average number of years a person is expected to live. It is one of the indicators used for measuring the wellbeing of a population (Ortiz-Ospina, 2017). Factors contributing to life expectancy values include the educational level of individuals, access to the quality health system, economic empowerment, health behaviours among others (HPF, 2012).

Recent statistics show that Hong Kong has a life expectancy of 84.462 years, the highest in the world followed by Japan with a value of 83.995 years. Furthermore, the life expectancy values of France, Australia, Israel, Iceland, and the United States are 82.74, 82.91, 82.93, 83.06, and 79.50 years, respectively (World Population Review, 2017). The average life expectancy in Europe was 75 years for males and 82 years for females in 2018; Western Europe had 79 years for males and 84 years for females, while Eastern Europe had 69 years for males and 78 years for females. The average life expectancy in Africa in 2019 was 61 years for males and 65 years for females (Statista, 2019). Table 1 shows the life expectancy at birth in Africa in 2019, by gender and region. Life expectancy values from the Northern Africa region are higher than those from other regions of Africa. Many African countries, especially West African countries, have low life expectancies because they are still grappling with high under-five mortality

rates, extreme poverty, hunger, high level of illiteracy, lack of access to quality medical care, environmental hazards, HIV/AIDS, malaria, road accidents, conflicts, wars, lifestyle diseases among others (Nkalu and Edeme, 2019; Otekunrin *et al.* 2019a; Otekunrin *et al.* 2019b; Uchendu, 2018; Mondal and Shitan, 2013; Wiysonge, 2018). Therefore, this study is motivated by the need to provide evidence-based results that would be beneficial to policymakers in West African countries as they strive towards improving the wellbeing of their populace.

Table 1: Life Expectancy in Africa in 2019, by gender and region

Country/Territory/Region	Both Sexes	Males	Females
Eastern Africa	64.8	62.7	66.8
Burundi	61.6	59.8	63.4
Comoros	64.3	62.6	66.1
Djibouti	67.1	65.1	69.4
Eritrea	66.3	64.2	68.6
Ethiopia	66.6	64.7	68.5
Kenya	66.7	64.3	69.0
Madagascar	67.0	65.4	68.7
Malawi	64.3	61.1	67.4
Mauritius	75.0	71.7	78.5
Mayotte	79.5	76.2	83.0
Mozambique	60.9	57.8	63.7
Réunion	80.5	77.7	84.0
Rwanda	69.0	66.8	71.1
Seychelles	73.4	69.9	77.4
Somalia	57.4	55.7	59.1
South Sudan	57.8	56.4	59.4
Uganda	63.4	61.0	65.6
Tanzania	65.5	63.6	67.2
Zambia	63.9	60.8	66.9
Zimbabwe	61.5	59.8	62.9
Middle Africa	59.9	58.1	61.6

Angola	61.1	58.4	64.0
Cameroon	59.3	58.0	60.6
Central African Republic	53.3	51.1	55.5
Chad	54.2	52.8	55.7
Congo	64.6	63.1	66.0
Dem. Rep. of Congo	60.7	59.1	62.2
Equatorial Guinea	58.7	57.7	59.9
Gabon	66.5	64.4	68.7
Sao Tome and Principe	70.4	68.0	72.8
Northern Africa	72.6	70.7	74.5
Algeria	76.9	75.7	78.1
Egypt	72.0	69.7	74.3
Libya	72.9	70.1	76.0
Morocco	76.7	75.4	77.9
Sudan	65.3	63.5	67.2
Tunisia	76.7	74.7	78.7
Western Sahara	70.3	68.6	72.3
Southern Africa	63.8	60.4	67.3
Botswana	69.6	66.5	72.4
Eswatini	60.2	56.0	64.8
Lesotho	54.3	51.2	57.6
Namibia	63.7	60.7	66.5
South Africa	64.1	60.7	67.7
Western Africa	57.9	56.8	58.9
Benin	61.8	60.2	63.3
Burkina Faso	61.6	60.7	62.3
Cabo Verde	73.0	69.5	76.2
Côte d'Ivoire	57.8	56.6	59.1
Gambia	62.1	60.7	63.5
Ghana	64.1	63.0	65.2
Guinea	61.6	60.9	62.1
Guinea-Bissau	58.3	56.3	60.2
Liberia	64.1	62.7	65.5
Mali	59.3	58.5	60.1
Mauritania	64.9	63.3	66.5
Niger	62.4	61.3	63.6
Nigeria	54.7	53.8	55.6
Senegal	67.9	65.8	69.9
Togo	61.0	60.2	61.9

