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February 2019

Online at https://mpra.ub.uni-muenchen.de/93939/
MPRA Paper No. 93939, posted 16 May 2019 13:17 UTC

Hysteresis of Unemployment Rates in Africa: New Findings from Fourier ADF test

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Abstract

We investigate unit root in the unemployment rates of 42 African countries. The essence is to clarify if the hypothesis of hysteresis holds or unemployment rate is dubbed as having natural rate, that is, stationarity. Having considered a novel approach that considers the nonlinear Fourier and a structural break in the unit root testing framework, we find the classical unit root test wrongly accepting the hysteresis hypothesis of unemployment rate in selected African countries more than 60% of the cases. Meanwhile, our approach finds fewer cases of hysteresis in the unemployment rate than initially detected by the conventional classical test: the hysteresis hypothesis is found to hold in only 7 countries (Algeria, Botswana, Cabo Verde, Congo DR, Guinea-Bissau, Liberia and Tanzania) out of the 42 African countries. This implies that with the exception of the seven countries mentioned, shocks to unemployment will be transitory and strong policy action will not be required to address unemployment challenges. This suggests that hysteresis effects will be offset in overall since these are concentrated in smaller African economies and portends for a faster recovery to shocks in the broader African context. Robustness check proves the superiority of the Fourier unit root tests with structural break over other lower alternatives.

Key words: Africa; Fourier function; Hysteresis hypothesis; Structural breaks; Natural rate of unemployment; Unemployment rate; Unit root test

JEL Classification: C22; E24; J64

1.0 Introduction

Africa has in recent years undergone an economic downturn where high inflation has co-exited with high unemployment. A less supportive external environment has been accompanied with rising uncertainty (International Monetary Fund, 2018). These problems have, however, affected African countries to different degrees. In the period up to 2024, only one in four of Sub-Saharan African's youth will find a job, and only a small fraction of those jobs will be formal jobs (World Bank, 2014). Traditionally, inflation and unemployment were thought to have an inverse relationship. From a policy perspective, it was believed that policies that were effective at increasing economic output and bringing down unemployment tended to exacerbate inflation, while policies that reined in inflation frequently constrained the economy and worsen unemployment. However, in the situation of stagflation, high unemployment rates may be associated with high inflation rates (Lucas and Sargent, 1978). This has in recent times become prevalent in many developing African economies.

The equilibrium unemployment rate is known to depend on this history of the actual unemployment data (Blanchard and Summers, 1986). One of the properties of such time series history is the stationarity condition. A driving theory supporting this is the "hysteresis theory", a termed borrowed in the physical sciences, meaning a situation where equilibrium is path-dependent (Blanchard and Summers, 1986). Mitchel (1993) and Song and Wu (1998) (among others) argue that unemployment dynamics has continued in its natural rates, and the hysteresis theory of unemployment has challenged the prevailing macroeconomic theory. Thus, there is agreed theory that could define the dynamics of unemployment rate (Furuoka, 2017a). Specifically, three contradicting hypotheses explain the behaviour of unemployment rate according to Gomes and da Silva (2008), the natural rate hypothesis of the non-accelerating inflation rate of unemployment rate (NAIRU) (see Phelps, 1967; Friedman, 1968) that assumes fluctuation of unemployment rate around the equilibrium level. Thus, unemployment rate is assumed to be a stationary time process. The second is the structural slump hypothesis, which assumes that unemployment rates fluctuating around the equilibrium level shifts occasionally due to structural changes (see Phelps, 1994). The third is the hysteresis hypothesis, which assumes path-dependent structure for unemployment rates and has a weak tendency to return to its equilibrium level (Blanchard and Summers, 1986). Under this, unemployment rate is characterized as a nonstationary process.

Furuoka (2012) noted that trade unions and unemployment benefits are factors that clarify levels of unemployment behaviour. For example, countries with strong trade unions have less dynamics labour markets and the rate of unemployment rate of such country tend not to revert to normalcy. But if the trade union is weak, labour market becomes more dynamic and by implication, unemployment rate will be mean reverting. The provision of unemployment benefits will also ginger the unemployed to remain jobless for longer periods of time, and lack of unemployment benefits will prompt the jobless person to find job on time. The initial provision of unemployment benefits could lead to hysteresis in unemployment rate, while lack of these benefits could force unemployment to revert to its equilibrium level.

Following Friedman (1968), the unemployment rate has the tendency to revert to its mean level after a recession, thus contradicting the hysteresis hypothesis. Hysteresis hypothesis is such that a recession has lasting effect on the unemployment rate, implying high inflation rate according to Blanchard and Summers (1986). Furuoka (2017a) provides some reviews on the unemployment hysteresis. While Fosten and Ghoshra (2011) and Chen et al. (2012) studies could not confirm hysteresis in the unemployment rates considered, the differences in their findings could have been as a result of the different econometric tests employed.

In this present paper, we investigate the hysteresis hypothesis in the unemployment rate of selected African countries, using annual dataset spanning between 1991 and 2017. We follow the methodological approach of Furuoka (2017a) who applied the Augmented Dickey

Fuller [hereafter, ADF], Fourier ADF and Fourier ADF-structural break tests. The Fourier function in ADF test allows for modelling of smooth breaks in short time series, and other structural breaks can be modelled using dummies as in Perron (2006) unit root break test. This approach is novel and is hardly applied in the investigation of unemployment hysteresis. Taking a cue from Caporale and Gil-Alana (2018a), we consider a larger panel of African countries, while investigating the unemployment hysteresis of selected African countries' unemployment rates under a battery of unit root testing frameworks, with the inclusion of the non-linear Fourier function with structural break framework.

