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Does higher income lead to more renewable energy consumption? evidence from Indonesia

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Abstract. Indonesia is aimed to reach the use of renewable energy by up to 23 percent by 2025. Increasing society's income is considered as one of the effective ways to encourage society to shift to renewable energy consumption. Therefore, the aim of this study was to investigate the impact of income on renewable energy consumption in Indonesia. This study employed Engle Granger Error Correction Model and used hydroelectricity consumption as the proxy of the renewable energy consumption and real gross domestic product (GDP) per capita as the proxy of the income. The result of this study suggested that hydroelectricity consumption can be written as a quadratic function of real GDP per capita. It means that at the beginning, increasing real GDP per capita reduced the hydroelectricity consumption, and at a certain level it turns to opposite direction, where the rise of the real GDP per capita increased hydroelectricity consumption. In conclusion, higher income leads to higher renewable energy consumption. The policy implication for policymakers is straightforward, i.e., it is important to increase the income of the society, not only for the sake of the wealth of the society, but also for the protection of the environment through more clean energy consumption.

1. Introduction

Global primary energy demand raised by 5.8% in 2021, higher than 2019 levels by 1.3%. Unfortunately, the high demand was fulfilled by fuel energies that cover 82% of the consumption of total energy in 2021 [1]. However, fossil fuels are non-environmentally friendly energy sources. Burning fossil fuels will release enormous amounts of carbon dioxide (CO_2) into the air and leads to climate change. CO_2 emissions recorded a new all-time high level in 2019 and it was a fourth consecutive high CO_2 ever recorded [2]. In addition, 4.3 million deaths in 2012 occurred due to indoor air pollution [3]. The concern over the severe impacts of fossil fuels have sparked the campaign of the importance of use of renewable energy sources. Especially, the United Nations also concerned about this matter and announced Sustainable Development Goal {SDG) to promote the use of modern energy for all by 2030 [3].

About 75% of the growth of the world's energy consumption because higher consumption in China, followed by India and Indonesia [2]. Indonesia's primary energy supply is from fossil fuels (it accounts 88% of the national power capacity), but Indonesia is aimed to reach the use of renewable energy by up to 23% by 2025 and reach net-zero emissions by 2060. However, signs of progress in renewable energy projects have shown no promising development. For example, installed capacity of renewable energy sources in Indonesia remains low, as it does not meet to achieve the 23% target. Furthermore, investments on renewable energy in Indonesia are still low, the total investment is only 30% in the energy segment in 2021. Renewable energy projects only received USD 1.1 billion while fossil fuels received USD 2.5 billion at the same time [4].

Humans are largely to blame to the destruction of the environment [5]. Their economic activities led to the degradation of the environment. Therefore, increasing the consumption of clean energy sources is important for the purpose of changing fossil fuels consumption to clean energy consumption. Recently, Indonesia's renewable energy consumption is kept at 19%. Since there is a low level of the use of renewable energy in Indonesia, it is vital to increase the renewable energy use through changing human behaviour to shift from use of fossil fuels to use renewable energy.

Previous studies have investigated the factors of renewable energy in developed and developing countries (for examples: [6], [7], [8], [9], [10] and [11]). Those studies indicated that per capita Gross Domestic Product (GDP), as the proxy of income, was considered as one of the effective ways to encourage society to shift to renewable energy consumption. Based on Consumption Theory, there is a connection between income and consumption. Since the theory is in general term, one can establish the connection between income and renewable energy consumption. [11] indicated that the rise in per capita income at the household level encouraged individuals paid more money on clean energy services to get better comfort for their life. Moreover, since the demand for renewable energy increases, additional renewable energy production is needed to cover the demand.

Even previous studies indicated positive impact of per capita GDP on renewable energy spending, other study showed the opposite direction [12] and some other findings did not find the impact of income on renewable energy (for examples: [13] and [14]). Therefore, it is concluded that the empirical results on the effect of income on the renewable energy consumption are not certain and mixed. In addition, to the best of our knowledge, the investigation about the impact of income on the renewable energy consumption in Indonesia does not exist. So, it is vital to investigate empirically how income may affect renewable energy consumption in Indonesia.

