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A Reboot on Energy Consumption at Different Income Levels: A Panel Quantile Regression Touch

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Abstract

The field of energy economics is steeped in numerous studies that have centered on the relationship between energy consumption and economic growth, using multiple causality tests. However, with leveraging the previous studies, the literature needs to be expanded and enriched by harnessing modern, alternative econometric techniques. The aim of this study is to estimate panel quantile regression (PQR) models to find out the relationship between the energy consumption and the economic growth, by employing this technique on three separate models based on total, renewable and non-renewable energy consumption. With this three-tier feature built on the PQR models, our study is separated from the others and becomes a candidate to be a trailblazer. We unveil the effects of the energy usage on the economic growth at different quantile levels by using the annual dataset comprising the time span 2012-2022 for E7 countries. By and large, the aggregated numbers indicate that the renewables could be considered as a drive for the EG among higher-income countries, yet a drawback for lower-income countries. As for the renewables, while the solar EC poses a threat for the EG of the E7 countries as a whole at any level, the wind EC stands out as a driving force. On the non-renewables side of the study, the oil EC has a potential to ruin the higher-income countries as opposed to the coal EC, which supports the EG for the higher-income countries. When it comes to the gas EC, it shows a positive pattern for all countries.

Keywords: Renewable Energy, Nonrenewable Energy, Energy Consumption, Economic Growth, Panel Quantile Regression

Jel Codes: P28, N10, C33

Farklı Gelir Düzeylerinde Enerji Tüketimine Yeni Bir Soluk: Panel Kantil Regresyon Yaklaşımı

Özet

Enerji ekonomisi alanında çok sayıda çalışmanın enerji tüketimi ile ekonomik büyüme arasındaki ilişkinin ortaya çıkartılmasında çeşitli nedensellik analizleri üzerine yığıldığı görülmektedir. Ancak, gerçekleştirilen bu çalışmaların bir basamak olarak kullanılarak söz konusu literatürün modern ve alternatif ekonometrik tekniklerle genişletilmesi ve zenginleştirilmesi ihtiyacı ortaya çıkmaktadır. Buradan hareketle, bu çalışmanın amacı toplam, yenilenebilir ve yenilenebilir olmayan enerji tüketiminin ekonomik büyümenin farklı düzeylerindeki etkisinin 2012-2022 yıllarını kapsayan bir veri seti kullanılarak E7 ülkeleri için araştırılmasıdır. Bu çalışmada panel kantil regresyon (PKR) yöntemi kullanılmış ve enerji tüketiminin toplam, yenilenebilir ve yenilenebilir olmayan enerji bazında farklı kantil düzeylerindeki etkisi üç aşamalı bir çalışma ile ortaya konulmuştur. PKR modelleri üzerine bina edilen bu üç kademeli niteliği ile çalışmamız diğer çalışmalardan ayrılmakta ve yol gösterici bir çalışma olmaya aday hale gelmektedir. Bütün olarak bakıldığında, toplam rakamlar yenilenebilir enerjinin yüksek gelirli ülkelerin ekonomik büyümeleri için bir destek, düşük gelirli gruplar için ise bir engel olarak görülebileceğine işaret etmektedir. Yenilenebilir enerji için detaylı analiz sonuçlarına göre, güneş enerjisi tüketimi tüm E7 ülkeleri

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için her kantil düzeyinde bir tehdit oluştururken, rüzgar enerjisi kullanımı ise itici güç olarak ön plana çıkmaktadır. Çalışmanın yenilenebilir olmayan yanına ilişkin sonuçlara göre ise, petrol tüketimi yüksek gelirli ülkelerde ekonomik büyümeye zarar verebilme potansiyeline sahipken, kömür tüketimi büyümeyi destekler niteliktedir. Doğal gaz kullanımı ise, tüm ülkeler için pozitif bir kalıp sergilemektedir.

Anahtar Kelimeler: Yenilenebilir Enerji, Yenilenebilir olmayan Enerji, Enerji tüketimi, Ekonomik Büyüme, Panel Kantil Regresyon

Jel Kodları: P28, N10, C33

1. Introduction

In this day and age, it is undeniable that the energy consumption penetrates into our lives and affects almost every single part of it from the daily routine activities such as transportation and cooking to mass production. Considering this on a large scale, it is of a paramount importance for countries to reach their potential economic growth. Likewise, the energy usage has played a crucial role in various industries like construction, automotive, agriculture, textile and electronic industry, which are considered as the drives of the countries' economic growth, henceforth EG.

In the realm of energy consumption, henceforth EC, there are two major types of energy being consumed, renewables and non-renewables. The renewable energy is obtained from unlimited, naturally refurbished resources like the sun, wind and tides. In addition, this sort of energy could be utilized for the purpose of power generation, heating and cooling, and transportation, to name a few. The renewables offer diminished carbon emissions and air pollution that stem from energy production, lower energy costs, and job creation via manufacturing of renewable energy technologies, which are the most prominent outcomes of the clean energy. Their decent and infinite nature puts them into the eco-friendly energy category, for their desirable and ideal features support the environment and sustainable growth (The Office of Energy Efficiency and Renewable Energy, 2024). For all these reasons, a considerable number of researchers and policymakers are still on the way to come up with an idea to use them for a sustainable EG.

