Energy Intensity–Economic Growth Nexus: A Panel Study of Multi-Country Data Set

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Abstract

Exploring the relationship between energy intensity and per-capita income for the period of 1981-2015 in 42 countries has been targeted in this study. In order to achieve that target, the study has used the fixed effect model for these 42 countries. A non-linear relationship between energy intensity and per capita income has been ascertained. The surge in per-capita income gives birth to the rise of energy intensity in the beginning however, the energy intensity begins to fall down when the per-capita income reaches at the specific level. And, that specific level has been invested as US $ 5499.07 in this study. The main contribution of this study is to ascertain the threshold level of income and support the inverted U-shaped linkage between energy intensity and per capita income. The per capita income has been discovered as one of the main determinant of energy efficiency in the conclusion of this study that helps out the policy engineers in launching the policy instruments causing increase in per-capita income; but, that increase in per- capita income will only be saluted if the energy intensity falls down at higher levels of per-capita income. The study concludes that the rise of industrialization gives boost to the energy intensity but it does not mean that it put the promotion of industrialization on the back burner. Instead, it advises the policy designers to take steps to decrease the destructive offshoots of industrialization on energy intensity.

Introduction

Across the global world, the energy efficiency related issues have become a center of discussion and attention for the policy makers and researchers for the last 30 years. The economic interests of all countries are being affected by the efficient use of energy because it unleashes inevitable and incredible effects on energy, economic, social and environmental and national security. Among the global energy preferences, the energy consumption reduction and energy efficiency improvement gained much importance in present times where the green economy and sustainable development have become a common slogan across the economic world.

What are the correct determinants that may cause the energy efficiency changes in the countries has become the Centre of debates and discussions at political, research and scientific level in the present era? After extensive discussions and research, the research identified economic growth, energy prices, industrialization, introduction of innovative technologies etc as the most pertinent determinants affecting energy efficiency. Energy efficiency is earned through the usage of fewer energy units where an equivalent level of economic activity remains constant. In other words, the energy intensity means the amount of energy consumed per unit of output. The energy efficiency and its change is gauged by energy efficiency that is considered as one the most sustainable development indicator (Freeman and Niefer,1997; Streimikiene,2007). The preeminent and

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appreciate indicators are those which bear relevance to the aim, comprehensibility, viability, reliability and availability of the data Golusin and Munitlak-Ivanovi (2009). The changes popped up in energy intensity are caused by a function of more than one determinants because energy intensity can only be noted as a proxy for energy efficiency. Among the determinants, the economic growth (a rise in GDP per capita) of the economy is the most credible and important determinant of energy intensity Gonzaleset al. (2013). For energy efficiency improvement, the economic growth is the most important driver; the empirical outcomes floated by Zhang (2013) higher per capita GDP may unleach its impact on other determinants of energy efficiency if it lets the entry of new technologies and increases capital stock.

In the circles of empirical discussions, the impact of GDP per capita on energy intensity is still felt at large. If it is accepted that the level of economic development determines the level of energy intensity, then it may be supposed that higher income mounts pressure on the demand for energy which ultimately will give rise to the energy intensity. On the flipside of this argument, it means that income decides the level of development. On account of such development, it is hoped that the households and producers use the energy-saving instruments and newt t1echnologies which ultimately will decrease energy intensity. For all that, many authors applied econometric analysis to reflect that the energy intensity of an economy takes after an inverted U shape across surging levels of per capita income Medlock and Soligo (2001) i.e. As economic development precedes, the shifts in the structure of GDP will result into rise thereafter lower the energy intensity. This patter is consistent remains with the theory of de-materialization Bernardini and Galli (1993) i.e energy intensity mounts up at initial stage thereafter it gets downfall with the rise of GDP per capita that show a non-monotonic linkage between energy intensity and GDP per capita.

The study intends to investigate how per capita income influence energy intensity during 1981-2015 in 42 countries. Further, it also finds the thresh hold level of per-capita income that is the main contribution of this research. The study follows a sequence, section1 is devoted to brief introduction and literature review, data and methodology is explained in section 2, results are presented in section 3 whereas conclusions and policy recommendations are detailed in section 4.

