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Research article

Are output fluctuations transitory or permanent? New evidence from a novel Global Multi-scale Modeling approach

Mumtaz Ahmed[1,*], Muhammad Azam[2,3], Stelios Bekiros[4,5] and Syeda Mahlaqa Hina[6]

[1] Department of Economics, COMSATS University Islamabad (CUI), Park Road Chak Shehzad, Islamabad, Pakistan
[2] Department of Economics, Faculty of Business & Economics, Abdul Wali Khan University Mardan, Khyber Pakhtunkhwa, Pakistan
[3] School of Economics, Finance & Banking, College of Business, Universiti Utara Malaysia, Sintok, Kedah, Malaysia
[4] University of Malta, Department of Banking and Finance, FEMA, Msida, Malta
[5] European University Institute, Department of Economics, Via delle Fontanelle, 18, I-50014, Florence, Italy
[6] Department of Management Sciences, COMSATS University Islamabad, Pakistan

* **Correspondence:** Email: mumtaz.ahmed@comsats.edu.pk, mumtaz.mumtazahmed@gmail.com.

Abstract: This paper provides new insights to the long-standing debate initiated by Nelson-Plosser (1982) regarding the mean reverting behaviour of real GDP per capita. The empirical analysis is based on wavelet framework introduced in Aydin and Pata Aydin (2020) which considers not only frequency domain along with time domain but also takes care of smooth structural changes ignored by earlier wavelet based unit root tests, and covers latest available data on 177 countries across the globe. Specifically, the countries are classified into seven different regions (East Asia and Pacific Region, Europe and Central Asia, Latin America and the Caribbean, Middle East and North Africa, North America, South Asia and Sub-Saharan Africa) as per guidelines of World Bank. The empirical findings yield interesting insights and several new lessons for practitioners and policy analysts.

Keywords: discrete wavelet transform; stationarity; real GDP per capita; multi-resolution approach; wavelet unit root test; smooth structural change

JEL Codes: E01, C22, C23, C54, C63

1. Introduction

In general, one of the criteria for measuring economic growth is the real GDP per capita (RGDPPC) of a country. The discussion on the nature of economic variability always remains a hot topic at the center of macroeconomic research. An important issue is whether the business cycle is exclusively transitory or whether it is considered mostly by permanent rather than temporary shifts. Albeit, there is a conventional wisdom of the business cycle that hypothesizes that GDP growth rate fluctuations are perpetual deviations from trend. It requires employing macroeconomic stabilization strategy encompassing both monetary and fiscal policies to manage with GDP disturbance as put forward by Keynes arguing neoclassical macroeconomic view. The RGDPPC is one of the most critical signs of the affluence of nations. Therefore, it is crucial to determine whether the per capita income follows a trend stationary or a difference stationary process[1].

Lucas (1977) mentions with the question, "*Why is it that, in capitalist economies, aggregate variables undergo repeated fluctuations about trend, all of essentially the same character?*" Similarly, Nelson and Plosser (1982) on the investigation of the time-series properties of real output levels reveal that "*we are unable to reject the hypothesis that these series are non-stationary stochastic processes with no tendency to return to a trend line. Based on these findings and an unobserved components model for output that decomposes fluctuations into a secular or growth component and a cyclical component, we infer that shocks to the former, which we associate with real disturbances, contribute substantially to the variation in observed output*". After the influential work of Nelson and Plosser (1982), several other studies examine the potential time-series properties of crucial macroeconomic variables. Nelson and Plosser expound that a unit root in real output is uneven with the belief that business cycles are stationary variations all over a deterministic trend. Many prior studies including Perron (1988) endorse the findings of Nelson and Plosser (1982).

In a similar vein, Campbell and Mankiw (1987) summarize that as per the conventional view of the business cycle, fluctuations in output characterize transitory deviations from the trend. The empirical findings reveal a natural complement to standard tests of non-stationarity, while, using quarterly postwar US data. The study further adds that several business cycles' traditional theories sustain two simple ideas. First, fluctuations in output are supposed to be determined mainly by shocks to aggregate demand, like fiscal and monetary policies, or animal spirits. Second, shocks to aggregate demand are supposed to have merely a transitory influence on output; the economy returns to the natural rate in the long run. Li (2000) notes the rational implication of the government set off structural reform would certainly be of limited value if real output holds a unit root. Smyth and Inder (2004) using RGDPPC find a unit root for the majority of provinces of China. The study suggests that the government launched structural reform will be offset by other shocks, limiting its effects on the long-run growth track for all these provinces in China.

To examine empirically the time-series properties of output, cross-sectional and panel data analysis have been carried out by several existing studies for different countries using different sample periods.

[1]Zeren and İşlek (2019).

Where visible criticism of unit root tests has been observed, notably the Augmented Dickey-Fuller (ADF) test due to its low power against substantial, but stationary replacements with generally existing time lengths of data. While some researchers are in favor of the panel unit root techniques because of having more power as compared to unit root tests designed for univariate time series[2]. However, every country indeed has its own administrative, cultural, economic, political and social characteristics; therefore, time series analysis has its own undeniable features over the other one. Thus, the primary purpose of the present study is to empirically investigate the stationarity property of output fluctuations for a set of 177 countries from the whole World over the period ranging from 1960 to 2018. The critical feature of this study is that, to the best of the authors' knowledge, the research in hand is the first of its kind to employ the newly developed wavelet unit root tests proposed by Aydin and Pata (2020)[3]. These tests are developed in the wavelet framework that takes into account both frequency as well as time dimensions and also considers the issue of smooth structural break(s), thus it provides more robust inferences as compared to existing wavelet unit root tests such as Fan and Gencay (2010) which have low power particularly under negative moving averages and also when there are structural break(s) (see Eroglu and Soybilgen (2018) for more details). The wavelet tests proposed by Aydin and Pata (2020) are the wavelet version of popular Augmented Dickey Fuller (ADF) tests and named as Wavelet ADF (WADF) and its Fourier version—the Fourier WADF (FWADF) which considers the frequency dimension as well and which has the ability to take into account any smooth structural break(s). Thus, this study makes use of these recently developed WADF and FWADF by Aydin and Pata (2020). Further, this is the first study, using the maximum available numbers of countries along with a considerable length of the time period (minimum 25 years of annual observations), particularly, countries from all seven regions (East Asia and Pacific, Europe and Central Asia, Latin America and the Caribbean, Middle East and North Africa, North America, South Asia and Sub-Saharan Africa) across the globe are selected and analyzed. Therefore, the present study contributes significantly to the literature on the investigation of time series properties of per capita GDP for almost the entire World economies with more holistic empirical techniques.

Note that the the categorization of countries on the basis of geographical location is done to make the presentation of results more convenient and presentable. Previous, several studies on the energy-growth nexus, have adopted a similar approach and analyzed the nexus by considering different regions across the globe. See for example, Apergis and Payne (2009) for Central America; Eggoh et al. (2011) for African countries; Noor and Siddiqi (2010) for South Aisan countries; Jalil (2014) for net energy exporter and importer countries; Ozturk (2010) for a survey of studies on several geographical locations; Tiba and Omri (2017) for a survey of studies on energy, environment and economic growth; Rodríguez-Caballero and Ventosa-Santaulària (2017) for Latin American economies; Rodríguez-Caballero (2021) for four different regions, Asia and Pacific, Europe, Africa, The Americas. All these studies make use of conventional unit root tests (considering time dimension only) to assess the stationarity of the chosen data series as part of their empirical analysis. However, as highlighted in Aydin and Pata (2020) and the findings of current study show that ignoring the frequency dimension while applying unit root test may lead to misleading inferences regarding the stationarity of series under examination. So, one may re-assess the claims made by these studies by following our approach which provides better insights, as it not only takes into account the time dimension but also the frequency dimension as well along with (any) smooth structural change. Note

[2]Banerjee et al (2005).

[3]See also Aydin (2019).

that, the above studies are taken from energy-growth literature, however, there are several other studies, where real GDP per capita (RGDPPC) series is considered and its nexus is considered with other potential (macroeconomic) time series, and stationarity of RGDPPC is established using conventional (time domain based) unit root tests as part of their empirical analysis, so their results should also be re-analyzed and updated under the light of empirical findings presented in our study.

The remainder of the study is structured as follows. Section 2 deals with the literature review of the research. Section 3 introduces the econometric methodology used. Section 4 interprets the empirical findings while Section 5 concludes the study.