On the other side of the coin, the non-renewable energy refers to oil, gas, coal and nuclear energy, whose detrimental effects are proven scientifically by a plenty of studies. This type of energy comes from finite sources and creates pollution. Due to its perilous and alarming feature, it has remained as a major threat to the world to this day.

It is a given that the countries exploit energy resources to grow and flourish economically. At this point, it is critical to know that whether this growth is generated by sustainable resources or not. The sustainable growth is always considered desirable. However, when it is put under the scope, the answer may vary depending on the income level. Some studies show that the renewable EC might have a negative or positive impact on the growth depending on the income level (Uyar and Gökçe (2017); Gozgor et al. (2018)).

The literature of the energy economics clearly shows that the number of the studies is ample. However, it is observed that they are heavily piled on the causality tests applied on the total number of the EC and GDP growth to unveil the connection between them. This approach lacks of exhibiting any details about the connection between the EC and the EG, rather merely points at a causal relationship between the two variables and gives the direction of that link but nothing more.

More importantly, the vast majority of the studies in the field have run the analyses only with the aggragated figures. The reason behind this practice is that the datasources are scarce and up until 2020 there had been no detailed information in terms of a comparable unit. This is where the British Petrol's, BP, enhancement comes in. To create comparable units, the BP promulgated that they changed their methodology and switched the energy units from million tonnes of oil equivalent to exajoules in 2020 (BP Statistical Review of World Energy, 2020). Prior to this adjustment, it was not manageable to convert the renewable resources individually into the same unit as the non-renewables, so it was a huge stumbling block for the researchers to investigate the renewables in detail. Considering this methodology upgrade as an opportunity to contribute to the literature of the energy economics, we are motivated to use this new comparable unit, exajoules, in our article, offering the reader new information along with a modern econometric approach, which we believe will help us stand out among the other studies.

To fill the void in the literature, firstly, we examine three individual PQR models, referring to total, renewables and non-renewables. Secondly, we break down both the renewables and non-renewables and analyze the effects on the EG. To do so, we aim to estimate three different models guiding the policymakers through their decision-making process and also to extend the literature of energy economics by using PQR models for the E7 group, seven emerging economies with high-growth rates namely China, India, Brazil, Mexico, Indonesia, Russia and Türkiye.

The reason why we study E7 countries in this paper is that this group is a great sample to represent emerging economies with intensified non-renewable resource depletion (Wang et al., 2024). These are the emerging economies standing out with their rapid growth levels among others. They are also placed in the same category by the World Bank's lending groups definition, IBRD. For the recent 2024 fiscal year, the World Bank has defined the countries by income based on the World Bank Atlas method, as well. The institution's announcement is as follows: "*Low-income economies are defined as those with a GNI per capita, calculated using the World Bank Atlas method, of $1,135 or less in 2022; lower middle-income economies are those with a GNI per capita between $1,136 and $4,465; upper middle-income economies are those with a GNI per capita between $4,466 and $13,845; high-income economies are those with a GNI per capita of $13,846 or more*". (The World Bank, 2024). According to the calculation, India is classified as a lower middle-income economy; on the other hand, the rest of the E7 group falls into the upper middle-income category. As a result, instead of working with all the emerging countries in the world, which creates the data unavailability, we agreed to narrow down the sample group and work with the E7 countries for the data availability in addition to their favorable features above.

With this study, we aim to answer a burning question: Is there a neat and feasible solution for these non-renewable energy dependent economies to switch their resources from the detrimental ones to the eco-friendly alternatives without requiring any significant compromise from their high-level economic growth. If so, does it differ significantly among the income levels?

We are encouraged by the studies using only the total figures, and we acknowledge them as a foundation of our work and take them up a notch by applying an intricate method, allowing us to offer the reader as far more information as possible. We are well aware that lower-income emerging economies have been striving to upgrade their economic landscape and targeting to be a member of the higher-income economies to complete their purpose of economic development. However, they inevitably have to place emphasis on the manufacturing industry to accomplish this goal, typically prioritizing to reach for the non-renewables with a great demand of energy, leading to the destruction of the environment. To put this notion into practice, we offer a thorough study to dive deep into this relationship by a more sophisticated method, the PQR. With this novel technique, we will be able to scrutinize the details of the EC at different income levels respectively at the quantile levels of the 5th, 10th, 25th, 50th, 75th and 90th.

In a nutshell, taking every detail into account, we desire to uncover the fact that whether the renewables could be an alternative drive for these excessively non-renewable energy consuming emerging economies, hence creating a more clean and bright environment for their futures by switching to the clean and sustainable energy.

