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Article

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International Journal of Energy Economics and Policy

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2020, 10(5), 608-614.

Estimating the Impact of Energy Consumption on Carbon Emissions Using Environmental Kuznets Curve

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Received: 09 May 2020 **Accepted:** 28 July 2020 **DOI:** https://doi.org/10.32479/ijeep.10244

ABSTRACT

The objective of this study is to examine the equilibrium relationship in the short and long term of energy consumption in Indonesia (ECI) and carbon dioxide emissions in Indonesia (CO_2EI) for the period of 1980-2014. The dependent variable is environment and CO_2 emissions have been selected as an indicator for this variable while the independent variable in this study is energy consumption. In this study, quantitative method-based methodology has been selected. The quantitative method enable researcher to examine the relationship objectively using numbers, digits, and ratings as empirical evidence. In addition, the researcher used deductive reasoning to present the arguments. Deductive approach was selected because the research aims to test Environmental Kuznets Curve hypotheses and test it within the context of Indonesia and assess whether there is long term relationship between ECM and CO_2EM. In order to analyse the panel data, this study used statistical techniques. Firstly, descriptive statistics has been used to assess the central tendency of data using mean and standard deviation. In addition, Dickey Fuller test was performed to check stationarity in the data. Finally, ARDL model was developed to check the impact of independent variables on dependent variable. Through time series models this study found that there is long-term equilibrium relationship between CO_2E and EC. Furthermore, it can be concluded that there is a short-term relationship between the variables also. Finally, in general the results show that EC positively influences CO_2E in the short and long term.

Keywords: Energy Consumption, Carbon Emissions, Environmental Kuznet Curve, Indonesia
JEL Classifications: Q43, Q5

1. INTRODUCTION

Currently, the rising trend in carbon dioxide (CO_2) emissions is an important and common environmental challenge in the world, since it is experiencing climatic changes in our environment due to the consumption of energy from of fossil fuels such as oil used for power generation for different activities, therefore, this contributes to environmental deterioration generating global warming and, in turn, negative impact on economic society of a country. Total energy consumption represents 77% and per capita consumption was 1143.31 in 2016, with respect to CO_2 emissions it represents 0.15% and emits 1.9 however, it is evident that the Ecuadorian economy continues to depend on fossil energy, which represents between 75% to 80% of carbon emissions, according to the Organization of United Nations (UN), in 2014 it represented 83%. For example, 31% of the energy consumed in the country was in the form of diesel and the consumption of gasoline represented 28% of the total energy demanded. The utilization of various fossil fuels (such as gasoline and diesel) in transportation is the biggest source of CO_2E, having a share of 42% in the total CO_2E. In order to capture this problem, this study is based on the hypothesis of the Environmental Kuznets Curve (EKC). EKC assumes the hypothesis that in the short term there is a negative impact of economic development on the environment; but in case of long term, beginning from a specific income level, the pollution caused by economic growth shows lower levels. Therefore the shape of graph under the EKC is U shaped (Mousavi et al., 2017).

In this study the objective is to examine the relationship both in the long run and in the sort run for energy consumption in Indonesia (ECI) and carbon dioxide emissions in Indonesia (CO_2EI). The research project is designed as time series data econometrics, the elasticities are estimated to short and long term of CO_2E and EC, with the purpose of verifying the link between these variables according to the hypothesis posed by the EKC. This research work answers the question: What is the relationship between ECM and CO_2E in the short and long-term in Indonesia?

There are five main sections in this research report. Current section is the introduction providing justification for the topic and a brief discussion of methodology. Next section presents a comprehensive literature review supporting the argument that the relationship of CO_2 and EC is positive. The third section provides discussion and methodological detail. In the fourth section, the empirical results are presented using statistical techniques as well as discussion of results. The conclusions of the study are presented in the final fifth section.

