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Re-assessing the Contribution of Energy Consumption to GDP Per-capita: Evidence from Developed and Developing Countries

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ABSTRACT

After the math of 1970's, various theories of macroeconomics argued that, like capital and labor, energy use as a factor of production has a contribution to increase the GDP. This study explores energy-GDP per capita relationship in 78 countries over the period: 1980-2014. ARDL co-integration approach is applied in pure time-series setting for each country as well as in panel data setting separately for developed and developing countries. The results confirm the presence of a positive relationship between energy consumption and GDP per capita in both the categories of countries. However, to what extent energy consumption affects GDP per capita varies both between and within the two categories of countries. Results from time-series ARDL analysis justify panel ARDL analysis. Specifically, the contribution of energy consumption to GDP per capita is higher in developed countries as compared to developing countries. The study concludes that the efforts of developing countries to sustain their living standard, Energy consumption per capita is the crucial. Further, the findings lessened to developing countries to increase the energy consumption per capita thereby increase the GDP per capita.

Keywords: Energy Consumption, GDP Per-capita, ARDL, Developed and Developing Countries
JEL Classifications: Q430, C32, C33

1. INTRODUCTION

Increase in energy consumption leads to increase in economic growth and this proposition has invited extensive deliberations in literature, especially after publication of the famous article of Kraft and Kraft (1978) on the relationship between energy and GNP. Thereafter a vast literature has emerged that highlights the importance of energy as a basic input consumed in all spheres of production and, thereby, in welfare generation (See, for example, Altinay and Karagol, 2005; Odhiambo, 2009; Apergis and Payne, 2010; Iyke, 2015; Ranjbar et al., 2017; Rathnayaka et al., 2018). This has been named as the growth hypothesis in the literature assuming energy as one of the major factors/indicators of economic growth. Some researchers disagreeing to this hypothesis consider a little or neutral role in economic growth. (See, for example, Yu and Hwang, 1984; Cheng, 1995; Hondroyiannis et al., 2002; Ozturk et al., 2010; Chang et al., 2017).

For policy makers of energy sector, it is imperative to understand the link between energy consumption and GDP per capita because the final result will help them to design a proper energy policy. For instance, government will pay more attention on the policy of stimulated energy use in case reduction in energy consumption causes GDP to go down. Hence, the government will encourage energy consumption in order to foster GDP since GDP is also related to many factors such as unemployment, investment, savings and economic development (See, for example, Ozturk et al., 2010; Apergis and Payne, 2011).

Although an extensive literature has evolved on the study of how energy consumption affects output, yet there is still no consensus on the magnitude of this effect. There are two broad categories of econometric approaches in this context. One category attempts to obtain empirical evidence in a broad sense using panel data of a set of countries in order to prescribe general policies applicable to all countries. The advantage of this approach is that it is backed by a large data set and is considered to be more robust and reliable, while the disadvantage is that it does not distinguish between countries at different stages of development. The second approach is to apply time-series econometric techniques for one particular country or a group of countries considering one at a time. This approach does not normally lead to one standard policy prescription applicable to all countries. Rather varying policies are likely to emerge for different countries. This approach is beneficial in terms of gaining better insight into the energy-output relationship but at the cost of relatively low reliability due to country-wise small samples.

The present study adopts an approach that can take advantage of both the panel and country-wise time-series data. The study employs data for 33 developed and 45 developing countries with 35 annual observations from 1980 to 2014. This yields a larger sample than used in the previous panel data studies. In addition, the number of time series observations for each country is also large enough to carry out time-series analysis for each country. Further, to what extent energy use contributes in GDP of both categories of the countries. Thus, we use time-series as well as panel ARDL approaches to co-integration. The results from time-series ARDL estimation are used as stepping stone for Panel ARDL estimation. The results from time series ARDL estimation show that on average the contribution of energy use to increase output is higher in developed countries as compared to developing countries, thereby justifying the need for separate data analysis for developed and developing countries. Therefore, at the panel level separate analyses are conducted for the sets of developed and developing countries.

The study uses financial development, trade openness and investment as control variables. The study also applies some important diagnostic tests including cross-sectional dependency and structural break unit tests to prevent misleading inference and inconsistent estimates in the models.