2. Literature review

The available literature provides much empirical evidence on the investigation of time-series properties of macroeconomic variable namely per capita GDP or GDP or Gross National Product GNP (real). However, the empirical results of these previous studies are yet elusive. For example, Nelson and Plosser (1982) find that US real GDP to be a non-stationary process using annual data, mostly averages for the year, with a start from 1860–1909 and ending in 1970 in all cases. Campbell and Mankiw (1987) reveal regarding short-run dynamics that make GNP divergent from a random walk with drift. The long-run implications of the study estimates indicate that shocks to GNP are mostly permanent. Haan and Zelhorst (1993) observe that the traditional unit root tests fail to discard the null hypothesis of a unit root which exhibits stationarity of output in 12 OECD countries with the exception of US. Similarly, Li (2000) shows that China's output series is trend stationary while employing unit root tests with structural breaks for the empirical analysis carried over the period 1952 to 1998.

Chang et al. (2005) intensely reject the null of unit root process for one-third in 26 African countries during 1960–2000. Based on the empirical results, their study suggests that fiscal and/or monetary policies are expected to have only provisional impacts on the real output levels of over one-third out of 26 African countries. Narayan (2007) rejects the unit root null hypothesis for G7 countries at the 5% level except for Germany and Italy, over the period from 1870–2001, while employed Lagrange Multiplier test. In a similar vein, Narayan (2008) investigates whether GDP per capita for 15 Asian countries is panel stationary. The study indicates prodigious evidence of panel stationarity of real GDP per capita for different panels in the context of Asian countries. The empirical findings of Chen (2008) favor the view that the real GDP per capita of six countries namely Australia, France, Germany, Japan, UK and USA is illustrated by a stationary process when making use of one-break unit root test. However, the study rejects the null of unit root for 11 of 19 developed countries' real GDP per capita when employed the two-break unit root test. Thus, it suggests that results are reliable with the view that business cycles show stationary fluctuations around a deterministic trend. Chang et al. (2010) empirical results direly reject the unit root process for most of the Chinese provinces during 1952–1998 while the null doesn't get rejected for 11 out of 25 provinces.

Cuestas and Garratt (2011) observe evidence of a worldwide stationary ESTAR process around a nonlinear deterministic trend in more or less half of the studied countries. The study further adds that our findings reveal that nonlinearities act on real GDP series, while abandoning them; one can reach to ambiguous conclusions from unit root tests. Chang et al. (2011) confirm that real GDP is well exemplified by a non-linear mean returning process in three out of nine Central Eastern European (CEE) countries namely Bulgaria, Latvia and Romania during 1969–2009. Tiwari et al. (2012a) investigate

stationarity properties of GDP per capita for 17 Asian countries[4] and sub-panels during 1950–2009. The empirical results of the second-generation tests for unit root show stationarity of GDP per capita for the whole Asian panel and even for the East Asian and high-income Asian sub-panels as well. However, in the case of sub-panel for the South Asia, the study provides a weak indication for stationarity of GDP per capita. While, in another study by Tiwari et al. (2012b), the results show that real GDP per capita is nonlinear stationary indicating that shocks to economy by external or internal policies have lasting influence on real per capita GDP of SAARC countries during 1980–2010. Shen et al. (2013) find that a real shock would be lastingly affect the real per capita real GDP of three CEE countries namely, Bulgaria, Hungary and Poland during 1991–2012. The empirical evidence supports the real shocks which have a transitory influence on the long-run output levels, implying in these six CEE countries that their real GDP per capita settlement is a mean reversion in the direction of equilibrium values which shows periods of exploding behavior. The study further maintains that real GDP per capita follows a steady growth rate where policy implications then have transitory influences in the case of 6 CEE countries (i.e., Czech Republic, Estonia, Latvia, Lithuania, Romania, and Slovakia).

The findings of Jannati et al. (2013) reveal that the real GDP per capita over the period 1970–2009 in 5 countries is stationary while carrying out empirical analysis of 16 countries in Asia with non-linear approaches to test for stationarity. Dogru (2014) evaluates the stationarity property of real GDP per capita fluctuations for a panel of 11 MENA countries during 1970–2012. The empirical results of both seemingly unrealated ADF (SURADF) and cross-sectional ADF (CADF) approaches lead support to stationarity of real GDP per capita. The study demonstrates that the shocks to the output are mostly lasting rather than temporary. The empirical findings of Chang et al. (2014) from numerous conventional unit root tests validate that real GDP per capita for 52 African countries is non-stationary, while, when the SPSM using the Panel KSS unit root test with a Fourier function is employed, the study observes that real GDP per capita are stationary in 50 out of 52 selected countries. The empirical outcomes suggest that real GDP per capita fluctuations for these countries are inclusively transitory during 1969v2011. Using the BCIPS panel unit root test by Zeren and İşlek (2019) in the case of D8 economies from 1960–2014 reveal that GDP per capita is stationary in multifactor situations in chosen D8 economies. Using Box-Jenkins approach (known as ARIMA), Nyoni and Muchingami (2019) suggest that Botswana GDP per capita is not mean reverting over the period 1960–2017 with stable estimates, indicating that in next few years, the overall standard of life will for Botswanian people will improve.

Table 1 portrays the summary of erstwhile empirical work available analyzing the stationarity property of output fluctuations. The forgoing analysis demonstrates that evidently the empirical results are inconclusive and still the stationarity property of output fluctuations is unsolved and further research on the topic under the study is required.

[4]Countries includes Bangladesh, Cambodia, China, Hong Kong, India, Indonesia, Japan, Malaysia, Myanmar, Pakistan, Philippines, Singapore, South Korea, Sri Lanka, Taiwan, Thailand, and Vietnam.

Table 1. Previous studies on stationarity properties of output fluctuations.

Author (s)	Timeperiod and chosen country	Econometric approach	Results regarding stationarity behavior
Emirmahmutoglu et al. (2019)	1929–2013, 48 States (US)	SPSM, ESTAR-LSTAR	M
Baktemur (2019)	1961–2017, Turkey	TAR and STAR models	S
Firat (2016)	1960–2011, 35 advanced countries	ADF, PP, KPSS, Panel unit root test (1st and 2nd generation)	N
Oskooe and Akbari (2015)	2000–2012, 27 OPEC Countries	Panel unit root test (IPS)	N
Azimi (2015)	2001–2014, Afghanistan	ADF, Phillips-perron	N
Lee (2014)	1979–2009, 31 provinces of China	SPSM and Panel KSS Unit Root Test	N
Tiwari and Suresh (2014)	1950–2009, 17 Asian Countries	Nonlinear panel unit root test	M
Ying et al. (2014)	1960– 2011, 32 African countries	Fourier Unit Root Test[5]	N
Aslanidis and Fountas (2014)	1870–2008, 19 industrial countries	CIPS, CADF	N
Ying et al. (2013)	1960–2011, 32 African countries	Fourier stationary unit root test	S
Ahmed et al. (2012)	1971–2009, Bangladesh	ADF, Phillips-Perron	S
Tiwari et al. (2012b)	1980–2010, SAARC	Nonlinear panel unit root	S
Furuoka (2011)	1970–2007, ASEAN-9 countries	1st and 2nd generation tests[6]	N
Chang et al. (2010)	1960–2000, 14 Asian countries	Panel stationary test	S
Murthy and Anoruo (2009)	1960–2007, 27 African countries	KSS or the NLADF test	S
Guloglu and Ivrendi (2008)	1965–2004, A sample of Ninteen countries in Latin America	CADF and SURADF panel unit root tests	S
Zhang et al. (2007)	1952–1998, 25 Chinese provinces	Panel SURADF tests	N
Ozturk and Kalyoncu (2007)	1950–2004, 27 OECD countries	Panel ADF	N
Hegwood and Papell (2006)	(1956–1996), (1950–1992), (1900–1987), OECD Countries	Panel unit root test with structural change	S
Chang et al. (2006)	1980–2004, 47 African countries	Panel SURDF tests	M
Chang et al. (2005)	1960–2000, 26 African countries	Nonlinear (Logistic) Unit Root Tests	M
Narayan (2004)	1952–1998, China, 24 provinces	Panel LM unit root test	S
Smyth (2003)	1952–1998, China, 24 provinces	IPS panel unit root test	M
Rapach (2002)	1956–1996, 13 OECD countries	Panel ADF	N
Fleissig and Strauss (1999)	1900–1987, 15 OECD	Panel unit root tests, bootstrap methods	S

1) S: stationary, N: non-stationary, M: mixed.