Source: World Mortality 2019: Data Booklet

Kontis *et al.* (2017) projected future life expectancy in 35 industrialized countries with a Bayesian model ensemble. One of their results showed a 90% probability that life expectancy at birth will be greater than 86.7 years in 2030, among South Korean women. Nmeth and Missov (2018) presented the Gamma-Gompertz-Makeham model as a better alternative to existing techniques for calculating life expectancy values because of its ability to adequately handle right-censoring in the last open-ended age group of a life table, especially, where this group has the highest proportion of the population. They showed the applicability of this model in revising life expectancy trends of historical populations usually used for mortality forecasts. Using high correlations in life expectancy values between females and males over time, and among different countries, Pascariu *et al.* (2018) proposed the double-gap life expectancy forecasting model to predict life expectancy values and compared their results with two popular approaches.

Stevens *et al.* (2019) developed a technique for computing a reference life expectancy metric using mathematical simulations. The developed model was able to give accurate predictions of the life expectancy of the United States population. Barthold Jones *et al.* (2018) developed formal demographic measures for studying relationships between the shared life expectancy of two birth cohort peers, the proportion of their lives expected

to overlap, and longevity. Their results showed that almost all changes to mortality schedules that result in higher life expectancies also result in higher proportions of life shared. van Baal *et al.* (2016) extended the Li-Lee model originally developed for coherent mortality forecasts for a group of populations by adapting it to forecasts of life expectancy for different educational groups within a population. Using the population aged 65 and above in the Netherlands, the results of the analyses implied an increase in life expectancy for all educational groups coupled with widened differences in life expectancy between educational groups.

Since there are variations in the life expectancy globally based on geographical locations, the present paper, therefore, investigates the possibility of convergence of life expectancy values in West African countries to those of North Africa, utilizing the time series approach (see Bernard and Durlauf, 1996; Greasley and Oxley, 1997; and Cuñado and Pérez de Gracia, 2006; among others). These authors proposed convergence in the time series whenever the difference of natural logs of bigger and smaller magnitude time series is stationary. In this case, the bigger magnitude time series is the life expectancy of countries in North Africa, while the smaller magnitude time series is the life expectancy of countries in West Africa. We then conduct unit root tests on the log differences to

establish convergence, in this context. The rejection of the null hypothesis in a given life expectancy difference series implies the impossibility of life expectancy of the West Africa country to meet up with that of the corresponding North Africa in the West and North Africa country pair.

Following Yaya, Ogbonna and Atoi (2019) and Yaya, Ogbonna and Mudida (2019) study, we adopt a battery of ADF-based unit root testing frameworks. We adopt the classical Augmented Dickey-Fuller [ADF] (Dickey and Fuller, 1979) unit root test as a base testing framework, which is known to have limitations in the presence of structural breaks of any form and nonlinearity. Also, the ADF test result is inconsistent in a small sample, since the lag augmentation component is required in the implementation, and such requires a long time series. Furthermore, other robust unit root testing frameworks applied herein include those established in Perron and Vogelsang (1992), Enders and Lee (2012a,b) and Furuoka (2017). These are the ADF with structural break (ADF-SB) test, Fourier ADF (FADF) and FADF with breaks (FADF-SB) tests, respectively. The Fourier ADF induces smooth breaks, unlike the instantaneous break induced by the ADF-SB test of Perron and Vogelsang (1992) ADF-SB test. Our consideration of unit root testing frameworks that incorporate each of Fourier function, structural breaks and both, is informed by our interest to account for plausible

nonlinearity and structural breaks. Details of the FADF-SB test and its variant subsets are described in Section 2 that follows.