This paper proceeds as follows: Section 2 presents a brief literature survey on the EG and EC. Section 3 introduces the data and the preliminary test results for PQR models. Section 4 sheds light on the PQR methodology. Section 5 demonstrates the empirical results of the analyses. Section 6 concludes.

2. Literature Survey

We have done a comprehensive research on the literature of the EC and the EG, and noticed there is a substantial number of studies available depending on the country, time and empirical method. In the literature, there is a myriad of country-specific studies as well as country-group studies such as G7, emerging and developing countries and advanced countries.

Despite the sheer number of studies, we detected a gap in the field. These studies differ based on their approach, data sample, and country groups and it is true that they are definitely enriching the literature. Nevertheless, some of them are too broad to help a policy maker to come to a decision, some accomplish their analysis with only total numbers without going deeper, and most of the studies are mainly clustered on the causality tests, which only prove the existence of a causal relationship and its direction but fail to go beyond. This paper; however, is designed to encapsulate the current trends in the econometrics, more detailed information, and pioneering features for the other studies further down the road.

In this section, we epitomize a laconic compilation of the researches we pored over to navigate through our analyses.

Oh and Lee (2004) handle the link between the energy usage and the EG by using two multiple time series models. The dataset covers the monthly period 1981:1-2000:4. The first model displays a demand-oriented model including GDP and energy prices. The second model, on the other hand, is a supply-oriented model that utilizes the variables of the GDP, energy, capital and labor. They prefer a VECM model to establish the cointegration, thus testing the Granger causality. The empirical results show that in Korea there is no causality between the EC and the GDP in the short run whereas there is a one-way Granger causality from the GDP to the EC in the long run. It is concluded that it is possible to apply an energy saving policy without a reconciliation with the EG. Furthermore, a sustainable growth is only manageable with the low level CO2 emissions coming from fossil fuels.

Lee (2005) explores the co-movement and causal relationship between the EC and the GDP based on 18 developing countries for the years 1975-2001. They apply heterogeneous panel cointegration and panel-based error correction models. The empirical findings prove the existence of a long-run cointegration after allowing heterogeneous country effects. They estimate the long-run relationship through full-modified OLS. According to test results, both short-run and long-run causalities are running from the EC to GDP, but not vice versa. In conclusion, regardless of the fact that they are temporary or permanent, energy saving policies have a potential to ruin the EG in developing countries.

Narayan and Symth (2008) scrutinize the nexus between the capital formation, the energy usage and real GDP for G7 countries by harnessing the panel cointegration, Granger causality and long-run structural estimation techniques. The empirical results point out that the capital formation, the EC and the GDP are cointegrated in the long term. Moreover, the capital formation and the EC cause the GDP in the long-run. Lastly, while a 1% increase in the EC causes a 0.12-0.39% increase in the real GDP, a 1% increase in the capital formation causes a 0.1-0.28% in the real GDP.

Lee and Chang (2008) examine the causal relationship between the EC and the GDP by developing a heterogeneous panel cointegration and panel-based error correction model for 16 Asian countries over the period 1997-2002. They benefit from the aggregate production function for these models and the results strongly support a positive long-term relationship. There is no evidence for a short-term relationship; however, a one-way causality running from the EC to the EG is proven. In other words, mitigating the EC does not have an adverse effect on the growth in the short-term, but it might occur in the long-term. They suggest that these Asian countries should embrace a more vigorous energy policies.

Pao and Fu (2013) run a Granger causality test to uncover the link between the renewable EC excluding the hydroelectricity and the EG as well as employ a Johansen cointegration test in order to reveal the long-term relationship between the two for the Brazilian economy for the time period 1980-2010. The results point to a one-way Granger causality running from the renewable EC to the EG.

Ucan et al. (2014) investigate the long-term and causal relationship between the renewable and non-renewable EC and the EG for 15 EU countries over the years 1990-2011. They implement panel cointegration and panel causality tests, implying that as the renewable EC increases the real GDP goes up. Furthermore, the results prove the link between greenhouse gas emissions and the real GDP. As for the non-renewable side of this study, the EC has a negative effect on the GDP in total. However, considering the detailed analyses, there is found to be a difference between solid fuels only and petroleum only results. While the solid fuels affect the GDP negatively, total petroleum use has a positive effect on the GDP. Lastly, a one-way causal relationship running from the non-renewable EC to the EG is proven.

Zhu et al. (2016) implement a PQR to reveal the impact of foreign direct investment (FDI), the EG and the EC on carbon emissions among ASEAN-5 countries. Except for the 5th quantile, the FDI affects the carbon emissions negatively and shows a significant path at higher quantiles. The energy usage causes the carbon emissions to rise greatly at higher quantiles. For high-emission countries, a greater EG and population size seem to reduce emissions. With this study, the halo effect hypothesis is verified in the countries with high emission levels. Nonetheless, there is not sufficient evidence to advocate an inverted U-shaped curve for this sample.