2) ADF = Augmented Dickey-Fuller, ARIMA = Autoregressive Integrated Moving Average.

3) CADF = Cross- Sectionally Augmented Dickey-Fuller, NLADF = Non-Linear Augmented Dickey-Fuller.

4) SPSM = Sequential Panel Selection Method, SURADF = Seemingly Unrelated Regression Augmented Dickey-Fuller.

[5]Enders and Lee (2012).

[6]1st and 2nd generation panel unit root tests respectively are those proposed in Levin et al (2002), Im and Shin (2003), Maddala and Wu (1999); Pesaran (2007) and Choi (2006).

3. Econometric approach and data

3.1. Econometric approach

This paper makes use of recently developed unit root tests developed by Aydin and Pata (2020) based on a general wavelet spectral approach. Working in parallel to Aydin and Pata (2020) and Yazgan and Ozkan (2015), the following DGP is considered which takes into account the smooth structural change as well: $x_t = \gamma(t) + \epsilon_t$
where, $\gamma(t)$ is unknown deterministic component (Becker et al., 2006), given by:

$$\gamma(t) = \beta \sum_{i=1}^{n} [(2i-1)^{-1} sin\{(2\pi(2i-1)kt)/T\}] \quad (1)$$

Note that "*k*" and "*n*" respectively denotes frequency of fourier term and deterministic component and when n = 1, the series contains a smooth break and when n > 1, break becomes more sharp and abrupt (see Aydin and Pata (2020) and Yazgan and Ozkan (2015) for more details). The case of smooth break (n = 1) is considered by Aydin and Pata (2020) by using the Wavelet ADF (WADF) test by Eroglu and Soybiligen (2018). The same is considered in this study and is given below:

$$\Delta Y_{1,t} = \sum_{i=1}^{p} \theta_i \Delta Y_{1,t-i} + \tau Y_{1,t-1} + \delta \sin\left(\frac{2\pi kt}{T}\right) + \epsilon_t \quad (2)$$

where, $Y_{1,t}$ indicates scaling coefficients that show low frequency components obtained via wavelet filter (we used Haar filter, which according to Aydin and Pata (2020) is powerful). The focus is made on testing the following null and alternative hypotheses:

H_0: $\tau = 0$ (unit root) against H_1: $\tau < 0$ (no unit root)

The null is tested via standard ADF statistic:

$$ADF_t^* = \left(\hat{\tau} - \tau_{H_0}\right)/SE(\hat{\tau}) \quad (3)$$

where, $\hat{\tau}$ and $SE(\hat{\tau})$ are the estimate of τ and its corresponding standard error.

To carryout FWADF unit root test, a two-step procedure suggested in Enders and Lee (2012) is adopted, where, model in Equation (2) is estimated for different frequencies, k = 1,2,…,5., and residuals sum of squares (RSS) is calculated for each model and then a model is selected among all these candidate models which RSS. In the next step, a standard t-test is applied to has lowest value of assess non-linearity and if fourier term in Equation (2) is found to be insignificant then WADF unit root test is applied, and in case of significant fourier term, the FWADF unit root test is applied. The critical values are obtained by following guidelines in Becker et al. (2006) and the same are provided in Table 10 (A–C) in Supplementary for different sample sizes that we considered in this study.

3.2. Data and its sources

We use annual time series data on real GDP per capita of all countries across the world. It is measured in constant 2010 US dollars. The data source is WDI 2020, the World Bank database. The total number of countries selected for the analysis are 177 out of a total available 218 countries on WDI. For the remaining 41 countries, either the data was not available at WDI or the data span was less than 25 years. We set minimum limit to 25 data points to get reasonable power of the wavelet tests

considered in this study even under small samples. The countries are classified into seven different regions (East Asia and Pacific Region, Europe and Central Asia, Latin America and the Caribbean, Middle East and North Africa, North America, South Asia and Sub-Saharan Africa) as per guidelines of World Bank. Note that the idea of classifying countries is not necessary, however, this is done to present the empirical results in a more meaningful way as most of the time, the empirical researchers are interested in carrying out analysis by considering a particular region. The same countries can be sub categorized as per different income groups as well, but we thought it better to present the analysis region-wise as this will give us deep insights of the issue at hand and it will portray a clear picture for different regions of the world which is currently not available anywhere in the existing literature. The time period for most of the countries is 1960 to 2018, while for some countries, we use a different time period to make use of maximum available data for the analysis of chosen countries. The names of countries along with their three-digit code as per WDI guidelines and the selected time period is provided in each table for clarity. The results of basic summary statistics are calculated but are not reported here to save space but these are available from authors upon request.

4. Empirical findings and discussions

This section provides results of wavelet-based unit root tests—the WADF and FWADF. Please note that as per World Bank, the total number of countries included in East Asia and Pacific Region are 38. Among these 38 countries, we are able to get data of 26 of them with at-least 25 observations, and carried out analysis for these 26 countries reported in Table 2. The empirical findings reveal useful insights of the behavior of the time series under consideration. Specifically, only one country, Brunei Darussalam is found to be stationary under both specifications (constant as well as constant and trend) while for 4 out of 26 countries (Brunei Darussalam, Vanuatu, Samoa and Cambodia), the null of non-stationarity gets rejected under constant and trend specification and for 3 out of 26 countries (Japan, Micronesia Fed. Sts. and Brunei Darussalam), null gets rejected under only constant specification. Overall, for 6 countries (Japan, Micronesia Fed. Sts., Vanuatu, Samoa, Cambodia and Brunei Darussalam), the null of unit root gets rejected under any of the two specifications (with constant and constant plus trend) considered. So in total, out of 26 countries, the null hypothesis that the series has a unit root gets rejected by 6 countries while for the rest of 20 countries, the series is found to be stationary and null couldn't get rejected by the wavelet tests considered.

The results related to countries included in Europe and Central Asia are provided in Table 3. According to guidelines by World Bank, the total number of categories in this region are 58. From these 58 countries, we are able to get data of 46 of them with at-least 25 observations, and carried out analysis for these 46 countries. The empirical findings reveal useful insights of the behavior of the time series under consideration. Specifically, in case of model with constant specification, 7 out of 46 countries namely, France, Greece, Georgia, Tajikistan, Ukraine, Russian Federation and Belarus are found to be stationary while rest of 39 countries have non-stationary per capita GDP, and when the constant and trend specification is considered, 21 countries out of 46, namely, Spain, Finland, Greece, Iceland, Norway, Andorra, Albania, Tajikistan, Kyrgyz Republic, Ukraine, Azerbaijan, Czech Republic, Kazakhstan, North Macedonia, Romania, Slovenia, Hungary, Slovak Republic, Bosnia and Herzegovina and Serbia are found to be stationary while rest of 25 countries have non-stationary per capita GDP and for three countries (Greece, Tajikistan and Ukraine), the null of unit root gets rejected under both specifications considered (constant and constant plus trend), while for 25 countries the null

gets rejected under any of the two specifications considered. So in total, out of 46 countries, the null hypothesis that the series has a unit root gets rejected by 25 countries while for the rest of 21 countries, the series is found to be stationary and null couldn't get rejected by any of the specifications considered.

Table 2. East Asia and Pacific Region.