Following the introductory section, the rest of the paper is structured as follows: Section 2 provides a detailed description of the data and methods employed in the study. Section 3 presents some empirical results and the interpretation of the findings, while Section 4 concludes the paper with some health policy implications.

2.0 Data and Methods

The data used in this work are the annual life expectancy at birth for newborn infants in North and West African regions, spanning a period between 1960 and 2016. These estimates were obtained in 2017 by the United Nations Population Division⁴. The sampled countries in the Northern African region are Algeria (ALG), Libya (LBY), Egypt (EGY), Morocco (MOR) and Tunisia (TUN); while those West African countries are Benin (BEN), Burkina Faso (BFA), Cote D'Ivoire (CIV), Mali (MLI), Niger (NER), Nigeria (NGA) and Senegal (SEN). These countries were selected based on geographical locations and disparities, as we reduced the number of paired differences. Meanwhile, North Africa has seven countries in which five countries were selected, while the West African region has 17 countries in

⁴ World Population Prospects: 2017 Revision.

which seven countries were selected. The selected African countries are paired - one from the Northern African region and the other from the Western African region.

Consequently, given that there are five (5) selected North African countries and seven (7) selected West African countries, our sample, therefore, comprises a total of thirty-five (35) of such paired samples. The differences between the log-transformed annual life expectancy of the paired African countries (one North African country and one West African country) are obtained. The time series of these obtained differences in life expectancy between the African country pairs are thereafter examined for the presence of unit root, as a test for the plausibility of convergence of the annual life expectancy of the West African counties to their Northern counterparts, which have been earlier shown to have higher life expectancies.

The methodology for convergence of life expectancy is similar to that of income convergence defined in Bernard and Durlauf (1996) and Greasley and Oxley (1997). This framework is widely applied in convergence and catching up theory, where the difference in life expectancy is given as,

$$\lim_{K \rightarrow \infty} E(y_{i,t+k} - y_{j,t+k} | I_t) = \lim_{K \rightarrow \infty} E(IG_{ij,t+k} | I_t) = 0 \quad (1)$$

where E is the expectation operation on the difference, $IG_{ij,t}$ between the two time series, i and j in the year t ; $y_{i,t}$ is the logarithm of life expectancy

of a North African country, while $y_{j,t}$ is the life expectancy of a country in the West African region. I_t is information available up to time t . The null hypothesis of convergence of life expectancy of any West African country to that of a North African country is rejected if the long-term predicted life expectancy gap has a unit root, otherwise, the hypothesis of possible convergence is not rejected.

Empirically, to test for a unit root in the differences defined in (1), we adopt an unrestricted ADF-based model with Fourier functions proposed by Furuoka (2017), which has also been applied to several times series in extant literature (see Yaya, Ogbonna and Atoi, 2019; Yaya, Ogbonna and Mudida, 2019; among others). This is the Fourier Augmented Dickey-Fuller with structural break (FADF-SB) test, given by the testing regression,

$$\Delta y_t = \mu + \beta t + \gamma_1 \sin(2\pi kt/N) + \gamma_2 \cos(2\pi kt/N) + \delta DU_t + \theta D(T_B)_t + (\rho - 1)y_{t-1} + \sum_{i=1}^p c_i \Delta y_{t-i} + \varepsilon_t$$