The rest of the study is organized as follows. Sections 2, 3 and 4 present the model, data and econometric procedure. Section 5 presents estimation results and section 7 concludes the paper.

2. ANALYTICAL MODEL

In the literature of economic growth theories, Solow model pointed out that in long run growth rate of per capita income is determined exogenously by technological progress. However, Romer (1986) led the development of new growth theory in which technological progress is endogenized by allowing positive externalities and investment in human capital and technological advancement through research and development. Technological progress and, hence, economic growth, have also been explained by a number of factors, including trade liberalization and openness (Barro and Sala-i-Martin, 1997; Rivera-Batiz and Romer, 1991). McKinnon (1973), Shaw (1973), Fry (1998), Ghura and Goodwin (2000) and Almasaied (2010) argued that investment could be boosted up by financial development. Considering the prominent role of energy in

Table 1: Structural break unit root test results

Countries	# of I(1) variables	Countries	# of I(1) variables	Countries	# of I(1) variables	Countries	# of I(1) variables	Countries	# of I(1) variables
Developed countries									
Australia	5	Denmark	3	Israel	3	Norway	3	Switzerland	4
Austria	5	Finland	4	Italy	5	Oman	5	Trinidad and Tobago	5
Bahrain	2	France	5	Japan	4	Portugal	4	United Kingdom	3
Belgium	4	Germany	4	Korea, Rep	4	Saudi Arabia	5	United States	4
Canada	4	Greece	5	Malta	4	Singapore	5	Uruguay	3
Chile	3	Iceland	4	Netherland	5	Spain	4		
Cyprus	4	Ireland	5	New Zealand	5	Sweden	3		
Developing countries									
Algeria	2	Congo, Dem, Rep.	5	Honduras	4	Nicaragua	4	Thailand	5
Argentina	3	Congo, Rep	5	India	3	Nigeria	5	Togo	4
Bangladesh	4	Cote d'Ivoire	4	Indonesia	2	Pakistan	4	Tunisia	3
Benin	3	Dominican Republic	5	Jordan	1	Panama	3	Turkey	2
Bolivia	4	Ecuador	4	Kenya	4	Peru	5	Venezuela, RB	2
Botswana	3	Egypt, Arab Rep.	2	Malaysia	4	Philippines	3		
Brazil	5	El Salvador	3	Mauritius	5	Senegal	4		
Cameroon	0	Gabon	3	Mexico	5	Siri Lanka	5		
China	3	Ghana	1	Morocco	4	South Africa	5		
Colombia	5	Guatemala	3	Nepal	4	Sudan	4		

economic growth, Berndt and Wood (1975), Rasche and Tatom (1977) and Renshaw (1981) consider energy as an input in production function.

In the light of above considerations and assuming Cobb-Douglas technology, we propose the following econometric model for estimation.

$$Y = \alpha + \beta K + \gamma E + \delta \mathrm{OP} + \theta FD + U \qquad (1)$$

where *Y*, *K*, *E*, *OP* and *FD* stand for per capita output, per capita capital stock, per capita energy consumption, trade openness (trade to GDP ratio) and financial development respectively.

3. DATA

As mentioned earlier, the study is carried out for panels of 33 developed and 45 developing countries[1] using time-series annual data over the period 1980-2014. Selection of these countries rests mainly on the availability of consistent time series data. Data on all the variables are either directly available or extractable from the information available in World Development Indicators (WDI). Thus, following the standard practice, the available data on gross capital formation are used to construct capital stock series using perpetual inventory method by setting growth rate of capital stock equal to the compound growth rate of real GDP and rate of capital depreciation equal to 0.05. The data on GDP and gross capital formation are measured in constant US$ prices of the year 2010. Energy consumption includes the consumption of all types of energy by all types of users. Data on energy expenditure are measured in term of tons of oil equivalent. Domestic credit to private sector is used as a proxy for financial development. Data on real GDP, capital stock, energy consumption and financial development variable are transformed into per capita terms. Trade openness is measures as total trade as ratio to GDP. All the variables are taken in natural logarithmic scale for estimation of equation (1).