S. No.	Country	Code	Time span	sample size	With Constant						With Constant and Trend					
					k	p	FWA DF	t-stat	p	WA DF	k	p	FWA DF	t-stat	p	WA DF
1	Australia	AUS	1960–2018	59	1	0	−1.13	−2.55***	-	-	1	0	0.28	−2.13**	-	-
2	China	CHN	1960–2018	59	4	1	0.17	2.17	1	0.24	4	1	0.09	1.87	1	0.14
3	Fiji	FJI	1960–2018	59	5	1	0.20	−1.94**	-	-	1	1	−4.07	3.13	1	−2.51
4	Indonesia	IDN	1960–2018	59	3	0	3.07	−2.20**	-	-	3	0	−0.37	−2.20**	-	-
5	Japan	JPN	1960–2018	59	5	0	−2.72*	−1.72*	-	-	5	0	−0.41	−1.68*	-	-
6	Korea, Rep.	KOR	1960–2018	59	1	0	0.86	−3.46***	-	-	1	0	−2.02	−2.92***	-	-
7	Myanmar	MMR	1960–2018	59	1	1	0.12	−2.25**	-	-	5	1	−1.62	−2.00**	-	-
8	Malaysia	MYS	1960–2018	59	3	0	3.12	−1.98**	-	-	3	0	−0.32	−1.76*	-	-
9	Philippines	PHL	1960–2018	59	3	1	1.38	−1.36	1	1.40	1	1	−3.97	4.79	1	−0.01
10	Papua New Guinea	PNG	1960–2018	59	3	0	−1.37	−2.75***	-	-	1	1	−3.29	2.40	1	−2.22
11	Singapore	SGP	1960–2018	59	3	0	2.20	−0.90	0	2.46	3	0	−1.73	−2.16**	-	-
12	Thailand	THA	1960–2018	59	4	0	3.02	2.61	0	2.41	4	0	−1.34	2.60	0	−1.49
13	Hong Kong SAR, China	HKG	1961–2018	58	4	0	2.28	2.06	0	1.93	4	0	−2.06	2.38	0	−1.83
14	Kiribati	KIR	1970–2018	49	1	2	−8.38	1.56	3	−3.75***	1	2	−6.97	1.48	3	−2.46
15	New Zealand	NZL	1970–2018	49	1	0	−0.22	−1.57*	-	-	5	1	−2.67	−1.75*	-	-
16	Brunei Darussalam	BRN	1974–2018	45	1	2	−2.81	−1.55*	-	-	1	2	−4.52**	−2.63**	-	-
17	Vanuatu	VUT	1979–2018	40	3	2	0.00	3.24	2	-0.56	4	2	−3.45	1.71	3	−5.08***

Continued on next page

S. No.	Country	Code	Time span	sample size	With Constant						With Constant and Trend					
					k	p	FWADF	t-stat	p	WADF	k	p	FWADF	t-stat	p	WADF
18	Mongolia	MNG	1981–2018	38	1	0	1.01	−2.76***	-	-	5	2	−0.71	2.34	0	−0.28
19	Tonga	TON	1981–2018	38	5	0	−0.28	−1.16	0	−0.37	2	0	−4.04	2.37	0	−2.42
20	Macao SAR, China	MAC	1982–2018	37	5	1	−1.30	1.87	1	−1.32	2	1	−1.50	−1.81**	-	-
21	Samoa	WSM	1982–2018	37	2	1	0.56	2.96	0	−0.07	1	2	−4.17	1.32	2	−3.82**
22	Lao PDR	LAO	1984–2018	35	1	2	1.88	−1.29*	2	1.66	2	0	10.94	−10.7***	-	-
23	Vietnam	VNM	1984–2018	35	3	1	1.90	0.53	1	2.24	3	0	0.34	4.71	0	−0.48
24	Micronesia, Fed. Sts.	FSM	1986–2018	33	1	0	−4.42**	−3.27***	-	-	1	0	−3.69	−3.95***	-	-
25	Tuvalu	TUV	1990–2018	29	3	0	−1.61	1.53	0	−1.44	3	0	−2.83	1.24	0	−2.62
26	Cambodia	KHM	1993–2018	26	3	1	0.99	−1.70**	-	-	3	0	−5.13***	−2.40**	-	-

Note: k = frequency; p = optimal lag length chosen via SIC; ***, ** and * denote significance at 1%, 5% and 10% respectively. WADF is used for the cases where t-statistic is found to be insignificant.

The empirial results for the Latin America and the Caribbean region are presented in Table 4 and as per World Bank, this region constitutes of a total of 42 countries. We were lucky to obtain data on 36 countries comprising of at-least 25 annual observations and thus, the empirical analysis is done for the 36 countries. The empirical findings provide detailed analysis of data series considered. Specifically, considering the model with constant specification, 7 out of 36 countries, namely, Bahamas, Suriname, Venezuela RB, Jamaica, Barbados, Dominica and Aruba are found to have a stationary per capita GDP, while rest of 29 countries have non-stationary per capita GDP, and in case of model with constant and trend specification, 12 countries out of 36, namely, Bahamas, Belize, Brazil, Ecuador, Guatemala, Suriname, Trinidad and Tobago, Venezuela RB, Jamaica, Switzerland, Grenada and Aruba are found to have stationary per capita GDP, while rest of the 19 countries have non-stationary per capita GDP. In addition, 5 countries (Bahamas, Suriname, Venezuela RB, Jamaica and Aruba) have stationary per capita GDP under both specifications, while 14 out of selected 46, have per capita GDP stationary under either of the two specifications. These include, Bahamas, Belize, Brazil, Ecuador, Guatemala, Suriname, Trinidad and Tobago, Venezuela RB, Jamaica, Switzerland, Barbados, Dominica, Grenada and Aruba. So in total, out of 36 countries, the null hypothesis that the series has a unit root gets rejected by 14 countries while for the rest of 22 countries the series is found to be non-stationary and null couldn't get rejected by any of the tests considered.

Table 3. Europe and Central Asia.

S. No.	Country	Code	Time span	sample size	With Constant						With Constant and Trend					
					k	p	FWKSS	t-stat	p	WADF	k	p	FWKSS	t-stat	p	WADF
1	Austria	AUT	1960–2018	59	1	0	−2.39	−1.79*	-	-	1	1	−1.76	−1.89**	-	-
2	Belgium	BEL	1960–2018	59	2	0	−0.81	1.56	0	−1.55	1	1	−2.38	−1.36	1	−2.18
3	Denmark	DNK	1960–2018	59	2	0	−0.60	1.75	0	−1.31	1	0	−3.32	−2.42**	-	-
4	Spain	ESP	1960–2018	59	2	2	−0.58	2.16	2	−1.11	3	1	−4.10	0.89	1	-4.16***
5	Finland	FIN	1960–2018	59	3	0	−0.25	2.52	0	−0.72	3	1	−3.12	1.71	1	-3.47**
6	France	FRA	1960–2018	59	2	0	−2.13	1.51	0	−2.94**	2	0	0.02	1.50	0	−0.52
7	United Kingdom	GBR	1960–2018	59	1	0	−1.53	−1.96**	-	-	1	0	−2.56	−2.28**	-	-
8	Greece	GRC	1960–2018	59	1	1	−3.05*	−1.95*	-	-	3	1	−3.09	1.28	1	-3.17*
9	Iceland	ISL	1960–2018	59	3	0	0.21	1.66	0	−0.12	2	1	−4.70***	−2.68***	-	-
10	Italy	ITA	1960–2018	59	2	1	−1.70	1.24	1	−1.94	2	0	1.04	1.37	0	1.06
11	Luxembourg	LUX	1960–2018	59	1	0	−2.21	−2.89***	-	-	1	1	−3.08	−3.25***	-	-
12	Netherlands	NLD	1960–2018	59	1	1	−2.16	−2.18**	-	-	5	1	−2.67	1.10	1	−2.70
13	Norway	NOR	1960–2018	59	1	1	−1.92	−1.54*	1	−1.17	1	1	−3.47*	−3.18***	-	-
14	Portugal	PRT	1960–2018	59	2	2	−1.53	2.85	2	−1.72	2	1	0.34	2.78	1	-2.57
15	Sweden	SWE	1960–2018	59	3	0	0.81	2.55	0	0.17	3	0	−1.20	2.30	0	-1.62
16	Turkey	TUR	1960–2018	59	3	0	2.97	−0.67	0	3.30	3	0	2.08	−1.56*	-	-
17	Georgia	GEO	1965–2018	54	2	1	−3.03	−1.52*	1	−2.65*	1	1	−4.38	3.13	1	−2.57
18	Andorra	AND	1970–2018	49	1	1	−1.66	−1.85**	-	-	2	1	−1.15	1.95	1	−3.09*
19	Germany	DEU	1970–2018	49	4	0	−0.56	−1.39	0	−0.42	4	0	−3.11*	−1.58*	-	-
20	Greenland	GRL	1970–2018	49	1	0	−0.75	−1.28	0	0.01	1	1	−2.19	1.41	1	−1.86
21	Ireland	IRL	1970–2018	49	4	1	0.71	−1.38	3	1.33	2	1	−2.67	1.70	1	−2.49
22	Monaco	MCO	1970–2018	49	4	2	2.44	−1.84**	-	-	4	2	0.59	−1.80**	-	-
23	Cyprus	CYP	1975–2018	44	2	0	−1.69	1.97	0	−1.56	1	1	−2.35	−1.41*	-	-