(2)

where $\Delta = (1 - B)$ and $\pi = 3.1416$; μ represents the constant term; β and ρ are, respectively, the slope parameters for the trend term t and the lagged dependent variable y_t , with $\rho = 1$ indicating unit root; γ_1 and γ_2 are the Fourier function slope parameters; k is the Fourier frequency; N is the

number of observations; T_B indicates the point of observed structural break; δ and θ are, respectively, the slope parameters for the structural break dummy (DU_t) and the one-time break dummy ($D(T_B)$). We define $DU_t = 1$ if $t > T_B$ and $DU_t = 0$, otherwise; and $D(T_B)_t = 1$ whenever $t = T_B$ and $D(T_B)_t = 0$, otherwise. From the test regression in (2), in the absence of structural break dummies (where the structural break is not significant), the FADF-SB test reduces to the FADF test, and similarly in the testing regression. Also, whenever the Fourier parameters γ_1 and γ_2 are not significantly different from 0, the FADF test further reduces to the classical ADF test. In the FADF-SB test, insignificance of Fourier parameters alone calls for testing ADF-SB regression in judging unit root. Thus, we have three other variants of FADF-SB tests: FADF, ADF-SB and ADF unit root tests. For details about each of these tests, readers are referred, respectively, to Enders and Lee (2012a, 2012b), Perron and Vogelsang (1992) and Dickey and Fuller (1979).

The preference for a test over the others is not arbitrarily or trivially implied on the basis of rejecting the null of a unit root. Preference for model adequacy is, however, made in a more formal way using the F-test as

suggested by Furuoka (2017). This approach entails a comparison of a restricted model with an unrestricted model, and is given by:

$$F = \frac{(SSR_0 - SSR_1)/q}{SSR_1/(T - r)} \quad (3)$$

where SSR_0 and SSR_1 represent the sum of squares residuals (SSR) from the restricted and the unrestricted models, respectively; q and r are, respectively, the number of restrictions in the restricted model and the number of regressors in the unrestricted model. By this, the ADF regression model is perceived as the restricted ADF-SB model whenever the series is not characterized by the presence of structural breaks. In the same vein, the ADF regression model is a restricted FADF model whenever the Fourier function parameters are not significant. For the FADF-SB model case, the ADF regression is a restricted FADF-SB model whenever both nonlinearity and structural breaks are absent. The FADF model, in a similar manner, is a restricted FADF-SB model when there is no structural break in the series. Finally, the ADF-SB could be considered a restricted FADF-SB model whenever nonlinearity functional form is absent. These combinations of restricted and unrestricted models results in five pairs, which are tested using the F-test. They include $F_{(FADF, ADF)}$, $F_{(ADF-SB, ADF)}$, $F_{(FADF-SB, ADF)}$,

$F_{(FADF-SB, FADF)}$ and $F_{(FADF-SB, ADF-SB)}$ tests, and serve as robustness checks in this paper.

3.0 Empirical Findings

We commence the unit root test of the differences of the log-transformed series for each of the thirty-five (35) paired life expectancy samples from the classical ADF test viewpoint. This is examined under three different ADF model structures – model with no regressors, model with constant only and model with constant and trend; with automatic lag selection option. We, however, are only interested in the model with the most negative significant t-statistics among the three model structures, and thus, interpret the result of the same. In line with the aforementioned criteria, the model with constant and trend seems to be mostly preferred except in the cases of LBY-BFA, EGY-NER, and TUN-NGA, where the model with constant only is preferred, and MOR-NER, TUN-BFA, TUN-MLI and TUN-SEN, where the model with no regressor is preferred. The classical ADF test (see Table 2) suggests that most of the paired differences have unit roots.

Table 2: Classical ADF tests

Differences	No regressor	Constant only	Constant with trend
ALG-BEN	0.6208[6]	-1.5726[6]	-2.4617[6]
ALG-BFA	-0.3450[6]	-4.6970[3]	-4.8085[5]
ALG-CIV	1.1854[7]	-4.6255[5]	-5.1855[5]
ALG-MLI	-1.7767[6]	0.2517[6]	-2.8899[9]
ALG-NER	-1.4155[3]	-1.7293[3]	-1.9979[3]
ALG-NGA	-0.6069[3]	-3.8014[5]	-3.9154[5]
ALG-SEN	-1.0990[6]	-1.2432[6]	-4.5188[10]
LBY-BEN	-1.9699[3]	-2.1341[3]	-4.0889[3]

