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The Relationship between Energy Efficiency and Economic Performance in G20 Countries

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Abstract

The relationship between the concept of energy efficiency and economic performance is a continuing debate and there is no consensus on it. The main motivation behind this paper is based on a trade-off that exists between energy efficiency and economic growth. Motivated by this trade-off, this paper investigates the long-run equilibrium relationships and causal relationships between energy consumption, economic performance (GDP per capita) and energy intensity in (G20) Countries. Panel data variables over the periods from 1992 to 2012 are employed in empirical tests. Panel cointegration tests suggest that these three variables tend to move together in the long-run. In addition, Panel Granger causality tests indicate that there is a unidirectional causality running from energy intensity to economic performance but not vice versa. Motivated by the panel granger causality findings, we estimated the energy intensity model using the fixed and the random effect model and evaluated the relationship between energy intensity, economic growth and energy consumption of (G20) countries.

Keywords: Energy intensity; GDP per capita; Energy Consumption; G20

JEL classification: O13; O4; Q43

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1. Introduction

Energy efficiency can be defined as using less energy to produce the same amount of outputs (Patterson, 1996: 377). Strong energy efficiency policies play an important role in achieving energy-policy targets such as reduction of the energy bill, dealing with climate change, ensuring security of supply, and increasing energy access (IEA, 2016: 5). The International Energy Agency (IEA) has identified multiple benefits and co-benefits of energy efficiency on the public budget, the health and well-being of the community, the industrial sector, and energy delivery such as reduced greenhouse gas emissions, a reduction in energy prices, supporting economic development, reduced energy poverty, increasing the affordability of energy services, reducing energy infrastructure spending, increasing industrial productivity, increasing disposable income and so on (IEA, 2014). In addition, energy efficiency is an important element of emission reduction policy to pursue the target of limiting global warming to well below 2°C as stated in the Paris Agreement of December 15, 2016. Energy intensity has been investigated globally in terms of its trend as a macro indicator of energy efficiency. Global energy intensity improved by 2% as of 2016 (Enerdata, 2017); however, this is not enough to achieve the climate goals determined in the Paris Agreement. Therefore, global energy intensity should be decreased to at least 2.6% per year to reach climate goals (IEA, 2016: 13).

Energy efficiency is a priority for many G20 members, and G20 members are a leading force in improving energy efficiency in the world. G20 has remarkable success in achieving energy reductions and in making considerable investments in energy efficiency. The total energy consumption per unit of gross domestic product (energy intensity) decreased by 1.4% across G20 members (European Commission - EC, 2016: 4), as shown in Figure 1 between 1990 and 2012. Besides, G20 makes remarkable investments valued at USD 221 billion on energy efficiency which are investment in building sector with USD 118 billion (53%), investment in transport with USD 64 billion (29%) and investment in industry with USD 39 billion (18%) through “a combination of the necessary policies, income levels, institutional support and market sizes to stimulate and foster them” (IEA, 2017: 19). In this regard, the relationship between energy efficiency and economic growth have importance. Most analysts agree that many countries are concerned about the trade-off existing between energy efficiency and economic growth. However, the relationship between the concept of energy efficiency and economic growth is a continuing debate and there is no consensus on it. Most studies use energy intensity as a key indicator of energy efficiency.

Brookes's work (1990) considers the impacts of energy efficiency on long-run economic growth. Brooke believes that if energy intensity of output decreases, it will not be harmful for the economy because technological progress will improve the productivity of energy which refers to falling energy intensity of output, promoting capital investment and improvements in economic productivity. Howarth (1997), however, finds that there are two basic factors that improved energy efficiency causeing increased energy use. The first factor is that energy costs account for a large amount of the total cost of energy services, and the other one is that the production of energy services constitutes a large amount of economic activity. Feng et al. (2009) investigates the casual relationship between energy consumption structure, economic structure, and energy intensity in China and concludes that there is a unidirectional causality running from energy intensity to economic structure. He finds that there is a long-term cointegration relationship among these three variables due to the tendency to decline energy consumption. Wu (2010) focuses on China and states that energy intensity declines significantly in China because of improvements in energy efficiency, but the impact of structural changes in the economy is very limited. Phoumin and Kimura's research (2014) takes the ASEAN and East Asia countries as a model to examine the trade-off relationship between energy intensity and income level, and they concluded that energy intensity has a trade-off relationship with income level. A contribution is provided by Cantore et al. (2016), who examine the trade-off between energy efficiency and economic performance in developing countries. Cantore et al.'s key insight is that lower levels of energy intensity are associated with higher total factor productivity for most 29 developing countries on the manufacturing sector.

Adopting the works of Group of Twenty (G20), Baek and Kim (2011) based their work on the dynamic interrelationships between trade, income growth, energy consumption and CO_2 emissions for G20 countries by using time series. Their study finds that there is a long-run relationship between CO2 emissions, trade liberalization, income and energy consumption. Also, they find that trade liberalization and income growth have a positive impact on improving environmental quality for the developed countries in G20, while they have a negative impact on environmental quality for the developing countries in G20. Lee (2013), on the other hand, investigates the effects of foreign direct investment (FDI) on clean energy use, carbon emissions and economic growth by using panel data for 19 nations of G20. He concludes that FDI inflows lead to economic growth and increase energy use in G20, whereas there is no relation to clean energy use and carbon emissions.