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S. No.	Country	Code	Time span	sample size	With Constant						With Constant and Trend					
					k	p	FWKSS	t-stat	p	WADF	k	p	FWKSS	t-stat	p	WADF
24	Albania	ALB	1980–2018	39	1	1	−0.49	−4.54***	-	-	4	1	−2.21	−1.21	3	−3.79***
25	Bulgaria	BGR	1980–2018	39	2	0	3.12	3.55	0	1.23	4	1	−1.61	−2.49**	-	-
26	Isle of Man	IMN	1984–2017	34	4	0	1.67	−2.51**	-	-	2	2	−2.25	1.95	2	-2.61
27	Tajikistan	TJK	1985–2018	34	2	1	−3.35**	−2.14**	-	-	2	2	−4.90	0.97	3	−10.35***
28	Kyrgyz Republic	KGZ	1986–2018	33	1	1	−0.37	−3.23***	-	-	4	2	−5.67	−0.91	3	−9.98***
29	Turkmenistan	TKM	1987–2018	32	1	1	3.00	−4.31***	-	-	5	2	−2.96	2.84	2	−1.91
30	Ukraine	UKR	1887–2018	32	1	1	−3.89***	−2.29**	-	-	5	2	−5.31	1.67	3	−5.08***
31	Uzbekistan	UZB	1987–2018	32	1	2	4.39	−6.00***	-	-	1	2	0.51	−3.48***	-	-
32	Russian Federation	RUS	1989–2018	30	5	2	−2.09	1.53	3	-2.97**	5	2	−3.25	2.16	3	−2.92
33	Armenia	ARM	1990–2018	29	3	1	−2.14	−3.07***	-	-	3	2	−1.51	−1.99**	-	-
34	Azerbaijan	AZE	1990–2018	29	1	1	−3.24	−4.00***	-	-	1	1	−4.60***	−4.27***	-	-
35	Belarus	BLR	1990–2018	29	1	2	−10.15***	−9.70***	-	-	1	1	−2.25	−10.7***	-	-
36	Czech Republic	CZE	1990–2018	29	2	1	−0.52	3.95	1	−0.49	2	2	−3.89	3.81	3	−3.97**
37	Kazakhstan	KAZ	1990–2018	29	5	2	−2.38	1.82	2	−2.22	1	1	−5.00**	−3.00***	-	-
38	North Macedonia	MKD	1990–2018	29	1	1	0.35	−1.96**	-	-	1	0	−2.14	−1.31*	0	−5.57***
39	Romania	ROU	1990–2018	29	2	0	3.32	5.05	1	0.48	2	2	0.19	2.63	3	−3.17*
40	Slovenia	SVN	1990–2018	29	2	1	−2.09	1.73	3	−1.74	1	1	−6.36***	−4.68***	-	-
41	Hungary	HUN	1991–2018	28	2	1	−0.25	−1.57**	1	−0.39	2	1	−4.46	2.48	1	−3.52**
42	Slovak Republic	SVK	1992–2018	27	2	0	0.88	4.94	0	0.20	3	2	−5.01***	−2.62**	-	-
43	Estonia	EST	1993–2018	26	4	0	−0.83	1.45	0	−0.76	2	0	−3.39	2.59	0	−1.97
44	Bosnia and Herzegovina	BIH	1994–2018	25	1	2	−2.29	3.30	2	−2.28	2	2	−5.44	2.75	3	−5.91***
45	Latvia	LVA	1994–2018	25	2	0	−1.76	1.87	0	−0.56	2	0	−4.69	4.77	1	−2.33
46	Serbia	SRB	1994–2018	25	5	2	−1.47	−1.52**	2	−1.66	4	2	−4.76	2.23	2	−3.34*

Note: k = frequency; p = optimal lag length chosen via SIC; ***, ** and * denote significance at 1%, 5% and 10% respectively. WADF is used for the cases where t-statistic is found to be insignificant.

Table 4. Latin America and The Caribbean.

S. No.	Country	Code	Time span	sample size	With Constant						With Constant and Trend					
					k	p	FWKSS	t-stat	P	WADF	k	p	FWKSS	t-stat	P	WADF
1	Argentina	ARG	1960–2018	59	4	0	−1.12	1.07	0	−0.67	1	0	−3.44	2.33	1	−2.55
2	Bahamas	BHS	1960–2018	59	1	0	−4.46***	−3.41***	-	-	1	1	−4.26**	−2.64***	-	-
3	Belize	BLZ	1960–2018	59	1	1	−2.90	−2.83***	-	-	1	1	−4.21**	−3.05***	-	-
4	Bolivia	BOL	1960–2018	59	3	1	−0.65	−2.22***	-	-	1	1	−5.32	4.61	1	−2.47
5	Brazil	BRA	1960–2018	59	5	1	−1.73	1.78	1	−1.72	2	1	−3.97**	−2.81***	-	-
6	Chile	CHL	1960–2018	59	1	0	−0.21	−3.28***	-	-	1	0	−0.29	−2.29**	-	-
7	Colombia	COL	1960–2018	59	3	2	1.95	−2.64***	-	-	1	1	−3.70	2.61	1	−2.37
8	Costa Rica	CRI	1960–2018	59	3	0	1.89	−2.02**	-	-	3	0	−0.10	−2.03***	-	-
9	Dominican Republic	DOM	1960–2018	59	5	0	4.34	1.86	0	3.99	5	0	1.60	1.87	0	1.31
10	Ecuador	ECU	1960–2018	59	2	1	−1.30	−2.23**	-	-	2	1	−4.08**	−2.63***	-	-
11	Guatemala	GTM	1960–2018	59	3	1	−1.14	−2.29**	-	-	1	1	−3.82	2.15	1	−2.95*
12	Guyana	GUY	1960–2018	59	3	1	2.15	−3.28***	-	-	3	1	0.35	−3.06***	-	-
13	Honduras	HND	1960–2018	59	4	0	0.33	1.40	0	0.10	1	0	−5.98	5.41	0	−1.32
14	Haiti	HTI	1960–2018	59	1	1	−2.96	2.71	1	−1.35	2	1	−3.20	−3.66***	-	-
15	Mexico	MEX	1960–2018	59	5	0	−1.80	−1.90**	-	-	5	0	−1.83	−1.68*	-	-
16	Nicaragua	NIC	1960–2018	59	1	1	−2.02	1.46	1	−1.68	1	1	−2.51	2.04	1	−1.45
17	Panama	PAN	1960–2018	59	3	0	3.15	−0.62	0	3.45	1	0	−1.17	1.48	0	1.39
18	Peru	PER	1960–2018	59	1	1	−0.30	−2.32**	-	-	4	1	−1.60	−1.03	1	−0.43

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S. No.	Country	Code	Time span	sample size	With Constant						With Constant and Trend					
					k	p	FWKSS	t-stat	P	WADF	k	p	FWKSS	t-stat	P	WADF
19	Puerto Rico	PRI	1960–2018	59	1	0	−2.57	−2.27**	-	-	1	0	−1.75	−2.31**	-	-
20	Paraguay	PRY	1960–2018	59	4	1	−0.08	1.88	1	−0.31	4	1	−1.94	1.33	1	−2.44
21	Suriname	SUR	1960–2018	59	2	1	−4.04***	−2.58***	-	-	2	1	−5.17***	−3.62***	-	-
22	Trinidad and Tobago	TTO	1960–2018	59	1	1	−2.79	−2.26**	-	-	5	1	−3.15*	−2.07**	-	-
23	Uruguay	URY	1960–2018	59	3	0	1.55	−3.06***	-	-	3	1	−0.68	−2.96***	-	-
24	St. Vincent and the Grenadines	VCT	1960–2018	59	1	0	−1.37	−2.63***	-	-	1	0	−2.69	−2.06**	-	-
25	Venezuela, RB	VEN	1960–2018	59	1	1	−3.21	1.94	1	−2.44*	2	1	−3.85**	−2.06**	-	-
26	El Salvador	SLV	1965–2018	54	4	1	−1.05	−1.45	1	−1.10	4	1	−1.71	−1.42	1	−1.77
27	Jamaica	JAM	1966–2018	53	1	1	−3.72**	−2.43***	-	-	2	1	−4.14	2.25	3	−4.81***
28	Switzerland	CHE	1970–2018	49	3	0	0.36	2.19	0	−0.16	2	1	−4.87**	−1.91**	-	-
29	Cuba	CUB	1970–2018	49	4	1	−0.78	1.23	1	−0.95	1	1	−3.20	2.37	1	−2.04
30	Barbados	BRB	1974–2018	45	1	0	−2.30*	−1.85**	-	-	5	1	−2.21	−2.32**	-	-
31	Antigua and Barbuda	ATG	1997–2018	42	5	0	−1.86	−1.43	0	−1.85	5	0	−1.80	−1.35*	0	−1.87
32	Dominica	DMA	1977–2018	42	1	1	−3.67**	−2.40**	-	-	1	1	−1.09	−2.35**	-	-
33	Grenada	GRD	1977–2018	42	2	0	0.18	1.60	2	−0.16	2	1	−4.31	1.15	1	−4.35**
34	St. Kitts and Nevis	KNA	1977–2018	42	3	0	−1.80	−0.99	0	−1.73	3	0	−0.21	−0.93	0	−0.62
35	St. Lucia	LCA	1977–2018	42	2	0	−2.57	−1.74*	-	-	3	2	−2.68	1.00	3	−2.52
36	Aruba	ABW	1986–2017	32	5	1	−1.66	1.60	0	−6.00***	4	0	−7.33***	−2.30***	-	-

