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Empirical Trends and Mean Reversion in GDP: Comparing Low, Middle and High-Income Countries during 1960-2016

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ABSTRACT

This paper examines the Gross Domestic Product (GDP) series across countries for recent empirical trends and mean reversion properties. The sample consists of countries categorized according to income thresholds defined by the World Bank. 14 low-income, 34 middle-income and 25 high-income countries are studied over the period 1960-2016. In order to examine mean reversion properties, the study applies three univariate unit root tests and four panel unit root tests. Results show that low- income countries struggle to achieve a sustained secular increase in per capita real GDP whereas high income countries enjoy long periods of secular upward trend in per capita real GDP. The study also finds strong presence of unit roots in low and middle-income countries, which means that effects of shocks stay for long periods in these countries. Results for high income countries are mixed. These findings are also crucial because a proper specification of mean reversion (unit root) improves long term forecasting of GDP.

Keywords: Unit Roots; Low, Middle and High-income Countries JEL Codes: C23, C33, O57

INTRODUCTION

"Lord, who made the lion and the lamb, you decreed I should be what I am; would it spoil some vast, eternal plan, if I were a wealthy man?" (Fiddler on the Roof)

Income and economic growth disparities across countries is a subject of immense interest in economics. Transition of a low-income economy whose majority of the population struggles with poverty, into a modernized high-income country with its population enjoying material prosperity is a desirable goal. The strategy to achieve this goal cannot be formulated in the absence of sufficient understanding of dynamics of output generation and the behavior of output data series. It is in this context that empirical and econometric analysis of output data becomes crucial. This paper attempts to understand the differences in GDP trends in low, middle and high-income countries. For this research objective, the paper documents and analyses the empirical trends in Per Capita Real Gross Domestic Product (GDP) over the period 1960-2016.

The second question investigated by this paper relates to whether shocks to an economy have permanent or transitory effects. This study compares whether low, middle and high-income countries differ in this respect. These shocks could be either positive or negative, and due to technological innovations or monetary and fiscal policy or external environment. Econometrically, this question can be understood in terms of 'stationarity' or 'mean reversion' of output time series.[1] A stationary time series is one that exhibits a tendency to revert to a mean level. Presence of unit root in data indicates non-stationarity and lack of mean reversion. Moreover, study of mean reversion in output data helps macro econometricians to forecast GDP better. It is in this context that analysis of unit roots is extremely important. Therefore, from a macroeconomic perspective, this study is central to understanding the movements in output.

A brief, selected overview of empirical studies on unit roots shows that various techniques[2] have been applied, different time periods, different samples of countries have been studied. The pioneering study on US for the period 1860-1970 found that GDP has

[1] A time series is weakly or covariance stationary if the mean and auto-covariances of the series do not epend on time.

[2] For instance, Box-Jenkins methodology, Structural Modelling, Autocorrelation and Partial Autocorrelation functions, various unit root tests for univariate series and for panels.

unit root (1). However, for Switzerland, Great Britain, France and West Germany, it was found that for time series over 1947-1983, unit root is present (2). Some significant studies that followed included other countries of OECD but found widely conflicting results (3-15). Among low and middle-income countries, studies on Latin American countries (16, 17), Asian countries (18, 19) and African countries (20-25) continued to find opposing results even while using a wide array of techniques.

Interestingly therefore, an unambiguous conclusion is not yet achieved in this vast literature. This study attempts to fill this gap in the existing literature by applying a combination of univariate time series as well as newer panel methods, particularly for cross-sectionally independent panels to arrive at an answer.

METHODOLOGY

Data Description

The study uses annual data for per capita real GDP (in constant 2010 U.S. dollars) for the period 1960 to 2016. The data is taken from World Development Indicators, World Bank. 3 panels are constructed for the purpose of comparison of results: Panel A consisting of 14 low income countries, Panel B consisting of 34 middle income countries and Panel C with 25 high income countries. The countries included in the study appear in Tables on descriptive statistics in the Appendix. The map of the world showing countries by income is also presented in the Appendix.

Table 1: Summary Statistics for Per Capita Real GDP (1960-2016): Country Panels

	Low Income	Middle Income	High Income
Mean	566.7554	2976.839	28748.01
Median	589.1949	2838.446	28237.85
Maximum	663.6774	4814.348	44546
Minimum	449.603	1610.648	12057.36
Std. Dev.	62.51042	844.1285	10363.29
Skewness	-0.339837	0.388569	0.055942
Kurtosis	1.796009	2.579287	1.688547
Jarque-Bera	4.539935	1.854735	4.114517
Probability	0.103316	0.395594	0.127804
Observations	798	1938	1425

In order to describe and characterize the data, Table 1 shows some descriptive statistics for the three panels for the period 1960-2016.[3] Mean value for low income countries is 566.75 USD, for middle income countries 2976.83 USD and for high income countries it is 28748 USD. The vast differences in dispersion are also equally stark, with high income countries having highest standard deviation. per capita real GDP is negatively skewed in low income countries which means i.e. left tail is longer than right tail and most of the data observations are clustered towards the right side. This means most values of the income lie towards the higher end of the distribution. An asymmetrical distribution with a long tail to the left (lower values) has a negative skew if the peak is toward the right. Frequency distribution for output series in middle income countries exhibits positive skewness while that of high income countries is nearly symmetrical. Kurtosis measure indicates a tall sharp peak in the distribution near the mean per capita GDP for middle income countries. Low and high-income countries have no excess kurtosis over a bell curve. Jarque-Bera statistic reveals that the hypothesis of normality of the distribution cannot be rejected for any of the panels.

Analysing selected descriptive statistics for low income countries, we find that mean value of per capita real GDP is the lowest for Burundi, at less than 300 USD while Zimbabwe (at 1070 USD) has the highest mean in the sample. The highest variation in mean as measured by standard deviation is for Liberia. The minimum income and the maximum income of Liberia lies in the extremes of the distribution. At its lowest, Liberia had per capita real GDP of 115 USD which is the lowest for any country in this sample. Again, the maximum income of Liberia is the highest of all countries, even more than that of Zimbabwe (which, as already noted, has the highest mean). However, coefficient of variation (CV) is a more consistent measure of dispersion as it is independent of units. From column 5, we can see that Liberia did indeed have the highest coefficient of variation too.