In this context, relationships between energy efficiency and economic performance still does not have significant evidence. Past studies mostly focus on different countries or associations in their analysis, but there is a gap in the literature which examines the trade-off relationship between energy efficiency and economic growth for G20 countries. Therefore, to fill this gap, the main motivation behind this paper is to investigate the trade-off between gross domestic product per capita (GDP per capita) and energy intensity in G20 countries. This paper uses energy intensity as a measure of energy efficiency to explain the impact of energy efficiency on economic performance.

The main objective of this paper is to show whether a reduction in energy intensity is associated with higher gross domestic product per capita for many G20 countries for the period 1990-2012. The remainder of the paper is organized as follows. Section 2 evaluates energy efficiency, energy consumption and economic growth in the G20 Countries. Section 3 defines the data and provides the results of econometric analysis. We finally conclude with policy implications in the last section 4.

2. G20 as a Leading Force in Improving Energy Efficiency, Energy Consumption and Economic Growth

2.1. Energy Efficiency in G20

Energy efficiency is a long-run priority for G20. Therefore, G20 has adopted the *Energy Efficiency Leading Programme (EELP)* in 2016 with the *Energy Efficiency Action Plan* (*EEAP)* which was adopted in 2014. EELP is based on four basic frameworks which are long-term, comprehensive, flexible and adequately resourced to be able to strengthen voluntary cooperation on energy efficiency (EC, 2016: 3).

Energy intensity is the key indicator of energy efficiency, so G20 countries are willing to reduce their energy intensity by increasing energy efficiency cooperation because changes in energy intensity can represent changes in energy efficiency. During the period from 1990 to 2012 that reflects the panel data analysis established in this study, energy intensity decreases continuously for G20 countries as shown in Figure 1. The highest energy intensity level of primary energy in G20 countries belongs to Russia, South Africa, China, Canada and South Korea which are respectively 9.49; 9.31; 8.34; 7,28 and 6.91 MJ/$2011 PPP GDP. The biggest improvement in terms of energy intensity comes from China which verifies the idea that emerging economies improve their energy intensity more than industrialized economies. We used EI to reflect energy intensity which was defined as the energy supply per unit of gross domestic product.

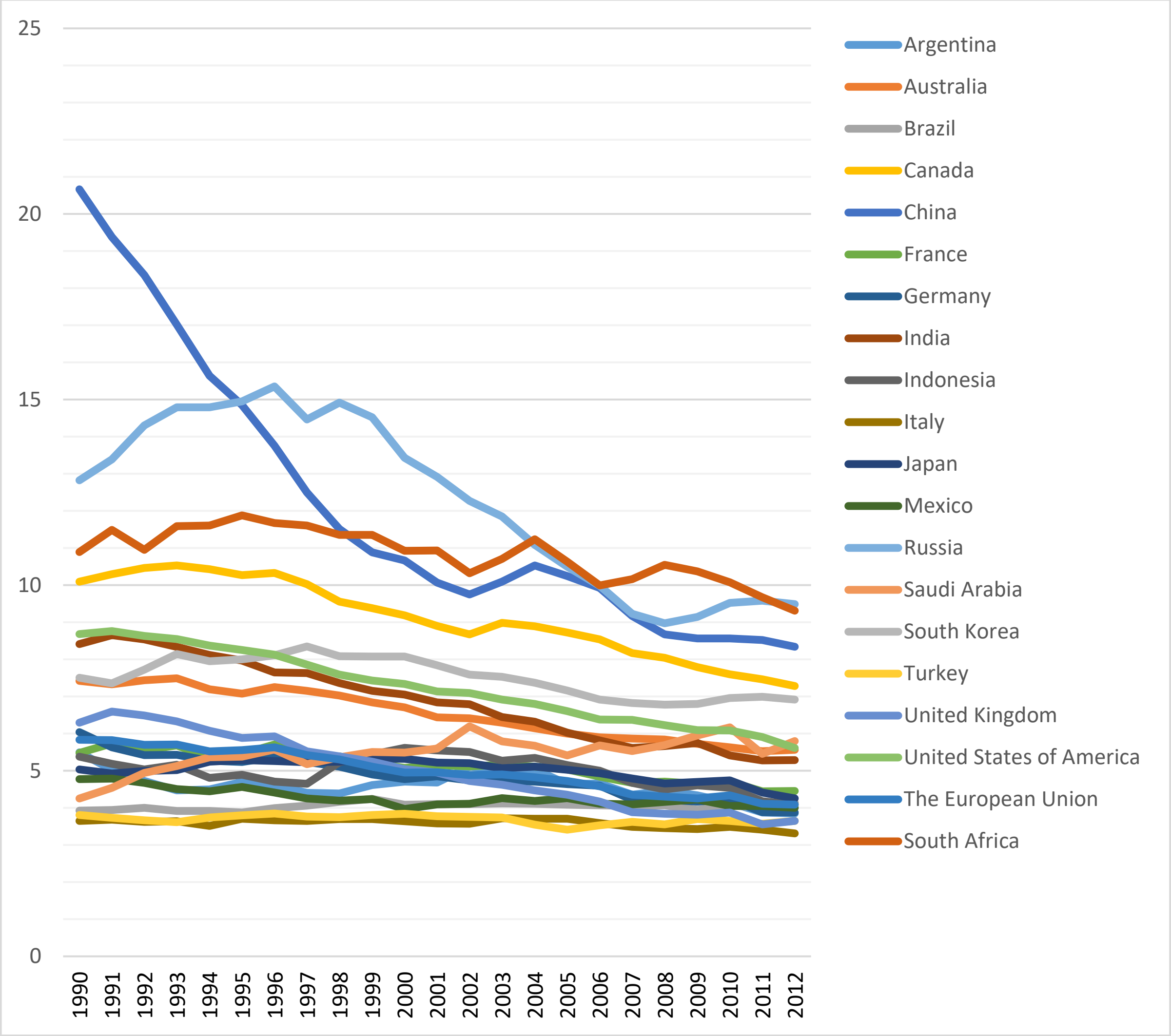

Figure 1: Time-dependent Variations of the Energy Intensity Variable

Source: World Development Indicators.