LBY-BFA	-1.4873[3]	-1.8121[3]	-0.9751[10]
LBY-CIV	-0.4854[3]	-2.2175[3]	-2.2347[3]
LBY-MLI	-2.0600[4]	-0.0651[4]	-2.6865[4]
LBY-NER	-2.5402[5]	-2.6562[5]	-2.8803[5]
LBY-NGA	-1.1824[3]	-1.9195[3]	-1.5517[3]
LBY-SEN	-1.9024[4]	-0.3177[4]	-4.3651[3]
EGY-BEN	-2.3632[6]	-0.0756[6]	-4.1869[3]
EGY-BFA	-1.2552[6]	-0.1678[6]	-6.0723[3]
EGY-CIV	-0.1175[4]	-2.1008[4]	-6.0627[3]
EGY-MLI	-2.0720[6]	0.4590[6]	-5.2433[3]
EGY-NER	-0.7945[5]	-3.5876[3]	-2.3110[3]
EGY-NGA	0.3194[5]	-4.1738[3]	-7.2086[3]
EGY-SEN	-2.1840[6]	-2.5185[3]	-5.5084[3]
MOR-BEN	-0.2056[3]	-2.7751[3]	-3.0619[3]
MOR-BFA	-1.0178[6]	-2.9752[3]	-3.9615[5]
MOR-CIV	0.9926[6]	-4.0205[3]	-5.7309[3]
MOR-MLI	-2.0190[6]	-0.8639[6]	-5.0506[3]
MOR-NER	-2.4056[3]	-0.9971[3]	-2.1025[3]
MOR-NGA	-0.4574[3]	-2.8659[3]	-4.0597[3]
MOR-SEN	-2.3161[6]	-3.0854[6]	-4.9771[5]
TUN-BEN	-0.5022[3]	-3.1105[3]	-2.5215[3]
TUN-BFA	-0.8243[3]	-1.8103[3]	-0.1028[3]
TUN-CIV	-0.8385[3]	-2.2856[3]	-3.1636[3]
TUN-MLI	-1.7446[3]	-0.5202[3]	-0.8679[6]
TUN-NER	-1.8710[3]	-3.4057[4]	-4.4992[4]
TUN-NGA	-1.4505[3]	-2.3456[3]	-1.3866[3]
TUN-SEN	-1.3240[6]	0.2893[6]	-1.2203[6]

Note: In bold denotes rejection of the null hypothesis of unit root at 5% level.

Contrasting the classical ADF test results (Table 2) with the ADF test, where the lag specification is restricted to unity (see the second column in Table 3), we find that the stance of the latter differ markedly from the former, as only ALG-BFA was found to have a unit root. This suggests the dependence of the ADF unit root test on the lag specification and its sensitivity to the choice of lag, which limits the power of the conventional classical ADF test. In a bid to overcome this limitation, the FADF, ADF-SB, and FADF-SB tests are employed. The FADF test, which incorporates the ADF test in a Fourier framework, suggests stationarity of the log-transformed series in all cases except in ALG-BFA. However, both ADF-

SB (which incorporates structural breaks in the ADF test framework) and FADF-SB (which accounts for structural breaks and incorporates a Fourier function in the ADF testing framework) agree on the stationarity stance of the paired differences in all the cases considered. Except for the case of ALG-BFA, all four unit root tests suggest stationarity of all the paired differences. It appears that the incorporation of structural breaks in the unit root testing framework further improves the power of tests for both ADF and FADF tests.