Next, among the middle-income countries we find that Gabon has the highest while Bangladesh has the lowest mean per capita real GDP. Gabon at 9928 USD had twenty times the mean income of Bangladesh (487 USD). All the three South Asian countries (Bangladesh, India and Pakistan) included in our sample lie at the bottom of the ranking of

[3] Descriptive statistics consist of mean and median (measures of central tendency), maximum and minimum values, number of observations, standard deviation (measures of dispersion, skewness and kurtosis. Skewness is a measure of asymmetry of the distribution of the series around its mean. Kurtosis measures the peakedness or flatness of the distribution of the series. Jarque-Bera Statistic is a test statistic for testing whether the series is normally distributed. The link for tables discussed here is: https://bit.ly/2M0TA4L

countries. China had the highest dispersion over this period, as measured by coefficient of variation. For China, standard deviation was much higher than the mean. This is indicative of a non-normal distribution, amply corroborated by the Jarque-Bera statistic whose p-value is 0.0000. Now we discuss the Jarque-Bera statistic results. For 20 countries the null hypothesis of normal distribution is not rejected, at 5 percent level of significance. Among these, South Africa with the highest p-value, 0.9320, for the Jarque-Bera statistic is nearest to resembling a normal distribution. Of the 14 countries with non-normal distribution, ten are leptokurtic and four are platykurtic. From this table we also note that seven countries have negative skewness i.e. left tail is longer than right tail and most of the data observations are clustered towards the right side. These seven countries are: Algeria, Brazil, Congo Republic, Guatemala, Kenya, Mexico and Zambia.

Finally, among high income countries, Chile had the lowest mean income (7473 USD) and Luxembourg had highest (64800 USD). If we look at dispersion measured by coefficient of variation, Korea Republic had highest dispersion. Canada had lowest dispersion. 21 countries had a normal distribution. The four countries that do not have normal distribution are Chile, Luxembourg, Trinidad and Tobago and Uruguay.

Graphical Examination of Plots

Historical plots for the per capita real GDP for the period 1960-2016 for all the three panels are shown in Figure 1. From this graph, it can be seen that the high-income countries per capita real GDP increasing over time. The increasing trend in income in middle income countries is more clearly visible in Figure 2b. The upward trend for high income countries is also seen in Figure 2c. Interestingly, for low- income countries, where Figure 2a shows how fluctuations remain throughout the period and a secular upward trend fails to emerge, leave alone sustain for long period. Thus, Figure 1 hides the fluctuations experienced by low income countries.

Figures 2a, 2b and 2c show that differences among the three panels of countries are huge. The scale of y-axis in the three figures is vastly different, bringing out the differences more clearly. This can also be read off the first row in Table 1, which provides summary statistics for the three panels. While low-income countries have the mean income of 566 USD, middle income countries have 2976 USD and high-income countries are much higher, at 28748 USD.

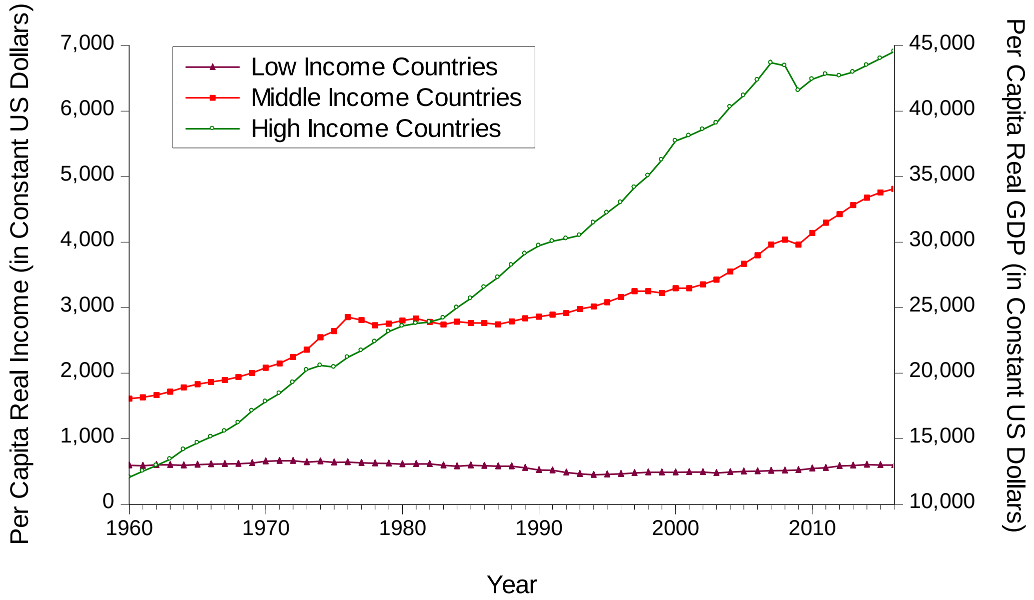

Figure 1: Per Capita Real GDP (in constant US Dollars): Country Panels

Figure 2 a): Low-Income Countries

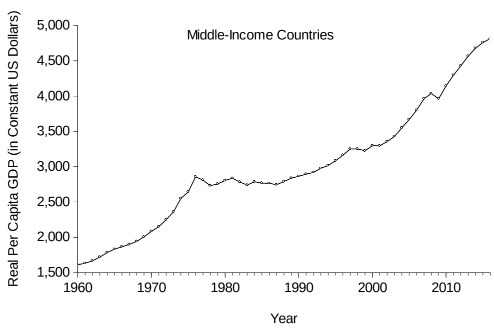

Figure 2 b): Middle-Income Countries

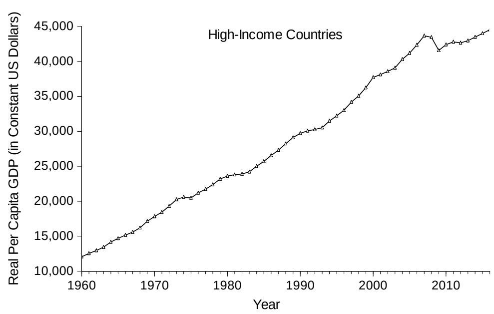

Figure 2 c): High-Income Countries

Figure 2: Per Capita Real GDP (in constant US Dollars)

Figure 3 (in Appendix) shows the time plots for each low-income country in our study. We differentiate between types of movements in the plots as follows: An upward trend throughout the period (Benin, Burkina Faso and Nepal), downward trend throughout the period (Niger, Congo Democratic Republic and Central African Republic) and more than two sharp changes in trend over the period (all other countries in the sample). In Figure 4 (in Appendix), we can examine the time plots of middle income countries: An upward trend throughout the period (Bangladesh, Costa Rica, Colombia, Democratic Republic, Belize, Brazil, Honduras, Malaysia, Pakistan, Lesotho, Mexico, Thailand and Turkey), a steady, constant GDP in the initial period and then an upward trend (Bolivia, China, Guyana, India and Sudan) and more than two turns in trend (all other countries). Plots of high-income countries in Figure 5 show that most countries saw an upward trend in per capita real GDP, disturbed only once by a dip around the Global Financial Crisis of 2008.

It can be inferred from the above graphical examination that low and middle-income countries went through many ups and downs in their per capita real GDP during this period. In these countries, an upward trend is not frequently achieved or sustained for prolonged periods. Low income countries in particular experienced more fluctuations than middle income countries. In contrast, during 1960-2016, high-income countries enjoyed upward trend in output; only a very serious crisis affected their trend adversely.