As of 2015, the five countries out of the first ten[1] of the world with the highest energy intensity of GDP at constant PPP belongs to G20 countries: Russia (0.337 koe/$2005p)[2], South Africa (0.228), China (0.194), Canada (0.184) and South Korea (0.169) (Enerdata, 2016). Figure 2 shows the ranking level of energy intensity of GDP at constant PPP in G20 countries

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[1] The highest ten are Russia, Ukraine, Uzbekistan, South Africa, Iran, Taiwan, Kazakhstan, China, Canada and South Korea, respectively (Enerdata, 2016).

[2] koe/$2005p: kilo of oil equivalent / GDP at constant 2005$ PPP.

as of 2015. Comparing the values of 2012 and 2015, the greatest decrease in terms of energy intensity is in China from 0.225 to 0.194 koe/$2005p, thanks to the decline of coal share.

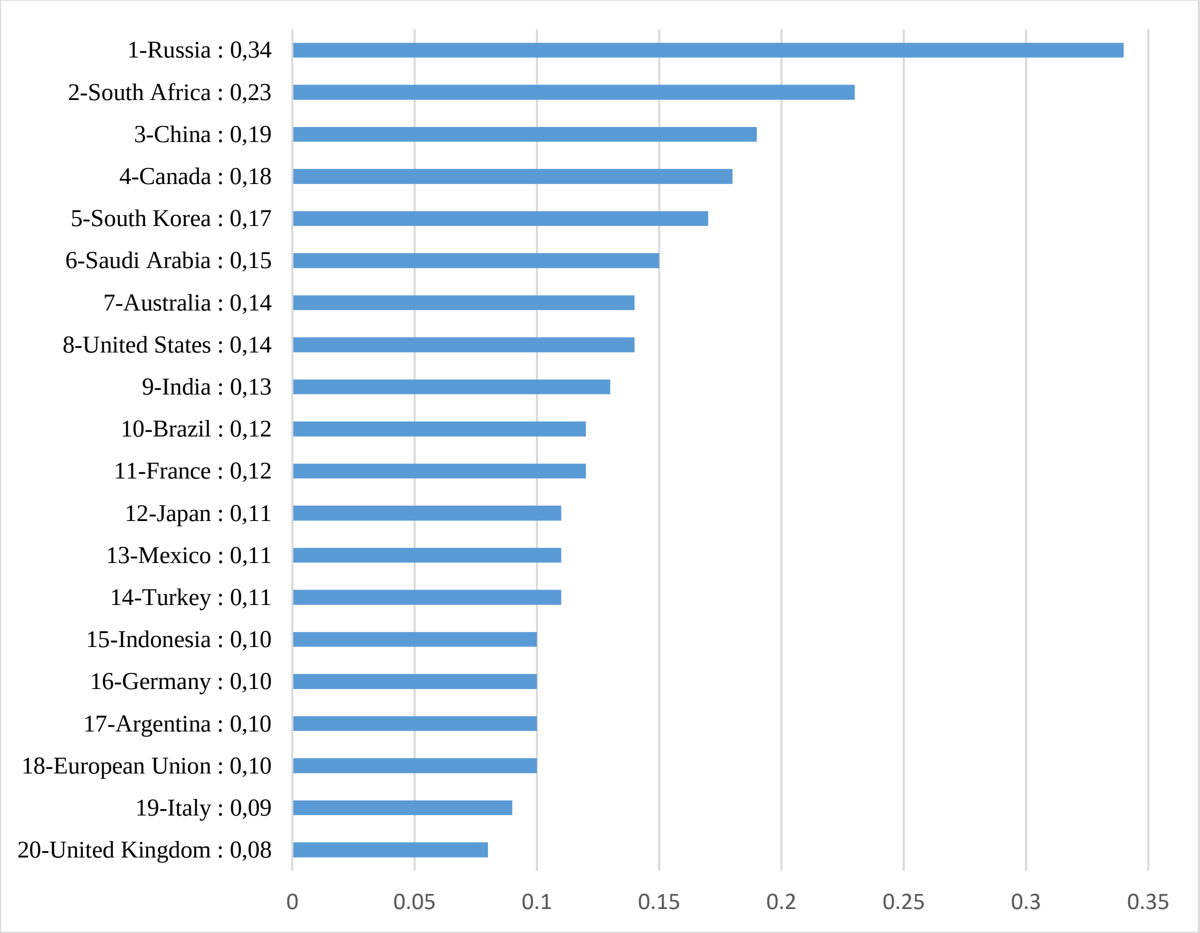

Figure 2: Energy Intensity of GDP at constant PPP (koe/$2005p) (2015),

Source: Enerdata, Global Energy Statistical Yearbook 2016: Energy intensity of GDP at constant purchasing power parities.

2.2. Energy Consumption in G20

The G20 accounts for more than 80% of primary energy consumption which represents 11.663,014 billion tons of oil equivalent (btoe) out of 13.147,3 btoe in the world. The leading country in terms of energy consumption is China both in G20 and the world. As of 2015, China consumed about 3.014 btoe, accounting for 22.9% of the world's total (BP, 2016). Figure 3 indicates that coal plays a dominant role in primary energy in G20 with 3.653 btoe. After coal consumption, oil (3635.5), natural gas (2433.3), hydroelectric (709.4), nuclear energy (682.9) and renewables (417.2) come respectively (BP, 2016). Coal consumption in G20 reflects almost

95% of total coal consumption in the world that is mostly consumed in China. It can be seen easily that the energy mix in G20 varies, but fossil fuels are heavily consumed.