The rest of the paper is structured as follows: Section 2 presents available literature on hysteresis in unemployment rate. Section 3 presents the data and unit root testing framework. Section 4 presents the empirical results, while Section 5 concludes the paper.

2.0 Review of Literature

The economic implications of high rates and persistence in unemployment, as it relates to the performance of one or more macroeconomic fundamentals, is one subject matter that cannot be overlooked. Song and Wu (1998) highlights these implications with specific focus on the aftermaths of periods of recession, which are observed to have more costly influence on the rate of unemployment than the natural rate. Extant literature are, however, awash with studies that examine the stationarity of the unemployment rate across regions of the world and consequently, divided into two differing standpoints based on research findings – proponents of the hysteresis hypothesis (see Blanchard and Summer, 1986; Brunello, 1990; Mitchell, 1993; Jaeger and Parkinson, 1994; Chang 2011; García-Cintado *et al.*, 2015; Munir and Ching, 2015; Marjanovic, Maksimovic and Stanisic, 2015; Klinger and Weber 2016; Albulescu and Tiwari, 2017; Marques, Lima and Troster, 2017; Caporale and Gil-Alana, 2018; among others) and those in opposition (see Phelps, 1968; Srinivasan and Mitra 2012; Cheng *et al.*, 2014; Akdoğan 2016; Khraief and Azam, 2018; Xie, Chang, Grigorescu and Hung, 2018; among others).

Although, some studies report mixed findings for both hysteresis hypothesis and the natural rate theory [non-accelerating inflation rate of unemployment (NAIRU)] (see Breuer et al., 2001; Bolat *et al*., 2014; Furuoka, 2015a,b; Furuoka, 2017a; Cekic, 2016; Dursum, 2017; among others).

The hysteresis hypothesis of unemployment, where the current unemployment rate depends on the past values (Blanchard and Summers, 1986), has often been tested using conventional standard unit root tests, such as Dickey Fuller (1979; 1981) [hereafter, ADF] and Phillips and Perron (1988) [hereafter, PP] tests. However, the power of these conventional standard unit root tests to reject the null of unit root in unemployment rates have been shown to be quite low (see Campbell and Perron, 1991; Cochrane, 1991; DeJong et al., 1992; among others), even when structural breaks have been accounted for (Mitchell, 1993). As a consequence, more unit root testing frameworks have been considered to ascertain the true stationarity stance of unemployment rate. These include Levin and Lin (1992) and Im *et al*. (1997) panel-based unit root tests (see Song and Wu, 1998; Leon-Ledesma, 2002; Li, Ranjbar and Chang, 2017); Breuer et al. (2001) panel SURADF (Chang et al., 2005); autoregressive fractionally integrated moving average models [ARFIMA] (see Gil-Alana, 2001; 2002; Caporale and Gil-Alana, 2007; 2008; Caporale et al., 2017; Cuestas and Gil-Alana, 2017; Caporale and Gil-Alana, 2016; 2018a,b, Gil-Alana, Ozdemir and Tansel, 2019, among others); Kapetanios Schmidt and Shin [KSS] non-linear unit root test (Guris, Tiftikcigil and Tirasoglu, 2017); Quantile unit root tests with breaks (see Jiang, Cai, Peng and Chang, 2018; Xie, Chang, Grigorescu and Hung, 2018); linear and nonlinear Fourier-based unit root structural breaks (Meng, Strazicich and Lee, 2017; Khraief and Azam, 2018); a battery of unit root tests, such as ADF, FADF, ADF-SB and FADF-SB (see Garcia-Cintado, Romero-Avila and Usabiaga, 2015; Furuoka, 2017a,b) among others.

Empirically, the hysteresis hypothesis of unemployment rate has however been examined for diverse regions, which include Spanish regions (Garcia-Cintado, Romero-Avila and Usabiaga, 2015); Nordic countries (Furuoka, 2017a,b); OECD member countries (Meng, Strazicich and Lee, 2017; Khraief and Azam, 2018); G7 countries (Jiang, Cai, Peng and Chang, 2018); Turkey (Guris, Tiftikcigil and Tirasoglu, 2017); European countries with US and Japan (Akdogan, 2017); Eastern European countries (Xie, Chang, Grigorescu and Hung, 2018); specific categorization of five high debt countries - Portugal, Ireland, Italy, Greece and Spain (Li, Ranjbar and Chang, 2017); eleven African countries - Botswana, Ethiopia, Ghana, Kenya, Malawi, Mauritius, Nigeria, Senegal, South Africa, Tanzania and Zambia (Caporale and Gil-Alana, 2018a); among others.

This current paper would thus focus on a battery of four unit root tests - ADF, FADF, ADF-SB and FADF-SB to test the hysteresis hypothesis for a panel of African countries.

3.0 Data and Methods

Annual time series of unemployment rates considered in this work are the percentage total of labour force, obtained from the database of the World Bank – the World Development Indicators (WDI) (www.wdi.worldbank.org). Forty two (42) African countries were selected, and each series spanned between 1991 and 2017. The summary report of the entire dataset is given below in Table 1, indicating unemployment rates in 1991 and 2017, and as well the minimum and maximum rates in the sampled period across those countries. From the results in Table 1, occasions of high unemployment rates, since 1991, approaching 2-digits; are found in Algeria, Botswana, Cabo Verde, Gabon, The Gambia, Kenya, Lesotho, Morocco, Mozambique, Namibia, Senegal, South Africa, Sudan, Tunisia and Zambia. These rates range from about 10% to 27%. Majority of other countries with lower unemployment rate, range from about 2% to 10%, while Benin, Rwanda and Uganda have unemployment rate less than

1.0% in 1991. Looking at the 2017 rates, the unemployment rate of Egypt entered two (2) digits, while that of Senegal and Zambia improved to a single digit. The range between the maximum and minimum rates are very wide across all the countries that are considered, implying fluctuations of unemployment rates over the sampled years, and these also imply high unemployment rates in Africa.