On top of it, this study also offers a new insight that renewable energy consumption can be formed as a quadratic function of income to examine the possibility of the existence of U-shape connection between income and renewable energy consumption. The U-shape means that initially greater income level will reduce renewable energy consumption, until at a particular level, that the greater income level will increase sustainable energy consumption. To the best of our knowledge, no previous studies examine the likelihood of the presence of U-shape link between income and renewable energy consumption.

To sum up, this paper makes two important contributions. Firstly, this study adds to current literature by justifying the connection between income and clean energy consumption in Indonesia. Secondly, this study tries to examine the likelihood of the presence of U-shape relationship between income and renewable energy consumption in the case of Indonesia. This study offers new-found evidence to current literature.

The structure of this paper is arranged as follow: Part 1 explained introduction and concisely discussed at the background and literature review on the subject. Part 2 explains the empirical method. Part 3 described the analysis of the results, and the Part 4 is the conclusion.

2. Methodology

This research applied econometric procedures, i.e., Engle-Granger Error Correction Model (E-G ECM) to mainly investigate the impact of income on renewable energy consumption in Indonesia. The variables are summarized as follow:

Table 1. Variables in the Model

Variable	Proxy of	Source
hydroelectricity consumption (HEC)	the renewable energy consumption	British Petroleum
real GDP per capita (YCAP)	Income	World Bank
Oil Price (OIL)	Crude Oil Price	British Petroleum
CO_2 (CO2)	CO_2 Emission	British Petroleum

HEC was a dependent variable; YCAP, OIL and CO2 were the independent variables. OIL and CO2 were used as those variables were likely have impact on renewable energy consumption. The E-G ECM was applied for this study because the E-G ECM offered not only the dynamic short run but also long run among the cointegrating variables. As economists are concerned mainly in long-run relations, the concept of E-G ECM is very convenient. The E-G ECM consists of two models. The basic model with quadratic function of real GDP per capita, known as the long run model, is expressed as follow:

$$L(\text{HEC})_t = \mu_o + \mu_1 L(\text{YCAP})_t + \mu_2 L(\text{YCAP})^2_t + \mu_3 L(\text{OIL})_t + \mu_4 L(\text{CO2})_t + e_t \ldots\ldots\ldots\ldots \quad (1)$$

In the next step, the equation (1) was converted into ECM form, known as the short run model, as follow:

$$\Delta L(\text{HEC}))_t = \delta_o + \delta_1 \Delta(L(\text{YCAP}))_t + \delta_2 \Delta((L(\text{YCAP}))^2)_t + \delta_3 \Delta(L(\text{OIL}))_t + \delta_4 \Delta(L(\text{CO2}))_t + \delta_5 \text{ECT}_{t-1} + \varepsilon_t \ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where, L symbolized the logarithm function, HEC was hydroelectricity consumption, YCAP was real GDP per capita, YCAP^2 was real GDP per capita squared, OIL was raw oil price and CO2 was CO_2 emissions, e and ε were the errors or disturbances, t was the time. μ_o, μ_1, μ_2, μ_3 and μ_4 were the coefficients for the long run model, δ_0, δ_1, δ_2, δ_3, δ_4 and δ_5 were the coefficients for the short run model, Δ is the difference between the N_t observation and N_{t-1} observation. ECT was the error-correction term and ECT was the most important variable in E-G ECM model. The coefficient of ECT, in this case δ_5, informed the speed of adjustment to equilibrium takes place in each period. The value of α_5 lies from 0 to 1. In summary, if $\alpha_5 = 1$ then 100% of the adjustment occurs within a given time, or the adjustment is instant and finish within a given period; If $\alpha_5 = 0.5$ then 50% of the adjustment occurs in each period and if $\alpha_5 = 0$ then there is no adjustment at all.