2. LITERATURE REVIEW

The relationship between EC and CO_2E has been a frequently discussed issues in past couple of decades. One of the commonly used theoretical frameworks for this relationship is the EKC framework in order to verify that an inverted U-shaped exists to explain the relationship between EC and CO_2E. The arguments can be diverse for the affirmation of the Kuznets theory in the world. There is an extensive literature of studies carried out on the subject, which was classified into three categories of empirical evidence (Chen et al., 2016; Alam et al., 2016; Rauf et al., 2018; Solarin et al., 2017).

Before explaining the empirical evidence, it will be shown that the drivers of the changes in CO_2E according to Mousavi et al. (2017) allude that the Implementation of the Kyoto Protocol seems to have a positive impact on CO_2E. Referring to Bekhet et al. (2017), who carry out the decomposition analysis in order to effectively quantify the contribution of various factors that affect CO_2E, and to conduct an effective of the technological and policy measures. The identity presented by Kaya has been commonly referred for this task, to allow break down of CO_2E in different factors.

In the first category we consider the studies of the dynamic relationship of the study variables of this research, that is, CO_2E and EC. While the second category focuses on the studies that are focused on examining the connection link between EC and economic growth. In the last category there are studies which use other variables for example, financial development, income, foreign direct investment (FDI), and international trade, among others.

Finally investigating the impact of EC on CO_2E, it is important to include the EC from renewable sources. According to Bekhet et al. (2017) CO_2E indicate an upward trend driven mainly by per capita household consumption and energy intensity. Furthermore, the EC will continue to have an upward trend and therefore generating CO_2E that will increase between 4.3% and 5% in the case of Iran. Furthermore, they also show the urgent need for energy savings due to excessive EC, as Mirza and Kanwal (2017) alludes. Continuing along the same line, Appiah (2018) indicates that in the residential, commercial sector, they are more likely to consume energy, with a total of 56% also generating more pollution. This implies that the relationship between EC and CO_2E is positive and the results explain that carbon dioxide undergoes structural changes due to the variation in EC (Wang et al., 2016).

Mirza and Kanwal (2017) examined relationship among EC, CO_2E and economic growth focusing on Pakistan and applied the cointegration approach in combination with ARDL. The results mention that higher economic growth rates have shown adverse impact on environment and sustainability of resources and therefore the quality of economic growth is low. In addition to an increase in EC that could also give due to high CO_2E in the long term in the economy, and vice versa. There are also the findings that suggest that there is long-term cointegration among these variables. The same results are detailed by Appiah (2018), in his work carried out in Ghana. On the other hand, Bastola and Sapkota (2015) demonstrate long-term equilibrium using two ARDL techniques and autoregressive vectors (VAR). The findings also support a long-term as well as bi-directional causality between the EC in an economy and CO_2E. A bi-directional causality also was found between economic growth, EC and CO_2E. However, using panel data relates the three variables, the results found allude that there is no long-term balance.

Focusing on the African countries Ehigiamusoe et al. (2020) used co-integration and causality limits of the Granger type, and assessed long-term EC and economic growth and CO_2 and asserted that all of these factors tend to contribute towards environmental pollution. The results of the causality tests indicate that there is negative impact of economic growth on environment causing increase in CO_2E but in the short term. In this same direction, Ehigiamusoe et al. (2020) reported that a long-term relationship was found between GDP, EC, and CO_2E. Furthermore, the same study also found that there is a causal relationship between CO_2E and GDP as well as between EC and CO_2E. From these, they inferred that the in the short run economic growth is detrimental to the environmental change manifested by trends in CO_2E but the long run relationship shows different effect.

With respect to Alkhathlan and Javid (2013) they used the distributed lag autoregressive approach (ARDL) and as per the results they showed that there is an increase in the CO_2E if there is positive trend in per capita income. In the short term, on the other hand there was a reduction in the CO_2E caused by the per capita income. Al-Mulali (2014) used panel data for in his study to examine the long term effects of EC CO_2E via the Granger causality. This study revealed that EC shows a causal connection with economic growth, while a negative short-term causal relationship with CO_2E. In the studies by Saboori and Sulaiman (2013) they examined the relationship between the same three variables and also aimed to test and apply the EKC hypotheses and long term relationship by the Granger causality test. Therefore, from these results we infer that the study also found an inverted U-shaped relationship and supported the EKC hypothesis. Furthermore, they also showed long-term causality and bidirectional relationship.