RESULTS

The empirical trends in section 2 raise a very pertinent question: do shocks and crises affect low, middle and high-income countries differently? Does the effect of a shock stay for different time periods in these three sets of countries? Is there a tendency for GDP to return to its mean level and trend? Is the tendency for mean reversion different in different groups of countries? These questions are important because they help us understand how to raise GDP using policy intervention if a shock's effect needs to be mitigated. We now conduct various tests for unit roots to answer these questions.

Univariate Unit Root Tests

For each country, GDP data is tested for unit roots using time series data.[4] We begin by conducting three tests. The first test, ERS - DFGLS, is a version of Augmented Dickey Fuller (ADF) test where the data is de-trended such that explanatory variables are eliminated from the test regression (26). Both variables in the ADF regression estimated are

[4] Time Series Data is data for a single variable collected over a period of time at a regular frequency, monthly or quarterly or annual. This data is ordered in a sequence.

in quasi- differenced form. Next, we apply KPSS test, with stationarity null hypothesis (27). Finally, we conduct another test, Ng Perron test, with four statistics, also based on GLS de-trended data (28). Results for the low-income countries are reported in Table 2. The absolute value of the ERS DFGLS statistic for all countries in this panel is less than the critical values. Critical values for all the statistics of all the tests are reported below each table. We cannot reject the null hypothesis of unit root. Thus, we conclude that according to this test, each country in the panel has a unit root. Next, we discuss results from Ng Perron test which consider 4 statistics: MZa, MZt, MSB and MPT.

Table 2: Individual Series Unit Root Tests on Per Capita Real GDP 1960-2016
Low Income Countries

Country	KPSS Test	Ng Perron Test				ERS-DFGLS
	LM-Stat	MZa	MZt	MSB	MPT	t-statistic
Benin	0.207	-4.313	-1.348	0.313	20.046	-1.183
Burkina Faso	0.202	-2.627	-1.056	0.402	31.591	-1.541
Burundi	0.184	1.687	1.100	0.652	37.545	-2.574
CAR	0.084	-14.117	-2.596	0.184	6.805	-2.832
Chad	0.222	-2.567	-0.847	0.330	26.128	-0.495
CDR	0.237	-2.813	-1.091	0.388	29.608	-1.475
Liberia	0.123	-4.144	-1.329	0.321	20.849	-1.563
Malawi	0.112	-9.952	-2.209	0.222	9.253	-2.159
Nepal	0.126	-4.825	-1.552	0.322	18.879	-1.581
Niger	0.185	-8.707	-2.074	0.238	10.511	-2.055
Rwanda	0.229	-1.321	-0.620	0.470	46.128	-0.481
Senegal	0.212	-4.327	-1.260	0.291	19.250	-1.463
Sierra Leone	0.146	-7.785	-1.807	0.232	12.115	-1.530
Zimbabwe	0.132	-4.072	-1.387	0.341	21.929	-1.427

Notes: Critical Values of the test statistics

	KPSS Test	Ng Perron Test				ERS-DFGLS
	LM-Stat	MZa	MZt	MSB	MPT	t-statistic
1% level	0.216	-23.8	-3.42	0.143	4.03	-3.751
5% level	0.146	-17.3	-2.91	0.168	5.48	-3.174
10% level	0.119	-14.2	-2.62	0.185	6.67	-2.875

Remarkably, on count of all these four statistics, for each low-income country in our sample, we are unable to reject the null hypothesis. We again conclude that all low-income countries have a unit root in their per capita real GDP. Now we discuss the results from the KPSS test whose null is stationarity of the series. Here, we get mixed results. For four countries (viz. Chad, Congo Democratic Republic, Rwanda and Senegal) LM statistic shows that Ho is rejected at 1 percent level of significance, for four countries. We reject the null for four countries (viz Benin, Burkina Faso, Burundi and Niger) at 5 percent and for (viz. Liberia, Nepal, Sierra Leone and Zimbabwe) at 10 percent. For the remaining two countries (Central African Republic and Malawi), the null hypothesis is not rejected. Thus, we can conclude that per capita real GDP is non-stationary in all fourteen countries as per the two unit root tests and in twelve countries as per KPSS test.

The results for middle income countries are presented in Table 3. The DF GLS statistic shows that only for one country, i.e. Lesotho, the null hypothesis is rejected. Ng Perron test results show that null hypothesis is rejected for Cameroon by all the four statistics and for Algeria by both the MZ statistics. KPSS test gives mixed results for middle income countries too, like the low-income countries discussed earlier. As per KPSS LM statistic, the stationarity null hypothesis is rejected for seven countries: Bangladesh, Botswana, China, Ghana, India and Sudan. For fifteen countries, non- stationarity is indicated at 1 percent. These countries are Belize, Bolivia, Brazil, Congo Republic, Cote d Ivoire, Gabon, Guyana, Kenya, Malaysia, Nicaragua, Nigeria, Pakistan, Peru, Thailand and Zambia. For eight countries (viz. Algeria, Cameroon, Ecuador, Honduras, Lesotho, Philippines, South Africa and Turkey) non-stationarity is indicated at 5 percent level of significance. For four countries i.e. Colombia, Costa Rica, Dominican Republic and Guatemala, the null hypothesis cannot be rejected even at 10 percent level of significance, thus indicating stationarity for these countries.

For high-income countries, results from all the univariate tests are presented in Table 4. The DF GLS and Ng Perron’s statistics all show that the null hypothesis of unit root cannot be rejected. KPSS test however gives mixed results. For ten countries, LM statistic shows that the null hypothesis is rejected at 1 percent. These ten countries are Austria, Belgium, Denmark, France, Italy, Japan, Republic of Korea, Norway, Portugal and Singapore. For eleven countries (viz. Canada, Chile, Finland, Greece, Iceland, Israel, Netherlands, Spain, United Kingdom, United States and Uruguay) stationarity cannot be accepted at 5 percent and for Trinidad and Tobago at 10 percent. For the remaining three countries (viz. Australia, Luxembourg and Sweden) stationarity is indicated.