INSERT TABLE 1 ABOUT HERE

The ADF unit root test with the three regression specifications: (i) no intercept and trend, (ii) intercept only and (iii) intercept with trend; are conducted and the results obtained are presented in Table 2. In these results, automatic selection of augmentation lags was considered and the optimal lag was selected based on the minimum information criteria. These optimal lags are reported in squared brackets. Based on the results of the t-statistics recorded, we found, in most of the countries, evidence of unit root in the unemployment rates, implying the acceptance of hypothesis of hysteresis in unemployment rate. The cases of rejection of unit root in the unemployment rates, based on constant and trend specification, are for Benin, Burkina Faso, Central African Republic, Cote D'Ivoire, Egypt, Guinea-Bissau, Lesotho, Libya, Namibia, Niger, Rwanda, Senegal, Togo and Uganda, out of the 42 African countries considered.

Note also that the classical ADF unit root regression specification does not consider structural breaks. Unemployment rate could have experienced instantaneous or smooth breaks over the years (see Perron, 1989; Furuoka, 2017a). In what follows, Enders and Lee (2012a,b) extended the classical ADF test in a nonlinear framework using Fourier function of varying frequencies for the trigonometry. The general form of the Fourier form is:

$$F(t) = \alpha + \beta t + \sum_{k=1}^{n} \lambda_k \sin(2\pi kt/T) + \sum_{k=1}^{n} \gamma_k \cos(2\pi kt/T); \quad n \le T/2; \; t = 1, 2, ... \tag{1}$$

where α and β are the intercept and trend coefficient, respectively, in the model function, λ_k and γ_k measure the amplitude and displacement of the sinusoidal component of the deterministic term, respectively; π is conventionally taken to be approximately 3.1416; n is the optimal number of frequencies in the approximation, and such is to be determined by an information criteria, where k is a particular frequency, initially set to 1, 2, …., up to n; T is the total number of observations, that is, the length of the unemployment rate in this case. The nonlinear parameters in the Fourier function setup are the λ_k and γ_k, which assumes real values on estimation, and once these are 0, the entire process becomes linear, and the significance of at least one of (λ_k, γ_k) implies nonlinearity. The ADF testing regression is

$$\Delta Ump_t = \alpha + \beta t + (\rho - 1) Ump_{t-1} + \sum_{i=1}^{p} c_i \Delta Ump_{t-i} + \varepsilon_t \tag{2}$$

where Ump_t is the unemployment rate of a particular country at time t, ε_t is the error term, while ρ, the slope parameter for the first lagged dependent variable, Ump_{t-1} is unity when the series has unit root property, c and p in the augmented component are the slope and the lag length for the augmentation, respectively. Now, combining (2) with (1) leads to the Fourier ADF (FADF) test regression of Enders and Lee's,

$$\Delta Ump_t = \alpha + \beta t + (\rho - 1) Ump_{t-1} + \sum_{k=1}^{n} \lambda_k \sin(2\pi kt/T) + \sum_{k=1}^{n} \gamma_k \cos(2\pi kt/T) + \sum_{i=1}^{p} c_i \Delta Ump_{t-i} + \varepsilon_t \tag{3}$$

The FADF unit root test considers smooth breaks to be modelled during the unit root testing procedure in a given time series (Becker, Enders and Lee, 2006). Furuoka (2017a) further extended this test regression with one structural break to be simultaneously determined in the framework. The setup of this break is similar to Perron (2006) one structural break (SB)-unit root test. Thus, we have both ADF-SB of Perron (2006) and FADF-SB of Furuoka (2017a), respectively as,

$$\Delta Ump_t = \alpha + \beta t + \delta DU_t + \theta D(T_B)_t + (\rho - 1) Ump_{t-1} + \sum_{i=1}^{p} c_i \Delta Ump_{t-i} + \varepsilon_t \quad (4)$$

$$\Delta Ump_t = \alpha + \beta t + \delta DU_t + \theta D(T_B)_t + (\rho - 1) Ump_{t-1} + \sum_{k=1}^{n} \lambda_k \sin(2\pi kt/T)$$

$$+ \sum_{k=1}^{n} \gamma_k \cos(2\pi kt/T) + \sum_{i=1}^{p} c_i \Delta Ump_{t-i} + \varepsilon_t \quad (5)$$

where δ is the coefficient of the structural break dummy, DU_t, with $DU_t = 1$ if $t > T_B$, otherwise, $DU_t = 0$; T_B indicates the break date; the coefficient for the one-time break dummy is denoted by θ; $D(T_B)_t = 1$ if $t = T_B$, otherwise $D(T_B)_t = 0$.

Similar to the ADF unit root test, the t-statistic tests the null hypothesis of unit root $\rho - 1 = 0$ in the three models in (3), (4) and (5) for FADF, ADF-SB and FADF unit root tests. The optimal frequency $\hat{k}$ in (3) and (5) is selected by minimizing the residual sum of squares errors (SSR),

$$SSR_{FADF}(\hat{k}) = \inf_k SSR_{FADF}(k); \quad SSR_{FADF-SB}(\hat{k}) = \inf_k SSR_{FADF-SB}(k) \quad (6)$$

where in the case of FADF-SB and ADF-SB, following Zivot and Andrews (1992) and Perron (2006), a structural break is determined endogenously, rather than exogenously, and the optimal break date $(\hat{T}_B)$ is then selected. The break fraction $(\hat{\xi})$ is calculated as,

$$\hat{\lambda} = \frac{T_B}{T} \quad (7)$$

It is noted in Furuoka (2017a) that the optimal break date, $\hat{T}_B$, in FADF-SB regression model is sensitive to both break-position $(\hat{T}_B)$ and frequency $(\hat{k})$, the optimal location of the break date and frequency are jointly determined by,

$$\tau_{FADF-SB}\left(\hat{\xi},\hat{k}\right)=\inf_{\xi,k}\tau_{FADF-SB}\left(\xi,k\right) \tag{8}$$

which will minimize the FADF-SB statistic for equation (5).