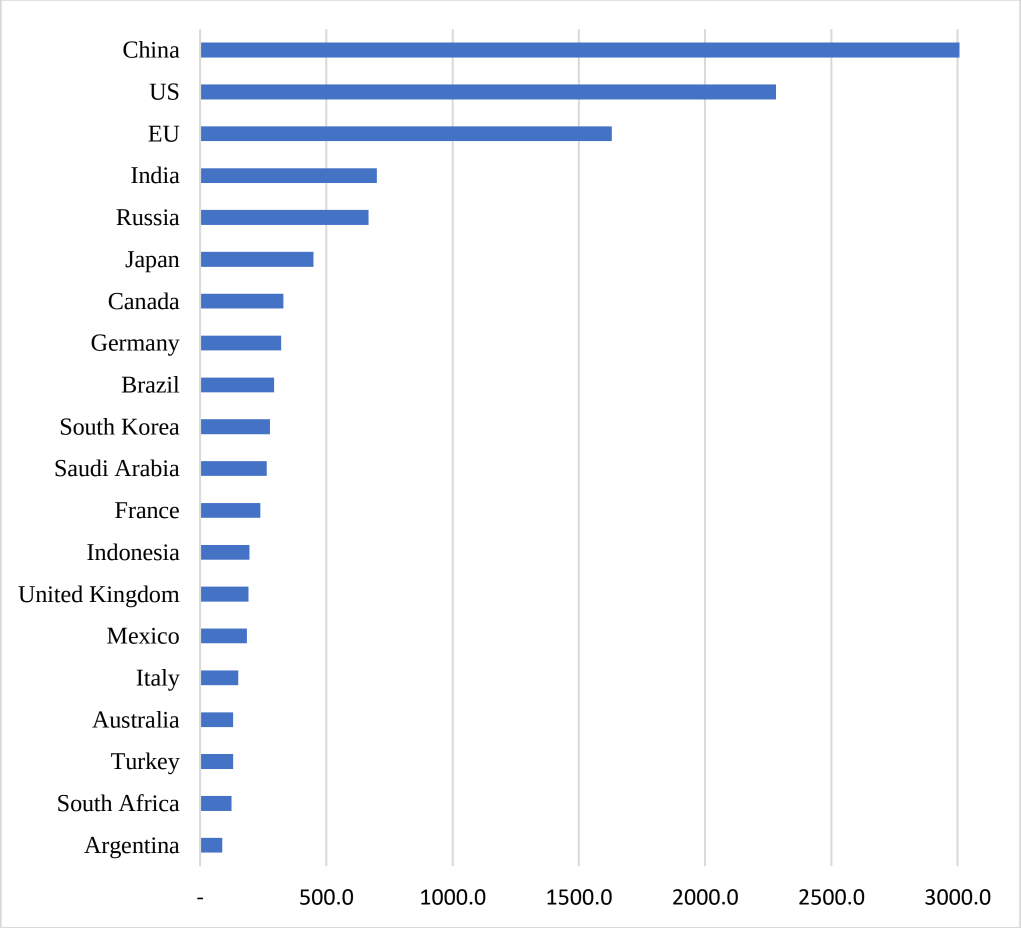

Figure 3: Primary Energy Consumption in G20 countries (mtoe) as of 2015,

Source: BP, 2016, Statistical Review of World Energy.

2.3. Economic Growth in G20

The G20 is constituted of the world's major economies “accounting for around 84% of the world’s total economic output, more than 80% of primary energy consumption and 80% of global greenhouse gas emissions” (EC, 2016: 5). As of 2015, except for Russia and Brazil, the other G20 members increased their GDP. The biggest value of GDP per capita belongs to Australia, followed by US and United Kingdom, as is illustrated in Figure 4.