Table 3: Individual Series Unit Root Tests on Per Capita Real GDP 1960-2016: Middle Income Countries

Country Name	LM	MZa	MZt	MSB	MPT	t-stat
Algeria	0.145	-14.438	-2.686	0.186	6.314	-2.046
Bangladesh	0.232	-0.218	-0.104	0.476	54.164	-0.224
Belize	0.171	-13.170	-2.367	0.180	8.010	-1.880
Bolivia	0.188	-4.259	-1.262	0.296	19.590	-1.125
Botswana	0.227	-3.123	-1.053	0.337	24.849	-0.926
Brazil	0.170	-4.869	-1.447	0.297	18.086	-1.203
Cameroon	0.126	-24.568	-3.505	0.143	3.710	-1.659
China	0.258	-1.651	-0.776	0.470	44.087	-1.008
Colombia	0.112	-8.548	-2.038	0.238	10.763	-2.009
Congo Rep	0.190	-8.440	-2.027	0.240	10.889	-1.906
Costa Rica	0.113	-7.954	-1.955	0.246	11.564	-2.160
Cote D Ivoire	0.150	-3.397	-1.284	0.378	26.463	-1.304
Domin Rep	0.101	-8.639	-2.013	0.233	10.777	-2.080
Ecuador	0.130	-6.681	-1.825	0.273	13.641	-1.858
Gabon	0.211	-4.553	-1.449	0.318	19.567	-1.454
Ghana	0.226	-1.981	-0.740	0.374	31.826	-0.726
Guatemala	0.111	-7.360	-1.917	0.260	12.384	-1.977
Guyana	0.181	-4.666	-1.376	0.295	18.530	-1.322
Honduras	0.125	-9.710	-2.197	0.226	9.415	-2.327
India	0.238	0.718	0.464	0.647	99.042	-0.067
Kenya	0.185	-3.623	-1.342	0.370	25.088	-1.923
Lesotho	0.124	-10.558	-2.284	0.216	8.700	-3.731
Malaysia	0.175	-6.049	-1.618	0.267	14.954	-2.012
Mexico	0.213	-2.049	-0.889	0.434	37.547	-1.491
Nicaragua	0.154	-4.080	-1.320	0.324	21.156	-1.234
Nigeria	0.156	-3.058	-1.163	0.380	28.014	-1.784
Pakistan	0.210	-2.537	-1.013	0.399	31.777	-1.506
Peru	0.186	-6.013	-1.606	0.267	15.026	-1.480
Philippines	0.139	-8.367	-1.882	0.225	11.405	-1.518
South Africa	0.130	-5.551	-1.666	0.300	16.416	-1.734
Sudan	0.250	-3.561	-1.122	0.315	22.261	-1.095
Thailand	0.163	-9.145	-2.000	0.219	10.500	-1.879
Turkey	0.126	-9.967	-2.132	0.214	9.590	-2.526
Zambia	0.189	-2.894	-0.988	0.342	25.881	-0.326

Notes: Please see Table 2 for critical values of the test statistics

Table 4: Individual Series Unit Root Tests on Per Capita Real GDP: 1960-2016

High-Income Countries

Country	LM-Stat	MZa	MZt	MSB	MPT	t-statistic
Australia	0.078	-5.663	-1.561	0.276	15.834	-2.227
Austria	0.245	-0.442	-0.192	0.435	46.358	-0.159
Belgium	0.237	0.528	0.327	0.620	90.083	-0.379
Canada	0.202	-3.989	-1.222	0.306	20.683	-1.404
Chile	0.202	-5.261	-1.589	0.302	17.200	-1.636
Denmark	0.220	-0.505	-0.219	0.433	45.719	-0.658
Finland	0.195	-6.691	-1.578	0.236	13.780	-1.377
France	0.247	-1.721	-0.666	0.387	34.214	-0.609
Greece	0.178	-3.302	-1.058	0.320	23.289	-0.941
Iceland	0.212	-9.291	-2.099	0.226	10.037	-2.451
Israel	0.198	-1.971	-0.844	0.428	37.358	-1.350
Italy	0.260	-0.463	-0.204	0.440	46.979	-0.145
Japan	0.254	-1.548	-0.657	0.425	39.134	-0.634
Korea Rep	0.219	-0.883	-0.348	0.394	38.581	-0.282
Luxembourg	0.113	-7.599	-1.826	0.240	12.267	-1.734
Netherlands	0.151	-4.347	-1.267	0.292	19.208	-1.687
Norway	0.247	-2.142	-0.693	0.324	26.955	-0.313
Portugal	0.224	-3.061	-1.004	0.328	24.472	-1.026
Singapore	0.227	-0.359	-0.180	0.501	57.336	-0.754
Spain	0.183	-4.586	-1.326	0.289	18.562	-1.327
Sweden	0.113	-7.644	-1.885	0.247	12.085	-1.898
Tr - Tobago	0.141	-5.917	-1.718	0.290	15.399	-1.778
UK	0.164	-9.986	-2.034	0.204	10.004	-1.871
United States	0.208	-5.202	-1.383	0.266	16.653	-1.545
Uruguay	0.172	-17.109	-2.826	0.165	5.919	-2.741

Notes: Please see Table 2 for critical values of the test statistics

Table 5 summarizes the conclusions from these tests, based on 5 percent level of significance. All 14 low income countries and 25 high income countries contain unit root in their per capita real GDP series as per DF GLS and Ng Perron tests. KPSS test agrees with these two unit root tests only partially; for 8 low income countries and 21 high income countries, non-stationarity is indicated. For middle income countries, the match of conclusions between the unit root tests is nearly identical. All 34 middle income countries show non-stationarity as per DF GLS test and 32 of them as per Ng Perron test. KPSS test agrees with them only for 22 countries. Finally, in order to get an all-encompassing picture, we have calculated how many times non- stationarity is indicated (at 5 percent level of significance) for all the three tests combined. 85 percent test statistics indicated unit root for low income countries, 86 percent for middle income countries and 94 percent for high income countries.

Table 5: Summary of Results from Individual Unit Root Tests

	N	Number of Countries with unit root		
		KPSS Test	Ng- Perron Test	ERS DF-GLS Test
Panel A	14	8	14	14
Panel B	34	22	32	34
Panel C	25	21	25	25

Panel Unit Root Tests

Panel Data for a variable is collected for several entities (cross-sectional units) over time. This data combines the cross-sectional with the time dimension of the data. The emergence of panel unit root tests over the past two decades has been outstanding in both theoretical and applied arena. Panel unit root tests have higher power as they utilize the information in data from not only the time dimension (T) but also the cross- sectional dimension (N) of the panel. This allows for higher number of observations and hence higher power. For our study, these tests are particularly appropriate because our data is in the form of macro panels i.e. panels for whom both T and N are large.[5] The tests consider time series for a variable y, observed over T time periods (denoted by $t = 1, 2, . . . , T$) and for N cross-sectional units (countries in case of the present study) (denoted by $i = 1, 2, . . . , N$). The data generating process for $[Y_{NT}]$ (variable being tested for unit root), is considered to be a simple first-order autoregressive one, whose corresponding Dickey-Fuller Regression is then estimated.

The first test we conduct, proposed by Levin, Lin and Chu (LLC) assumes a homogeneous alternative hypothesis i.e. coefficient for the first order autoregressive term ξ in the estimated equation is same across all cross-sections (29). The testing procedure involves running a pooled fixed-effects regression. The test statistic is the t-statistic for ξ. This test statistic converges asymptotically, to standard normal distribution under H_0. Next, we conduct Im Pesaran Shin test (IPS), that assumes a heterogeneous alternative i.e. ξ in the estimated equation may not be same across the cross-sections (30). While LLC test pools the panel data, in IPS test, *t*- statistics for all the estimated ξ for all cross-sections (across the panels) are averaged which yields the IPS statistic. We conduct two more tests, MW and

[5] By convention, these tests are now classified into two categories based on the criterion whether they incorporate cross-sectional dependence or eliminate it. First generation of panel unit root tests that consider cross-sectional units to be independent are applied in this paper.