1 For list of countries see Table 1.

4. ECONOMETRIC METHODOLOGY

Empirical analysis in this study follows two rounds. In the first round equation (1) is estimated for each country in the sample. This

Table 2a: Parameter estimates of ARDL models from time-series data for developed countries

Country name	Long run				Short run					Diagnostics		
	E	K	FD	OP	E	K	FD	OP	EC	Adj R^2	LM test	Norm-ilty
Australia	−0.015	0.151	0.189*	0.301***	−0.002	0.177*	0.031**	0.049***	−0.162*	0.87	0.90	0.23
Austria	0.588*	0.235*	0.146*	0.149*	0.094***	0.115**	-0.045	0.165*	−0.764*	0.91	0.44	0.51
Bahrain	−0.580	−0.38***	0.095	−0.132	−0.305**	0.077**	0.188**	0.140	−0.3***	0.83	0.01	0.61
Belgium	1.008*	−0.150	0.073***	0.402**	−0.010	0.167*	0.015***	0.038	−0.2***	0.94	0.15	0.37
Canada	−0.807**	0.478*	0.060	0.487*	0.179**	0.184*	0.011	0.087*	−0.179*	0.93	0.50	0.09
Chile	0.552	0.477	−0.098	0.248	0.069	0.170*	−0.012	0.031	−0.124	0.75	0.33	0.80
Cyprus	0.593**	0.217***	0.022	0.199	0.017	0.120*	0.095***	0.047	−0.31**	0.78	0.71	0.31
Denmark	−0.58***	3.839**	−0.63***	−0.559	0.034	0.281*	−0.009	−0.055	−0.1***	0.83	0.10	0.05
Finland	0.996*	0.287*	−0.078	0.325*	0.136*	0.246*	−0.011	0.044**	−0.136*	0.82	0.52	0.15
France	0.761*	−0.077	0.232**	0.275**	0.043	0.175*	0.031	0.037	−0.13**	0.85	0.06	0.50
Germany	0.210**	1.557*	−0.19***	0.530*	0.144**	0.245*	−0.030*	0.083*	−0.157*	0.96	0.70	0.32
Greece	0.267*	0.021	0.198*	−0.115**	0.030	0.159*	0.132*	−0.092**	−0.794*	0.92	0.05	0.46
Iceland	0.324*	0.003	0.109*	−0.100	0.205**	0.079**	0.069*	−0.215**	−0.632*	0.88	0.75	0.23
Ireland	0.201*	0.025	−0.084	0.722*	0.334*	0.196*	−0.014	0.120*	−0.166*	0.89	0.38	0.77
Israel	−0.73***	2.875**	−0.058	1.440**	−0.010	0.284*	−0.055	0.249*	−0.17**	0.94	0.04	0.70
Italy	0.702*	−0.408**	0.188*	−0.13***	0.133***	0.188*	0.036	0.017	−0.19**	0.96	0.62	0.30
Japan	0.197***	−0.106	0.641*	0.316*	0.443*	0.261*	0.123**	0.019	−0.587*	0.88	0.93	0.66
Korea, Rep	0.299**	0.353***	0.088	0.062	0.052	0.216*	0.015	0.011	−0.2***	0.72	0.01	0.42
Malta	0.306	−0.090	0.301**	0.316	0.046***	0.065**	0.045	0.047	−0.149*	0.72	0.76	0.25
Netherland	0.626**	0.100	0.209*	0.204**	0.040	0.229*	0.015	0.136*	−0.341*	0.81	0.36	0.13
New Zealand	0.543***	0.769*	0.038	−0.311	−0.068	0.200*	0.052*	−0.053**	−0.260*	0.83	0.83	0.04
Norway	0.920*	−0.483**	0.087	1.716*	−0.024	−0.008	0.013	0.387*	−0.3***	0.78	0.81	0.27
Oman	0.075*	0.030***	0.217*	−0.269*	0.025	0.005	0.231*	−0.052	−1.316*	0.81	0.90	0.62
Portugal	0.647*	−0.244*	0.083*	0.181***	0.035	0.092*	0.033	−0.026	−0.610*	0.88	0.83	0.01
Saudi Arabia	0.134	0.116	0.142	0.273***	0.052	0.045	0.032	0.106**	−0.388*	0.73	0.81	0.79
Singapore	−0.087	−1.342	1.323	−1.110	−0.033	0.049	0.094	−0.158	−0.095	0.67	0.34	0.44
Spain	2.194	−0.324	0.297	−0.286	−0.057	0.197*	−0.008	0.074*	0.026	0.70	0.20	0.72
Sweden	1.799	−0.646	0.146	0.799	0.093**	0.168*	0.008	0.041	−0.051	0.72	0.10	0.81
Switzerland	0.933*	−0.096*	0.167*	0.493*	0.106***	−0.042	0.056	0.147*	−0.753*	0.87	0.50	0.62
Trinidad	0.762*	0.538*	−0.725**	0.564	0.147*	0.033	−0.140**	0.108**	−0.192*	0.92	0.41	0.17
U.K	0.451**	0.376*	−0.023	−0.089	0.037	0.248*	−0.011	−0.006	−0.485*	0.86	0.81	0.87
United states	0.060***	0.077***	0.323*	0.102*	0.113**	0.188*	0.105*	0.019	−0.766*	0.93	0.73	0.92
Uruguay	4.791	4.703	−0.992	3.744	0.284*	0.223*	−0.023	−0.093*	−0.033	0.83	0.70	0.09

