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Life expectancy in West African countries: Evidence of convergence and catching up with the north

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ABSTRACT

The article aims to investigate the possibility of the convergence and catching up of life expectancy values observed in West African countries with those noted in North African countries. Following the theory of time series convergence, documented in Bernard and Durlauf (1996) and Greasley and Oxley (1997), more robust unit root tests, based on the Fourier nonlinearity and instantaneous breaks proposed in Furuoka (2017), are used in investigating the convergence of each pair of a West African country and its North African counterpart. As no unit root in the differences of the pairs implies convergence, the results obtained by means of the new statistical approach quite outperform those produced by classical unit root tests. The results provide general evidence of the convergence of life expectancy values recorded in West Africa and North Africa.

Key words: Africa, convergence, Fourier function, life expectancy ratio, nonlinearity, unit root.

1. Introduction

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 well-being 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

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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). 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 well-being of their populace.

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. 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 Division[4]. 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 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,

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

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.

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[4] World Population Prospects: 2017 Revision.

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,

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

where $\Delta = \left(1 - B\right)$ 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 $\left(DU_t\right)$ and the one-time break dummy $\left(D\left(T_B\right)\right)$. We define $DU_t = 1$ if $t > T_B$ and $DU_t = 0$, otherwise; and $D\left(T_B\right)_t = 1$ whenever $t = T_B$ and $D\left(T_B\right)_t = 0$, 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, insignificancy 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:

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

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 result 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. 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 1) suggests that most of the paired differences have unit roots.

Table 1. 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]**

Table 1. Classical ADF tests (cont.)

Differences	No regressor	Constant only	Constant with trend
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 1) with the ADF test, where the lag specification is restricted to unity (see the second column in Table 2), we find that the stance of the latter differs 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 2. 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 3). $F_{(FADF,\ ADF)}$ 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 3). 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 3. Robustness checks

Differences	$F_{(FADF,\ ADF)}$	$F_{(ADF-SB,\ ADF)}$	$F_{(FADF-SB,\ ADF)}$	$F_{(FADF-SB,\ FADF)}$	$F_{(FADF-SB,\ ADF-}$
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**

Table 3. Robustness checks (cont.)

Differences	$F_{(FADF,\ ADF)}$	$F_{(ADF-SB,\ ADF)}$	$F_{(FADF-SB,\ ADF)}$	$F_{(FADF-SB,\ FADF)}$	$F_{(FADF-SB,\ ADF-}$
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. 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 well-being 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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