Choi tests, based on heterogenous alternative (31, 32). Both these tests combine p-values from individual time series unit root tests. For calculating the underlying statistic, MW test uses the ADF statistic whereas Choi test uses DFGLS statistic.

For each test discussed below, γ specification contains no deterministic effects, α specification includes individual effects and time trends.

Levin, Lin and Chu (2002) Test

Table 6 shows results based on adjusted t-statistics for two bandwidth parameters- Individual bandwidth parameters (Newey-West and common lag truncation parameter, as proposed by (29) ($\bar{K} = 3.21T^{1/3}$). For testing the robustness across kernels, 2 kernels- Bartlett kernel function and Quadratic Spectral kernel function were considered. Results for the models with time trend and without time trend are reported separately. For all statistics p-values are reported in parentheses, below the statistics in each row. For the γ specification, t* show unit root in all variables in all panels. This is true across kernels and bandwidth parameters.

Table 6: Levin, Lin and Chu (2002) Panel Unit Root Test

	$(t^*_\rho)\gamma_1$	$(t^*_\rho)\gamma_2$	$(t^*_\rho)\gamma_3$	$(t^*_\rho)\tau_1$	$(t^*_\rho)\tau_2$	$(t^*_\rho)\tau_3$
Panel A	17.6476 (1)	17.6476 (1)	17.6476 (1)	−0.4391 (0.3303)	0.2579 (0.6018)	−0.7861 (0.2159)
Panel B	17.209 (1)	17.209 (1)	17.209 (1)	-1.3133 (0.0945)	-0.4757 (0.3171)	-1.4327 (0.076)
Panel C	16.3972 (1)	16.3972 (1)	16.3972 (1)	−3.8134 (6.8532e − 05)	−4.9631 (3.4686e − 07)	−5.0999 (1.6991e − 07)

Notes: Panel A: Low Income Countries, Panel B: Middle Income Countries, Panel C: High Income Countries

$(t^*_\rho)\tau_1$ = Adjusted t-statistic with individual effects and time trends, using Bartlett kernel function and common lag truncation parameter

$(t^*_\rho)\tau_2$ = Adjusted t-statistic with individual effects and time trends, using Quadratic Spectral kernel function and individual bandwidth parameters (Newey-West)

$(t^*_\rho)\tau_3$ = Adjusted t-statistic with individual effects and time trends, using Bartlett kernel function and individual bandwidth parameters (Newey-West)

$(t^*_\rho)\gamma_1$-$(t^*_\rho)\gamma_3$ are the corresponding Adjusted t-statistics for the model with no individual effects

For the α specification, only per capita real GDP in low income and middle-income countries have unit root. If we include both intercepts and time trends in the specification, real GDP does not have unit root in any panel and per capita real GDP does not have unit root in high income countries. If we look at these results panel wise, we find that for low income countries panel, for τ model, there is unit root. γ specification. For middle income countries, results are exactly the same as for low income countries. For high income countries, results are different for PRGDP in γ and τ specifications, where there is no unit root. We may also note that results do not differ across kernels and bandwidth parameters individual effects but not time trends and τ specification with individual effects and time trends.

Im Pesaran and Shin (IPS) Test

Table 7 reports three statistics each for the α and τ specifications for IPS test. For low income and middle-income countries, unit root hypothesis is not rejected by any of the statistics. In high income countries, unit root hypothesis is not rejected by W_{bar} statistic for both the α and τ specifications. However, it is rejected by the other two statistics. Also, for robustness check, for all cases, two maximum lag orders (p = 6 and p =12) were considered but results did not differ across them.

Maddala and Wu (1999) and Choi (2001) Tests

Table 8 shows that as per both statistics P_{MW} and Z_{CHOI}, the null of unit root cannot be rejected for low income and middle income countries panels. Both statistics give same conclusions as per all the three specifications. Results for high income countries are not so unambiguous (as was in the case of IPS test). For the specification where individual effects are included by time trends are not, unit root hypothesis is rejected by both statistics P_{MW} and Z_{CHOI}.

Table 7: Im, Pesaran and Shin (2003) Panel Unit Root Test

	$W_{bar\alpha}$	$Z_{bar\alpha}$	Z^{DF}_{bar}	$W_{bar\tau}$	$Z_{bar\tau}$	$Z^{DF}{}_{bar}$
PANEL A	2.888 (0.9981)	2.9273 (0.9983)	3.4911 (-0.9998)	1.7351 (0.9586)	-1.1856 (0.1179)	-0.2196 (0.4131)
PANEL B	4.8297 (1)	4.9969 (1)	7.0082 (1)	3.0543 (0.9989)	-1.4445 (0.0743)	1.6966 (0.9551)
PANEL C	-8.7709 (0.9831)	-8.747 (0.042)	-10.8735 (0.8685)	2.1224 (0.8575)	-1.7282 (0.0039)	1.1191 (0.8685)

Notes: Panel A: Low Income Countries, Panel B: Middle Income Countries, Panel C: High Income Countries

Table 8: Fisher-Type Panel Unit Root Tests:
Maddala and Wu (1999) and Choi (2001) Tests

	$P_{MW}\,\gamma$	$Z_{CH}\,\gamma$	$P_{MW}\,\alpha$	$Z_{CH}\alpha$	$P_{MW}\,\tau$	$Z_{CH}\tau$
PANEL A	15.4205 (0.9736)	-1.681 (0.9536)	14.0852 (0.9866)	-1.8594 (0.9685)	15.3691 (0.9743)	-1.6879 (0.9543)
PANEL B	3.9877 (1)	-5.489 (-1)	43.6366 (0.9906)	-2.0891 (0.9817)	45.4306 (0.984)	-1.9353 (0.9735)
PANEL C	0.7939 (1)	-4.9206 (1)	132.8755 (0)	8.2876 (0)	46.8988 (0.5986)	-0.3101 (0.6218)

Notes: Panel A: Low Income Countries, Panel B: Middle Income Countries, Panel C: High Income Countries

DISCUSSION

Comparing results from the panel unit root tests, for α specification, identical conclusions for all panels are obtained, viz. unit root in low and middle-income countries coupled with no unit root in high income countries. (See columns 1-3 in Table 7 with columns 3-4 in Table 8) For the time trend included specification, results from two of the three IPS test statistics agree with both the Fisher-type tests. (See columns 4-6 in Table 7 with columns 5-6 in Table 8). This can be understood somewhat by the similarity in the statistics of these tests (33). Construction of statistics of all these three tests involves combining information from individual time series unit root tests. More specifically, while the standardized IPS test combines individual t-statistics, P_{MW} and Z_{CHOI} combine p-values from individual statistics. Another remark regarding heterogeneous panel unit root tests is that rejection of unit root hypothesis only indicates that some of the countries in the panel have stationarity, not all countries. This is in contrast to the conclusions from LLC test where the alternative hypothesis is that no country in the panel has unit root.