At this juncture, apart from the ability to further reject more unit roots based on the inducement of the nonlinear Fourier forms and a structural break, one still needs to determine the "best" or most preferred testing regression model. Furuoka (2014; 2017a) recommend using an F-statistic,

$$F=\frac{\left(SSR_0-SSR_1\right)/q}{SSR_1/\left(T-r\right)} \tag{9}$$

where SSR_1 is the sum of squares residuals (SSR) from the unrestricted model, SSR_0 is the SSR from the restricted model, q is the number of restrictions in the restricted model, and r is the number of regressors in the unrestricted model. For example, the ADF regression is considered a restricted model of the FADF model, whenever the nonlinear trigonometrical terms are zeros, that is, $\lambda_k=\gamma_k=0$. Secondly, the ADF regression is considered a restricted model of ADF-SB, if no structural break is detected. Thirdly, the ADF regression is considered a restricted model of FADF-SB, if both nonlinearity and structural break forms are absent in the model. Fourthly, the FADF regression is considered a restricted model to FADF-SB, if structural break dummies are absent. Lastly, the ADF-SB regression is considered a restricted model to FADF-SB regression, if nonlinearity form via trigonometry is absent. Thus, we have five paired cases to consider, which are F_{FADF_ADF}, F_{ADF-SB_ADF}, $F_{FADF-SB\_ADF}$, $F_{FADF-SB\_FADF}$ and $F_{FADF-SB\_ADF-SB}$ tests. Details about the critical values for each pair of the F test is reported in Furuoka (2017a). In a case of no significance improvement of an unrestricted model over a restricted choice, the model with a smaller Type I error is considered the better model that determines the unit root hypothesis of unemployment rate.

4.0 Empirical Findings

Following from the earlier reported pre-test results of the ADF unit root tests, under the three regression specifications, we re-conducted the ADF test with the augmentation lag fixed to unity, and also maintain same lag augmentation in the ADF-SB, FADF and FADF-SB tests.[1,2] Also, all the estimated test regression models include both constant and time trend. The results are given in Table 3. Based on the ADF test, we rejected the hysteresis hypothesis of the unemployment rates in the cases of Equatorial Guinea, Lesotho, Namibia, Rwanda, Togo and Uganda, which is approximately 14.29% of the total cases considered. These decisions are not too different from those by the ADF test, under the automatic lag selection of the augmentation. By considering the Fourier form in the ADF framework, the hysteresis hypotheses was rejected in 11 (approximately 26.19% of total) cases, which include Burkina Faso, Cote D'Ivoire, Equatorial Guinea, Guinea, Lesotho, Mali, Namibia, Rwanda, Senegal, Uganda and Zimbabwe. Now, the unit root results by both ADF and FADF tests rejected the hysteresis hypothesis of the unemployment rate in Equatorial Guinea, Lesotho, Namibia, Rwanda, Togo and Uganda. Noting that FADF test regression does not account for breaks, while ADF-SB allows for instantaneous break, we found more rejections of the hysteresis hypothesis of unemployment rates using ADF-SB with about 31 (approximately 73.81% of total) cases of rejections, which suggests the superiority of ADF-SB over the FADF test, given the present dataset, and more so, the 11 (approximately 26.19% of total) cases of hysteresis hypothesis rejections using the FADF test are subsets of the rejections when the ADF-SB test is employed. By considering the FADF-SB test that allows for smooth breaks, we reject the hysteresis hypothesis in 35 (approximately 83.33%) cases, where the remaining 7 (approximately

[1] Fixing lag of augmentation component to 1 reduced complication of the programming in the case of classical ADF test, and from the results of ADF test by automatic selection, presented in Table 2, lag of 0 were picked in most of the cases, while up to maximum of lag 5 were picked in occasional cases.
[2] Fourier-based ADF test were designed to test unit roots in small time series samples, $N \leq 200$.

16.67%) cases of acceptance of the hysteresis hypothesis include Algeria, Botswana, Cabo Verde, Congo DR, Guinea-Bissau, Liberia and Tanzania. Considering the consistency in the non-rejections of unit root by FADF, ADF-SB and FADF-SB, in the cases of these seven countries, and the non-rejection of unit roots by the joint tests (FADF-SB and any one of FADF and ADF-SB tests), we found non-rejection of unit root hypothesis in the unemployment rate in the seven countries, which implies and confirms the existence of unemployment hysteresis.