Table 2b: Parameter estimates of ARDL models from time-series data for developing countries

Country name	Long run				Short run					Diagnostics		
	E	K	FD	OP	E	K	FD	OP	EC	Adj R^2	LM test	Normality
Algeria	0.372***	0.055	0.032	0.280***	−0.050	−0.002	0.016	0.047	−0.442**	0.78	0.92	0.61
Argentina	0.757**	0.351**	−0.039	0.030	−0.178	0.385*	0.006	−0.043**	−0.256**	0.81	0.72	0.78
Bangladesh	1.350*	−0.057	0.012	0.039	0.260*	−0.176**	0.049***	0.063*	−0.919*	0.89	0.80	0.70
Benin	−0.134	0.319*	0.036	0.140	−0.041	0.050**	0.011	0.108*	−0.306**	0.90	0.60	0.18
Bolivia	0.568*	−0.061	0.055***	0.372*	0.033	0.008	0.079*	0.061***	−0.356*	0.86	0.51	0.41
Botswana	1.332*	−0.384	0.348*	−0.175	0.651**	−0.009	0.045	0.322**	−0.488**	0.83	0.44	0.24
Brazil	0.796*	0.123*	−0.002	0.035	0.730*	0.076*	−0.001	−0.060*	−0.615*	0.81	0.05	0.72
Cameroon	0.169**	0.149	0.075*	0.537**	0.083**	0.104***	0.050***	0.136*	−0.491*	0.91	0.73	0.33
China	0.706*	−0.352	0.761*	0.277**	−0.116	0.041	0.327**	0.096**	−0.430*	0.92	0.89	0.22
Colombia	−1.215**	1.079	−0.094	−0.001	−0.10***	0.151*	0.053***	0.099**	−0.087	0.87	0.75	0.70
Congo Dem R	0.747	0.197***	0.226**	−0.550**	0.049	0.013	0.015***	0.041**	−0.066*	0.85	0.82	0.12
Congo Rep	0.237*	0.110*	0.008	−0.06***	0.236*	−0.028	0.008	−0.071	−0.996*	0.90	0.90	0.32
Cote d’lovior	−0.085**	0.218*	0.071*	−0.114**	−0.020	0.072*	0.169*	−0.025	−1.468*	0.96	0.88	0.21
Dominican Republic	−1.296	0.052	1.052	−0.568**	−0.084	0.168*	0.039***	0.031	0.119**	0.91	0.61	0.12
Ecuador	−0.398**	0.396*	0.168*	0.071***	−0.177	0.190*	0.052	−0.036	−1.415*	0.92	0.17	0.83
Egypt	1.270	0.055	0.325	2.280	0.021	0.046**	0.082*	0.037*	−0.016	0.73	0.72	0.51
El Salvador	−0.496**	0.988*	−0.117	0.648**	0.012	0.116*	−0.030**	0.144*	−0.257*	0.79	0.06	0.31
Gabon	−0.069	0.576	−0.122	−0.562	−0.024	0.208*	−0.042	−0.012	−0.34***	0.69	0.91	0.60
Ghana	−0.243	0.113	0.347*	−0.19***	0.069	0.022	0.034	−0.032	−0.191**	0.73	0.81	0.34
Guatemala	0.259	−0.059	0.149	0.145	0.042**	0.048	0.024	0.024	−0.16***	0.70	0.70	0.03
Honduras	0.353*	0.097*	0.244*	0.012	0.225**	0.062*	0.104**	0.008	−0.637*	0.88	0.80	0.68