Finally, Table 9 provides a summary of conclusions from all the above four tests. Comparing results for the three panels, we find that for low income countries, unit root exists as per all the statistics. This means that in low and middle-income countries, GDP displays non-stationarity irrespective of model specification (i.e. whether time trends or individual effects are included or not). This result can therefore be said to be robust. However, for high income countries, results are mixed. 5 out of the 8 statistics considered in the study support unit root hypothesis whereas remaining 3 do not suggest unit root.

Table 9. Summary of Conclusions from First Generation Tests

	LLC		IPS		MW		ZCH	
	γ	τ	α	τ	γ	τ	γ	τ
Panel A	UR	UR	UR	UR	UR	UR	UR	UR
Panel B	UR	UR	UR	UR	UR	UR	UR	UR
Panel C	UR	No UR	No UR	No UR	UR	UR	UR	UR

The findings of the study are very far-reaching. The results suggest that GDP in low and middle-income countries behaves in a similar way but that this behavior is vastly different from high income countries. At lower levels of income, unit root is a robust characteristic property of the GDP data. Thus, any shocks to output stays in the economy for longer periods. This shock could be internal to the domestic economy (either fiscal or monetary policy, or demand side) or external (from global factors). In high income countries, effects of any shocks to GDP could be transitory or permanent. Results from present study do not yield conclusive answers for high income countries. We have till now discussed our results in terms of effects of shocks. Alternately, we can interpret our results in terms of mean reversion. GDP in low and middle-income countries exhibits no tendency towards reverting to mean level. As Pierre Perron pertinently notes,

". . . the presence of a unit root implies a stochastic non-stationarity instead of a deterministic one (such as a linear time trend). This distinction has profound implications for economic theory; in the former case, the ran-dom shocks have an enduring effect on future values of the variable, while in the latter, they have a vanishing effect" (34).

In contrast, for GDP in high income countries, there is only mixed evidence of a tendency to return to a mean level i.e. permanence of shocks has not been conclusively established by tests conducted in this study. When we discuss mean reversion, me may note here that trend in the mean has to be accounted for, as in the various specifications considered for our tests statistics.

CONCLUSIONS

This paper investigates the income differences across countries. Using World Bank data on GDP and World Bank's classification of countries, it first conducted a preliminary data analysis. The study finds more fluctuations in per capita real GDP for low-income countries while the high-income countries enjoy sustained periods of secular growth.

It is of significance to determine whether a shock to an economy has transient or permanent effects. In macro econometrics, this question is equivalent to asking whether the time series or panel data has unit roots. Towards answering this question, in this study we first conducted unit root tests for individual countries. Further, noting the potential for better utilization of both cross-section dimension (along with time dimension) in panel data, we conducted some panel unit root tests. The study finds that in low and middle-income countries, shocks have a permanent effect on GDP. Output in high income countries overcomes the effects of shocks more quickly. This means a recovery from a crisis would take longer in low and middle-income countries. In addition, we note that despite the negative connotation of the word 'shock', a positive sudden boost to output would have similar effect as one causing depression.

Our results are interesting from not just the specific research question posed here. They have implications beyond that because findings on mean reversion in GDP are helpful to infer the principal impulses driving business cycles, to infer better forecasts and to improve macroeconomic modelling apart from analyzing the impact of a shock. This would be of interest to evaluate the success of any policy across groups of countries governed by a single macroeconomic framework. Development economists would be interested in knowing whether the experience of low, middle and high-income countries differs fundamentally. In view of the fact that income and economic growth disparities across countries is not simply an academic issue but also has welfare implications, this study makes an important contribution.

One of the future directions of research in this area would be to conduct tests that allow for cross-sectional dependence in GDP panels. This can be done by using the second-generation panel unit root tests. Secondly, unit root tests on first differences of the GDP series might provide us with a better understanding of trends and fluctuations in the process of growth. We have taken some preliminary steps in this direction using plots of log-differenced GDP series (not presented here due to space constraints). These plots indicate towards stationarity. However, a more detailed and robust econometric analysis of the first differences of GDP series is required before we can reach any firm conclusions. Policy prescriptions would require further testing for firmer conclusions especially after considering that countries are interdependent. Further tests are also required for bringing out differences in low and middle-income countries in a better way. We leave these exercises as possible avenues for future research in this area.

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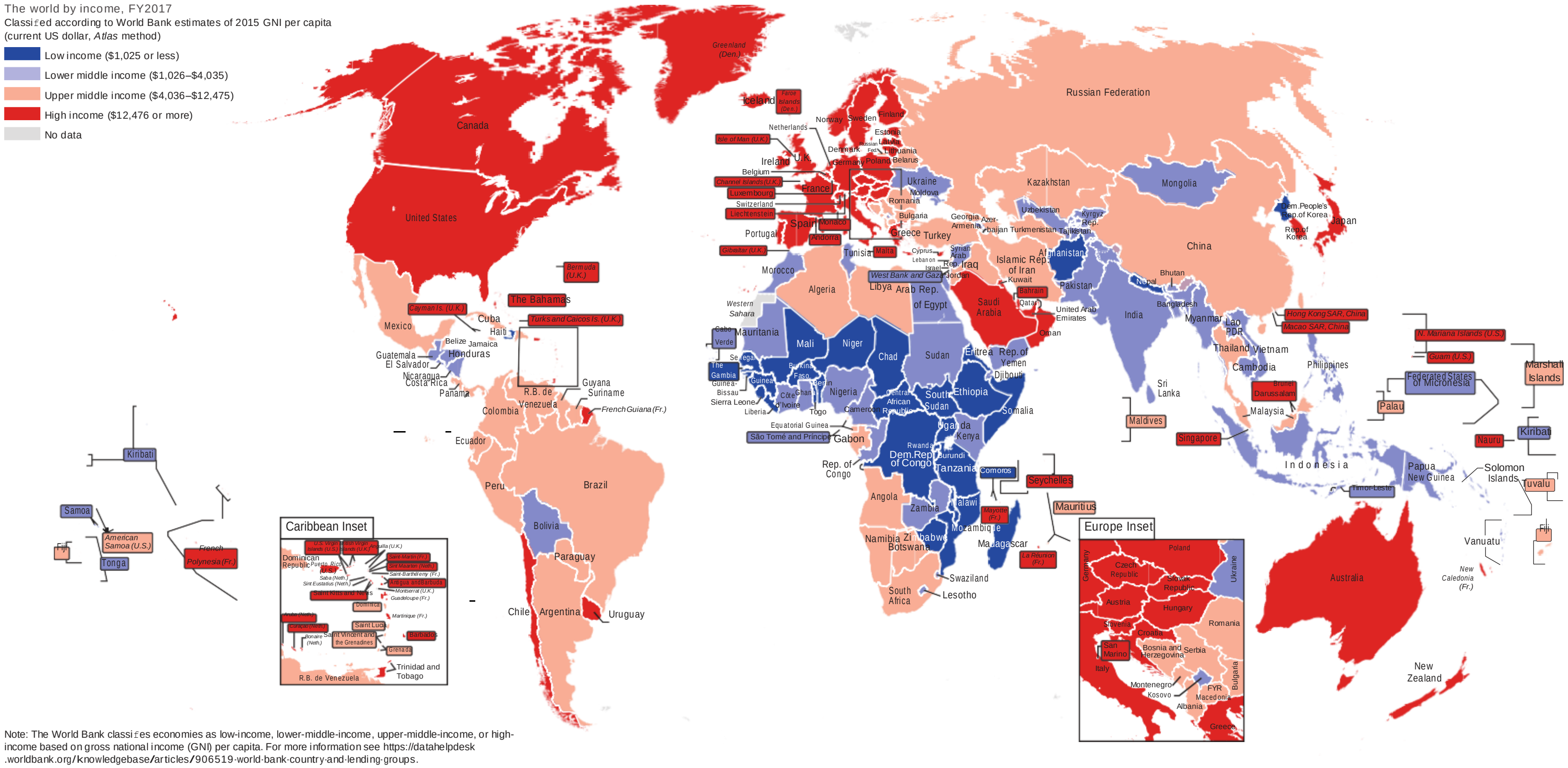