Note: k = frequency; p = optimal lag length chosen via SIC; ***, ** and * denote significance at 1%, 5% and 10% respectively. WADF is used for the cases where t-statistic is found to be insignificant.

Table 5. Middle East and North Africa.

S. No.	Country	Code	Time span	sample size	With Constant						With Constant and Trend					
					k	P	FWKSS	t-stat	P	WADF	k	p	FWKSS	t-stat	p	WADF
1	Algeria	DZA	1960–2018	59	1	2	−2.09	−1.31	2	−1.60	2	2	−6.60***	−6.31***	-	-
2	Egypt, Arab Rep.	EGY	1960–2018	59	2	2	1.80	−2.47***	-	-	2	2	−2.69*	−2.39**	-	-
3	Israel	ISR	1960–2018	59	3	0	−0.83	−2.34**	-	-	3	0	−3.20*	−2.99***	-	-
4	Iran, Islamic Rep.	IRN	1960–2017	58	1	1	−2.76	1.10	1	-2.52*	1	1	−3.07	1.72	1	−2.49
5	Oman	OMN	1965–2018	54	1	0	−4.39***	−2.57***	-	-	1	0	−2.80	−2.49**	-	-
6	Tunisia	TUN	1965–2018	54	2	0	0.58	1.54	0	0.81	2	1	−0.73	0.81	1	−1.55
7	Morocco	MAR	1966–2018	53	1	0	0.27	−1.25	1	1.33	2	0	−1.51	−1.15	1	−1.36
8	Iraq	IRQ	1968–2018	51	5	0	−0.27	1.88	0	−0.35	1	0	−3.60	2.44	0	−2.14
9	Saudi Arabia	SAU	1986–2018	51	4	2	−3.12**	−1.94**	-	-	4	2	−2.85	−1.79**	-	-
10	Malta	MLT	1970–2018	49	2	2	1.23	2.13	2	0.59	5	1	−3.74**	−1.83**	-	-
11	United Arab Emirates	ARE	1975–2018	44	2	2	−3.21	1.10	2	-3.00**	2	2	−3.90	1.84	2	−3.23*
12	Jordan	JOR	1975–2018	44	1	1	−3.14*	−1.81**	-	-	4	1	−2.69	−0.76	1	−3.13*
13	Bahrain	BHR	1980–2018	39	5	2	−3.86***	−2.63**	-	-	5	2	−3.46**	−2.48**	-	-
14	Lebanon	LBN	1988–2018	31	1	1	−3.92**	−2.17**	-	-	3	1	−3.77	2.99	3	−3.38*
15	Yemen, Rep.	YEM	1990–2018	29	4	1	−1.70	−1.36*	-	-	4	2	2.33	−1.87**	-	-
16	Kuwait	KWT	1992–2018	27	3	1	−2.13	2.02	1	−2.05	1	1	−3.52	−2.95***	-	-
17	West Bank and Gaza	PSE	1994–2018	25	1	0	1.01	−3.93***	-	-	3	2	−1.95	1.11	3	−3.26*

Note: k = frequency; p = optimal lag length chosen via SIC; ***, ** and * denote significance at 1%, 5% and 10% respectively. WADF is used for the cases where t-statistic is found to be insignificant.

Table 5 provides the findings of unit root tests for the Middle East and North African region which comprises of 21 countries in total (as per World Bank). A careful inspection yields data on 17 out of 21 countries with a minimum of 25 years of span. Thus, the sample for this group comprises of 17 countries. The empirical results are interesting in the sense that for the model with constant specification, 7 out of 17

countries, namely, Iran, Islamic Rep., Oman, Saudi Arabia, United Arab Emirates, Jordan, Bahrain and Lebanon are found to have a stationary series for per capita GDP, while the rest of 10 countries have non-stationary per capita GDP, similarly, for the model with constant and trend specification, 9 countries out of 17 considered, namely, Algeria, Egypt, Israel, Malta, United Arab Emirates, Jordan, Bahrain, Lebanon and West Bank & Gaza are found to be stationary while rest of 8 countries have non-stationary per capita GDP. In addition, 4 countries (United Arab Emirates, Jordan, Bahrain and Lebanon) have stationary per capita GDP under both specifications, while 12 out of selected 17, have per capita GDP stationary under either of the two specifications. So in total, out of 17 countries, the null hypothesis that the series has a unit root gets rejected by 12 countries while for the rest of 5 countries, the series is found to be non-stationary and null couldn't get rejected under any of the two specifications considered.

The North American region includes only three countries and all three have been considered in this study due to availability of relevant data. The results for these countries are provided in Table 6. The results suggest that for the model with constant specification, none of the three selected countries has stationary per capita GDP i.e., all countries have non-stationary per capita GDP, while, for the model with constant and trend specification, only one country (Bermuda) out of three, has stationary per capita GDP while the other two Canada and United States have non-stationary per capita GDP and none of the selected countries is found to be stationary under both specifications (constant as well as constant and trend), while only one country (Bermuda) is considered stationary under either of the two specifications. So for all the countries included in North America region, the GDP per capita series is found to be trend stationary and its in case of Bermuda only.

Table 6. North America.

S. No.	Country	Code	Time span	sample size	With Constant						With Constant and Trend					
					k	P	FWKSS	t-stat	p	WADF-stat	k	p	FWKSS	t-stat	p	WADF
1	Bermuda	BMU	1960–2013	54	1	0	−2.90	−2.07**	-	-	2	1	−4.22*	−3.19***	-	-
2	Canada	CAN	1960–2018	59	3	0	0.24	1.69	0	−0.18	2	0	−2.63	−1.98**	-	-
3	United States	USA	1960–2018	59	3	0	0.13	1.57	0	−0.18	3	0	−2.44	2.00	0	−2.14

Note: k = frequency; p = optimal lag length chosen via SIC; ***, ** and * denote significance at 1%, 5% and 10% respectively. WADF is used for the cases where t-statistic is found to be insignificant.

The total number of countries in South Asia is eight. A total of 6 countries were able to meet the goal of containing a minimum of 25 years of data, so these countries are sorted for this region and final analysis is carried out for these and is presented in Table 7. The empirical findings suggest that under constant specification, the per capita GDP of all 6 selected countries is found to be stationary, while, under constant and trend specification, the per capita GDP of 5 out of 6 selected countries is found to be stationary. In addition, none of the selected countries is found to be stationary under both specifications while only one is considered stationary under either of the two specifications. Thus, out of 6 countries, the null hypothesis that the series has a unit root gets rejected by only one country, while for the rest of 5 countries the series is found to be stationary and null couldn't be rejected under any of the two specifications considered.