India	1.392*	0.163**	0.037	0.004	0.390	0.139*	0.148**	0.004	−0.856*	0.83	0.91	0.22
Indonesia	0.605*	0.380*	0.035	0.013	−0.086	0.193*	0.018	−0.068**	−0.509*	0.85	0.35	0.41
Jordan	−1.428	−0.402	1.273*	1.032	0.203	0.077	0.114	−0.134**	−0.276**	0.79	0.86	0.72
Kenya	0.817*	0.166*	0.159*	0.172*	0.117	0.113*	0.014	0.004	−0.680*	0.92	0.43	0.41
Malaysia	0.723*	0.176***	0.069	−0.073	0.149**	0.185*	0.014	−0.015	−0.206**	0.89	0.70	0.60
Mauritius	−0.327**	0.228*	0.481*	−0.306*	0.261*	0.138*	0.033	−0.186*	−0.608*	0.94	0.01	0.43
Mexico	0.201	0.299	0.199***	0.009	0.036	0.236*	0.035*	−0.077**	−0.17***	0.84	0.40	0.14
Morocco	0.374**	0.168	0.136***	0.001	0.141	0.178**	0.052	−0.166**	−0.378**	0.85	0.76	0.66
Nepal	0.443***	0.104	0.214*	−0.094	0.111	0.026	0.054*	0.031	−0.250*	0.79	0.11	0.81
Nicaragua	1.665*	0.056	0.330*	−0.320*	1.202**	0.039	0.063	0.037	−1.286**	0.78	0.90	0.50
Nigeria	4.925*	−0.053	0.165**	−0.206	1.594*	0.075	0.053	−0.06***	−0.324**	0.74	0.16	0.32
Pakistan	0.421*	0.250*	0.099*	0.122**	0.293**	0.229*	0.026	0.013	−0.916*	0.86	0.62	0.43
Panama	4.655*	−0.299**	−0.640*	1.558*	0.136	0.058**	0.088	0.299*	−0.324*	0.93	0.43	0.80
Peru	1.656**	−1.26***	0.303***	0.733**	0.282*	0.068	0.164*	−0.105**	−0.170**	0.91	0.90	0.32
Philippine	19.740	−1.319	−1.555	−3.893	0.150	0.069***	0.045	0.140***	0.020	0.84	0.51	0.17
Senegal	0.387**	0.224*	−0.057	−0.362*	0.067	0.099*	−0.025	−0.160*	−0.441*	0.94	0.35	0.55
Sri Lanka	−0.421	1.109*	0.067	0.433*	−0.236**	0.319*	0.014	−0.05***	−0.252*	0.93	0.60	0.81
South Africa	0.288	0.070	0.131*	0.442*	0.096	0.084*	0.044*	0.119*	−0.335*	0.87	0.30	0.50
Sudan	−2.950*	−0.032	0.077**	0.360***	0.012	0.066*	0.022	0.105*	−0.291**	0.77	0.89	0.04
Thailand	0.490**	0.076	0.123***	0.148	0.149	0.152*	0.122**	−0.050	−0.304**	0.86	0.51	0.63
Togo	−0.433*	0.146**	−0.014	0.115***	0.029	0.097*	−0.009	0.261*	−0.669*	0.91	0.42	0.07
Tunisia	1.109*	0.169**	0.041	−0.086	0.132	0.207*	−0.083**	−0.038	−0.446*	0.86	0.30	0.02
Turkey	1.008*	−0.020	−0.035	0.099	0.260**	0.139*	0.039***	−0.028	−0.258*	0.88	0.74	0.72
Venezuela	−0.020	0.228**	0.090*	0.794*	−0.009	0.149*	0.039**	0.176**	−0.432**	0.96	0.40	0.51