Uyar and Gökçe (2017) conduct a PQR on VISTA group, which stands for Vietnam, Indonesia, South Africa, Türkiye and Argentina, to unveil whether there is a relationship between the EC and the EG by different quantiles. This research encompasses the annual dataset from 1985 to 2013. The empirical findings draw attention to the fact that the effect of oil consumption on the EG is decreasing at the high quantile levels. Nonetheless, the effect of hydroelectricity and primary energy consumption on the EG goes up at the higher quantiles.

Tang et al. (2016) analyze the connection between the EC and the EG for Vietnam. They adopt the neoclassical Solow growth framework over the period 1971-2011 to apply Johansen cointegration test and MWAL causality test so as to unearth the relationship between these two variables in the long-run. The results suggest that the EC supports the EG. Furthermore, there is a one-way causality running from the EC to the EG. In conclusion, since Vietnam has an energy-dependent economy, any attempt offering an energy saving policy in the country could jeopartize the economic development.

Dam (2018) aims to find out how the EG and the EC affects pollution in the EU countries within the period of 2000-2015. They estimate a panel regression model that exploits the EC and the EG per capita as explanatory variables. The results are signaling that the energy usage increases pollution. In other words, the EC has a negative and significant effect on the environmental pollution, because the energy consumption heavily depends on fossil fuels. The study offers to use the renewable energy for a sustainable and clean environment.

Gozgor et al. (2018) examine the impact of the renewable and non-renewable energy usage on the EG through a panel autoregressive distributed lag (ARDL) and a PQR model for 29 OECD countries for the period from 1990 to 2013. According to their findings, both the renewable and non-renewable EC are positively connected with a higher rate of the EG. As a policy implementation, they suggest that policy makers should consider rising the non-renewable energy to propel the EG besides supporting the renewable EC.

Şanlı (2019) does a pioneering research on the long-run connection between the energy usage and export sophistication in OECD countries with a panel dataset covering 1990-2016. In this study encapsuling 31 OECD countries, they employ a panel cointegration analysis as well as a cointregration regression exploiting FMOLS and DOLS. The test results point at a strong two-way causality between the energy usage and the export sophistication, validating the feedback hypothesis between the two variables.

Doğdu (2022) scrutinizes the nexus between the energy production and the EG by running Toda-Yamamoto panel causality test for the E7 and G7 groups individually. They use the aggragated numbers for the renewables excluding the hydroelectricity and the GDP growth covering the annual dataset 2000-2015. According to the analysis results, there is proved to be a presence of a two-way causal relationship between the renewable energy production and the EG.

Liu (2022) focuses on the Grey Markov Model for the renewable energy usage and the EG over 34 sample countries for the time span 1994-2014. In this paper, they include the renewable and non-renewable energy as independent input factors in the Cobb-Douglas function. Considering the sequential correlation and endogeneity of panel data, they utilize DOLS & FMOLS techniques in order to analyze the long-term output elasticity of the panel data. On this note, they find out that the renewable EC significantly affects the EG. To wrap up, they propose a combination model of the wavelet grey and verify the grey theory method with a tangible example.

Wang et al. (2024) assess the asymmetric influence of Fintech, digital trade, and the renewables on mineral resources footprint (MF) by using a novel panel method of Moment Quantile Regression (MMQR) including 2005-2020. The empirical results show that the Fintech and the renewables diminish MF significantly at the 50th to higher quantiles, yet are negligible at the lowest grid. On the other hand, digital trade strongly supports the MF from lower levels to middle quantiles whereas it has no impact at the higher MF quantiles.

3. Data

In this research, we aim to estimate the impact of the renewable and non-renewable EC on the EG by different quantiles in the E7 countries, which consist of China, India, Brazil, Russia, Mexico, Indonesia and Türkiye, via a panel quantile regression, PQR.

The dependent variable is the Gross Domestic Product (GDP) per capita with constant prices 2015 US$ year-on-year growth obtained from The World Bank World Development Indicators to represent income. To embody the renewable EC, we use the renewables as a total renewable EC, as well as hydroelectricity, henceforth hydro, solar, wind and geothermal, biomass and other EC, henceforth geo. On the other hand, to juxtapose the results, we incorporate the total non-renewable EC on top of oil, gas and coal consumption in the study. These are all independent variables and are acquired from the BP Statistical Review of World Energy 2023 database as exajoules. Our dataset is formed annually from 2012 to 2022, covering the E7 countries available at the time. The analyses are performed by using Stata15.

The figures regarding the EC are originally obtained from the BP Statistical Review of World Energy 2023 source. To create comparable units, the institution has changed their methodology and switched the energy units from million tonnes of oil equivalent to exajoules in 2020 (BP Statistical Review of World Energy, 2020). Before this adjustment, it was not feasible to convert the renewable resources individually into the same unit as the non-renewables, so it was a major challenge for the researchers to elaborate on the renewables. Now, taking advantage of this comparable unit, we use all the variables as exajoules different from other studies in the literature performed until 2020.