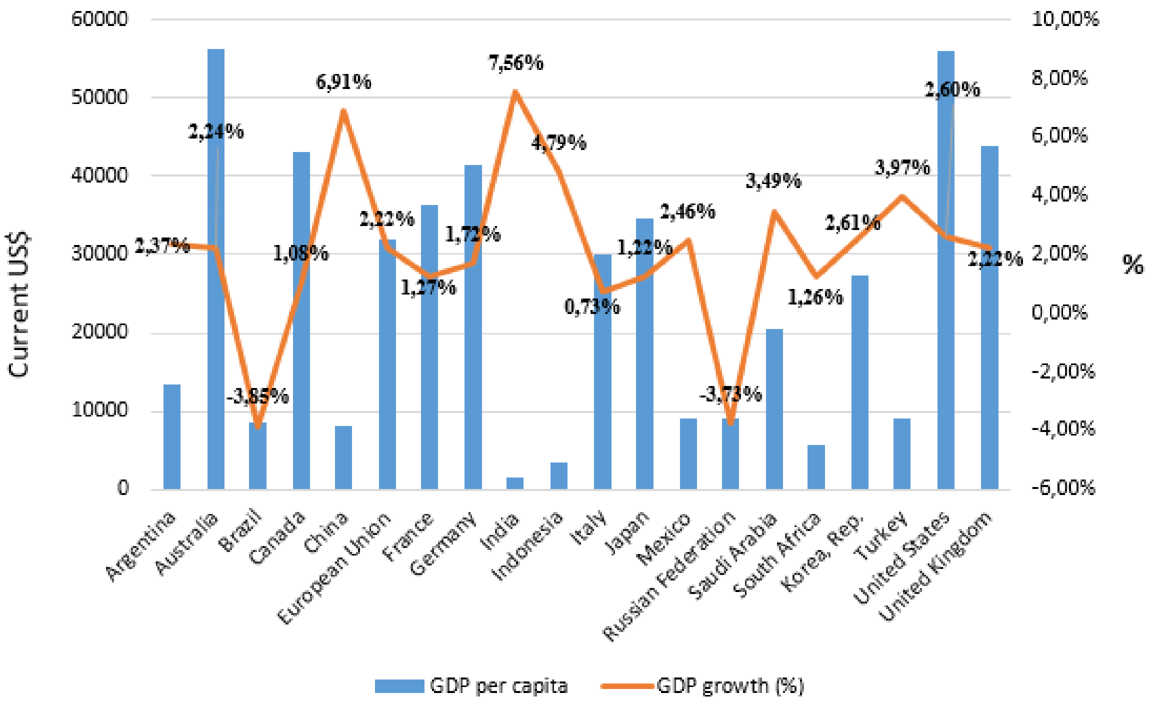

Figure 4: GDP per capita and GDP growth in G20 Members (2015),

Source: World Development Indicators.

3. Empirical Analysis

In the following section, we describe the data set and then calculate the descriptive statistics to check if the data is normally distributed or not. Then we apply several panel unit root tests to null hypothesis of no unit root and determine whether the data is stationary. Then, we apply panel cointegration and panel granger causality tests to specify the direction of causality. Finally, we estimate the model using traditional panel data models.

3.1 Data Description

The relationship between economic performance and energy efficiency is analyzed by using panel data on GDP per capita, energy consumption and energy intensity variables of the G20 countries covering the period of 1990-2012. The data set used in the analysis is gathered from different sources. The annual data on total energy consumption (million tons of oil equivalents) is obtained from BP Statistical Review of World Energy 2016. The data for the GDP per capita (current US dollars) and the energy intensity level of primary energy[3]

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[3] Primary energy is the energy available in nature and directly usable without transformation. Primary energy sources are divided by type into renewable and non-renewable (fossil fuels) energy sources (Yücel, 1994: 6).

(MJ/$2011 PPP GDP)[4] are taken from World Bank, World Development Indicators. In the data set, GDPPC is the gross domestic product per capita, EI is energy intensity level of primary energy. Energy intensity indicates that if the energy intensity is at a lower ratio, less energy will be used to produce one unit of output so it is defined as: EI= ES / GDP where EI is energy intensity level of primary energy, ES is energy supply, GDP is gross domestic products. Accordingly, energy intensity level of primary energy is the ratio between energy supply and gross domestic product measured at purchasing power parity.

3.2 Descriptive Statistics

Table 1 reports the mean, median and the statistics which state the shape of variables. Skewness is a measure of asymmetry of the distribution of the series around its mean. Our variables are far from having symmetric distribution. LEC and LEI both have positive skewness which means that the distribution has a long right tail. LGDPPC has negative skewness implying that the distribution has a long left tail. Kurtosis measures the peakedness or flatness of the distribution of the series. The kurtosis of the normal distribution is 3. If the kurtosis exceeds 3, the distribution is peaked (leptokurtic) relative to the normal; if the kurtosis is less than 3, the distribution is flat (platykurtic) relative to the normal. Since kurtosis of the three variables is less than three, the distribution is flat (platykurtic) relative to the normal. Also, the Jarque-Bera statistic exceeds (in absolute value) the observed value under the null hypothesis—a small probability value leads to the rejection of the null hypothesis of a normal distribution. For our three-series displayed above, we reject the hypothesis of normal distribution at the 1% level.

Table 1
Descriptive Statistics

	LEC	LEI	LGDPPC
Mean	5.551429	1.777448	9.159971
Median	5.395213	1.683956	9.466463
Maximum	7.935695	3.028406	11.12205
Minimum	3.799974	1.197570	5.728186
Std. Dev.	1.012688	0.381692	1.321309
Skewness	0.697181	0.769693	-0.792308
Kurtosis	2.741572	2.897092	2.751539
Jarque-Bera	38.54470	45.62237	49.31091
Probability	0.000000	0.000000	0.000000
Sum	2553.658	817.6263	4213.587

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[4] MJ: Megajoule and PPP: Purchasing power parity.

Sum Sq. Dev.	470.7211	66.87126	801.3485
Observations	460	460	460

3.3 Panel Unit Root Tests Results

A necessary condition before testing for the possible existence of a long-run relationship between GDP per capita, the energy intensity, and the energy consumption variables, is that all variables should be integrated in the first order. To examine this condition, we perform the LLC, the Im, Pesaran and Shin (IPS), the Breitung, ADF - Fisher Chi-square and PP - Fisher Chi-square tests. These tests incorporate both cross-sectional independence and cross-sectional dependence cases. The results of these tests are presented in Table 2. The results suggest that the null hypothesis of the unit root cannot be rejected at the 1% level of significance for the three panel time series taken in level. However, by testing for the unit root in the first difference, all panel unit root tests reject the null hypothesis at the 1% level of significance. Based on these results, we conclude that all panel time series are integrated with the first order. These results of non-stationarity in level and stationarity in first difference are confirmed by the Breitung and Hadri unit root tests reported in Table 2 as well. To summarize, we note that regardless of the type of tests employed, cross-sectional independence or cross-sectional dependence for the group of G-20 countries results showed strong evidence for non-stationarity at level and stationarity at first difference.