Data and Methodology

Energy intensity and per capita income is complex relationship Ramos-Martin (2002). The nature of the relationship between these two variables is investigated by Galli (1998) and found it be a non-monotonic. This relationship can be modeled in to functional form following the Galli work as follows,

$$ei = f(y, y^2, ind) \text{--} (1)$$

In equation 1, energy intensity is abbreviated by ei. y and ind represent the income per capita and industrialization respectively. The square term of income per capita (y^2) is included in the model to capture the non-monotonic nature of the relationship. In order to estimate the above relationship, we transform the dependent and independent variables in logarithmic form just to reduce the effect of outlier and to express the change in dependent variable due to independent variables in term of elasticities. We also include the disturbance term which demonstrates the randomness of the data. Thus the above said relationship can be written as follows,

$$Ln(ei_{it}) = \delta_0 + \delta_1 Ln(ind_{it}) + \lambda_1 Ln(y_{it}) + \lambda_2 [Ln(y_{it})]^2 + \theta_1 [Ln(y_{it}) -$$
$$Ln(y_1)]^2 * R_1 + \theta_2 [Ln(y_{it}) - Ln(y_2)]^2 * R_2 + \theta_3 [Ln(y_{it}) - Ln(y_3)]^2 * R_3 +$$
$$\theta_4 [Ln(y_{it}) - Ln(y_4)]^2 * R_4 + \theta_5 [Ln(y_{it}) - Ln(y_5)]^2 * R_5 + \theta_6 [Ln(y_{it}) - Ln(y_6)]^2 * R_6 +$$

$$\theta_7[Ln(y_{it})-Ln(y_7)]^2*R_7+\theta_8[Ln(y_{it})-Ln(y_8)]^2*R_8+\theta_9[Ln(y_{it})-Ln(y_9)]^2*R_9+\varepsilon_{it} \quad (2)$$

In equation 2, δ's , λ's, θ's are the parameters which are required to estimate. Our study is based on panel data so the subscript i represents to each country where as the time period is symbolized by the subscript t. The equation 2 is a type of spline[a] regression model. Spline function are used to smooth fit. Spline regression models are of two types in general. In type one, the locations and number of knots are supposed to be known in advance where as in other type the number of knots and their locations are explored during the estimation procedure. We introduce the first type of spline regression model in which number of knots and their locations are supposed to be identified. The purpose of practice spline regression model in our study is to investigate the specific level of per capita income beyond that energy intensity declines. The study defines the numbers and location of knots on per capita income variable considering the range of data. The total number of knots are 9 and these knots are introduced in the regression model through dummy variables i.e. Ri whereas i = 1 …..…9. First knot is abbreviated by R_1 and is located against the ln7.5. Similarly, the second knot is denoted by R_2 and is placed against the ln8. Following the same procedure, R_3, R_4, R_5, R_6, R_7, R_8 and R_9 are located against ln8.5, ln9, ln9.5, ln10, ln10.5, ln11 and ln11.5 respectively. The numbers and locations of knots are assumed on the basis of range of the data on variable per capita income. After mentioning the numbers and locations of the knots, equation 2 can be modified as follows,

$$\begin{aligned}Ln(ei_{it}) &= \delta_0+\delta_1 Ln(ind_{it})+\lambda_1 Ln(y_{it})+\lambda_2[Ln(y_{it})]^2+\theta_1[Ln(y_{it})-\\ &Ln(7.5)]^2*R_1+\theta_2[Ln(y_{it})-Ln(8)]^2*R_2+\theta_3[Ln(y_{it})-Ln(8.5)]^2*R_3+\\ &\theta_4[Ln(y_{it})-Ln(9)]^2*R_4+\theta_5[Ln(y_{it})-Ln(9.5)]^2*R_5+\theta_6[Ln(y_{it})-Ln(10)]^2*R_6+\\ &\theta_7[Ln(y_{it})-Ln(10.5)]^2*R_7+\theta_8[Ln(y_{it})-Ln(11)]^2*R_8+\theta_9[Ln(y_{it})-Ln(11.5)]^2*R_9+\varepsilon_{it} \quad (3)\end{aligned}$$

Data and Variables

The variables in this study are energy intensity, per capita income and value added as a percentage of GDP (proxy for industrialization). Energy intensity means units of energy required to produce per unit of GDP. Real GDP divided by population is defined as per capita income whereas value added as a percentage of GDP is used as proxy for industrialization. Gross domestic product (GDP) is used at constant $ 2010 in all variables Energy intensity is dependent where as other variables are treated as independent variables. The source of data on these variables is WDI (data base of World Bank). Data on variables under consideration of 42 countries[b] from 1981-2015 is used in this study. The study uses the panel data. We select those countries where the energy intensity changes remarkably over the time and subject to availability of data for the period of under consideration.