Table 1 summarizes each variable in the study. Clearly, there is no significant fluctuations in the dataset. Besides, it indicates the Jarque-Bera test results, which show the skewness and kurtosis figures of each variable to diagnose whether the series are normally distributed. The test results are pointing to the non-normality for each variable. Since the PQR is impervious to outliers, we prefer to adopt this approach considering the non-normal distribution.

Table 1. Descriptive Statistics

Variable	**Mean**	**Std. Dev.**	**Minimum**	**Maximum**	**Skewness**	**Kurtosis**	**Jarque-Bera**
EG	2.7350	3.5927	-9.3135	10.4294	-0.7696	3.8673	8.77**
Renewables	1.3984	2.4105	0.0047	13.3026	3.1579	13.5573	52.89***
Nonrenewables	28.1460	37.7627	4.4130	130.3026	1.8446	4.8158	24.73***
Hydro	2.7190	3.6311	0.1263	12.4962	1.7354	4.6289	22.92***
Solar	0.2757	0.7003	0.0000	4.0144	3.6250	16.4591	59.90***
Wind	0.6320	1.3223	0.0000	7.1584	3.2617	13.8641	54.22***
Geo	0.3307	0.4081	0.0041	2.0294	2.2714	8.8315	37.73***
Oil	7.7972	7.6741	1.4109	29.5219	1.8038	4.9365	24.54***
Gas	4.9227	5.2009	1.1312	17.0861	1.2922	2.9919	13.52***
Coal	15.4260	28.0497	0.1984	88.4141	1.9048	4.8569	25.57***

Note: ***, ** and * respectively refer to the statistical significance at 1%, 5% and 10%.

4. Methodology for the Fixed Effect PQR

In this paper, we proceed with the fixed effect PQR methodology to investigate the impact of the EC on the EG. Since traditional methods mainly focus on the mean effects, which might bring about under-or-overestimated coefficients or even a failure in capturing the significant relationships, we prefer adopting a PQR model over them to practice the determinants of the EG throughout the conditional distribution, especially within the countries with the lowest and the highest income (Binder and Coad, 2011).

The quantile regression, henceforth QR, method was originally introduced by Koenker and Bassett (1978), which is a generalization of a median regression analysis to other quantiles. The QR is robust to outliers and heavy distributions. The main advantage of this method is that it is capable of minimizing the biases stemming from the outliers, and the PQR estimator is proven to be more efficient than OLS estimators when error terms are not normally distributed. Nevertheless, the QR technique does not take the unobserved heterogeneity of a country into account. In this study, following Zhu et al. (2016), we conduct the PQR technique with the fixed effects to estimate the conditional heterogeneous covariance effects of the EG, hence controlling for unobserved individual heterogeneity (Zhu et al., 2016; Gozgor et al., 2018).

More to the point, the effects of the renewable and nonrenewable EC may vary for each country at different productivity levels. The fixed effect PQR is as follows:

$$Q_{y_{it}}(\tau_k|\alpha_i, x_{it}) = \alpha_i + x'_{it}\beta(\tau_k). \tag{4.1.}$$

The major setback of the fixed effect PQR is that it includes a great deal of fixed effects (α_i), and so exposing the incidental parameters problem (Lancaster, 2000, Neyman and Scott, 1948). The estimator is inconsistent in the case that the number of individuals goes to infinity but the number of observations for each cross-sectional unit is fixed (Zhu et al., 2016). Koenker (2004) puts forward a suitable method to troubleshoot these issues. The author treats the unobservable fixed effects as the parameters to be jointly estimated with the covariate effects for various quantiles. This method introduces a penalty term in the minimization to cope with the computational problem of estimating a mass of parameters specifically. The calculation of the parameter estimate is as follows:

$$\underset{(\alpha,\beta)}{min} \sum_{k=1}^{K}\sum_{t=1}^{T}\sum_{i=1}^{N} w_k\, \rho_{\tau_k}(y_{it} - \alpha_i - x_{it}^{T}\,\beta(\tau_k)) + \lambda \sum_{i}^{N}|\alpha_i|, \tag{4.2}$$

where i stands for the countries (N), T is the index for the number of observations per country, K denotes the quantiles, x is the matrix of the explanatory variables, ρ_{τ_k} is the quantile loss function. w_k represents the relative weight given to the k-th quantile, which controls the contribution of the k-th quantile on the estimation of the fixed effect. λ is the tuning parameter that diminishes the individual effects to zero to enhance the performance of the estimate of β.