Figure 3: World Map: Countries by Income

Source: World Bank

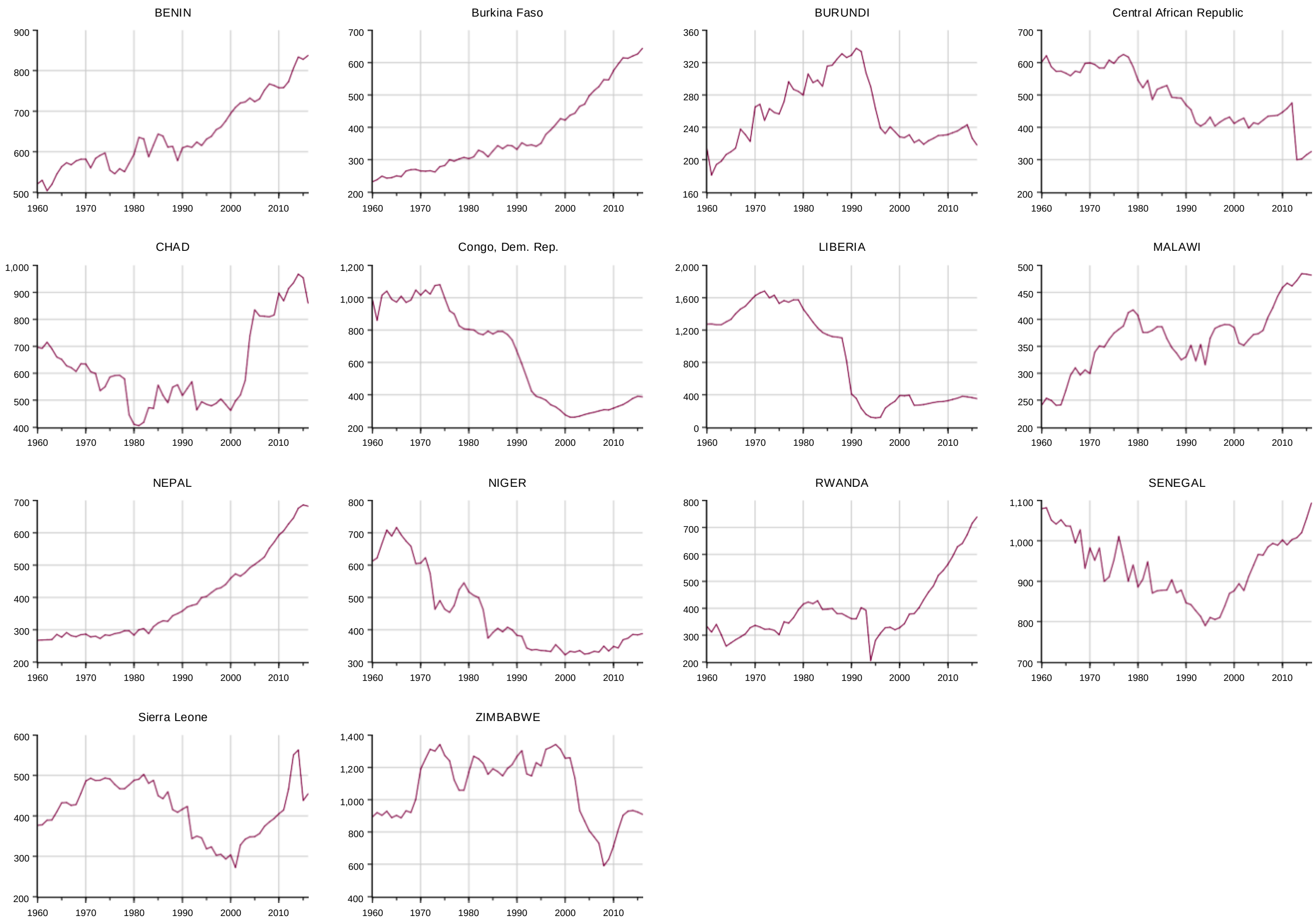

Figure 3: Per Capita Real GDP(in constant US Dollars): Low Income Countries (1960-2016)