Table 3: Fourier ADF Break tests

Differences	ADF		FADF		ADF-SB			FADF-SB			
	t stat.	k	t stat.	T_B	λ_B	t stat.	T_B	λ_B	k	t stat.	
ALG-BEN	-4.451	2	-5.000	2002	0.75	-5.495	1968	0.16	1	-7.014	
ALG-BFA	-2.532	1	-4.278	2015	0.98	-4.606	2015	0.98	1	-5.206	
ALG-CIV	-4.646	1	-5.375	2011	0.91	-5.999	2011	0.91	1	-6.370	
ALG-MLI	-5.156	2	-5.718	1992	0.58	-7.124	1992	0.58	2	-7.957	
ALG-NER	-4.725	2	-5.063	2006	0.82	-5.545	1972	0.23	1	-7.853	
ALG-NGA	-4.869	1	-5.845	1987	0.49	-7.160	1987	0.49	1	-7.228	
ALG-SEN	-4.480	2	-4.968	2001	0.74	-5.617	2001	0.74	2	-5.825	
LBY-BEN	-4.043	1	-5.468	2014	0.96	-6.397	2014	0.96	1	-6.760	
LBY-BFA	-4.527	2	-4.776	1996	0.65	-7.368	1996	0.65	2	-7.230	
LBY-CIV	-4.874	2	-5.536	1991	0.56	-6.863	1991	0.56	2	-7.146	
LBY-MLI	-4.741	2	-5.131	2005	0.81	-5.507	1971	0.21	1	-7.310	
LBY-NER	-4.872	1	-5.841	1986	0.47	-6.642	1986	0.47	1	-6.857	
LBY-NGA	-4.913	2	-5.578	2000	0.72	-6.328	2000	0.72	2	-6.658	
LBY-SEN	-4.569	1	-5.989	2012	0.93	-6.713	2012	0.93	1	-7.041	
EGY-BEN	-4.842	2	-5.270	1995	0.63	-7.709	1995	0.63	2	-7.818	
EGY-BFA	-4.977	1	-5.242	2009	0.88	-6.258	1975	0.28	1	-6.670	
EGY-CIV	-5.059	2	-5.442	2004	0.79	-5.876	1970	0.19	1	-7.757	
EGY-MLI	-5.451	1	-6.086	1985	0.46	-6.622	1988	0.51	2	-6.832	
EGY-NER	-4.697	2	-5.393	1999	0.70	-6.180	1999	0.70	2	-6.508	
EGY-NGA	-4.872	1	-6.120	2011	0.91	-6.350	1979	0.35	1	-6.616	
EGY-SEN	-4.540	2	-4.923	1994	0.61	-7.135	1994	0.61	1	-7.420	
MOR-BEN	-4.548	1	-4.823	2008	0.86	-5.599	1974	0.26	1	-6.789	
MOR-BFA	-5.043	2	-6.083	1989	0.53	-6.735	1989	0.53	1	-6.879	
MOR-CIV	-4.828	1	-6.098	1987	0.49	-6.088	1987	0.49	2	-6.655	
MOR-MLI	-4.679	2	-5.259	1998	0.68	-6.685	1998	0.68	2	-6.896	
MOR-NER	-4.579	1	-5.587	2005	0.81	-5.840	2012	0.93	1	-6.380	
MOR-NGA	-4.971	2	-5.510	1993	0.60	-7.157	1993	0.60	2	-8.102	
MOR-SEN	-4.487	1	-4.759	2007	0.84	-5.575	1973	0.25	1	-6.879	

TUN-BEN	-4.999	1	-6.082	1988	0.51	-7.071	1988	0.51	1	-7.475
TUN-BFA	-4.621	2	-5.198	2002	0.75	-5.669	1968	0.16	1	-7.143
TUN-CIV	-4.691	2	-5.065	1997	0.67	-6.710	1997	0.67	1	-6.937
TUN-MLI	-4.600	1	-5.649	2009	0.88	-6.029	2011	0.91	1	-6.615
TUN-NER	-5.408	2	-5.806	1992	0.58	-7.666	1992	0.58	2	-8.388
TUN-NGA	-4.691	1	-4.933	2006	0.82	-6.090	1972	0.23	1	-6.985
TUN-SEN	-4.811	1	-5.874	1987	0.49	-6.766	1987	0.49	1	-7.195

In bold denotes rejection of the null hypothesis of unit root at a 5% level. For details about this test as well as critical regions, see Furuoka (2017).