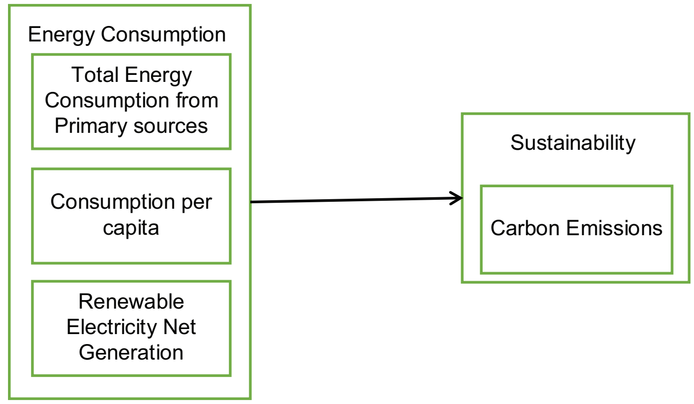
On the other hand, Narayan and Popp (2012) studied whether the GDP and EC shows relationship in the long run and reported that there exist a negative relationship for these variables. For their part, Bah and Azam (2017) explored links among economic growth, EC, and CO_2E through ADRL test as panel data analysis. Their results validated that cointegration exists for all three variables in the long run.

Furthermore, Boutabba (2014) observed that financial development tends to have a positive impact on CO_2E in the long-term. In other words, the study concluded that is to say that this variable reduces the degradation of the environment. Authors such as Farhani et al. (2014) allude to the presence of a long-term relationship based on their model in which variables analyzed, included trade, cause CO_2E. In the same way, Allali et al. (2015) concluded that a positive long-term relationship can be observed between CO_2E and EC. This study also showed that there was a two-way causality. To conclude with this scenario, Tajudeen (2015) examines the role of energy deficiencies and non-economic factors, where they show that energy demand will continue to grow, so it affects CO_2E.

In addition to this, there is an impact of non-renewable and renewable energy emissions according to Bilgili et al. (2016), there is also a negative causality of renewable sources for emissions within the EKC model. According to authors who used the STIRPAT model, and indicate that the energy consumption from non-renewable energy are the main source of CO_2E, while the consumption of renewable energy decreases CO_2. In the same way, Ito (2017) uses panel data, and they mention that non-renewable energy shows negative impact with environmental degradation, and that renewable EC does contribute positively to economic growth in the In the long term, then it is said that even a certain level of development, that is, in the short term, will generate more CO_2. Finally, Brini et al. (2017) used a PRISM method in their research, the results indicate that CO_2 are from EC. In the investigation, most of the investigations carried out show the balance of short and long term and the support of the hypothesis in the different countries or regions.

The use of energy is essential for pacing up the economic growth and development of an economy, as argued by Chiu (2017) who continued to recommend that regarding EC and CO_2E, evidence suggested a non-linear link and thus energy efficiency improvement can effectively minimise CO_2E. On the other hand, Ajmi et al. (2013) allude that the there is a change in the environment governed by the relationships among EC, CO_2E and GDP over time, due to variations in economic growth. Furthermore, a bi-directional causality supports the assertions about variation in these links. A study carried out in South Korea used the regression analysis to relate EC, CO_2E and economic growth. The results show that growth and EC show a significant correlation is to say they emit carbon dioxide.

Referring to the study by Al-Mulali and Sheau-Ting (2014), on the econometric analysis of trade, EC and emissions, using panel data shows a positive long-term relationship between the variables of trade-consumption of energy and between the variable of exchange of CO_2E. Finally, it was shown that EC is a stable consequence of CO_2E in the face of minimal or excess consumption.