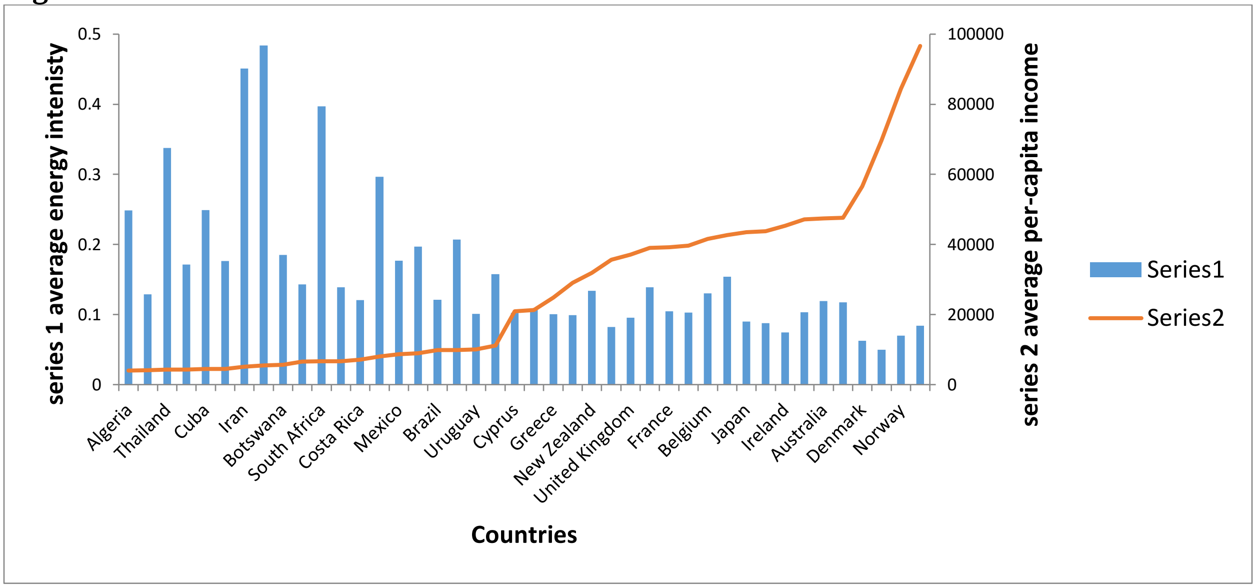
Results

In this section, study is continued in two stages. In stage one, study observe the trend of average energy intensity and average per-capita income considering all 42 countries in our sample for the time period of 1981-2015 in the following graph.

[a] For approximating the shape of a curvilinear stochastic **function**, Spline functions are used. See Suits et al.1978

[b] List of countries are given in Appendix A. Upper-middle and High income countries are included in our study.

Figure 1



The above figure shows that the average energy intensity increases at lower level of per-capita income but it starts decline after crossing a specific level of per-capita income. In addition to that, figure1 also explains that the most of the countries with low level of per –capita income have relatively high energy intensity and the majority of the countries with high per-capita income have low energy intensity.

Table 1. Results of Panel Regression ln ei is dependent variable

Predictor Variables	Predictor variables	Coefficient	t-stats	P-value
Intercept	Cons	-16.67*	-4.32	0.00
Industrialization	ln(ind)	1.67*	6.63	0.00
Per-Capita Income	ln(y)	2.24*	5.11	0.00
Per-Capita Income Square	$[\ln(y)]^2$	-0.41*	-5.32	0.00
1stDecile	$[\ln(y)-7.5]^2*R_1$	-0.19	-1.17	0.22
2ndDecile	$[\ln(y)-8]^2*R_2$	-0.29	-1.37	0.13
3rdDecile	$[\ln(y)-8.5]^2*R_3$	0.18*	2.11	0.00
6thDecile	$[\ln(y)-10]^2*R_6$	1.31*	6.53	0.00
7thDecile	$[\ln(y)-10.5]^2*R_7$	-0.27	-1.39	0.18
8thDecile	$[\ln(y)-11]^2*R_8$	1.47*	3.23	0.00

At stage two of the study, the relationship between energy intensity and per-capita income is estimated by using the equation3.

The pooled least square, random -effects and fixed- effects models were estimated respectively. However, fixed-effects estimator was appropriate and found to be consistent for which the results are presented in table 1. The choice of model selection among the pooled least Square, random-effects and fixed-effects models was not an arbitrary while it was selected by the means of Hausman[a] test.