Having shown that the paired differences in all cases considered are stationary, we further subject the contending unit root tests to some reliability tests, as a robustness check. This is by way of ascertaining the unit test that would be most appropriate for determining the stationarity stance of the paired differences. In this regard, we compare the performance of five pairs (restricted and unrestricted model constructs) of unit root tests using the F-statistics (see Table 4). $F_{(FADF, ADF)}$ tests whether the improvement of the FADF (unrestricted model construct) test over the ADF (restricted model construct) test is significant. We find statistically significant improvement of the FADF over the ADF unit root regression in only two (2) of the thirty-five (35) considered cases, and these include ALG_BFA and LBY-SEN. This is indicative of the relative similarity in the decision reached by both FADF and ADF unit root tests. On the other hand, $F_{(ADF-SB, ADF)}$ and $F_{(FADF-SB, ADF)}$ reveal the statistically significant improvement of ADF-SB and FADF-SB tests, respectively, over the ADF test, in all cases for the

former and thirty-two (32) cases for the latter. Similarly, the FADF-SB unit root test is observed to be more reliable in comparison with FADF and ADF-SB, as it outperformed both in thirty-two (32) and thirty-one (31) cases, respectively. Both ADF-SB and FADF-SB are found to be more reliable than the ADF and FADF tests. It is evident here that the decision on the stationarity, or otherwise, of the paired differences based on the FADF-SB unit root test is more reliable (see Table 4). This outperformance over other conventional unit root tests is again upheld (see Furuoka, 2017; Yaya, Ogbonna and Mudida, 2019; among others), as it hinges on accounting for both nonlinearity and plausible presence of structural breaks. Adopting a battery of reliable unit root testing frameworks would also enhance researchers' decisions.

Table 4: Robustness checks

Differences	$F_{(FADF, ADF)}$	$F_{(ADF-SB, ADF)}$	$F_{(FADF-SB, ADF)}$	$F_{(FADF-SB, FADF)}$	$F_{(FADF-SB, ADF-SB)}$
ALG-BEN	2.557	9.703	6.642	9.840	12.948
ALG-BFA	7.296	17.936	10.923	11.536	2.709
ALG-CIV	3.039	16.122	9.593	14.535	18.941
ALG-MLI	2.583	24.235	16.232	27.224	31.570
ALG-NER	1.673	8.937	8.600	14.632	16.406
ALG-NGA	4.173	23.622	13.990	20.600	26.858
ALG-SEN	2.424	10.279	6.089	8.993	9.936
LBY-BEN	6.008	12.488	7.603	7.634	0.432
LBY-BFA	1.654	25.071	12.816	22.578	25.490
LBY-CIV	2.928	22.370	13.815	22.260	27.107
LBY-MLI	1.906	7.308	6.784	10.921	12.679
LBY-NER	4.119	22.621	13.774	20.310	26.291
LBY-NGA	2.986	12.286	7.341	10.574	11.089
LBY-SEN	6.293	9.479	6.119	4.967	12.095
EGY-BEN	2.555	25.177	13.849	22.944	26.457
EGY-BFA	1.354	15.395	4.469	7.253	8.917