INSERT TABLE 3 ABOUT HERE

We proceed to formally verify the reliability of all four contending unit root tests adopted in this study, by way of determining which unit root test would lead to the most appropriate unit root decision, and how consistently it does so in comparison with the other contending tests. The F-test statistics is therefore employed to compare the different pairs of restricted and unrestricted model constructs, while examining which test regression will "best" capture the sum of squares regression variations in the unemployment rates. We found that the F-test $\left(F_{FADF\_ADF}\right)$, which tests the significance of the improvement of FADF test over ADF test, indicated significant improvement of the FADF unit root regression in only three (3) cases, that is, in Burkina Faso, Burundi and Guinea, thus revealing the low power of the FADF test compared to conventional ADF test. However, in the case of F_{ADF-SB_ADF}, testing for significant improvement of ADF-SB test over ADF test, there were 29 cases indicating improvement of the former over the latter. Glaringly, FADF-SB unit root test outperformed the other three unit root tests (ADF, FADF and ADF-SB) in all the African countries considered except in Angola, Central African Republic, Guinea-Bissau, Liberia, Namibia and Tanzania, implying that the unit root decision based on FADF-SB unit root test is reliable (see results in Table 4). In addition, we find the hysteresis hypothesis and/or natural rate theory to be significantly influenced by the presence of structural breaks, such that its combination with the Fourier functions in the unit root testing framework tends to enhance power of the test.

INSERT TABLE 4 ABOUT HERE

5.0 Conclusion

The study investigates unit root properties of the unemployment rate in forty-two (42) African countries from 1991 to 2017, to confirm if the unemployment hysteresis hypothesis holds or it follows the natural rate hypothesis of the non-accelerating inflation rate of unemployment rate (NAIRU), having fluctuations around the equilibrium level. Having applied the classical ADF unit root test, we found that the decision based on this test might lead to wrong decisions, as we found in more than 60% of the cases, where we failed to reject the hysteresis hypothesis. With the fact that time dynamics of unemployment rate might have undergone structural shifts, which could have induced non-linearities of different forms, the ADF unit root test in this regard lacks the ability to satisfactorily adjudge the stationarity properties of unemployment rates in the studied African countries. Consequent upon the foregoing, three additional unit root testing frameworks were considered in the study. These include FADF, ADF-SB and FADF-SB, which account respectively for 26.19%, 73.81% and 83.33% cases of rejection of the hysteresis hypothesis of unemployment rate among the examined African countries. By implication, we could say that for the period covered, the unemployment rate of most of the African countries seems to be mean reverting. This finding is, however, in direct contrast with the empirical results of Caporale and Gil-Alana (2018a) who found the unemployment rates to be non-stationary. However, on the basis of the most preferred unit root testing framework, we find the FADF-SB test to be the most reliable among the contending models, outperforming all others in majority of the African countries examined. Conclusively, the hysteresis hypothesis holds in only seven of the forty-two investigated African countries and they include Algeria, Botswana, Cabo Verde, Congo DR, Guinea-Bissau, Liberia and Tanzania. Unemployment rate in these countries do not revert to their mean levels and by implication, shocks may persist for longer time periods. This has important implications for public policy implying that in these seven countries strong policy action needs to be taken to address unemployment shocks. Depending on the origin of the shocks, a combination of strong expansionary monetary and fiscal may be required to address shocks. However, none of these seven countries are among the largest African economies implying that shocks are unlikely to strongly affect the performance of overall African economy. In the remaining African countries surveyed, shocks to unemployment are transitory and more moderate policy action can be taken to address unemployment shocks. Since the remaining countries where the hysteresis hypothesis does not hold include the largest African economies such as South Africa, Nigeria, Kenya, Angola, Egypt and Ethiopia, this implies that unemployment shocks in these large countries will not adversely affect Africa's overall position for long periods of time and Africa's overall economic recovery and position as a relatively stable emerging economy can be sustained. Hysteresis effects in the seven economies will be more than offset overall.

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Table 1: Data Summary

Country	Code	1991 rate	2017 rate	Min. rate	Max. rate
Algeria	DZA	20.60	11.37	9.82	29.77
Angola	AGO	6.73	6.60	6.47	7.03
Benin	BEN	0.86	1.00	0.69	1.51
Botswana	BWA	13.82	18.57	12.92	23.80
Burkina Faso	BFA	2.76	2.94	2.33	4.00
Burundi	BDI	1.61	1.65	1.57	1.66
Cabo Verde	CPV	11.15	10.53	10.38	11.15
Cameroon	CMR	5.28	4.59	2.90	8.12
Central African Republic	CAF	6.69	6.92	6.21	6.92
Chad	TCD	5.68	5.77	5.57	6.03
Congo, Dem. Rep.	COD	3.57	3.60	3.54	3.71
Cote d'Ivoire	CIV	8.99	9.31	8.99	9.40
Egypt, Arab Rep.	EGY	9.60	11.50	7.95	13.21
Equatorial Guinea	GNQ	6.62	7.73	6.54	8.55
Ethiopia	ETH	5.46	5.72	4.98	8.20
Gabon	GAB	21.56	18.14	16.68	21.56
Gambia, The	GMB	29.35	29.71	29.03	30.07
Ghana	GHA	6.08	5.87	3.60	10.36
Guinea	GIN	6.66	6.82	6.66	6.98
Guinea-Bissau	GNB	6.66	6.51	6.41	6.86
Kenya	KEN	10.49	10.82	8.10	12.18
Lesotho	LSO	26.55	27.50	24.44	39.30
Liberia	LBR	4.24	4.07	3.62	5.60
Libya	LBY	20.81	19.22	17.14	20.81
Malawi	MWI	6.89	6.78	6.36	7.80
Mali	MLI	7.23	8.07	3.30	12.24
Morocco	MAR	17.30	10.37	8.91	22.90
Mozambique	MOZ	24.71	24.14	22.55	25.30
Namibia	NAM	19.00	24.91	19.00	37.60
Niger	NER	2.79	2.66	1.47	5.10
Nigeria	NGA	5.94	5.42	4.28	7.60
Rwanda	RWA	0.30	2.38	0.30	3.44
Senegal	SEN	10.47	9.30	5.65	10.47
Sierra Leone	SLE	2.99	3.09	2.78	3.40
South Africa	ZAF	23.93	26.00	16.90	27.14
Sudan	SDN	14.88	13.41	12.86	15.20
Tanzania	TZA	3.60	2.73	2.00	5.10
Togo	TGO	6.94	6.78	6.78	7.23
Tunisia	TUN	14.44	14.59	12.40	18.33
Uganda	UGA	0.94	2.36	0.94	3.50
Zambia	ZMB	18.90	7.38	7.38	19.70
Zimbabwe	ZWE	5.77	5.05	4.17	6.93

Note, rates are given in percentages.