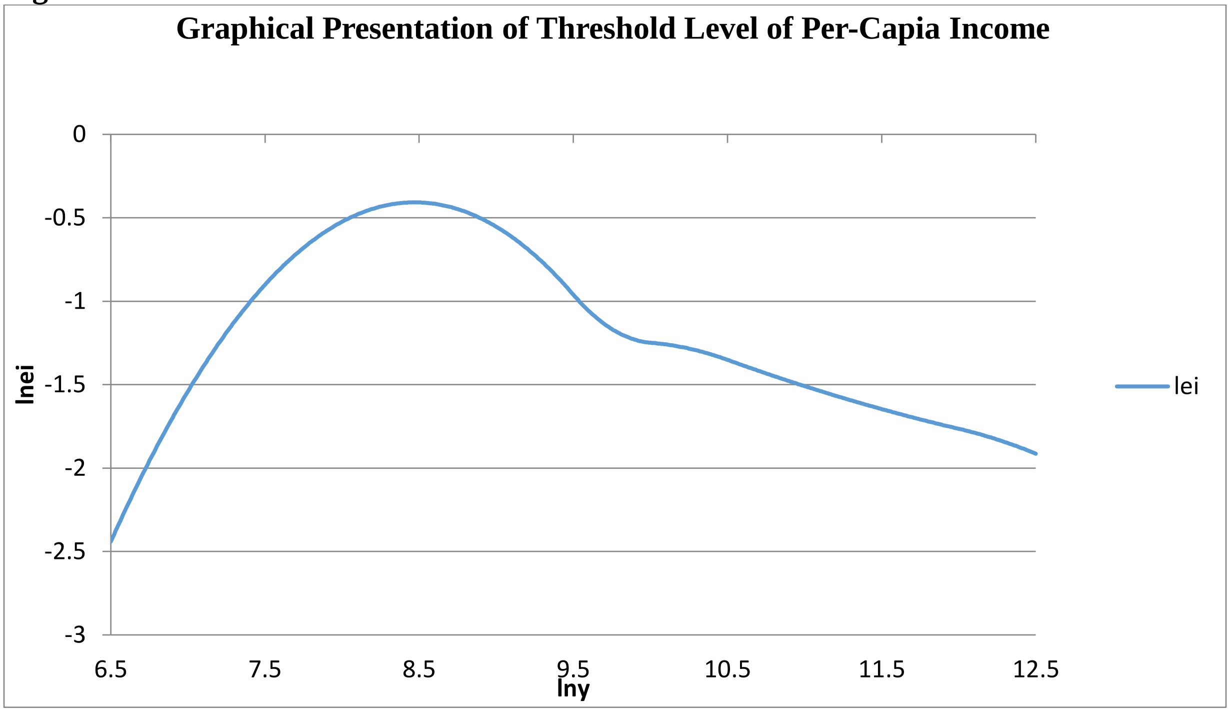
The results of fixed-effects estimator are shown in table 1. The coefficient of industrialization is positive and statistically significant showing that 1% increase in industrialization leads to increase in 1.67 % energy intensity. The reason of this positive relationship is that the most of the industries rely on energy through the use of machines and equipment, and in process of industrialization, the use of machines and equipment increase due to which energy intensity rises. Our findings are consistent with the results of research conducted by (Samouilidis and Mitropoulos, 1984; Poumanyvong and Kaneko, 2010) who find positive impact of the share of industrial activity on energy intenisty.

Further, per capita income has also positive impact on energy intensity. Since economic activities require energy consumption, increases in economic activities would be accompanied by increasing energy consumption which would invariably lead to a rise in energy intensity. In addition to that, the coefficient on the square of per capita income is negative reflecting the non-monotonic relationship between energy intensity and per-capita income. This non-monotonic relationship explains that, the increasing effect of per capita income on energy intensity changes beyond a certain threshold level i.e. energy intensity increases as per-capita income increases but it declines beyond a certain level of per-capita income (threshold level of per-capita income). Thus, an Inverted U-shaped relationship between per capita income and energy intensity exists which confirms the assertion of Galli (1998). That specific level of per-capita income (threshold level of income) after which energy intensity decline is investigated in our estimated regression. Regression results show a highest peak (threshold) at log per capita of 8.5[b]. However, the dummies for different deciles also show small peaks even after the highest peak (threshold level). The empirical non-linear relationship between per capita income and energy intensity is depicted in the following figure 2:

[a] Hausman test rejected the null hypothesis under which the random-effects estimator is consistent.

