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Examining the bi-directional long run relationship between renewable energy consumption and GDP growth

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ABSTRACT

The bi-directional long run relationship between renewable energy consumption and GDP growth has been investigated in high income, upper middle income, lower middle income, and high income countries. To achieve this goal, the fully modified OLS was utilized. The results revealed that 79% of the countries have a positive bi-directional long run relationship between renewable energy consumption and GDP growth. This represents the feedback hypothesis. On the other hand, 19% of the countries showed no long run relationship between the variables. This represents the neutrality hypothesis. Besides, 2% of the countries showed a one way long run relationship from GDP growth to renewable energy consumption, confirming the conservation hypothesis, and from renewable energy consumption and GDP growth representing the growth hypothesis. Despite the mixed results across countries, it has been proved that the more persistent and significant the bi-directional long run relationship between the variables is, the higher the income countries are.

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1. Introduction

The increasing concern about greenhouse gas emissions, which doubled over the last three decades, and the constant fluctuation in the price of fossil fuels encouraged many countries in the world to increase their investment on renewable energy. The renewable energy investment, industries, and policies have been rapidly increasing, especially in recent years. Based on the World Development Indicators (WDI), the renewable energy consumption increased more than 55% during the period 1980–2009. The increase in renewable energy consumption might have a huge impact on the world economic output. Despite the large amount of literature which has investigated the GDP growth–energy consumption relationship, there are only few studies that examine the relationship between renewable energy consumption and GDP growth. Moreover, most of the studies have focused on the bi-directional causal relationship between the energy consumption and GDP growth. Thus, the main goal of this study is to examine the renewable energy consumption–GDP growth relationship. In addition, unlike previous studies, this study will examine the bi-directional long run relationship

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between renewable energy consumption and GDP growth since the sign of the long run relationship between these variables has important consequences for policy implications. More than 108 countries categorized as low income, lower middle income, upper middle income, and high income will be investigated.

The investigation of the energy consumption–GDP growth relationship has been widely covered by different studies that investigate different countries and regions using different econometrics methodologies. Tables A1–A4 review (see Appendix A) the studies that investigated the relationship between total energy consumption–GDP growth, renewable energy consumption–GDP growth, electricity consumption–GDP growth, and fossil fuel energy consumption–GDP growth respectively. This paper covered 81 studies focusing on the Granger causality test results. A number of studies revealed a bi-directional causal relationship between energy consumption (by type) and GDP growth. This relationship represents the *feedback hypothesis*. The meaning of the feedback hypothesis is that the energy consumption and GDP are jointly determined and affect each other. In addition, a one way causal relationship from energy consumption to GDP growth was found by a number of studies. This relationship represents the *growth hypothesis*, which means that energy conservation policies on energy consumption adversely affect GDP growth. Moreover, a one way causal relationship from GDP growth to energy consumption was found in a number of studies. The relationship is called the *conservation hypothesis*. Thus, energy conservation policies might implement a little or no effect on GDP growth. Finally, a number of studies found no causal relationship between energy consumption and GDP growth. This relationship represents the *neutrality hypothesis*, which means that energy conservation policies have no effect on GDP growth.

While 45% of the studies found the feedback hypothesis, 10% of the studies found the neutrality hypothesis. In addition, while the conservation hypothesis was confirmed by 25% of the studies, the growth hypothesis was confirmed by 20% of the studies.

2. Data and methodology

Two variables will be used in this study. The first is the electricity consumption from renewable sources measured in kilowatt-hour (ELR). This variable is used by Apergis and Payne [35,37–41] as an indicator of renewable energy consumption. The other variable is the gross domestic (GDP) measured in millions of constant 2000 US dollars. In addition, the time period varied across the countries is based on data availability. The data source for both variables was taken from the World Development Indicators (WDI) [83] data base. Table B1 reviews the investigated countries based on income and the data availability for each country (see Appendix B).