E-G ECM must fulfil some requirements before can be used for the analysis. The requirements are (1) dependent variable and independent variables must not stationary at level, I(0); (2) dependent variable and independent variables must stationary at 1st difference, I(1); (3) all variables in the form pf cointegration on their linear combination. The stationary tests for both dependent and independent variables were ran using Phillips-Perron (PP) unit root tests (for conditions no. 1 and 2). The cointegration test was applied using Engle-Granger Cointegration test for the errors (for condition no. 3). If all requirements are achieved, E-G ECM can be applied.

3. Results and Discussion

the first requirement of the non-stationary variables was tested using with Phillips-Perron unit root tests. There are two types of Phillips-Perron tests, i.e., the test includes intercept, and the test includes trend & intercept. The Phillips-Perron tests showed that all variables were not stationary at level, as indicated by the probabilities values of all variables were greater than 10% (or 0.10). One variable (L (HEC)) was not stationary based on intercept-based calculation, two variables (L (YCAP) and L $(\text{YCAP})^2$) were not stationary based on both intercept- and trend & intercept-based calculations, and two variables (L(OIL) and L(CO2)) were not stationary based on trend & intercept-based calculations. For the second requirement, the unit root tests using Phillips-Perron tests suggest that all variables are stationary at first (1st) difference. The probabilities values of all variables were more than 10% (or 0.10) as presented in table 2. Therefore, it is concluded that the test fulfilled the first and second conditions of E-G ECM.

Table 2. Phillips-Perron Unit Root Test for Level and 1st Difference

Variables	**Unit root tests in Level**		**Unit root tests in 1st Difference**	
	Intercept	**Trend and Intercept**	**Intercept**	**Trend and Intercept**
L (HEC)	-2.189563	-5.207817	-8.384798	-8.207224

	(0.2139)	(0.0011)***	(0.0000)***	(0.0000)***
L (YCAP)	-0.851637 (0.7894)	-2.019710 (0.5674)	-5.477878 (0.0001)***	-5.375418 (0.0008)***
L $(YCAP)^2$	-0.735759 (0.8225)	-1.919506 (0.6196)	-5.248356 (0.0002)***	-5.145675 (0.0014)***
L (OIL)	-3.519227 (0.0143)***	0.871194 (0.9996)	-3.205647 (0.0299)***	-4.376286 (0.0086)***
L (CO2)	-6.419936 (0.0000)***	-1.354779 (0.8536)	-4.387319 (0.0017)***	-9.057867 (0.0000)***

Note: values in Parentheses () are probability values
*** significance at p-value ≤ 0.01, means the variables are stationary

Next requirement is the cointegration. The test demonstrated that the errors were stationary at level, I(0), as viewed in Table 3. The result of the test implied that variables in the model have a long-run relationship, in which it is important for the analysis. All three tests indicated that the model satisfied the all three requirements of E-G ECM, and it was continued to E-G ECM.

Table 3. Cointegration Test

Variable	**Unit root tests in Level**	
	Intercept	**Trend and Intercept**
Residuals	-2.189563 (0.2139)	-5.207817 (0.0011)***

The outcome of the short run of E-G ECM was shown in Table 4. Table 4 demonstrated that the coefficient of YCAP had negative value and significantly influence HEC and the coefficient of YCAP squared has positive value and it significantly influenced HEC. The results suggested that, in short run, in the beginning, if the real GDP per capita increased by 1%, the hydroelectricity consumption declined by 3.702%, and at certain point, the further increase of the real GDP per capita will led to the increase of the hydroelectricity consumption by 0.277% in with assumption that other variables are not changed, or *ceteris paribus*. This result suggested the existence of a quadratic function of real GDP per capita on hydroelectricity consumption. It means that at the beginning, increasing real GDP per capita reduced the hydroelectricity consumption because the Indonesian society preferred to fulfil the basic needs first without considering the renewable energy as one of the basic needs. It is important to note that renewable energy is not cheap. However, at a certain level, the more rise in the real GDP per capita increased hydroelectricity consumption because at this point, the society already fulfilled their basic needs, and they still have more money and immediately shift to spend their money on the renewable energy. In conclusion, higher income leads to higher renewable energy consumption, and it reduce the pressure on the environment.