In this paper, our three separate PQR models are established as follows:

Model 1: $Q_{y_{it}}(\tau|\alpha_i, \varsigma_t x_{it}) = \alpha_i + \varsigma_t x_{it} + \beta_{1\tau} renewables_{it} + \beta_{2\tau} nonrenewables_{it}$

Model2: $Q_{y_{it}}(\tau|\alpha_i, \varsigma_t x_{it}) = \alpha_i + \varsigma_t x_{it} + \beta_{1\tau} hydro_{it} + \beta_{2\tau} solar_{it} + \beta_{3\tau} wind_{it} + \beta_{4\tau} geo_{it}$

Model 3: $Q_{y_{it}}(\tau|\alpha_i, \varsigma_t x_{it}) = \alpha_i + \varsigma_t x_{it} + \beta_{1\tau} oil_{it} + \beta_{2\tau} gas_{it} + \beta_{3\tau} coal_{it}$

Where the countries are denoted by i and time by time t. y_{it} is the EG. The descriptions of the variables are provided further down the paper.

5. Empirical Findings

The empirical results are based on the three separate PQR models and thus are categorized into three parts as follows:

Model 1: Total energy consumption

$EG = f(\text{renewables}, \text{nonrenewables})$

Model 2: Renewable energy consumption only

$EG = f(\text{hydro}, \text{solar}, \text{wind}, \text{geo})$

Model 3: Non-renewable energy consumption only

$EG = f(\text{oil}, \text{gas}, \text{coal})$.

First and foremost, it is required to test the dependency of cross-section in the panel dataset. We apply Pesaran's test of cross-section independence (CD-test) to find out whether the series display a cross-sectional dependency. Based on the outcome, we will follow either the 1st or the 2nd generation panel root unit test methodology to test the stationarity in all series.

The CD-test results are exhibited in the Table 2. The null hypothesis points at the cross-sectional independence. It is understood that all the variables except "oil" and "coal" has the cross-sectional dependency. Therefore, we will take the Maddala and Wu (1999) into account, referring to the 1st generation unit root test for "oil" and "coal", and CIPS (2007), the 2nd generation unit root test, for the rest of the variables.

Table 2. Cross-Section Dependency Test Results

Variable	CD-test	P-value	corr	abs(corr)
EG	8.42***	0.000	0.554	0.554
Renewables	14.57***	0.000	0.958	0.958
Nonrenewables	2.44**	0.015	0.161	0.428
Hydro	2.90***	0.004	0.191	0.420
Solar	14.56***	0.000	0.958	0.958
Wind	13.35***	0.000	0.878	0.878
Geo	6.87***	0.000	0.452	0.722
Oil	0.80	0.423	0.053	0.592
Gas	1.97**	0.049	0.129	0.533
Coal	-1.15	0.251	-0.075	0.617

Note: ***, ** and * respectively refer to the statistical significance at 1%, 5% and 10%.

Before performing the PQR, we must fulfil the stationarity in all series. To make sure each variable is stationary, in the light of the CD-test results, we consider the most commonly used 1st generation panel unit root test, MW from Maddala and Wu (1999), for "oil" and "coal", and the 2nd generation panel unit root test, CIPS from Pesaran (2007), for the rest of the variables.

Drawing on the panel unit root test results, we will continue with the "EG","renewables", "solar", "wind", "geo" and "gas" at the first difference form, and the rest will be used at the level.

Table 3. Panel Unit Root Test Results

1st Generation Unit Root Test	**MW**		**Result**
	Constant	**Constant & Trend**	
Oil	18.258	29.016**	I(0)
Coal	4.705	30.161***	I(0)
2nd Generation Unit Root Test	**CIPS**		**Result**
	Constant	**Constant & Trend**	
	Z [t-bar]	**Z [t-bar]**	
EG	-0.653	-0.211	I(1)
Renewables	0.719	-0.764	I(1)
Nonrenewables	-2.902***	0.125	I(0)
Hydro	-5.617***	0.412	I(0)
Solar	2.328	0.674	I(1)
Wind	2.380	0.606	I(1)
Geo	2.030	-0.358	I(1)
Gas	0.545	2.685	I(1)

Note: (i) ***, ** and * respectively refer to the statistical significance at 1%, 5% and 10%. (ii) Optimal lag length is 1. (iii) "multipurt" command is used to generate the 1st and the 2nd generation unit root test results.

From here, capitalizing on these diagnostic test results, this paper will continue exhibiting the panel quantile regression results case by case, and elaborate on the details under each subsection.

5.1. The Effect of the Total Renewable and Non-renewable EC on the EG

As mentioned earlier in this section, this paper is created on a three-tier study of energy economics, namely the total renewable and non-renewable EC, the renewable EC and the non-renewable EC. In this section, we will examine the results of the PQR Model 1 in detail.

As seen in the Table 4, the total number of EC demonstrates that the non-renewable EC has no impact on the EG for the E7 countries whereas the renewables do. What is striking about the outcome is that the total renewable EC has a negative effect on the EG at the lower quantiles. However, this impact turns into positive at the higher quantile levels. In conclusion, lower income economies are affected adversely by the renewable energy usage while higher income countries are influenced positively. In other words, our results underscore that the renewable EC is a drive for higher income countries in this study while a drawback for the lower income countries.

