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Energy Consumption and Economic Growth: Evidence from Developed and Emerging Markets

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Abstract

This research analyzed the effect of energy consumption on economic growth using neo-classical one-sector aggregate production function with panel data from Emerging Markets and Developed countries over the period 2000–2013. This study has applied dynamic panel method in the form of two-step panel Generalized Method of Moments (both difference and system) GMM. The findings of this research exposed that both gross fixed capital formation and energy consumption have significant and positive effect on economic growth in both Developed and Emerging Market countries. In addition, labour force has been found to influence positively on economic growth in the group of Developed Market countries. However, labour force established the significant as well as negative effect on economic growth in the Frontier Market countries. Since the findings revealed that all the sampled countries are energy dependent, therefore, their policy makers should continue to promote the development of energy infrastructure with the aim to gain higher economic growth by making effective energy policies. This can be achieved through the allocation of more resources to the development of new sources of energy and ensure sustainability of energy use.

Keywords: Energy Consumption, Economic Growth, Panel Data, System GMM

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1. Introduction

In current scenario, the outcome of energy consumption on economic growth is an important issue in the global economy. Lee (2013) pointed that countries across the globe succeeded in shaking free from a subsistence economy as a result of the services provided by modern energy. This is because of the sufficient energy supply stimulates almost all socio-economic activities; it particularly boosts industrial and commercial activities as well as enhances the delivery of basic social and infrastructural services (Wesseh, 2012). The ratio of per capita energy consumption is one of the primary indicator of economic development of the country however, the share of energy consumption varies as developed countries absorbing larger amount, the Emerging Markets countries are only consuming least of the world's energy pie (Pirlogea, 2012). For instance, per capita consumption of primary energy in the United States recorded as 330 *gigajoules* in 1995, more than six times as much used by Emerging Markets countries, which used less than 47 gigajoules that year, when both the commercial and traditional energies are included (Energy and the Challenge of Sustainability, 2000)

Despite a great number of studies that have dealt with energy consumption and economic growth in both theoretical and empirical evidences studies (M. N. Kahsai, 2012; Lee, 2013; Noor, 2010; Raheem, 2015; Saidi & Hammami, 2015), the studies have failed to reach a harmony about the nature of the long-run along with the causality direction. Among the explanations for the failure to reach a consensus are the methodologies used, proxy variables for economic growth, the period of study, and energy consumption and the countries included in the analyses. Therefore, the main objective of this study is to observe the effect of energy consumption on economic growth for the panel of developed and emerging markets.

The contributions of this study are twofold. First, application of Generalized Method of Moments estimator (GMM) Arellano & Bond (1991) and its extension to system GMM for heterogeneous panel data of developed and emerging countries

within the framework of aggregate production function. While many studies have used static panel data in the form of Fixed-Effects (FE) or Random Effects (RE), some cross-country studies have used Integrate of order one I (1) variables in the form non-stationary panel. In addition, Phillips and Moon (2000) argued that non-stationary panels require large number of periods (T) and cross-sections (N). Nevertheless, in the presence of either heteroskedasticity or serial-correlation, the variances of the FE and RE estimators are not valid and the corresponding Hausman test statistic is inappropriate (Baum, 2006). As for non-stationary panels, the variables must be stationary at first difference. However, it is possible to estimate both with the levels and first differences of the variables with the system GMM panel data method (Blundell, 1998).

The second contribution of this study is that unlike most of the previous researches that examined the nexus between economic growth and energy consumption based on bivariate model. The multivariate framework in the form of neo-classical one-sector aggregate production function with inclusion of labour and capital is used to avoid the estimation problem that rose due to omission of relevant variables. In addition, the gains from the economic growth not only depend on the degree of energy consumption but also to which labour and capital act as complements. This is because of the incorporation of capital as well as labour as additional variables emphasize not only on the relevant of these two major factors of production for economic growth but also to test the hypothesis that capital and labour as an important determinants of economic growth.

To achieve this, the rest of the paper is ordered as follows: the next section presents literature review; the data and econometric methodology used in the study are described in section three; the fourth section explains empirical results and discussion, followed by conclusions and recommendation in Section five.

2. Literature Review

This section reviewed studies that emphasize on either testing the co-movement between energy consumption and economic growth or observing the causality direction between these two variables. Although the results of the positive role of energy on economic growth has been documented in the literature, but a general conclusion from these studies is that contradictory results are still being reported. For example, Apergis (2010) employed fully modified OLS (FMOLS) and error correction model (ECM) to determine the relationship between economic growth and energy consumption covering the period 1980-2005 for nine South American countries. The results showed a long-run relationship between real GDP, energy consumption, labour force and real gross fixed capital formation. In addition, the results from FMOLS showed that energy consumption, capital and labour have a positive and statistically significant effect on economic growth. The Granger causality test results revealed the existence of both short-run and long-run causality running from energy consumption to economic growth justifying growth hypothesis.