Table 4. Outputs of Short Run ECM

Explained Variable: Δ(Logarithm of Hydroelectricity Consumption (HEC))	
Constant	0.016 (0.449)
Δ(LOG (YCAP))	-3.702 (-2.068)**
Δ(LOG (YCAP)^2)	0.277 (2.053)*
Δ (LOG (OIL))	-0.064 (-0.530)
Δ(LOG (CO2))	-0.090 (-0.169)
ECT_{t-1}	-1.058 (-5.198)***
Adjusted R^2	0.541

Note: *** significance at p-value ≤ 0.01; ** significance at p-value ≤ 0.05; * significance at p-value ≤ 0.10; t-statistics are indicated in parentheses.

Additionally, this study also included two variables that were likely to have influence on renewable energy consumption. Nevertheless, OIL and CO2 were insignificant in the short run. The insignificant results indicated that the changes in oil price and CO_2 emission will not affect the renewable energy consumption in the short run. Coefficient of ECT was negative and statistically significant which indicated there was evidence of the convergence from short run to long run in the model.

Table 5 showed the result of the long run of E-G ECM. Similar to short run result, the result in table 5 showed that the coefficient of YCAP had negative value and significantly affect HEC and the coefficient of YCAP squared had positive value and it significantly affected HEC. The results suggested that, in long run, if the real GDP per capita rose, the hydroelectricity consumption drops until at certain point, where the additional increase the real GDP per capita led to the increase of the hydroelectricity consumption in with assumption that other variables are not changed, or *ceteris paribus*. Again, there was evidence of the existence of a quadratic function of real GDP per capita on hydroelectricity consumption in long run. Therefore, this study supported previous studies, such as [6], [7], [8], [9], [10] and [11]. In the long run, the change of behaviour occurs when at initial stage, society seems does not care about the protection of the environment as little are spent on the clean energy consumption, but at certain level, society allocates their money on the renewable energy consumption as they understand the importance of the protection of the environment. As mentioned before, economists are more concern on the long run results and this study validates the long run relationship between income and renewable energy consumption. It is concluded that income become one of the vital ways to the transition from fossil fuels to clean energy.

Table 5. Outputs of Long Run ECM

Explained Variable: Logaritm of Hydroelectricity Consumption (HEC)	
Constant	4.158 (1.164)
LOG (YCAP)	-2.546 (-2.723)***

LOG (YCAP)^2	0.175 (2.657)***
LOG (OIL)	-0.323 (-0.829)
LOG (CO2)	-0.702 (-2.370)**
Adjusted R^2	0.751

Note: *** significance at p-value ≤ 0.01; ** significance at p-value ≤ 0.05; t-statistics are indicated in parentheses.

The results of two additional independent variables as follows. There was not enough evidence to support the claim that oil price affects hydroelectricity consumption. This result does not support the previous study by [10]. Indonesia still relies on oil for its production of gasoline, so the oil price changes seem do not affect any effort to shift to renewable energy consumption. Finally, the increase of CO_2 emission concentration level by 1% leads to the higher hydroelectricity consumption by 0.702%, with assumption other variables being equal. This study contradicts the previous study by [10]. When CO_2 emission concentration level increases, it begins to harm the environment. So, in this case, the society acknowledges the importance of moving toward the renewable energy consumption

4. Conclusion

The awareness of the significance of the clean energy consumption to protect of the environment has become a main objective in this study. The objective of this study was to examine the probability of the impact of income on the renewable energy consumption. This study used Engle Granger Error Correction Model and used hydroelectricity consumption as the proxy of the renewable energy consumption and real GDP per capita as the proxy of the income. The result of this study suggested that hydroelectricity consumption can be expressed as a quadratic function of real GDP per capita. It means that at the beginning, increasing real GDP per capita reduced the hydroelectricity consumption, and at a certain level it turned to reverse direction, where the rise of the real GDP per capita increased hydroelectricity consumption. In conclusion, income is undeniably vital keys to shift toward the transition from traditional to renewable energy sources. The policy implication for policymakers is straightforward, i.e., it is important to increase the income of the society, not only for the sake of the prosperity of the society, but also for the protection of the environment through more clean energy consumption.

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