Table 4. PQR Analysis Results for Model 1: Renewable and Non-renewable EC

Dependent variable: ΔEG					
Quantiles (τ_i)					
Variables	$\tau = 0.10$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.90$
ΔRenewables	**-3.0091*** (0.8677) [0.001]**	**-2.2344*** (0.3862) [0.000]**	0.3723 (0.3008) [0.216]	**2.6857** (1.0927) [0.014]**	**5.3848*** (2.0209) [0.008]**
Nonrenewables	0.0256 (0.0509) [0.614]	0.0038 (0.0309) [0.901]	-0.0208 (0.0321) [0.516]	-0.0603 (0.0444) [0.174]	-0.0694 (0.1190) [0.560]
Constant	**-3.8224*** (1.4506) [0.008]**	-1.7140 (1.2538) [0.172]	0.3358 (1.0107) [0.741]	**2.6288** (0.0444) [0.034]**	**5.9795* (3.1984) [0.062]**

Note: (i) Each number in the first row refers to the estimated coefficient, the figures in brackets () indicate standard errors, and in square brackets [] show p-values. **(ii)** ***, ** and * respectively refer to the statistical significance at 1%, 5% and 10%. **(iii)** Clustered robust standard errors are used.

5.2. The Effect of the Renewable EC on the EG

In this part, we will delve into the renewable energy usage and go through the results of the PQR Model 2 in detail. In this model, we break down the renewable EC, represented by the variables hydroelectricity, solar, wind and geothermal, biomass and other EC.

As presented in the Table 5, hydroelectricity use has no significant effect on the EG at any quantile level. In addition, regardless of the income level, the solar EC ruins the EG for the E7 countries. As for the wind EC, it signals that it could be a driving force for the EG for both lower-income and higher-income countries. Surprisingly, the geothermal, biomass and other energy usage pose a threat to the EG for the lower-income countries while it has no notable impact on the higher-income countries.

Table 5. PQR Analysis Results for Model 2: Renewable EC

Dependent variable: ∆EG					
Quantiles (τ_i)					
Variables	$\tau = 0.10$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.90$
Hydro	0.3512 (0.2981) [0.239]	0.3505 (0.3161) [0.267]	0.1420 (0.1290) [0.271]	-0.1972 (0.2048) [0.335]	-0.3541 (0.2362) [0.134]
∆Solar	**-21.1855*** (6.5708) [0.001]**	**- 20.4829*** (5.2572) [0.000]**	**-16.9439*** (5.2243) [0.001]**	**-8.0912** (3.8066) [0.034]**	**-6.9602** (3.2085) [0.030]**
∆Wind	**13.8326*** (1.9626) [0.000]**	**14.1462*** (1.8232) [0.000]**	**10.5739** (4.4108) [0.017]**	**9.0686*** (3.0608) [0.003]**	**8.2607*** (2.4944) [0.001]**
∆Geo	**-8.5358** (4.1466) [0.040]**	**- 12.2857*** (3.0402) [0.000]**	-2.4450 (12.9996) [0.851]	-6.0020 (9.7253) [0.537]	-3.1121 (7.9690) [0.696]
Constant	**-3.6076*** (0.6014) [0.000]**	**-3.0295*** (0.7558) [0.000]**	-0.5494 (0.5773) [0.341]	**2.6453*** (0.5019) [0.000]**	**3.3804*** (0.6772) [0.000]**

Note: (i) Each number in the first row refers to the estimated coefficient, the figures in brackets () indicate standard errors, and in square brackets [] show p-values. **(ii)** ***, ** and * respectively refer to the statistical significance at 1%, 5% and 10%. **(iii)** Clustered robust standard errors are used.

5.3. The Effect of the Non-renewable EC on the EG

In this stage, we will go into details of the non-renewable EC and examine the results of the PQR Model 3. In this model, we break down the non-renewable energy use, represented by the variables oil, gas and coal consumption.

The Table 6 unmistakably shows that the effect of the gas usage has a significant and positive impact on the EG at all levels. When it comes to the oil consumption, it only affects the EG at the 90th quantile and this effect is negative. To suffice it to say, the results insinuate that the oil consumption has a potential to ruin the EG for the higher-income level countries.

Regarding the impact of the coal consumption, it has a potential drive for the higher-income level countries since it displays a positive and significant impact on the EG.