Table 2
Results of Panel Unit root tests for G-20 countries

Variable	**LLC***	**Breitung t-stat***	**Im, Pesaran and Shin W-stat ****	**ADF - Fisher Chi-square****	**PP - Fisher Chi-square****
Lgdppc	-0.71541(0.2372)	-0.15789(0.4373)	0.45370(0.6750)	31.6826(0.8232)	18.6015(0.9985)
D Lgdppc	-7.757***4(0.0000)	-7.87889***(0.00)	-6.0400***(0.00)	103.809***(0.00)	151.431***(0.00)
Lei	-1.9509***(0.025)	0.54111(0.7058)	-0.9703(0.1659)	47.6182(0.1904)	54.9797(0.06)
DLei	-6.7866***(0.00)	-4.2827***(0.00)	-6.2753***(0.00)	108.562***(0.00)	286.00***(0.00)
Lec	0.06678(0.5266)	2.86244(0.9979)	3.27587(0.9995)	25.1391(0.9679)	45.5543(0/252)
DLec	-1.8309***(0.03)	-5.658***(0.00)	-6.205***(0.00)	109.124***(0.00)	315.016***(0.00)

Notes: D is the first difference operator and L denotes logarithm. Panel unit root tests include intercept and trend. Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other test assumes asymptotic normality. * Null: Unit root (assumes common unit root process) ** Null: Unit root (assumes individual unit root process) ***denote significance at 1% level and (.) probabilities.

3.4 Panel Cointegration Tests Results

After the panel unit root tests confirm that all variables are I(1) in level, then the next step is to test for evidence of a long-run relationship. The panel cointegration tests used to test the null hypothesis of no cointegration against the existence of cointegration. Three panel cointegration tests including the Kao's residual cointegration tests, Johansen Fisher Panel Cointegration tests, and Pedroni Residual Cointegration are employed. Empirical results suggest strong evidence for panel cointegration between the GDP per capita, energy intensity and energy consumption for G-20 countries. The Kao's residual cointegration tests show that for G20 countries, the hypothesis of cointegration cannot be rejected at the 1% level of significance (see Table 3). Similarly, the Pedroni test show that we reject the null hypothesis and conclude in favor of cointegration with exception of the group Panel v-Statistic (see Table 4).

We also observed that the tests proposed by Johansen and Fisher as Panel Cointegration Test show that all test values of 1% level of significance indicating the rejection of the null hypothesis of absence of cointegration (see Table 5).

Table 3
Kao Cointegration Test

Series	**DLOG(GDPPC_?) DLOG(EI_?)**	**DLOG(GDPPC_?) DLOG(EC_?)**	**DLOG(GDPPC_?) DLOG(EI_?) DLOG(EC_?)**
ADF	-2.478928***(0.00)	-2.582051***(0.00)	-5.462790***(0.00)
Residual variance	0.032708	0.028469	0.023786
HAC variance	0.003672	0.003480	0.004071

Notes: For ADF we report the t-statistic and its probability. In the parenthesis, is the Null hypothesis: No cointegration. Trend assumption: No deterministic trend. Automatic lag selection based on SIC with maxlagof 5. *** denotes critical values at the 1% significance level.

Table 4
Pedroni Cointegration Test

Series	**DLOG(GDPPC_?) DLOG(EI_?) DLOG(EC_?)**			
	Alternative hypothesis: common AR coefs. (within-dimension)			
Statistics	**Statistic**	**Prob.**	**Weighted Statistic**	**Prob.**
Panel v-Statistic	-2.123356	0.9831*	-2.882813	0.9980*
Panel rho-Statistic	-5.902235	0.0000	-4.977439	0.0000
Panel PP-Statistic	-10.34699	0.0000	-9.265151	0.0000
Panel ADF-Statistic	-9.957397	0.0000	-9.040987	0.0000
	Alternative hypothesis: individual AR coefs. (between-dimension)			
Group rho-Statistic	-2.948007	0.0016		

Group PP-Statistic	-9.779304	0.0000		
Group ADF-Statistic	-9.423055	0.0000		
Series	**DLOG(GDPPC_?) DLOG(EC_?)**			
	Alternative hypothesis: common AR coefs. (within-dimension)			
Panel v-Statistic	-1.530883	0.9371*	-1.725449	0.9578*
Panel rho-Statistic	-9.872417	0.0000	-8.047085	0.0000
Panel PP-Statistic	-11.57740	0.0000	-9.830870	0.0000
Panel ADF-Statistic	-11.01152	0.0000	-9.392785	0.0000
	Alternative hypothesis: individual AR coefs. (between-dimension)			
Group rho-Statistic	-5.518282	0.0000		
Group PP-Statistic	-11.12720	0.0000		
Group ADF-Statistic	-9.361874	0.0000		
Series	**DLOG(GDPPC_?) DLOG(EI_?)**			
	Alternative hypothesis: common AR coefs. (within-dimension)			
Panel v-Statistic	-2.577767	0.9950*	-2.512812	0.9940*
Panel rho-Statistic	-10.04221	0.0000	-9.429116	0.0000
Panel PP-Statistic	-13.65632	0.0000	-11.98253	0.0000
Panel ADF-Statistic	-12.63302	0.0000	-11.17892	0.0000
	Alternative hypothesis: individual AR coefs. (between-dimension)			
Group rho-Statistic	-6.495522	0.0000		
Group PP-Statistic	-13.35199	0.0000		
Group ADF-Statistic	-9.672423	0.0000		

Notes: Null hypothesis shows no cointegration. Trend assumption is that there is no deterministic trend. Automatic lag length selection is based on SIC with a max lag of 4. We Used d.f. corrected Dickey-Fuller residual variances.
* denotes insignificant test value.