There are 48 countries in the Sub-Saharan Africa region (as per World Bank). A sample of 43 is finalized after removing the countries that had fewer number of observations, fewer than 25 (the set limit). The empirical results presented in Table 8 reveal that for the model under constant specification, 6 out of 43 countries, namely, Niger, Togo, Zambia, Zimbabwe, Guinea-Bissau and Equatorial Guinea are found to be stationary while rest of 37 countries have non-stationary per capita GDP, while for the model with constant and trend specification, 7 countries out of 43, namely, Botswana, Central African Republic, Cameroon, Zimbabwe, Gambia, Equatorial Guinea and Tanzania are found to be stationary while rest of 36 countries have non-stationary per capita GDP. In addition, 2 countries (Zimbabwe and Equatorial Guinea) have stationary per capita GDP under both specifications, while 11 out of selected 43 countries, have per capita GDP stationary under either of the two specifications. Overall, out of 43 selected countries, the null hypothesis of unit root gets rejected by 11 countries while for the remaining 32 countries we find evidence in favor of null under any of the two specifications considered.

Table 7. South Asia.

S. No.	Country	Code	Time span	sample size	With Constant						With Constant and Trend					
					K	p	FW KSS	t-stat	p	WA DF	k	p	FWK SS	t-stat	p	WA DF
1	Bangladesh	BGD	1960–2018	59	4	0	9.11	1.46	0	8.82	4	0	4.10	1.38	0	3.85
2	Bhutan	BTN	1980–2018	39	1	0	3.48	−1.55 *	0	5.65	5	0	0.63	1.31	0	0.45
3	India	IND	1960–2018	59	5	2	6.31	1.35	2	6.08	5	2	5.81	1.30	2	5.58
4	Sri Lanka	LKA	1961–2018	58	2	0	6.56	−1.49 *	0	7.41	2	0	1.50	−1.35	0	1.53
5	Nepal	NPL	1960–2018	59	3	0	7.58	−1.20	0	7.97	3	0	2.08	−1.17	0	2.14
6	Pakistan	PAK	1960–2018	59	5	1	0.43	−1.62 *	-	-	2	1	−3.93	1.84	1	−3.37 **

Note: k = frequency; p = optimal lag length chosen via SIC; ***, ** and * denote significance at 1%, 5% and 10% respectively. WADF is used for the cases where t-statistic is found to be insignificant.

In addition to the results presented in Table 2–8, the overall summary of these empirical results is presented in Table 9 to get a quick idea of the key results. These results exhibit that out of a total of 218 countries, 177 were selected for the analysis with at-least 25 years of available data and out of these 177 countries, the per capita GDP series is found to be stationary for 70, while for the rest of 107 countries it is found to be non-stationary. To get a summary containing exact names of countries for which per capita GDP is stationary, the findings are presented in the form of a bar graph (Figure 1), where a bar of unit length against a country is added, indicating the rejection of null of unit root. The empirical estimates related to stationarity of real GDP per capita income in 70 countries of this study are consistent with the findings by Narayan (2004), Murthy and Anoruo (2009), Ying et al. (2013) and Baktemur (2019), while results of non-stationarity of GDP per capita in 107 countries are in accord with Rapach (2002), Ozturk and Kalyoncu (2007), Aslanidis and Fountas (2014), Firat (2016), and Oskooe and Akbari (2015). Overall results are consistent with the findings by Smyth (2003), Chang et al. (2005, 2006), Tiwari and Suresh (2014), Emirmahmutoglu et al. (2019).

An important distinction of the empirical results presented in this study from the existing studies is that the tests used in present study makes use of both frequency and time dimensions into account which is ignored by all previous studies. As emphasized in Aydin and Pata (2020), ignoring information regarding frequency domain and structural change may lead to biased results. Thus, the findings presented in present study are more complete and robust and provide a better picture of the issue at hand which his ignored by previous studies considering the same issue and hence, the present study fills this much needed gap.

Table 8. Sub-Saharan Africa.

S. No.	Country	Code	Time span	sample size	With Constant						With Constant and Trend					
					k	p	FWK SS	t-stat	p	WADF	k	p	FWK SS	t-stat	p	WADF
1	Burundi	BDI	1960–2018	59	1	0	−1.46	2.68	0	−1.41	2	0	−1.53	−2.71***	-	-
2	Benin	BEN	1960–2018	59	4	0	1.95	−2.21**	-	−	4	0	−1.37	−1.68*	-	-
3	Burkina Faso	BFA	1960–2018	59	1	0	2.20	−1.24	0	3.86	3	0	0.35	1.09	0	0.30
4	Botswana	BWA	1960–2018	59	2	0	1.00	−1.70*	-	−	3	0	−3.08	−1.12	0	−3.11*
5	Central African Republic	CAF	1960–2018	59	1	0	−2.57	2.41	0	−0.68	2	1	−5.37***	−3.81***	-	-
6	Cote d'Ivoire	CIV	1960–2018	59	1	1	−4.25	3.65	1	−1.84	1	1	−4.15	3.03	1	−2.56
7	Cameroon	CMR	1960–2018	59	5	2	−2.93	1.26	1	−2.16	5	2	−3.30	1.32	2	−3.20*
8	Congo, Dem. Rep.	COD	1960–2018	59	4	1	−1.51	−3.29***	-	-	1	2	−5.05	4.08	2	−2.27
9	Congo, Rep.	COG	1960–2018	59	2	1	−2.33	−2.82**	-	-	2	1	−0.67	−3.01***	-	-
10	Gabon	GAB	1960–2018	59	3	0	−2.37	−1.69*	-	-	3	0	−2.00	−1.91**	-	-
11	Ghana	GHA	1960–2018	59	1	0	2.18	−3.38***	-	-	3	0	0.39	−1.25	0	0.61
12	Kenya	KEN	1960–2018	59	3	0	−1.12	−1.54*	0	−0.68	1	0	−3.92	4.73	0	−1.35
13	Lesotho	LSO	1960–2018	59	4	0	3.26	2.45	0	2.60	1	0	−1.45	1.02	0	−0.10
14	Madagascar	MDG	1960–2018	59	2	0	−1.49	1.48	0	−1.21	2	0	−0.01	1.50	0	−0.76
15	Mauritania	MRT	1960–2018	59	2	2	−1.32	−0.73	2	−1.12	1	2	−1.86	1.49	3	−1.93
16	Malawi	MWI	1960–2018	59	3	0	−0.98	−2.12**	-	-	1	0	−4.17	3.37	0	−1.37
17	Niger	NER	1960–2018	59	5	2	−3.24**	−2.33**	-	-	5	1	−1.35	−1.77*	-	-
18	Nigeria	NGA	1960–2018	59	2	1	−1.97	−1.14	1	−1.62	1	1	−3.75	3.14	1	−1.93
19	Rwanda	RWA	1960–2018	59	2	0	0.36	−1.83**	-	-	1	0	−2.90	3.68	0	−0.23
20	Sudan	SDN	1960–2018	59	1	0	1.66	−1.90**	-	-	3	0	−0.10	−1.18	0	−0.10