Table 6. PQR Analysis Results for Model 3: Non-renewable EC

Dependent variable: ∆EG					
Quantiles (τ_i)					
Variables	$\tau = 0.10$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.90$
Oil	-3.1012 (4.6487) [0.505]	0.6573 (0.5913) [0.266]	0.0107 (0.7279) [0.988]	-3.7173 (2.2704) [0.102][	**-3.9368*** **(2.2625)** **[0.082]**
∆Lgas	**4.8692**** **(2.4476)** **[0.047]**	**2.8704***** **(0.9169)** **[0.002]**	**3.8105***** **(0.8691)** **[0.000]**	**5.2646**** **(2.0644)** **[0.011]**	**5.2317**** **(2.0474)** **[0.011]**
Coal	1.2748 (2.1194) [0.548]	-0.3971 (0.2902) [0.171]	-0.1875 (0.3126) [0.548]	**1.6546*** **(0.9923)** **[0.095]**	**1.7263*** **(0.9859)** **[0.080]**
Constant	1.1736 (6.9280) [0.865]	-1.3828 (2.7226) [0.612]	2.0933 (1.4481) [0.148]	5.6361 (9.3421) [0.546]	6.5311 (10.0745) [0.517]

Note: **(i)** Each number in the first row refers to the estimated coefficient, the figures in brackets () indicate standard errors, and in square brackets [] show p-values. **(ii)** ***, ** and * respectively refer to the statistical significance at 1%, 5% and 10%. **(iii)** Clustered robust standard errors are used.

6. Conclusion

It is an undeniable fact that all economies are in the great need of the energy consumption to operate whether it is for the manufacturing, power generation, agricultural production, or so on. Every economy has its own unique feature with a different push factor to flourish. With this aspect, the type of energy being consumed is of a critical role for the environment besides the sustainability of the corresponding country economy.

Some E7-like economies tend to exceedingly exploit the non-renewable resources to reach a high-level economic growth, yet leaving the environment polluted and creating pernicious impacts in the environs. We take the seven emerging economies, E7, namely China, India, Brazil, Mexico, Indonesia, Russia and Türkiye, as a sample group because of their common characteristics such as rapid EG and heavily dependence on the non-renewable resources.

With this study, we searched for a solution for the E7-like economies that allows them to embrace the renewable resources helping continue to grow and thrive without causing any loss of EG, enabling them to cut down on their dependency on the non-renewables for a green and sustainable environment. To do so, instead of working with an entire dataset of the emerging economies, we settle for the E7 group as it is a satisfying sample to reflect this issue mentioned in the beginning and also for the data availability.

Moreover, we intend to prosper the energy economics area by following a distinct path from the other studies heavily centered on the causality tests by using aggregated numbers. To get to the bottom of the question how the effect of the EC on the EG differs from the lower-income to the higher-income economies, we apply the PQR method on the three different models. In this regard, we believe that an elaborate analysis to capture the impact of the energy usage on the EG, for the sub-renewable and sub-nonrenewable resources as well as the total numbers will contribute to the field meaningfully.

In this paper, with an access to a new comparable unit for each type of EC yearly-published by The Office of Energy Efficiency and Renewable Energy, we have capitalized on exajoules and performed a three-tier study. We started the analyses broadly taking the total consumption of renewables and non-renewables into account in the Model 1. Subsequently, as considering only total figures might be misleading, we elucidated the details for the renewables and non-renewables respectively in the Model 2 and Model 3. With this pioneering feature, we expect to open a new door into the upcoming studies.

We established the three PQR models for the E7 countries with a dataset comprehending the time period 2012-2022. The findings turned out to be striking for these countries. For the total EC in the Model 1, we understood that the renewable energy usage could be used as a drive for the EG for the higher-income countries while it is the opposite for the lower-income countries. However, it would be too soon to deduce a lesson from the aggregated figures. For a neat and appropriate decision, one has to look over the Model 2 and the Model 3.

The Model 2 for the renewable EC indicates that the hydroelectricity usage has no significant effect on the EG for the E7 countries. Regardless of the quantile levels, the wind EC signs to be a driving force while the solar EC poses a potential threat for the EG. The geothermal, biomass and other energy use, on the other hand, signals to have a destructive effect on the EG for the lower-income countries.

Finally the Model 3 for the non-renewable energy use, the gas EC stands out to be a motive for the EG for all levels of quantiles. However, the coal and oil usage has no significant impact on the EG for the lower-income countries. The oil EC has a significant-yet-negative effect only at the 90th quantile. In other words, it signs to jeopartize the highest income economies. In contrast, the coal usage supports the higher-income economies within the E7.

All in all, the results are noteworthy for this sample group. There are three takeaways from this study. First, scrutinizing the effect of the EC on the EG only with total numbers might be misguiding and/or insufficient to make an inference. Second, investigating the relationships by quantiles is a good help to avoid missing out on the real interactions. Last but not least, the consumption of gas, wind and solar are the outstanding indicators of this study. Since the gas and wind usage support the EG at all levels for the E7 group, it is not advisable to embrace energy saving policies related to these energy resources, for it would put the EG into risk. Similary, as the solar usage plays a detrimental role in the EG, the authorities should take this into consideration and offer some adjustments in that field to avoid its repercussions.

After all is said and done, the wind energy is inferred to be a nominee to alternate the non-renewables for the E7-like countries. On that note, it is conceivable that the wind energy should be more focused by these countries for an evergreen future whose region is conducive to generate. On the contrary, the solar, and geothermal, biomass and other energy fail to offer any contribution in this matter.

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