Table 5
Johansen Fisher Panel Cointegration Test

Series	**DLOG(GDPPC_?) DLOG(EI_?) DLOG(EC_?)**			
	Unrestricted Cointegration Rank Test (Trace and Maximum Eigenvalue)			
Hypothesized No. of CE(s)	**Fisher Stat.* (from trace test)**	**Prob.**	**Fisher Stat.* (from max-eigen test)**	**Prob.**
None	199.5	0.0000	114.3	0.0000
At most 1	131.0	0.0000	80.61	0.0001
At most 2	142.8	0.0000	142.8	0.0000
Series	**DLOG(GDPPC_?) DLOG(EI_?)**			
	Unrestricted Cointegration Rank Test (Trace and Maximum Eigenvalue)			
Hypothesized No. of CE(s)	**Fisher Stat.* (from trace test)**	**Prob.**	**Fisher Stat.* (from max-eigen test)**	**Prob.**
None	219.3	0.0000	125.8	0.0000
At most 1	205.3	0.0000	205.3	0.0000
Series	**DLOG(GDPPC_?) DLOG(EC_?)**			
	Unrestricted Cointegration Rank Test (Trace and Maximum Eigenvalue)			
Hypothesized No. of CE(s)	**Fisher Stat.* (from trace test)**	**Prob.**	**Fisher Stat.* (from max-eigen test)**	**Prob.**
None	185.5	0.0000	117.2	0.0000
At most 1	167.7	0.0000	167.7	0.0000

Trend assumption: Linear deterministic trend. Lags interval (in first differences): 1 1.
Cross section results are not reported here; however, can be requested from the corresponding author.

3.5 Causality Hypothesis and Panel Causality Testing

Before proceeding with panel causality test results, it will be helpful to state four causality hypotheses between energy efficiency, energy consumption, and economic growth.

i) The Growth Hypothesis

It is characterized by uni-directional causality running from energy consumption to economic growth. In such as situation, conservation measures will uphold economic growth because energy consumption is very important for economic growth to take place, either directly or indirectly, as a complement to labor and capital (Apergis and Payne, 2012). The Growth Hypothesis entails that increases in energy consumption, increase economic growth, while decreases in energy consumption, decrease economic growth.

ii) The Conservation Hypothesis

It is characterized by uni-directional causality running from economic growth to energy consumption. In an economy where the Conservation Hypothesis holds, conservation measures can take place without upholding growth. Such an economy is less energy dependent and more sustainable.

iii) The Feedback Hypothesis

It is characterized by bi-directional causality running from energy consumption to economic growth and vice-versa. Consequently, conservation measures will impact economic growth, and changes in economic growth will impact energy consumption as well. Therefore, when this hypothesis holds, it suggests that there are some complementarities between energy consumption and economic growth.

iv) Neutrality Hypothesis

It is characterized by the absence of any causality between energy consumption and economic growth. For economies where these two magnitudes are independent of each other, growth is driven by other factors. Together with the Conservation Hypothesis, the Neutrality Hypothesis can be encountered in more sustainable economies.

The results of testing for panel granger causality are reported in Table 6. We report the results of Pairwise Granger Causality Tests which is based on F-statistics with respect to the short run changes in the independent variables. We also report the results for the pairwise Dumitrescu-Hurlin tests. According to both tests, we reject the null that energy intensity does not Granger (homogeneously) cause GDP per capita. We conclude that energy intensity cause GDP per capita. This is an evidence of the growth hypothesis which shows one-way (uni-directional) causality running from energy intensity to GDP per capita for G20 Countries.

Table 6
Panel

Pairwise Granger Causality Tests			
Null Hypothesis:	**Obs**	**F-Statistic**	**Prob.**
DLGDPPC does not Granger Cause DLEI	340	1.46809	0.1998
DLEI does not Granger Cause DLGDPPC		3.10068	0.0095*
DLGDPPC does not Granger Cause DLEC	340	2.03933	0.0728*
DLEC does not Granger Cause DLGDPPC		1.75237	0.1222
Pairwise Dumitrescu Hurlin Panel Causality Tests			
Null Hypothesis:	**W-Stat.**	**Zbar-Stat.**	**Prob.**
DLGDPPC does not homogeneously cause DLEI	0.87517	-0.63729	0.5239
DLEI does not homogeneously cause DLGDPPC	0.42097	-1.79587	0.0725*
DLEC does not homogeneously cause DLGDPPC	3.23867	1.54500	0.1223
DLGDPPC does not homogeneously cause DLEC	2.07959	-0.37855	0.7050

Notes: 5 lags applied * denotes 1% significance level.

3.6 Estimation of the Energy Intensity Equation

In previous sub sections, we found that GDPPC, energy intensity and energy consumption all cointegrated. In addition, from the panel granger causality test we decided that the dependent variable is energy intensity and both energy consumption and GDP per capita are independent variables. Accordingly, we estimated the model using the fixed effects model using the pooled least squares technique. After estimating the equation with random effects, the Hausman test can be conducted to identify the most appropriate method to compare the fixed and random effect estimator. The results of the test are given in the Appendix. The result of the test is a chi-square of 12.68, which is larger than the critical. Hence, we reject the null hypothesis of random effects in favor of the fixed effect estimator. The model confirms that there is a negative relationship between economic growth and the growth rate of energy intensity, and a positive relationship for the growth rate of energy consumption. Empirical results of the short-run estimation confirm that, in the short-run, the impact of economic growth and energy consumption is statistically significant (different from zero).