*, ** and *** represents significance at 1%, 5% and 10% level of significance respectively

Table 3: Cross section dependence (CD) test results

Developed countries			Developing countries		
Variables	CD – Stats	P -value	Variables	CD – Stats	P -value
Y	115.43	0.00	Y	95.61	0.00
K	60.98	0.00	K	65.36	0.00
E	72.74	0.00	E	80.24	0.00
T	61.74	0.00	T	47.2	0.00
F	109.85	0.00	F	54.25	0.00

Under the null hypothesis of cross-section independence CD ~ N(0.1)

exercise is carried out to gain basic insight into the relationship and to motivate panel estimation of the model separately for developed and developing countries. The second round of estimation is carried out in panel framework.

4.1. Time Series Modeling

For time series data standard ARDL model is used that in the present context takes the form:

$$\Delta Y_t = \alpha + \pi_Y Y_{t-1} + \pi_K K_{t-1} + \pi_E E_{t-1} + \pi_T OP_{t-1} + \pi_F FD_{t-1} + \sum_{i=1}^{P_Y} \alpha_i \Delta Y_{t-i} + \sum_{i=0}^{P_K} \beta_i \Delta K_{t-i} + \sum_{i=0}^{P_E} \gamma_i \Delta E_{t-i} + \sum_{i=0}^{P_T} \delta_i \Delta OP_{t-i} + \sum_{i=1}^{P_Y} \theta_i \Delta FD_{t-i} + \varepsilon_t \quad (2)$$

Table 4: CIPS unit root test results

Variables	Developed countries					Developing countries				
	Level		First difference			Level		First difference		
	Constant	Constant and trend	Constant	Constant and trend	Remarks	Constant	Constant and trend	Constant	Constant and trend	Remarks
Y	0.03	0.71	0.00	0.04	I(1)	0.44	0.41	0.00	0.00	I(1)
K	0.05	0.96	0.00	0.00	I(1)	0.01	0.00			I(0)
E	0.51	0.31	0.00	0.00	I(1)	0.74	0.77	0.00	0.00	I(1)
T	0.00	0.06			I(0)	0.15	1.00	0.00	0.00	I(1)
F	0.03	0.90	0.00	0.00	I(1)	0.99	0.36	0.00	0.00	I(1)

Table 5: Hausman test results

Groups	Specification under null hypothesis	Chi-stat	P-value	Conclusion
Developing Countries	PMG is consistent and efficient	18.29	0.100	PMG is preferred
Developed countries	PMG is consistent and efficient	2.92	0.570	PMG is preferred

Note that parameters associated with the level variables indicate long-run relationship, while those associated with the variables in first differences represent short-run relationships. The parameter π_Y is the error correction coefficient. The existence of co-integrating relationship is verified if the null hypothesis: $\pi_Y=\pi_K=\pi_E=\pi_T=\pi_F=0$ is rejected against the alternative that at least one of these parameters is non-zero. All the variables are tested for unit root before estimation of this equation. The number of I(0) and I(1) variables will determine the critical value of F-statistic in Bounds testing for co-integration.

4.2. Panel Modeling

For the panel estimation also ARDL approach is adopted. However, the testing and estimation procedure is not straightforward as it depends on the possible existence of cross-sectional dependence in various time-series data sets. Thus the first step is to apply Cross-Sectional Dependence (CD) tests. In the presence of cross-sectional dependence, as in our case, the second generation CIPS unit root test of Pesaran (2007) based on the following test equation is applied."

$$\Delta X_{it} = \alpha_i + \beta_i X_{i,t-1} + \gamma_i \Delta \bar{X}_{t-1} + \sum_{j=0}^{p} \theta_{ij} \Delta \bar{X}_{t-j} + \sum_{j=1}^{p} \vartheta_{ij} \Delta X_{i,t-j} + \mu_{it} \quad (3)$$

Here α_i is the drift term and p is the lag length to be determined by some criteria like AIC or SBC. The null hypothesis is that all individuals series follow unit root process i.e all $\beta_i = 0$.