EGY-CIV	1.878	8.517	7.420	12.142	14.819
EGY-MLI	3.017	22.036	3.561	3.777	6.931
EGY-NER	3.036	13.503	7.943	11.589	15.294
EGY-NGA	5.575	6.366	4.499	2.987	8.900
EGY-SEN	1.828	26.046	16.761	29.642	32.872
MOR-BEN	1.291	13.936	5.821	9.900	11.622
MOR-BFA	4.386	16.212	9.956	13.395	16.305
MOR-CIV	5.538	5.522	4.309	2.709	5.271
MOR-MLI	2.522	18.042	10.000	15.995	19.826
MOR-NER	4.293	5.299	8.283	10.649	16.449
MOR-NGA	2.528	29.767	19.902	34.004	39.257
MOR-SEN	1.357	13.372	6.510	11.125	13.008
TUN-BEN	4.671	19.541	12.112	16.680	20.311
TUN-BFA	2.663	9.690	6.512	9.475	12.865
TUN-CIV	1.884	16.820	10.960	18.726	21.255
TUN-MLI	4.300	6.060	9.386	12.529	18.181
TUN-NER	1.943	28.841	18.389	32.440	35.624
TUN-NGA	1.255	16.276	6.246	10.757	11.711
TUN-SEN	4.502	20.916	13.416	19.129	25.502

Note: In bold denotes the significance of F tests at a 5% level. For more details about these tests, see Furuoka (2017).

Consequent upon the reliability of the decision reached using FADF-SB and ADF-SB unit root tests, the stationarity stance of the paired differences in life expectancy between African countries is upheld. By implication, the paired differences exhibit mean-reverting characteristics and the absence of persistence. Consequently, the life expectancy of West African countries have a tendency to converge to those of the North African countries with time.

4.0 Conclusion

This study set out to examine the stationarity; and by extension, the convergence; of life expectancy in any given pair of a West African country and a Northern counterpart. The study draws from the concept of

convergence and catching up theory as proposed by Bernard and Durlauf (1996) and Greasley and Oxley (1997). Consequently, a total of five (5) North African countries and seven (7) West African countries, which amounts to a total of thirty-five possible pairs, were considered. While the North African region is known to have a higher life expectancy, their West counterpart is observed to have a lower life expectancy. Therefore, the interest here is to examine the possibility of the life expectancy of the West African countries to converge to those of the North African countries based on the current evolution of the life expectancy time series dynamics. The difference between the log-transformed life expectancy rates of the country pairs is subsequently subjected to a battery of unit root testing frameworks.

In achieving this, we consider a battery of unit root tests, which is good practice as suggested by several extant literature (Yaya, Ogbonna and Atoi, 2019 and Yaya, Ogbonna, and Mudida, 2019). This battery of unit testing frameworks include the classical ADF test, ADF with structural breaks (ADF-SB) and the Fourier-based ADF tests – FADF and FADF-SB. These were all applied on the obtained differences, which resulted in some interesting results. We find the classical ADF to reject the stance of a unit root in fewer cases, compared to the other unit root testing frameworks. A notable feature is the significant influence of accounting for structural

breaks, especially, whenever they exist. We find FADF-BP and ADF-SB to consistently out-perform the classical ADF and FADF unit root tests that failed to account for structural breaks. However, we do not jump to draw rash decisions on these performances, as we further subject the results to some reliability tests. This draws from the F-statistics employed to compare the contending unit root testing model framework. Evidently, we find the FADF-SB to be most preferred, given its simultaneous incorporation of a Fourier function and accounting for structural breaks. Convincingly, we state here that the FADF-SB unit root testing framework is the most reliable in testing for the stationarity stance of the difference in life expectancy of any pair of countries.

Imperatively, the life expectancy of West African countries is most likely to converge to and catch up with the life expectancy of the North African countries. This stance is key for policymakers, as they make policy decisions that affect the lives of people in these countries. The information herein contained could spur governments of West African nations to pay greater attention to their economic growth and development, political stability, and security of life and property of their citizens. Also, the wellbeing of their citizens must be given utmost priority, through the provision of functional and efficient health and education systems, and the provision and

maintenance of social and infrastructural facilities. Furthermore, public enlightenment campaigns on the dangers of risky health behaviours should be intensified and sustained. However, higher life expectancy may also have its own health implications, which need to be taken into consideration. These may include an increased risk of age-related diseases among the elderly, dementia, and physical disabilities. Policies should, therefore, be put in place to increase the quality of life of the elderly, so that achieving longevity does not become a burden on the health of the citizens.

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