However, Noor (2010) assessed the relationship between energy consumption and economic growth for 5 South Asian countries during the period 1971-2006, using Pedroni-cointegration technique, fully modified OLS (FMOLS) and panel error correction model. Empirical results from Pedroni-cointegration test advise a long-run equilibrium relationship among all the variables. In addition, the results from FMOLS showed that capital and energy consumption have a statistically significant and positive effect on the economic growth. However, labour exerts a statistically significant and negative effect on the economic growth. The causality test suggests a one-way causality relationship running from economic growth to energy consumption for short-and long- run and feedback causality in the long-run.

In addition, Omri (2013) applied Generalized Method of Moment (GMM) technique to examine three-way linkages between carbon emissions, energy consumption and economic growth for the panel of 14 MENA countries during the period

1990-2011. The results showed that energy consumption has a significant and positive effect on economic growth for Saudi Arabia, Algeria, Iran, Kuwait, Bahrain, Oman, Qatar, Tunisia and the UAE, while significant and negative effects on economic growth for Lebanon and Egypt. In addition, the capital has a significant and positive relationship with economic growth for 7 out of 14 countries. As for labour, the coefficient showed a negative and significant relationship with economic growth for 10 out of 14 countries.

Moreover, M. S. Kahsai, Nondo, Schaeffer, and Gebremedhin (2012) applied fully modified OLS (FMOLS) and Granger causality tests within the framework of panel error correction model to explore the relationship between energy consumption and economic growth for 40 Sub-Sahara Africa segmented into low and middle-income countries over the period 1980-2007. The authors used GDP per capita proxied for economic growth, consumer price index (CPI) proxied for prices and energy use for energy consumption. The results showed no causality relationship between energy consumption and economic growth in the short-run excluding middle-income countries. Moreover, the long-run causality revealed a bi-directional relationship between the variables for low-income countries. As for middle-income countries, the causality runs from GDP to energy consumption in the short-run and neutrality hypothesis in the long-run. Nevertheless, the coefficient energy consumption showed that has a positive as well as statistically significant influence on economic growth.

Furthermore, Pao (2013) analyzed the relationship between energy consumption and economic growth within the framework of production function where energy is treated as a separate variable for Brazil over the period 1980-2009. For economic growth, Real GDP is used as a proxy; real gross fixed capital formation is also used as proxy for capital, labour force for labour as well as total energy resources and disaggregated levels. The Johansen cointegration test and Granger causality test is based on vector error correction model (VECM) are applied. The findings suggest a long-run relationship among real GDP, real gross fixed

capital formation, labour force and each of the three clean energy consumption variables. In addition, the results from FMOLS revealed that energy consumption, capital and labour have a statistically significant and positive effect on economic growth. The Granger causality tests result evidenced short-run causality running from real gross fixed capital formation to non-renewable energy consumption and bi-directional causality between economic growth and labour force. In the long-run, there is bi-directional causality between non-renewable energy consumption and economic growth and one-way causality from renewable energy consumption to economic growth.

Al-Mulali (2014) applied autoregressive distributed lag (ARDL) bound test and Toda-Yamamoto-Dolado-Lutkepohl (TYDL) to examine the relationship between energy consumption and economic growth for six Gulf Cooperation Council (GCC) countries covering the period 1980-2012. The authors' proxied economic growth by GDP per capita measured in constant US dollars, capital by gross fixed capital formation per capita measured in constant US dollars, labour by population and energy consumption by electricity consumption, exports and imports. The results revealed that energy consumption has a long-run equilibrium relationship with economic growth.

The results of energy consumption showed a positive and significant effect on economic growth for all the countries. But, capital is positively and significantly related to economic growth for Bahrain, Oman, Saudi Arabia and the UAE, while, labour has a negative and significant effect on the economic growth for Bahrain, Oman and Saudi Arabia. The Granger causality test revealed bi-directional causality between energy consumption and economic growth for Bahrain and United Arab Emirates (UAE) while unidirectional causality running from energy consumption to economic growth for Oman and Qatar. However, no causality relationship was observed for the remaining countries.