Table 2: Results of ADF Unit root test

Country	Code	None	Intercept only	Intercept &Trend
Algeria	DZA	-0.9293 [0]	-0.4643 [0]	-2.1463 [0]
Angola	AGO	-0.2882 [0]	-1.7780 [0]	-1.7174 [0]
Benin	BEN	-0.8021 [2]	**-3.7961 [0]**	**-3.7183 [0]**
Botswana	BWA	0.1026 [0]	-2.7106 [0]	-2.9680 [0]
Burkina Faso	BFA	0.1894 [2]	-1.0893 [2]	**-5.5738 [0]**
Burundi	BDI	0.9282 [2]	**-3.6924 [3]**	-2.9924 [2]
Cabo Verde	CPV	-1.7111 [0]	-0.8235 [1]	-1.8904 [1]
Cameroon	CMR	-0.5958 [0]	-1.7463 [0]	-2.2676 [0]
Central African Republic	CAF	0.2483 [0]	**-3.5910 [0]**	**-3.4935 [0]**
Chad	TCD	0.1458 [0]	-2.8236 [0]	-3.5505 [0]
Congo, Dem. Rep.	COD	0.2109 [0]	-1.6266 [0]	-0.4809 [0]
Cote d'Ivoire	CIV	0.6148 [0]	**-3.9018 [0]**	**-4.0467 [0]**
Egypt, Arab Rep.	EGY	1.4719 [5]	-1.6572 [0]	**-4.3200 [3]**
Equatorial Guinea	GNQ	0.5634 [3]	-2.1213 [2]	-1.7863 [3]
Ethiopia	ETH	-0.1213 [1]	**-3.2792 [0]**	-3.4611 [0]
Gabon	GAB	-0.7596 [0]	-2.9064 [0]	-3.1743 [0]
Gambia, The	GMB	0.3170 [0]	-2.2079 [0]	-2.1182 [0]
Ghana	GHA	-0.3288 [1]	-1.8136 [1]	-3.3136 [0]
Guinea	GIN	0.9790 [0]	**-4.6857 [5]**	-0.4750 [5]
Guinea-Bissau	GNB	-0.5553 [2]	-1.6920 [1]	**-5.0541 [0]**
Kenya	KEN	-0.0592 [0]	-1.5979 [0]	-2.2453 [0]
Lesotho	LSO	-0.2821 [5]	**-4.1765 [0]**	**-3.7129 [1]**
Liberia	LBR	-0.3448 [0]	-2.4892 [0]	-2.7688 [0]
Libya	LBY	-0.1980 [1]	**-4.5074 [0]**	**-4.3744 [0]**
Malawi	MWI	-0.1824 [0]	-1.6020 [0]	-1.7573 [0]
Mali	MLI	-0.5949 [0]	**-3.3049 [0]**	-3.2442 [0]
Morocco	MAR	-0.7319 [6]	**-5.9993 [5]**	-1.3326 [2]
Mozambique	MOZ	-0.2500 [0]	**-3.1541 [0]**	-3.1569 [0]
Namibia	NAM	-0.4176 [0]	**-3.4231 [0]**	**-4.6736 [1]**
Niger	NER	-1.1770 [1]	**-4.1607 [0]**	**-5.5530 [0]**
Nigeria	NGA	-0.4012 [0]	-1.9663 [0]	-1.8971 [0]
Rwanda	RWA	-1.0400 [0]	**-3.9387 [0]**	**-4.6592 [0]**
Senegal	SEN	0.1294 [2]	**-3.5253 [0]**	**-4.1454 [0]**
Sierra Leone	SLE	0.0815 [0]	-1.7196 [0]	-1.7090 [0]
South Africa	ZAF	-0.1328 [2]	-2.1704 [2]	-2.7664 [2]
Sudan	SDN	-0.7630 [0]	-1.4833 [0]	-2.9574 [0]
Tanzania	TZA	-0.7369 [0]	-2.4956 [0]	-3.5831 [0]
Togo	TGO	-0.3715 [1]	-1.7395 [1]	**-7.3623 [2]**
Tunisia	TUN	-0.2105 [0]	-2.5093 [0]	-2.4559 [0]
Uganda	UGA	-0.3447 [3]	**-5.3554 [0]**	**-5.2550 [0]**
Zambia	ZMB	-1.5401 [0]	-1.3152 [0]	-2.5530 [0]
Zimbabwe	ZWE	-0.5017 [0]	-2.8465 [0]	-3.1145 [0]

Note: In bold denotes significance of the ADF at 5% level, and optimal lag length of the augmentation is in squared bracket