H_1: Total Energy consumption from primary sources has a positive relationship with CO_2E

H_2: Consumption per capita has a positive relationship with CO_2E

H_3: Renewable electricity Net generation has a negative relationship with CO_2E.

3. RESEARCH METHODS

In this study, quantitative method-based methodology has been selected. The quantitative method enable researcher to examine the relationship objectively using numbers, digits, and ratings as empirical evidence. In addition, the researcher used deductive reasoning to present the arguments. Deductive approach was selected because the research aims to test EKC hypotheses and test it within the context of Indonesia and assess whether there is long term relationship between ECM and CO_2EM.

In order to gather empirical evidence, this study identified following indicators:

3.1. Dependent Variable

The dependent variable is environment and CO_2 emissions have been selected as an indicator for this variable. CO_2E data is publically available on the World Bank website database. The study collected annual CO_2E for the period from 1980 to 2014.

3.2. Independent Variable

The independent variable in this study is energy consumption. In order to operationalise this variable, three indicators have been selected from general literature review presented above. The first is the total energy consumption from primary resources (TEPR). This is a commonly used indicator of EC. Furthermore, this study also identified consumption per capita (CnCP). Consumption per capita is also a commonly used indicator of EC in an economy. Finally, this study selected renewable energy generation as an indicator of EC because renewable energy (RnEG) electricity shows an improvement in energy efficiency and resource consumption and these are more environment friendly.

In order to analyse the panel data, this study used statistical techniques. Firstly, descriptive statistics has been used to assess the central tendency of data using mean and standard deviation. In addition, Dickey Fuller test was performed to check stationarity in the data. Finally, ARDL model was developed to check the impact of independent variables on dependent variable.

The equation developed for this study is as followed:

$$CO_2\,E_t = \alpha + \beta_1 TEPR_t + \beta_2 TEPR_{t-1} + \beta_3 TEPR_{t-2} + \ldots \varepsilon$$

4. RESULTS

Following table is a summary of descriptive statistics for each variable included in the model. The descriptive statistics reflect the central tendency measures of data using mean and standard deviation commonly.

Variable|	Obs	Mean	Std. Dev.	Min.	Max.
Totalprima~n |	35	3.5704	1.726032	1.16	6.62
TotalRenew~t |	35	0.1257709	0.0693366	0.0232068	0.2608559
Consumption |	35	339.5266	230.5291	46.17	811.9
CO_2emissio~t |	35	268599.3	145719.9	94784.62	637078.9

The mean of total primary energy consumption is 3.5704 from which it can be implied that on average total primary energy consumption increased by 3.5% in Indonesia. Furthermore, the maximum value for this variable is 6.62 and the minimum value is 1.16 and therefore in the 35 years period, the total primary energy consumption in Indonesia increased by 3.5%. The standard deviation for the total primary energy consumption is 1.72%. The standard deviation indicates the difference between data values and mean. It can be observed that standard deviation is relatively low, therefore, this study implies that growth of total primary energy consumption in Indonesia has been consistent over the long term, thus making the variable more effective.

The mean of Total Renewable Electricity Net Generation is.1257 from which it can be implied that on average total primary energy consumption increased by.12% in Indonesia. Furthermore, the maximum value for this variable is.023 and the minimum value is.26 and therefore in the 35 years period, the Total Renewable Electricity Net Generation in Indonesia increased by 0.1257%. The standard deviation for the total primary energy consumption is 0.268%. The standard deviation is relatively low; therefore, this study implies that growth of Total Renewable Electricity Net Generation in Indonesia has been consistent over the long term, thus making the variable more effective.