Tang (2014) applied pooled ordinary least square (POLS), fixed-effect, random–effect and difference generalized method of moments (GMM) to examine the effect of energy consumption,

tourism and political instability on economic growth for 24 MENA countries during the period 2001-2009. The authors found that energy consumption, tourism and capital have positive and significant effect on the economic growth. However, political instability has a negative and significant effect on economic growth. Following similar methodology, applied generalized method of moments (GMM) to examine the effect of energy consumption and carbon dioxide emissions on economic growth for the panel 58 countries during the period 1990-2012. The authors found that energy consumption and foreign direct investment have a positive and statistically effect on economic growth. However, carbon dioxide emissions negatively affect the economic growth.

In addition, Raheem (2015) applied both linear and nonlinear ordinary least square (OLS) in the form of multiple regression analysis to examine the relationship between energy consumption and economic growth for 15 African countries during the period 1980-2010. The author used gross domestic product (GDP) as a proxy for economic growth, energy consumption, labour force, capital stock and export found that energy consumption has a positive and statistically significant effect on economic growth in Algeria and Zambia. However, energy consumption has a negative influence on the economic growth in Tunisia. While, capital stock has a positive and significant effect on economic growth for most of the countries under study, however, labour force has a negative and significant effect on the economic growth in Algeria and Bostwana.

Bhattacharyaa, Paramatib, Ozturkc, and Bhattacharya (2016) applied Pedroni-cointegration test, dynamic ordinary least square (DOLS) and fully modified ordinary least square (FMOLS) to examine the relationship between renewable energy consumption and economic growth for 38 top renewable energy consumption countries during the period 1991-2012. The results confirmed the existence of long-run equilibrium relationship among the variables. The results also found positive and significant effect of renewable, nonrenewable energy consumption, labour force and capital on economic growth. However, at country

specific basis, the results showed that both renewable and nonrenewable energy consumption have positive and significant effect on economic growth for most of the countries under study. While, gross fixed capital formation has a negative and significant effect on economic growth in Japan and Ireland. Moreover, labour force has a negative and significant effect on economic growth in Czech Republic, Italy, Poland, and Romania.

3. Data and Methodology

The data for this study covers 40 countries comprising both Developed and Emerging Market countries and a period of 14 years from 2000-2013. The data collected from the World Development Indicators on energy consumption, real GDP per capita, labour force and gross fixed capital formation. In order to examine the effect of energy consumption on economic growth for the countries, the study applied both dynamic and static panel estimation techniques.

3.1. Dynamic Panel Estimation Techniques

The dynamic panel estimation techniques used consist of difference and system generalized method of moments (GMM) estimator proposed by Arellano and Bond (1991), Arellano and Bover (1995) and Blundell (1998). Apart from capturing the dynamic relationship among the variables of interest, the GMM estimator would also overcome the endogeneity problem. The proposed model for this study is as follows:

$$LRGDP_{i,t} = \alpha_i + \beta_1 LRGDP_{it-1} + \beta_2 LGFCF_{i,t} + \beta_3 LLBFC_{i,t} + \beta_4 LENGC_{i,t} + \mu_{i,t} \quad (1)$$

where $LRGDP_{i,t}$ stands for the economic growth of a country at time t; β's are parameter estimates; $LRGDP_{i,t-1}$ is the lagged of dependent variable; α_i is country-specific effects assumed to be independently and constant over the countries; LGFCF logarithm of gross fixed capital formation, LLBFC logarithm of labour force, LENGC logarithm of energy consumption, and $\mu_{i,t}$ is

the error term which is assumed to be distributed independently in all time periods of the country *i*. The choice of difference and system GMM are justified because the estimators are designed for situations with "small T, large N" panels, meaning few time periods and many individuals as well as independent variables that are not strictly exogenous (Roodman, 2009).

3.2. Static Panels Estimation Techniques

As a robustness check, the study observes the effect of energy consumption on economic growth using a static panel estimation technique, the appropriate model that gives them ostrobust results is chosen;

$$LRGDP_{i,t} = \alpha_i + \nu_i + \lambda_i + \beta_1 LGFCF_{i,t} + \beta_2 LLBFC_{i,t} + \beta_3 LENGC_{i,t} + \mu_{i,t} \quad (2)$$

where: i is the number of cross-section units i= 1,2,…. N; from 1 to N, t is the number of period t= 1,2,…. T, LRGDP is the logarithm of real GDP per capita, αis the constant parameter, β_s are coefficients of the Independent Variables, LGFCF logarithm of gross fixed capital formation, LLBFC logarithm of labour force, LENGC logarithm of energy consumption, μ stochastic disturbance term. The choice of appropriate panel estimation model highly depends on the behavior of ν_i and λ_t. Here ν_i is the country-specific effect, while λ_t is the time-specific effect. If the time-specific effects are absent but there is country-specific effect, the estimation results with the FE model will be choosing. However, if the time-specific effects are absent but the country-specific effects characterized as random error term. Then the RE model is estimated.