Continued on next page

S. No.	Country	Code	Time span	sample size	With Constant						With Constant and Trend					
					k	p	FWKSS	t-stat	p	WADF	k	p	FWKSS	t-stat	p	WADF
21	Senegal	SEN	1960–2018	59	1	1	1.03	−2.73***	-	-	3	0	0.48	1.38	0	0.44
22	Sierra Leone	SLE	1960–2018	59	2	0	−1.94	−2.05**	-	-	1	0	−4.32	4.03	0	−1.27
23	Seychelles	SYC	1960–2018	59	3	0	0.70	−2.14**	-	-	3	0	−1.83	−1.79*	-	-
24	Chad	TCD	1960–2018	59	1	0	−0.85	−2.28**	-	-	1	0	−0.77	−1.00	0	−1.48
25	Togo	TGO	1960–2018	59	1	1	−3.88	2.28	1	−2.94**	1	1	−5.62	4.17	1	−2.93
26	South Africa	ZAF	1960–2018	59	2	1	−2.34	−1.54*	1	−1.75	2	1	−2.82	−1.88**	-	-
27	Zambia	ZMB	1960–2018	59	5	2	−3.11	2.10	2	−3.06**	5	2	−1.77	1.96	2	−1.63
28	Zimbabwe	ZWE	1960–2018	59	5	2	−3.86***	−2.63**	-	-	5	2	−3.46**	−2.48**	-	-
29	Gambia, The	GMB	1966–2018	53	5	0	−2.42	1.62	0	−2.38	5	0	−2.19	1.61	3	−4.30***
30	Mali	MLI	1967–2018	52	4	0	0.12	−2.46**	-	-	4	0	−1.81	−1.90**	-	-
31	Guinea−Bissau	GNB	1970–2018	49	5	0	−2.56	−0.90	0	−2.65*	1	0	−2.47	1.05	0	−2.56
32	Eswatini	SWZ	1970–2018	49	3	0	1.19	2.42	0	0.58	3	0	−1.68	2.06	0	−2.15
33	Mauritius	MUS	1976–2018	43	4	2	3.79	4.09	3	4.09	4	2	2.10	4.37	3	0.97
34	Angola	AGO	1980–2018	39	4	1	−2.36	−2.70**	-	-	1	2	1.33	−2.74***	-	-
35	Comoros	COM	1980–2018	39	4	1	−3.02	2.01	1	−2.08	4	1	−1.87	1.87	2	−1.64
36	Cabo Verde	CPV	1980–2018	39	3	1	−0.27	2.18	1	−0.47	3	1	−2.19	1.75	1	−2.65
37	Equatorial Guinea	GNQ	1980–2018	39	1	2	−6.33***	−6.77***	-	-	4	2	−3.38**	−1.72*	-	-
38	Mozambique	MOZ	1980–2018	39	1	1	1.28	−3.43***	-	-	1	2	−0.48	−1.41*	-	-
39	Namibia	NAM	1980–2018	39	1	1	0.19	−3.42***	-	-	4	0	−2.46	−1.80**	-	-
40	Ethiopia	ETH	1981–2018	38	1	0	3.36	−3.42***	-	-	1	0	2.30	−1.77**	-	-
41	Uganda	UGA	1982–2018	37	1	1	−1.24	−2.45**	-	-	4	1	−2.57	−0.86	1	−2.58
42	Guinea	GIN	1986–2018	33	1	2	8.15	6.22	2	1.58	2	0	2.78	−3.79***	-	-
43	Tanzania	TZA	1988–2018	31	5	2	0.62	−1.29*	2	0.86	2	1	−5.04	5.04	1	−5.48***

Note: k = frequency; p = optimal lag length chosen via SIC; ***, ** and * denote significance at 1%, 5% and 10% respectively. WADF is used for the cases where t-statistic is found to be insignificant.

Table 9. Summary of overall results.

Region	Total countries	Selected countries	Stationary under only "Constant" specification (A)	Stationary under only "Constant& trend" specification (B)	Stationary under both specifications (A∩B)	Stationary either specification (AUB)	Total stationary	Total Non-Stationary
East Asia and Pacific	38	26	3	4	1	6	6	20
Europe and Central Asia	58	46	7	21	3	25	25	21
Latin America and the Caribbean	42	36	7	12	5	14	14	22
Middle East and North Africa	21	17	7	9	4	12	12	5
North America	3	3	0	1	0	1	1	2
South Asia	8	6	0	1	0	1	1	5
Sub-Saharan Africa	48	43	6	7	2	11	11	32
Total	218	177	30	55	15	70	70	107

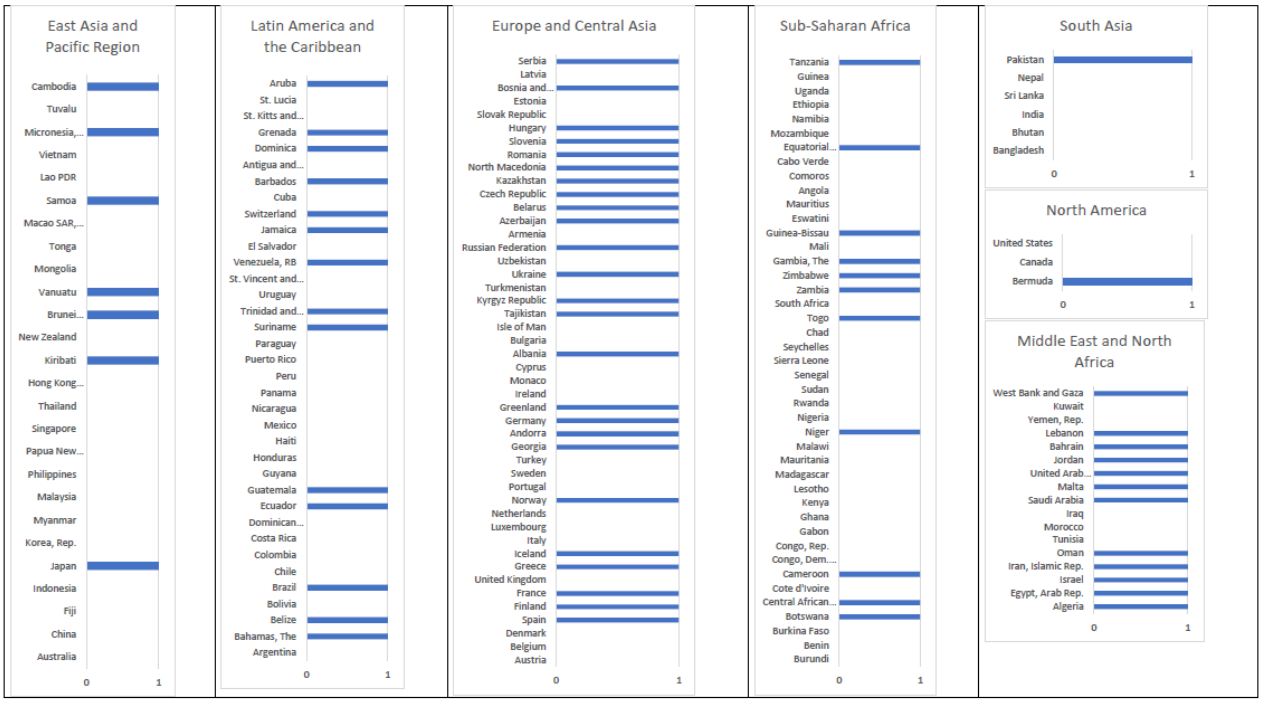

Figure 1. Key Findings (Note: A Bar of length one, against a country means null of unit root gets rejected for it).

5. Summary and conclusions

The role of GDP per capita cannot be overlooked measuring socio-economic status of individual and country's economic condition. Policy makers usually need stationary time series data for modeling and forecasting. They avoid using non-stationary data which are changeable and cannot be used for

modeling and forecasting due to its erratic (unstable) behavior. The empirical findings derived using non-stationary time series data may be forged. The non-stationary data may be converted in to stationary data which yields more reliable, consistent results. Therefore, it is indispensable to determine whether the GDP per capita income has a trend stationary or a difference stationary process. Thus, the broad aim this study is to evaluate the stationarity properties of GDP per capita for a panel of 177 out of total 218 countries over 1960–2018 with at-least 25 years of available annual data, considering seven sub-samples (regions) categorized by world bank. We utilized historical, longer period updated data, and covered the entire world which is never evaluated by any of erstwhile studies before. We implemented the newly developed unit root tests (WADF and FWADF) by Pata and Aydin (2020) based on discrete wavelet transform to analyze the stationarity properties. An important advantage of these wavelet unit root tests is that these have the ability to consider the smooth structural break into account which is not considered by any of the previous existing wavelet tests such as the one proposed by Fan and Gencay (2010). Thus, the empirical results presented in this study are better than existing approaches and provide new insight of long-standing issue of testing the stationarity of per capita GDP series across the globe.

The empirical estimates reveal that GDP per capita is found to be stationary in 70 including 6 out of 26 East Asia and Pacific countries, 25 out of 46 Europe and Central Asian countries, 14 out of 36 Latin America and the Caribbean countries, 12 out of 17 Middle East and North African countries, 1 out of 3 three selected countries in North America, 1 out of 6 South Asian countries and 11 out of 43 countries in Sub-Saharan Africa, while for the rest of 107 countries, the real GDP per capita is found to be non-stationary. It is obvious from the empirical findings that GDP per capita income is stationary in several countries. The stationary time series of per capita GDP is desirable for any public policy across the world, where as the non-stationary GDP per capita needs to be transformed into stationary data in order to avoid inconsistency in the data. These findings suggest that it is imperative for policy makers to check the stationary properties of real GDP per capita series prior to utilizing it for any policy formulation using the empirical approaches used in this study which not only considers both freqency and time domain into account but also smooth structural changes as well.

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Conflicts of interest

All authors declare no conflicts of interest in this paper.

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