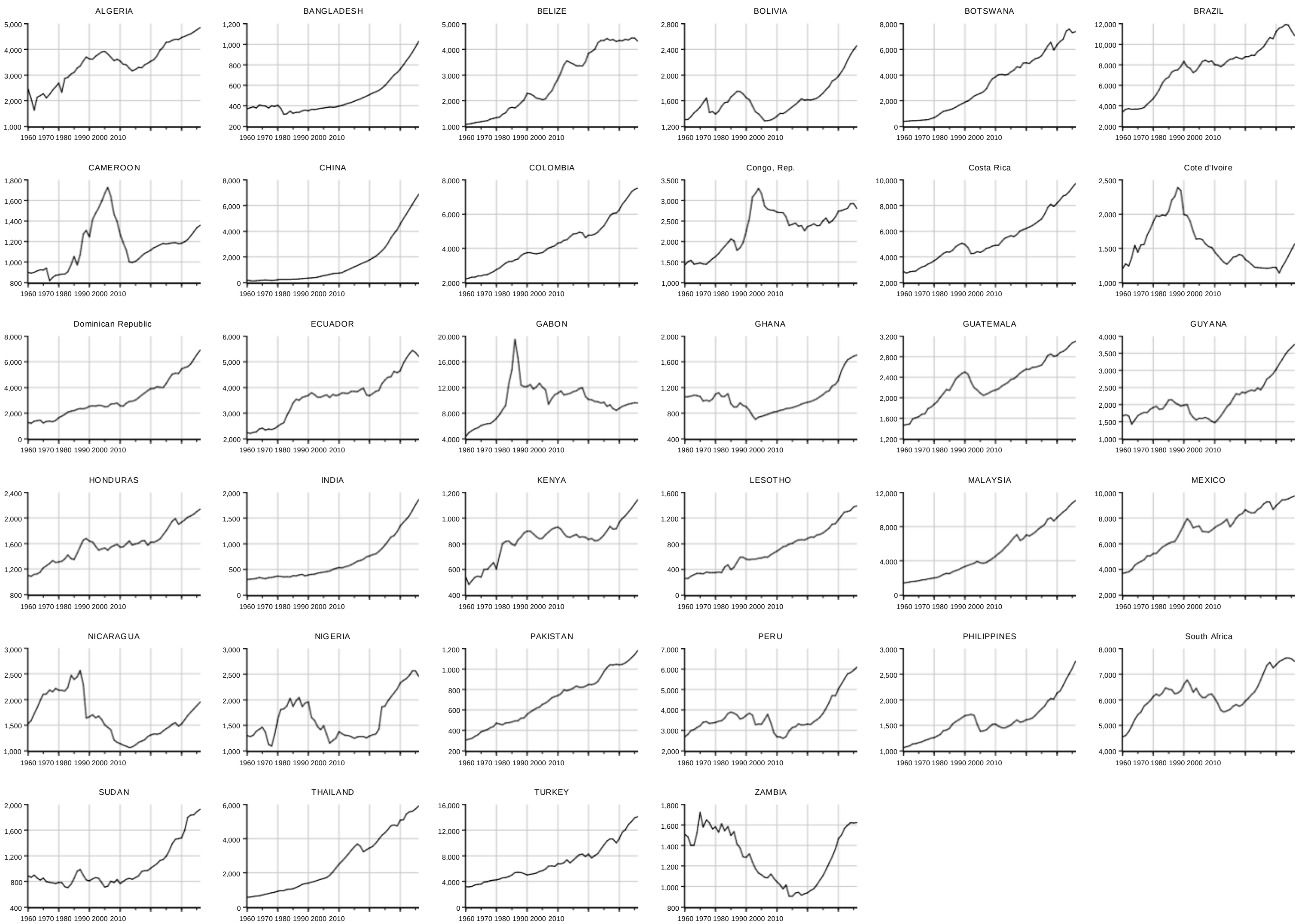

Figure 4: Per Capita Real GDP(in constant US Dollars): Middle Income Countries (1960-2016)

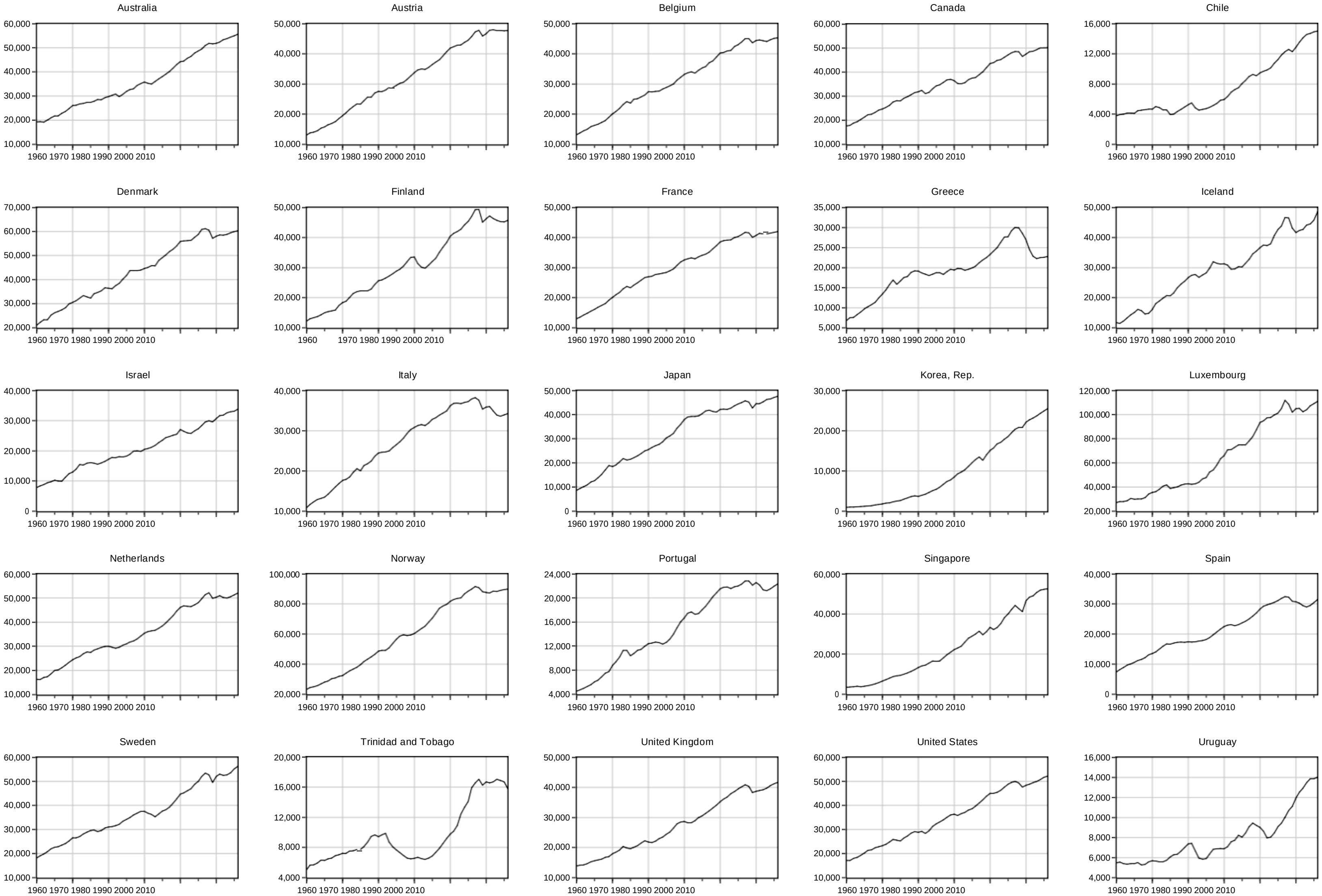

Figure 5: Per Capita Real GDP(in constant US Dollars): High Income Countries (1960-2016)