4. Empirical Results and Discussion

This section presents the results and discussion for each of the panel. The result of Developed Market countries are presented first and then followed by Emerging Market countries, as well as discussion of findings.

4.1. Developed Market Countries

Table 1 : Results of Two-Step Panel Generalized Method of Moments Fixed-Effects and Random-Effects Results, Dependent Variable: Log of Real Gross Domestic Product (RGDP)

Independent Variables	Difference GMM	System GMM
$RGDP_{t-1}$	0.5983***	0.5182***
	(30.41)	(29.72)
LENGC	0.1439***	0.1268***
	(8.45)	(57.53)
LGFCF	0.1511***	0.1555***
	(15.22)	(18.12)
LLBFC	0.2222***	0.4712***
	(2.52)	(5.94)
Diagnostics Tests		
Number of Observation	218	218
Number of Countries	20	20
Sargan Test	22.8255[0.1550]	17.8230[0.4674]
Arrelano-Bond AR(2) Test	-0.0020[0.9984]	-0.0934[0.1722]

Source: Author's computation using Eviews version 9
Note: Values in () are the t-ratios, while the values in [] are the p-values.
Variables are significant at (*** 1%)

The results of both difference and system-generalized method of moments (GMM) reported in Table 1 shows that, Sargan test fails to reject the null hypothesis of over- identifying restrictions at the conventional percent level. In addition, the Arellano-Bond serial correlation test cannot reject the null hypothesis of serial correlation at order two. Since system GMM is superior estimator, the interpretation is based on it. The results show that the coefficient of lagged dependent variable is positive

and significant at 1 percent. This suggests that this year's economic growth is positively influenced by economic growth in the previous year. The coefficient of energy consumption is positive and significantly related to economic growth. Thus, a 1 percent increase in energy consumption will increase economic growth by 0.13 percent. Also, the coefficients of gross fixed capital formation and labour force have a positive and statistically significant effect on economic growth Thus, a 1 percent increase in gross fixed capital formation and labour force lead to 0.16 and 0.47 percent increase in economic growth of Developed Market countries, respectively.

Table 2 : Fixed-Effects and Random-Effects Results, Dependent Variable: Log of Real Gross Domestic Product (RGDP)

Independent Variables	Fixed-Effects	Random-Effects
LENGC	0.1120***	-0.0337
	(2.29)	(-0.81)
LGFCF	0.3103***	0.3044***
	(11.46)	(11.31)
LLBFC	0.6365***	0.7726***
	(4.77)	(5.10)
Constant	-1.3407**	-0.1805
	(2.02)	(-0.28)
Diagnostics Tests		
Number of Observations	258	258
Number of Countries	20	20
R-Square	0.9856	0.5218
F-Statistics	730.1604[0.0000]	92.3902[0.0000]
Hausman Test	33.2760[0.0000]	

Source: Author's computation using Eviews version 9
Note: Values in () are the t-ratios, while the Values in [ ] are the p-values.
Significant at (*** 1%) (**5%)

Table 2 provides results of panel regression model based on Fixed-Effect (FE) and Random-Effect (RE) models in sorder to serve as a check to robustness. To facilitate this, Hausman specification test is also carried out. Based on the results obtained from Hausman specification test, the fixed-effects model is more appropriate than its Random-Effect (RE) counterpart is, and it is therefore preferred. Similar to the results obtained in panel GMM, the Fixed-Effect reveals that energy consumption has a positive and statistically significant effect on the economic growth. While, Random-Effect results show different results with that of panel GMM even though it is not choosing by Hausman test. This implies that both panels GMM are more robust because energy consumption has positive and statistically significant at 1 percent level. As for gross fixed capital formation and labour force, their coefficients show positive and statistically significant effect on economic growth at 1 percent level. This implies that a 1 percent increase in gross fixed capital formation and labour force will lead to an increase in 0.31 and 0.64 percent level in economic growth, respectively.