For penal ARDL analysis Mean Group (hereafter MG) model proposed by Pesaran and Smith (1995) and Pooled MG (hereafter PMG) model developed by Pesaran et al. (1999) are employed. There is no requirement for order of integration to be same for the application of MG and Pooled PMG models. The two models are given by:

MG Model:

$$\Delta Y_{it} = \theta_i \left(Y_{i,t-1} - \delta_i X_{i,t-1}\right) + \sum_{j=1}^{p-1} \rho_y^i \Delta Y_{i,t-j} + \sum_{j=0}^{q-1} \gamma_y^i \Delta X_{i,t-j} + \mu_i + \varepsilon_{it} \quad (4)$$

PMG Model:

$$\Delta Y_{it} = \theta_i \left(Y_{i,t-1} - \delta X_{i,t-1}\right) + \sum_{j=1}^{p-1} \rho_y^i \Delta Y_{i,t-j} + \sum_{j=0}^{q-1} \gamma_y^i \Delta X_{i,t-j} + \mu_i + \varepsilon_{it} \quad (5)$$

Here, $Y_{i,t}$ is GDP and $X_{i,t-j}$ is the vector of explanatory variables of group i and μ_i stands for fixed effect. Principally, p and q can differ across countries and thus the panel can be unbalanced. Further, δ_i and δ represent long-run parameters, while ρ_y^i, γ_y^i and θ_i are short-run parameters, the error correction parameters θ_i that measure the proportion of error with one period lag. The main difference between MG and PMG models is that the latter restricts long-run parameters to be common across time series. So, the PMG estimators will be inconsistent if this restriction does not hold. Hausman test will be applied to select between the two models.

5. RESULTS AND DISCUSSION

5.1. Results from Time Series Analysis

The structural-break unit-root test results in Table 1 show that for a large majority of countries not all the variables are I(1). Thus, ARDL approach for all the countries is justified.

The parameter estimates of ARDL models for all countries are presented in Table 2a and b. The table shows that out of the 33 developed countries, 27 show positive contribution of energy use to output in long run and out of these effects 21 are statistically significant. Similarly, for 32 of the 45 developing countries long-run effects are positive, out of which 25 are significant. The sample average of the estimated coefficients turns out to be substantially larger (0.90) for developing countries than for developed countries (0.55). Similarly, we find substantial differences in short-run contemporaneous energy coefficient as well as error-correction coefficients.

To move further, we need to consolidate our results through panel estimation. However, the above results mean that substantial gain in information is possible if panel models are estimated separately for the sets of developed and developing countries.

Table 6: Results of PMG Model (Dependent variable is per capita real GDP)

Pooled mean group estimates				
Variables	Developing countries		Developed countries	
	Short run	Long run	Short run	Long run
ECM	−0.0343*** [0.000]		−0.0715*** [0.000]	
Trade openness	−0.0085 [0.514]	0.05831 [0.183]	0.0162 [0.203]	0.02783*** [0.000]
Capital	0.1048*** [0.000]	0.4231*** [0.000]	0.1379*** [0.000]	0.3029*** [0.000]
Energy consumption	0.1004*** [0.000]	0.4797*** [0.000]	0.0573*** [0.000]	0.6056*** [0.000]
Financial development	0.02922*** [0.000]	0.2132*** [0.000]	0.01361 [0.212]	−0.0565** [0.018]
Constant	0.03322*** [0.000]		0.2366*** [0.000]	

*,** and *** represents significance at 10%, 5% and 1% level of significance respectively. P-values are reported in square brackets

5.2. Results from Panel Estimation

Starting with the issue of cross sectional dependence, the results given in the Table 3 (for the whole period) strongly reject the null hypothesis of cross-sectional independence at the 1% level of significance for all the variables. This result exposes the presence of shared dynamics in all the variables across countries within the sets of developing and developed countries.

The results of CIPS test reported in Table 4 suggest that the variables under consideration have mixed orders of integration. Gross capital formation is integrated of order zero, i.e., I(0) in developing countries group whereas trade openness is I(0) in developed countries group. Other variables are integrated of order one, i.e., I(1) in the two groups of countries.