The mean of Consumption per capita is 339.53 from which it can be implied that on average Consumption per capita increased by 339.53 on average per annum in Indonesia. Furthermore, the maximum value for this variable is 811.9 and the minimum value is 46.17 and therefore in the 35 years period, Consumption per capita in Indonesia increased by 339.5%. The standard deviation for the Consumption per capita is 230.53. The standard deviation is relatively low; therefore, this study implies that growth of Consumption per capita in Indonesia has been consistent over the long term, thus making the variable more effective.

The mean of CO_2E is 268599.3 from which it can be implied that on average CO_2E increased by 268599.3 per annum in Indonesia. Furthermore, the maximum value for this variable is 637078.9 and the minimum value is 94784.62 and therefore in the 35 years period, CO_2E in Indonesia increased by 268599.3. The standard deviation for the Consumption per capita is 145719.9. The standard deviation is relatively low; therefore, this study implies that growth of CO_2E in Indonesia has been consistent over the long term, thus making the variable more effective.

Next we conducted Dickey Fuller Test for each variable to check whether they are stationary. The null hypothesis is the test is that the data no stationary (with $\rho = 1$) and the alternate is data is stationary with ($\rho < 1$). The table provides summary of test statistics for all variables and the complete output is presented in Appendix.

Variable	t-statistics	P-value
Total primary Energy Consumption	1.124	0.995
Total Renewable Electricity Net	–0.573	0.8770
Consumption per capita	-5.247	0.0000
CO_2 Emissions	-1.047	0.7359

From the table it can be observed that in case of total primary energy consumption we accept the null hypothesis because the significance value is higher than 0.05. Furthermore, the t-statistics is not smaller than 10% critical value. Therefore there is unit root in this variable. Similarly, in case of Total Renewable Electricity the P value is higher than 0.05 and t-statistics is higher than 10% critical value, from which we interpret that the null hypothesis is accepted and that there is unit root in this variable. Furthermore, the t-statistics is not smaller than 10% critical value. Therefore there is unit root in this variable. Similarly, in case of consumption per capita the P value is less than 0.05 and t-statistics is higher than smaller than 10% critical value, from which we interpret that the null hypothesis is rejected and that there is no unit root in this variable. Finally, in case of CO_2E the P value is higher than 0.05 and t-statistics is higher than 10% critical value, from which we interpret that the null hypothesis is accepted and that there is unit root in this variable.

Furthermore, in order to assess the cointegration of variables, this study conducted ARDL, the results of which are presented in the following table.

From the table it can be inferred that the variability in CO_2E explained by total primary energy consumption, renewable energy consumption, and consumption per capital is 61.2% (R-square =0.6119). In addition, the total primary energy consumption is insignificant given that (t = 0.1.68, P = 0.105) the coefficient indicates that if there is a unit increase in total primary energy consumption, there is likely to be a.185 unit increase in CO_2E. In addition, total renewable energy generation is also insignificant given that (t = –0.09, P = 0.926). The coefficient indicates that if there is a unit increase in renewable electricity net generation, there is likely to be a 0.247 unit decrease in CO_2E. Finally, in case of consumption per capita, the variable is significant given that (t = 2.93, P = 0.007). Furthermore, if there is a unit increase in per capita consumption there is likely to be a.317 increase in CO_2E.

ARDL(1,1,1,1) regression						
Sample: 1981-2014				Number of obs=34		
Adj R-squared=0.5074				R-squared=0.6119		
Log likelihood=44.748589				Root MSE=0.0742		
D.Co_2emiss|	**Coef.**	**Std. Err**	**t**	**P>|t|**	**[95% Conf. Interval]**	
ADJ	|					
Co_2emiss	|					
L1.	–0.5512181	0.177634	–3.10	0.005	–0.91635	-0.1860862
LR	|					
Consump|	0.3171898	0.1082451	2.93	0.007	0.0946889	0.5396908
Total renewable electricity net|	–0.247328	2.651325	–0.09	0.926	–5.697205	5.202549
Totalprimary energy consumption|	0.1854567	0.1102762	1.68	0.105	-0.0412193	0.4121328
SR						
Consump|						
D1.|	0.4202065	0.4513084	0.93	0.360	–0.5074712	1.347884
Total renewable electricity net|						
D1.|	–2.575184	1.074135	–2.40	0.024	–4.7831	–0.3672686
Totalprimary energy consumption|						
D1.|	–0.0268169	0.1308122	–0.21	0.839	–0.2957053	0.2420715
_Cons|	5.502115	1.803525	3.05	0.005	1.794915	9.209314