4.2. Emerging Markets Countries

Table 3 provides the results of panel GMM, the instruments validity and reliability are indicated by the Sargan test and Arrelano-Bond serial correlation test AR(2), the results indicate the validity of the instruments used and the absence of serial correlation at second order. Since system GMM is superior to difference GMM, the results are interpreted based on it. Even though, the results are almost the same in terms of variables' sign with difference GMM. Nevertheless, there are some differences. The magnitude of the effect on economic growth differs by all the coefficients. That is, a 1 percent increase in energy consumption and gross fixed capital formation will lead to 0.09 and 0.11 percent increase in economic growth, respectively. However, the coefficient of labour force has a negative and significant effect on economic growth, which implies a 1 percent increase in labour force will decrease economic growth by 0.14 percent.

Table 3 : Results of Two-Step Panel Generalized Method of Moments, Dependent Variable: Log of Real Gross Domestic Product (RGDP)

Independent Variables	Difference GMM	System GMM
$RGDP_{t-1}$	0.5892***	0.7252***
	(165.46)	(46.74)
LENGC	0.1207***	0.0903***
	(7.02)	(8.10)
LGFCF	0.1721***	0.1105***
	(18.69)	(10.70)
LLBFC	-0.1567***	-0.1375***
	(-3.27)	(-4.40)
Diagnostics Tests		
Number of Observation	207	207
Number of Countries	20	20
Sargan Test	24.3763[0.1431]	19.4037[0.2483]
Arrelano-Bond AR(2) Test	-1.5224[0.1279]	0.1002[0.1553]

Source: Author's computation using Eviews version 9
Note: Values in ( ) are the t-ratios, while the Values in [ ] are the p-values.
Significant at (*** 1%)

In order to perform robustness check of the estimated results, the study applied fixed effect and random effect models. To compare the fixed-effects (FE) model with random-effects (RE) model, Hausman test is applied. The value of Hausman test is significant which indicates that fixed-effects model is a better choice for the analysis as compared to random-effects model. The results of fixed effect are consistent with panel GMM where all the coefficients have a statistically significant effect on the economic growth. The point worth noting is that the magnitude of the effect of energy consumption on economic growth is lower in the two-step panel GMM. The value of R^2 for the preferred model is 0.9969, which is very good. The F-statistic measures the overall goodness of fit of the model and it is statistically significant.

Table 4 : Fixed-Effects and Random-Effects Results, Dependent Variable: Log of Real Gross Domestic Product (RGDP)

Independent Variables	Fixed-Effects	Random-Effects
LENGC	0.2581	0.2198
	(5.33) ***	(4.46) ***
LGFCF	0.3937	0.4078
	(15.92) ***	(16.72) ***
LLBFC	-0.3666	-0.3879
	(-2.61) ***	(-2.78) ***
Constant	-2.9365	-2.7757
	(-4.66) **	(-4.22)
Diagnostics Tests		
Number of Observations	247	247
Number of Countries	20	20
R-Square	0.9969	0.8699
F-Statistics	3288.1510[0.0000]	541.7480[0.0000]
Hausman Test	17.3250[0.0006]	

Source: Author's computation using Eviews version 9
Note: Values in ( ) are the t-ratios, while the Values in [ ] are the p-values.
Significant at (*** 1%) (**5%) (*10%)

5. Conclusions and Policy Implications

This study examines the effects of energy consumption on economic growth for the panel of Developed and Emerging Markets over the period 2000-2013.The study applied dynamic panel method in the form of Two-Step generalized method of moments (both difference and system) GMM and static panel method in the form of Fixed-Effects and Random-Effects models in addition to the diagnostic tests in the form of Sargan test, Arrelano-Bond serial correlation test and Hausman test. The results revealed that both energy consumption and gross fixed capital formation have statistically significant and positive effect on economic growth for all the countries under study. In addition, labour force has been found to have effected positively on

economic growth in the panel of Developed Market countries. However, the study revealed that the labour force has a negative and significant effect on economic growth in Emerging Market countries.

Since the findings revealed that all the sampled countries are energy dependent, therefore, their policy makers should continue to promote the development of energy infrastructure with the aim to gain higher economic growth in making effective energy policies. This can be achieved through the allocation of more resources to the development of new sources of energy and ensure sustainability of energy use. Also, capital has been found to have effected positively on economic growth in both panels, the study suggests that in order to continue to sustain high economic growth rates, these sampled countries still need to expand their capital stock.

One way to increase the amount of capital stock in an economy is by increasing the spending on capital in the form of new tools, machinery and training. These forms of capital are the necessities of production that will increase output, which in turn stimulates economic growth. Furthermore, the study segmented the panels based on their level of developments and the effect of the coefficient of labour force is mixed, therefore, an overall "umbrella" policy recommendation would not be appropriate but individually designed strategies will go a long way in boosting the efficiency and productivity of their labour.

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