Table 3: ADF, ADF-SB, FADF and FADF-SB Unit root tests

Country	ADF	FADF	ADF-SB	FADF-SB
Algeria	-1.9644	-2.8744 [1]	**-4.7453 [2003 , 0.4815]**	-4.2085 [2003 , 0.4815 , 1]
Angola	-2.3717	-4.0166 [1]	-3.2445 [2014 , 0.8889]	**-4.7555 [1999 , 0.3333 , 1]**
Benin	-3.1962	-4.3140 [1]	**-4.0435 [2004 , 0.5185]**	**-6.0367 [1995 , 0.1852 , 2]**
Botswana	-3.4202	-3.7419 [2]	**-4.3511 [2008 , 0.6667]**	-4.1133 [2008 , 0.6667 , 1]
Burkina Faso	-2.9533	**-6.6379 [1]**	**-5.3709 [2004 , 0.5185]**	**-10.3520 [2005 , 0.5556 , 1]**
Burundi	-1.2905	-1.8462 [1]	-2.4978 [2008 , 0.6667]	**-4.4910 [2014 , 0.8889 , 1]**
Cabo Verde	-1.8904	-1.7558 [2]	**-4.1985 [2008 , 0.6667]**	-3.9506 [1997 , 0.2593 , 2]
Cameroon	-2.0674	-3.1465 [1]	-3.3133 [2004 , 0.5185]	**-4.9185 [1995 , 0.1852 , 1]**
Central African Republic	-2.9556	-3.1176 [2]	**-3.8067 [2013 , 0.8519]**	**-4.8532 [2016 , 0.9630 , 1]**
Chad	-2.8650	-3.6104 [1]	**-4.8857 [2004 , 0.5185]**	**-5.5508 [2003 , 0.4815 , 2]**
Congo, Dem. Rep.	-1.0256	-3.5008 [1]	-2.8250 [2014 , 0.8889]	-4.2149 [1994 , 0.1481 , 1]
Cote d'Ivoire	-3.2324	**-4.6866 [1]**	**-6.1774 [2011 , 0.7778]**	**-8.5574 [2011 , 0.7778 , 2]**
Egypt, Arab Rep.	-2.3301	-2.6403 [1]	**-3.9697 [2010 , 0.7407]**	**-5.1483 [2010 , 0.7407 , 2]**
Equatorial Guinea	**-3.9220**	**-6.3858 [1]**	**-4.7316 [2003 , 0.4815]**	**-8.5018 [1996 , 0.2222 , 1]**
Ethiopia	-2.3428	-3.4529 [1]	-3.4082 [2001 , 0.4074]	**-5.6772 [1997 , 0.2593 , 1]**
Gabon	-2.1947	-3.4666 [2]	**-5.0281 [2009 , 0.7037]**	**-5.8277 [2009 , 0.7037 , 2]**
Gambia, The	-1.7974	-3.8251 [1]	**-4.8095 [1997 , 0.2593]**	**-5.3567 [2010 , 0.7407 , 2]**
Ghana	-2.3805	-2.6573 [1]	-2.9232 [2002 , 0.4444]	**-5.8778 [2006 , 0.5926 , 1]**
Guinea	-2.3605	**-5.3950 [1]**	**-4.4216 [2012 , 0.8148]**	**-7.7407 [1997 , 0.2593 , 1]**
Guinea-Bissau	-0.2075	-1.4725 [1]	-2.9207 [2015 , 0.9259]	-4.6458 [2016 , 0.9630 , 1]
Kenya	-2.3103	-3.8080 [1]	-2.9572 [2005 , 0.5556]	**-7.2174 [1998 , 0.2963 , 1]**
Lesotho	**-3.7129**	**-5.5400 [1]**	**-5.1271 [1997 , 0.2593]**	**-6.8683 [1997 , 0.2593 , 1]**
Liberia	-2.3953	-2.1852 [2]	-3.4924 [2007 , 0.6296]	-3.9177 [2006 , 0.5926 , 1]
Libya	-2.3460	-3.4680 [1]	**-8.1448 [2011 , 0.7778]**	**-14.5375 [2011 , 0.7778 , 1]**
Malawi	-1.8378	-2.9445 [2]	**-6.7445 [2005 , 0.5556]**	**-5.7326 [2005 , 0.5556 , 1]**
Mali	-3.1991	**-4.2210 [2]**	**-4.3156 [2003 , 0.4815]**	**-5.9857 [1997 , 0.2593 , 2]**
Morocco	-1.9424	-3.7322 [1]	**-4.2526 [1998 , 0.2963]**	**-7.4009 [1994 , 0.1481 , 1]**
Mozambique	-2.7505	-3.6633 [1]	**-4.5151 [2013 , 0.8519]**	**-6.9232 [2013 , 0.8519 , 2]**
Namibia	**-4.6736**	**-4.6402 [1]**	**-5.2803 [2001 , 0.4074]**	**-5.9212 [2007 , 0.6296 , 1]**
Niger	-3.4091	-4.3052 [1]	**-5.7948 [2000 , 0.3704]**	**-6.6796 [2000 , 0.3704 , 2]**
Nigeria	-2.1182	-4.4071 [1]	**-5.7593 [2013 , 0.8519]**	**-6.1248 [2013 , 0.8519 , 2]**
Rwanda	**-4.0799**	**-4.4605 [2]**	**-5.1301 [2000 , 0.3704]**	**-6.6109 [2005 , 0.5556 , 2]**
Senegal	-3.0732	**-4.4627 [2]**	**-4.3585 [2001 , 0.4074]**	**-6.3328 [2001 , 0.4074 , 2]**
Sierra Leone	-2.0947	-3.6373 [1]	-3.0852 [2012 , 0.8148]	**-5.6831 [2011 , 0.7778 , 2]**
South Africa	-2.8325	-3.8385 [2]	-3.5143 [2005 , 0.5556]	**-4.5345 [2012 , 0.8148 , 2]**
Sudan	-2.3052	-2.6355 [1]	**-5.7078 [2008 , 0.6667]**	**-7.2009 [2008 , 0.6667 , 1]**
Tanzania	-3.3973	-4.0506 [2]	**-4.4794 [2001 , 0.4074]**	-4.5072 [2000 , 0.3704 , 2]
Togo	**-3.6046**	-4.4292 [1]	**-5.8783 [1994 , 0.1481]**	**-8.3774 [1994 , 0.1481 , 2]**
Tunisia	-2.3253	-2.9445 [2]	**-5.2190 [2010 , 0.7407]**	**-8.6852 [2010 , 0.7407 , 2]**
Uganda	**-4.6297**	**-5.4184 [1]**	**-6.9128 [2011 , 0.7778]**	**-6.9290 [2011 , 0.7778 , 2]**
Zambia	-3.0107	-3.6146 [2]	**-4.2163 [2002 , 0.4444]**	**-4.9590 [2007 , 0.6296 , 1]**
Zimbabwe	-3.0580	**-4.3201 [2]**	**-4.0598 [2002 , 0.4444]**	**-4.7848 [2002 , 0.4444 , 2]**