Since the variables under consideration have mixed orders of integration, Panel ARDL approach appears appropriate here. Furthermore, the results of Hausman test reported in Table 5 suggest that PMG estimation should be preferred to MG estimation.

Results of PMG estimation presented in Table 6 show statistically significant negative value of the estimated error-correction coefficient, confirming the existence of long-run equilibrium relationship among the variables within the groups of developed as well as developing countries.

The coefficient of energy consumption is highly significant and positive in both the short and long-run relationships in developed as well as developing countries. This finding implies that energy consumption per capita has a stimulating effect on the real GDP per capita both in short and long run for both groups of countries. This inference is also supported by Lee (2005), Mahadevan and Asafu-djaye (2007), Narayan and Smyth (2008) and Apergis and Payne (2009). Moreover, the long-run coefficient of energy consumption in developed countries is higher than that in the developing countries, that is, the contribution of energy consumption to GDP per capita is higher in developed countries than in developing countries. It follows that the cost of conserving energy in terms of lost output growth has been relatively higher in developed countries. In spite of this observation, energy intensity has declined in many developed countries (Mahmood and Eatzaz, 2018). This means that better environment is highly valued in developed countries. On average, citizen in developed world have gained sufficient consumption and they are now more inclined to improve their living standards on qualitative grounds by spending more on the luxury of better environment.

As expected, the per capita capital stock has significant and positive impact on economic growth in short run as well as long-run. The estimated long-run coefficients of capital are consistent with the generally held presumption that the share of capital in output is about 30% in developing countries and a bit higher in developing counties where wages are very low. The respective coefficients are much smaller in short run. Trade openness is statistically insignificant in short- run in both the groups of countries. However, in the long-run this effect is significantly positive in case of developed countries only. The reason is that developed countries are well equipped with resources of capital, entrepreneurial ability, advance technology and skilled labor and their terms of trade remain favorable. These countries also provide economic incentives and flourish environment of large scale production for earning the returns of economies of scale. Eventually, all these factors contribute to the enhancement of economic growth through trade. In contrast, in case of developing countries with a few exceptions, real trade does not contribute to economic growth because these countries are endowed with abundant supplies of unskilled labor, technological abasement, and unprocessed raw materials. Hence, these countries are bound to export the semi-finished products or supply raw goods.

Financial development (real domestic credit to private sector) has statistically significant positive long-run effect on economic growth in developing countries but significant negative impact in developed countries. The negative effect of financial development on growth in developed countries is on account of two factors. Firstly, developed countries had gained their potential level of economic growth before 1980 after which further financial development did not contribute to economic growth positively. Secondly, financial liberalization in these countries has liberalized financial markets, resulting in reallocation of global capital towards developing countries where manufacturing activity has flourished in recent decades. This has obviously had adverse impact on economic growth in developed countries. In short run also financial development has significant positive impact on growth in developing countries only whereas the same impact in developed countries is statistically insignificant.

6. CONCLUSION

This paper attempt to empirically analyze between energy consumption and GDP per capita with a focus on the possible differences in the relationship across developed and developing countries. The relationship is examined with the consideration of three complementary explanatory variables i.e real domestic credit to private sector as a proxy for financial development, real gross capital formation and trade openness. The study employs country wise time-series as well as panel estimation for 45 developing and 33 developed countries over the period 1980-2014. Based on preliminary diagnostic tests, all the estimation is carried out in ARDL framework.

The findings show that energy consumption contributes to GDP per capita both in developed and developing countries in short run as well as in the long run. The findings also indicate that the long-run contribution of energy to economic growth is higher in developed countries than in developing countries.

There are two important implications of the above results. First, the cost of energy conservation in terms of lost output growth is higher in developing countries. Therefore, their efforts to reduce energy intensity during the past few decades may be regarded as a significant contribution to global environment. Second, since the role of energy consumption to increase in GDP per capita is relatively less is developing countries; these countries could also be encouraged to conserve energy through technology transfer and other incentives such as energy-use sensitive trade policies in developed countries. That is, the products with lower energy content may be treated favorably in trade policies of developed countries.

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