[b] Antilog 8.5= US $

Figure 2



It can be realized from figure2, energy intensity increases with increase in income per-capita income up to per-capita income of US $ 5499.07 but energy intensity declines as income per-capita crosses this specific level (threshold level) of income. Most of the countries included in our panel follow this empirical fact. The non-linear relationship between energy intensity and per capita income implies a shift of structural changes in the economies towards environmental friendly use of energy practices. This may be due to the availability of improved technologies at both demand and supply sides of energy when per capita income crosses certain threshold level.

Conclusions and Policy Recommendations

The empirical implications of per capita income and industrialization on energy intensity have been ascertained in this study paper wherein a panel data has been used for 42 countries during 1981-2015. The study pointed out, after applying Fixed Effect Model, the industrialization as a cornerstone in the rise of energy intensity. Further, it concluded an inverted U-shaped relationship between income per capita and energy intensity backs to the theory of de-materialization i.e. in the beginning, the energy intensity mounts up thereafter gets downfall with the rise of per capita income that highlights a non-monotonic linkage between energy intensity and per capita income. The energy intensity declines after crossing a threshold level of per-capita income of US $5499.07 It has been noted that policy instruments give rise to the per-capita income but this would only be considered the best one if the energy intensity gets decreased at higher per capita income levels. Moreover, the outcomes of this study witness that the rise of industrialization has been resulted into the rise of energy intensity but this does not mean to put ban on industrialization. Rather, it emphasis on the policy engineers to devise such appropriate steps that could bog down the unhealthy effects of industrialization on energy intensity.

In order to achieve this objective, a thorough and consistent research and development activities may be staged to decrease the industrial energy intensity at maximum level. Further, it is pertinent to mention that the policies supporting the import of delicate technologies, methods and application are needed to be introduced at government level which could decline the energy intensity when the country is passing through the period of industrialization. The increasing offshoots of industrialization can easily be curtailed in the presence of energy intensity and higher per capita income. That is why; it is imperative for the country to consistently attain the higher per-capita income and makes sure the maintainability of higher per capita income for a long span of time in order to scale down the energy intensity as it believes.

References

- Bernardini, O., & Galli, R. (1993). Dematerialization: long-term trends in the intensity of use of materials and energy. *Futures*, *25*(4), 431-448.
- Freeman SL, Niefer MJ, Roop JM. Measuring industrial energy intensity: practical issues and problems. *Energy Policy* 1997; 25:703-14.
- Galli R. The relationship between energy and income levels: forecasting long term energy demand in Asian emerging countries. *Energy* J 1998;19(4):85-105.
- Golu_sin M, Munitlak-Ivanovi_c O. Definition, characteristics and state of the indicators of sustainable development in countries of Southeastern Europe. *Agric Ecosyst Environ* 2009; 130:67-74.
- Gonzales PF, Landajo M, Presno MJ. The Divisia real energy intensity indices: evolution and attribution of percent changes in 20 European countries from 1995 to 2010. *Energy* 2013; 58:340-9.
- Medlock III, K.B. and R. Soligo (2001), ʻEconomic development and end-use energy demand, *The Energy Journal*, 22(2): 77–105.
- Poumanyvong, P., & Kaneko, S. (2010). Does urbanization lead to less energy use and lower CO2 emissions? A cross-country analysis. *Ecological Economics*, 70(2), 434-444.
- Ramos-Martín, J. (2002). Analysing the energy metabolism of economies from a complex-systems perspective (Doctoral dissertation, MPhil dissertation. Keele University).
- Samouilidis, J. E., & Mitropoulos, C. S. (1984). Energy and economic growth in industrializing countries: the case of Greece. *Energy Economics*, 6(3), 191-201.
- Streimikiene D. Monitoring of energy supply sustainability in the Baltic Sea region. *Energy Policy* 2007; 35:1658-74.
- Suits, D. B., Mason, A., & Chan, L. (1978). Spline functions fitted by standard regression methods. *The Review of Economics and Statistics*, 132-139.
- Zhang F. The energy transition of the transition economies: an empirical analysis. *Energy Econ* 2013; 40: 679–686.

Appendix: Algeria, Argentina, Botswana, Brazil, Bulgaria, Costa Rica, Cuba, Dominican Republic, Ecuador, Gabon, Iran, Islamic Rep, Malaysia, Mauritius, Mexico, Panama, Peru, South Africa, Thailand, Australia, Austria, Belgium, Chile, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, United Kingdom, Uruguay