Note: The ADF statistics presented on this table are results obtained when the lag specification is constrained to one. The figures in the column labelled ADF-SB are the t-statistics with break dates and break fractions in square brackets. The FADF column contains t-statistics and Fourier frequency in square brackets, while the last column labelled FADF-SB contains the t-statistics with break dates, break fractions and Fourier frequencies, respectively, in square brackets. Bold figures indicate statistical significance at 5% level.

Table 4: Robustness checks

Country	F_{FADF_ADF}	$F_{ADF\text{-}SB\_ADF}$	$F_{FADF\text{-}SB\_ADF}$	$F_{FADF\text{-}SB\_FADF}$	$F_{FADF\text{-}SB\_ADF\text{-}SB}$
Algeria	6.2224	**12.0230**	**8.5251**	**7.1709**	**15.7815**
Angola	4.8199	2.5370	4.1899	2.7545	7.2425
Benin	5.2879	5.0294	**6.7165**	**5.7520**	**13.2009**
Botswana	1.3825	**11.6148**	5.4453	**8.5181**	**10.4388**
Burkina Faso	**15.0768**	**8.7993**	**45.5908**	**31.8327**	**77.3221**
Burundi	**34.4456**	2.8417	**47.0344**	**14.6953**	**48.6657**
Cabo Verde	3.7342	**10.5601**	**6.2776**	6.7693	**12.4527**
Cameroon	4.3641	3.7186	**14.3318**	**17.4587**	**27.5805**
Central African Republic	1.7378	**49.0638**	3.9288	**5.3927**	4.9476
Chad	2.4203	**21.1585**	**5.4800**	**7.1273**	**10.6397**
Congo, Dem. Rep.	7.1974	**5.8032**	**7.2270**	**4.7121**	**9.5012**
Cote d'Ivoire	8.0571	**13.2940**	**16.6646**	**14.7336**	**33.1810**
Egypt, Arab Rep.	1.9389	**5.8635**	**5.6782**	**8.1054**	**11.1017**
Equatorial Guinea	9.4475	2.7583	**11.1515**	**7.2405**	**15.4983**
Ethiopia	3.9933	3.8601	**8.1348**	**9.1694**	**15.0625**
Gabon	6.7719	**11.6863**	**10.1741**	**8.6455**	**18.4567**
Gambia, The	7.2811	**9.7921**	**7.3788**	4.8244	**14.4728**
Ghana	1.9328	2.2213	**13.0965**	**20.6443**	**25.3868**
Guinea	**10.7016**	**7.4263**	**13.8926**	**8.9654**	**26.0412**
Guinea-Bissau	3.3153	**16.3690**	**9.5169**	**12.1866**	7.7591
Kenya	6.4783	1.7524	**23.9247**	**25.9668**	**43.1402**
Lesotho	6.6458	**7.8068**	**8.4171**	**6.6269**	**15.9546**
Liberia	0.8998	**9.3740**	2.8138	4.4336	5.4430
Libya	3.4745	**67.2337**	**166.7824**	**248.2687**	**320.6173**
Malawi	6.7307	**36.4853**	**20.6315**	**21.4337**	**40.1598**
Mali	4.8186	**5.4198**	**8.7383**	**8.9908**	**17.4709**
Morocco	8.0100	**11.0428**	**19.5283**	**18.0442**	**34.5603**
Mozambique	2.9545	**7.6037**	**10.7669**	**14.7190**	**20.1491**
Namibia	0.5598	**7.8453**	3.0265	5.2658	4.7200
Niger	2.8843	**9.7708**	**8.0013**	**10.5068**	**14.8405**
Nigeria	7.8766	**15.2303**	**9.6689**	**6.9773**	**19.1507**
Rwanda	2.1663	4.8634	**5.6479**	**7.7391**	**9.9371**
Senegal	5.5603	4.1367	**7.4109**	**6.4012**	**14.3698**
Sierra Leone	6.6634	**7.5038**	**15.2945**	**15.0252**	**29.3553**
South Africa	5.1289	2.1453	4.2427	2.5832	**8.3871**
Sudan	2.4191	**18.9402**	**44.0454**	**69.8169**	**79.2987**
Tanzania	2.6240	**18.5830**	2.3437	1.8507	4.5600
Togo	2.8714	**31.4153**	**30.4003**	**45.7042**	**59.3835**
Tunisia	4.2271	**10.7432**	**21.4109**	**27.8039**	**42.7540**
Uganda	2.7548	**8.3386**	4.9156	5.8135	**9.6901**
Zambia	3.0756	3.7616	4.0146	4.0579	**8.0268**
Zimbabwe	5.4077	3.7641	4.2437	2.3727	**8.4817**

Note: In bold indicates significance at 5% level. For critical values, see Furuoka (2017a).