Prior to implementing the FMOLS, it is important to examine whether the variables are stationary, hence, the Phillips–Perron (PP) test, which is one of most common unit root test, will be used. The Phillips–Perron (PP) test uses non-parametric statistical methods to control the serial correlation in the error term. It is basically based on the following statistics:

$$t_{\alpha}^{\sim} = t_{\alpha}\left(\frac{\gamma_0}{f_0}\right)^{1/2} - \frac{T(f_0-\gamma_0)(se(\hat{\alpha}))}{2f_0^{1/2}s} \tag{1}$$

where $\hat{\alpha}$ is the estimate, t_{α} is the t-ratio of α, $se(\hat{\alpha})$ is the coefficient standard error, s is the standard error, γ_0 is a consistent estimate of the error variance, and f_0 is an estimator of the residual spectrum at frequency zero.

The PP unit root test has three cases. They are: without constant and trend ($\beta_1=\beta_2=0$), with constant but no trend ($\beta_2=0$), and with constant and trend as in the test Eq. 1 above. The following null and the alternative hypotheses for each of the three cases are H_0: $\alpha=0$ (y_t is non-stationary) and H_1: $\alpha<0$ (y_t is stationary).

Since α is generally expected to be negative, the estimated τ statistic will have a negative sign. The τ test statistic ($=\hat{\alpha}/se(\hat{\alpha})$) is used to test the null hypothesis, i.e., the more negative the critical value is, the stronger the rejection of the null hypothesis in favor of the alternative hypothesis. This means there is a unit root at some chosen level of significance. Therefore, a larger negative τ value is an indication of stationarity.

Since the main goal of this study is to examine the bi-directional long run relationship between renewable energy consumption and GDP growth in low, lower middle, upper middle and high income countries, the fully modified least square (FMOLS) established by Phillips and Hansen [82] will be used. This coitnegration equation can work with variables that are stationary at different levels. It can also eliminate the long run correlation problem that exists between the cointegrating equation and stochastic regressor innovations. The FMOLS is basically unbiased and has fully efficient mixture normal asymptotics allowing for standard Wald tests using asymptotic Chi-square statistical inference. Moreover, it can work with variables that are stationary in different levels. This has an important advantage because economic time series are stationary at different levels, which may lead to produce misleading results. This problem can be controlled by the FMOLS.

The FMOLS estimator is presented as follows:

$$\hat{\theta} = \begin{bmatrix}\hat{\beta}\\ \hat{\gamma}_1\end{bmatrix} = \left(\sum_{t=1}^{T} z_t z_t'\right)^{-1}\left(\sum_{t=1}^{T} z_t y_t^{+} - T\begin{bmatrix}\hat{\lambda}_{12'}^{+}\\ 0\end{bmatrix}\right) \tag{2}$$

where Z_t is the deterministic trend and stochastic regressor, and the estimation of the FMOLS is the construction of long run covariance matrix estimators, namely $\hat{\Omega}$ and $\hat{\Lambda}$. The scalar estimator can be defined as follows:

$$\hat{\omega}_{1.2} = \hat{\omega}_{11} - \hat{\omega}_{12}\,\hat{\Omega}_{22}^{-1}\hat{\omega}_{21} \tag{3}$$

where ω is interpreted as the long run variance of the residuals. We can also apply a degree of freedom correction to $\hat{\omega}_{12}$.

3. The econometric results

The PP unit root test is utilized. Tables B2–B5 (see Appendix B) review the PP unit root test results for low income, lower middle income, upper middle income, and high income countries. The results reveal that all the variables are stationary, thus, we will proceed with the FMOLS test to examine the bi-directional long run relationship between renewable energy consumption and GDP growth. The FMOLS results are separated based on the income level. Table C1 (see Appendix C) reviews the FMOLS test results for low income countries. The results show that 11 out of 17 countries have a bi-directional positive long run relationship between renewable energy consumption and GDP growth. This indicates a long run feedback relationship which represents the feedback hypothesis. On the other hand, four of the countries, namely Congo, Democratic Republic, Ghana, Kyrgyz Republic, and Togo have no relationship between renewable energy consumption and GDP growth. This indicates the neutrality hypothesis. In addition, while a one way long run relationship from renewable energy consumption and GDP growth in Uzbekistan is found confirming the growth hypothesis, a one way long run relationship is found from GDP growth to renewable energy consumption in Zambia indicating the conservation hypothesis. However, the results for all low income countries reveal that there is a long run bi-directional long run relationship between renewable energy consumption and GDP growth, confirming the feedback hypothesis.