Table 7
Estimation Results of Fixed Effects Model

Dependent Variable: DLOG(EI_?)

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	-0.015354	0.001660	-9.250265	0.0000
DLOG(EC_?)	0.391094	0.048200	8.114003	0.0000
DLOG(GDPPC_?)	-0.102736	0.010685	-9.615096	0.0000
Fixed Effects (Cross)				
ARG--C	-0.006787			
AUS--C	0.001102			
BRA--C	0.009826			
CAN--C	4.38E-05			
CHI--C	-0.037003			
EU--C	0.002630			
FRA--C	0.006783			
GER--C	0.000292			
INI--C	-0.019455			
INO--C	-0.009668			
ITA--C	0.012574			
JAP--C	0.009436			
KOR--C	-0.001864			
MEX--C	0.002511			
RUS--C	0.012378			
SAF--C	0.005908			
SAU--C	0.016375			
TUR--C	0.002940			

UK--C	-0.005033		
USA--C	-0.002987		
Effects Specification			
Cross-section fixed (dummy variables)			
R-squared	0.305106	Mean dependent var	-0.011971
Adjusted R-squared	0.270195	S.D. dependent var	0.032614
S.E. of regression	0.027861	Akaike info criterion	-4.274444
Sum squared resid	0.324475	Schwarz criterion	-4.070105
Log likelihood	962.3776	Hannan-Quinn criter.	-4.193832
F-statistic	8.739556	Durbin-Watson stat	1.907597
Prob(F-statistic)	0.000000		

4. Conclusions and Policy Implications

The G20 is constituted of the world's major economies, accounting for around 84% of the world’s total economic output, more than 80% of primary energy consumption and 80% of global greenhouse gas emissions. Additionally, G20 countries have 75% of total global deployment potential, and almost 70% of total global power sector investment potential for renewable energy (IRENA, 2016: 9). Energy efficiency is a long-run priority for G20. Therefore, G20 has adopted the Energy Efficiency Leading Program and agreed to take a global leadership role in promoting energy efficiency. Energy intensity is the key indicator of energy efficiency, so G20 countries are willing to reduce their energy intensity by increasing energy efficiency cooperation. During the period from 1990 to 2012, energy intensity decreases continuously for G20 countries. The highest energy intensity level of primary energy in G20 countries belongs to Russia, South Africa, China, Canada and South Korea. Energy intensity level in G20 decreases thanks to the long-run priority of energy efficiency and thus the decline of coal share. This is mostly because of a decrease in China (the decline of coal share in mix) and in the USA (the increase of natural gas consumption and decrease of coal consumption). These two countries are the most energy consuming countries in G20. In this respect, the main motivation behind this paper is on the trade-off existing between gross domestic product per capita and energy intensity in G20 countries. This paper tries to show whether a reduction in energy intensity is associated with higher gross domestic product per capita for many G20 countries for the period 1990-2012. In this paper, we show that a reduction in energy intensity is associated with higher gross domestic product per capita for many G20 countries. During this period energy consumption improved, per capita GDP growth was up-graded, and energy intensity decreased continuously.

Our findings have important policy implications, especially, because G20 is constituted of the world's major economies and G20 countries consume more than 80% of global primary energy. In G20, the most consumed energy source is coal, and decreases in coal consumption will lead to positive impacts on energy intensity. Therefore, G20 countries should improve utilization efficiency of coal at power plants. In other words, they need to consume coal in an eco-friendly manner and reduce the coal share in energy consumption. Moreover, there was a particular tendency for this proportion of energy consumption to decline. It would be reasonable to predict that this trend will continue, based on our findings, as there is a long-term cointegration relationship between energy intensity, energy consumption and per capita GDP growth in the past two decades. In addition, energy consumption has a positive effect on energy intensity, which indicates that decreasing the proportion of coal in energy consumption will contribute to reduced energy intensity. For G20 countries, the results of Granger causality tests show that energy intensity granger-causes GDP per capita, so decreasing energy intensity can promote upgrades in growth in economic structure.

Appendix A:

Table 1

Correlated Random Effects- Hausman Test
Pool: BASIC
Test cross-section random effects

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	12.687158	2	0.0018

Cross-section random effects test comparisons:

Variable	Fixed	Random	Var(Diff.)	Prob.
DLOG(EC_?)	0.391094	0.340907	0.000425	0.0150
DLOG(GDPPC_?)	-0.102736	-0.101993	0.000002	0.5990

Cross-section random effects test equation:
Dependent Variable: DLOG(EI_?)
Method: Panel Least Squares
Date: 03/19/17   Time: 21:46
Sample (adjusted): 1991 2012
Included observations: 22 after adjustments
Cross-sections included: 20

Total pool (balanced) observations: 440

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.015354	0.001660	-9.250265	0.0000
DLOG(EC_?)	0.391094	0.048200	8.114003	0.0000
DLOG(GDPPC_?)	-0.102736	0.010685	-9.615096	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.305106	Mean dependent var	-0.011971
Adjusted R-squared	0.270195	S.D. dependent var	0.032614
S.E. of regression	0.027861	Akaike info criterion	-4.274444
Sum squared resid	0.324475	Schwarz criterion	-4.070105
Log likelihood	962.3776	Hannan-Quinn criter.	-4.193832
F-statistic	8.739556	Durbin-Watson stat	1.907597
Prob(F-statistic)	0.000000		

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