4.1. Hypothesis Summary

S. No.	Hypothesis	Status
H_1	Total Energy consumption from primary sources has a positive relationship with CO_2E	Accepted
H_2	Consumption per capita has a positive relationship with CO_2E	Accepted
H_3	Renewable electricity Net generation has a negative relationship with CO_2E	Accepted

5. DISCUSSION OF RESULTS

In previous section, it can be observed that as per Augmented Dickey-Fuller test the variable CO_2E and EC have unit roots and therefore they are not stationary. This result is inconsistent with previous literature such as Dogan and Turkekul (2016). Meanwhile Al-Mulali et al. (2013) alluded the same but stressed that panel unit root tests show higher statistical strength as compared to the time series unit tests root.

Shahbaz et al. (2013), show that there are two integration vectors, so an additional variable was included, which is economic growth and the spoken variables. The previous results are consistent with those reported from other investigations applied in other countries, such as the work of, Sharif et al. (2017) and using the ARDL approach, as Bah and Azam (2017) alluded to the same thing. However, Ozcan (2013) and Al-Mulali (2014), mention that there is no long-term equilibrium using panel data. Meanwhile, counteracting with other investigations and compiled from the previous literature review, Tian et al. (2018) establish the presence of an integration vector using the methodology of panel, likewise mentions Zakarya et al. (2015), applying the same methodology. For their part, Ahmad et al. (2016) carried out a study relating the short and long-term balance between CO_2E, EC and economic growth. as per conclusions there is a long-term cointegration relationship.

The short-term equilibrium results obtained in this investigation between the variables of EC and CO_2E are similar to the previous results in the literature review obtained by Salahuddin et al. (2018). Although, on the contrary, using the panel data Al-Mulali (2014) mentions that there is no short-term balance. Contrasting with other studies, Marques et al. (2016), mentions that there is no presence of equilibrium in the short term. It also indicates that energy can be an important economic growth driver and, simultaneously it generates high levels of CO_2E in the environment. For their part, Rahman and Kashem (2017), EC shows a statistically significant impact and positive in nature in the short run on CO_2E.

Furthermore, Bah and Azam (2017) using time series methodology reported a statistical causal relationship between CO_2E and EC and economic development. They indicate an inverse type relationship between CO_2E and GDP as economic growth indicator. On the other hand they indicate that there is a one-way causality that ranges from EC and CO_2E. However Allali et al. (2015) allude to the presence of a bidirectional causality link between EC and CO_2E, pointing out as long as they are accompanied by other variables. For their part, Shahbaz et al. (2016), in their research work, identify the nature of the causality between CO_2E, EC, and economic growth based on data of 11 economies, the results mention that economic growth is the cause of CO_2E in Egypt and Bangladesh. Also economic growth causes EC in the Philippines, Turkey and Vietnam.

6. CONCLUSION

This research examined the short-term and long-term equilibrium relationship of EC on carbon dioxide emissions in case of Indonesia during the period 1980-2014, under the focus of the EKC hypothesis. Through time series models this study found that there is long-term equilibrium relationship between CO_2E and EC. Furthermore, it can be concluded that there is a short-term relationship between the variables also. Finally, in general the results show that EC positively influences CO_2E in the short and long term. The possible implication of public policy according to the results obtained, it is necessary that the Indonesian government implements energy efficiency measures. In addition it must apply a legal regulation where it establishes the limits of EC and more taxes on consumption, or also encouraging people to buy low carbon products, in this way the reduction of CO_2E caused by EC can be made effective.

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