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Public Debt – Energy Consumption Nexus

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ABSTRACT

As energy demand has risen and continues to rise, a growing body of research examines the impact of a variety of factors on energy use, including economic development, price changes, and international trade. The public debt–energy consumption nexus, on the other hand, has received little attention. This study looks at the effect of government debt on both renewable and nonrenewable energy usage in 17 OECD countries from 1980 to 2020. Using the Generalized Least Square (GLS) panel data estimation method and Panel Quantile Regression (PQR), this paper finds that public debt has a favorable influence on the utilization of renewable energy and a detrimental influence on the use of non-renewable energy. It can be noticed from the PQR that all variables have more favorable impacts on renewable and nonrenewable energy usage at higher quantiles.

Keywords: Public Debt, Renewable Energy Consumption, Non-renewable Energy Consumption, Panel Quantile Regression, OECD Countries
JEL Classifications: H63, Q43, O13

1. INTRODUCTION

In recent decades, the global economy has been subjected to major events, which have resulted in climate change as well as political and economic uncertainty. As a result, researchers are attempting to evaluate these modern challenges to enhance the quality and substance of the global economy. Almost every element of human life necessitates the use of energy. For example, there is a significant need for energy in the industries of heating, cooling, and transportation. In addition, energy is critical to the growth of the industry. In other words, energy is a necessary input for industrial production. It is essential for attaining economic growth and development objectives.

Energy may be classified into two main categories: the first sort of energy is non-renewable energy, which is obtained from the combustion of fossil fuels. The main sources of non-renewable energy are natural gas, crude oil, and nuclear power. The most significant advantage of using nonrenewable energy is its inexpensive cost of usage. These forms of energy, however, have several drawbacks. The widespread use of nonrenewable natural resources has a substantial impact on high emission levels and hence contributes to climate change. As a result of this situation, the public's health is in great danger. Due to climate change and air pollution, the country's residents are at significant risk of getting respiratory illnesses. This circumstance will result in a drop in the country's labor force as well as an increase in unemployment. Another problem with these sources of energy is that governments will be unable to use them if sufficient reserves are not available (Qi et al., 2020; Zhe et al., 2021).

The other type of energy is renewable energy sources. It emerges as a complement to traditional types of energy, and while it accounts for a large portion of the energy output in certain industrialized nations, it is still not the dominant source of energy in the energy sector. The main advantages of using renewable energy are that it emits no greenhouse gases into the atmosphere, and it allows future usage of finite fossil resources. This is the primary driver of increased investment in and use of renewable energy sources. The main disadvantage of using renewable energy is that it is primarily reliant on the weather for its supply. Renewable energy sources are incapable of producing energy in case of weather that does not provide certain types of climate conditions. It is also difficult to produce in large quantities. In addition, it requires a high initial investment or a high cost of production (Ahmed and Osman, 2016; Maradin, 2021).

In recent decades, energy demand has risen sharply and continues to rise. Enhanced lifestyles, population increases, economic competitiveness, and manufacturing advancements all contribute to the rising demand for energy. Energy is a critical element for meeting fundamental human needs as well as achieving economic growth and development goals. Many countries lack the necessary funds to invest in energy production or even to use energy, whether renewable or non-renewable. As a result, these countries rely on borrowing to finance these investments. In recent years, the literature on energy and economic performance has expanded. However, the literature on the link between energy use and public debt is still in its early phases.

This study's main objective is to investigate the effect of public debt on energy usage, both non-renewable and renewable energy, employing panel data for seventeen OECD countries from 1980 to 2020. The rest of this paper is structured as follows. Section 2 explores previous literature. Section 3 presents the model description and data sources. The key findings of the study are presented in section 4. Finally, section 5 illustrates the conclusion and the policy recommendations.

2. REVIEW OF LITERATURE

The linkage between public debt, use of energy and economic growth has been the subject of a considerable number of studies. The review of relevant literature is divided into two main subsections: the first deals with the link between energy usage and economic growth; and the second discusses the link between energy usage and public debt.

2.1. Energy - Growth Nexus

The empirical research on the linkage between economic development and the use of energy is substantial, and they continue to grow. The acquired results are quite diverse, and there is no consensus among the researchers not only on the presence of the interaction but also on the direction of causation between the two variables. The energy-growth nexus is investigated using four hypotheses (Campo and Sarmiento, 2013; Ozturk et al., 2010). First, the growth hypothesis assumes that increasing the use of energy enhances economic growth, and hence, energy is a key input for output. Second, the conservative hypothesis asserts that the connection between economic growth and energy use is unidirectional, and hence policies to reduce energy use may not have a negative effect on economic growth. Third, the feedback hypothesis states that using of energy and economic growth are inextricably linked, with bidirectional causality between both. Fourth, according to the neutrality hypothesis, there is no causative link between energy usage and a country's growth, and any policy that influences one will have no impact on the other (Belke et al., 2012; Destek and Aslan, 2017; Rahman and Mamun, 2016).

The growth hypothesis found support in many empirical studies (Lee, 2005), (Nkoro and Ikue-john, 2020), (Kabuga and Mohammed, 2021), (Wang and Lee, 2022). According to the growth hypothesis, energy, like capital and labor, is a necessary input in the process of manufacturing and plays a significant role in economic progress. As a result, energy consumption and economic development have a one-way relationship, and energy policy implementation affects the production level.

The feedback hypothesis highlights the interconnection and complementarity of energy use and economic growth. The occurrence of two-way causation between energy consumption and the growth of the economy lends credibility to the feedback hypothesis, as demonstrated by (Masih and Masih, 1997), (Mahadevan and Asafu-Adjaye, 2007), (Oh and Lee, 2004) in the long run, (Ozturk et al., 2010) (Rahman, 2021), (Le and Sarkodie, 2020), (Campo and Sarmiento, 2013) and (Brini et al., 2017) in the short-run.

As per the neutrality hypothesis, energy usage is a negligible element of a country's total output and so has minor or no influence on the growth of the economy. The neutrality hypothesis has been supported by (Huang et al., 2008; Hondroyiannis et al., 2002, and Eyuboglu and Uzar, 2021).

Finally, the conservation hypothesis claims that limiting energy use has no destructive effect on the growth of the economy. This hypothesis is verified if there is one-way causation between economic expansion to energy usage. It has been supported by (Hsiao, 1981), (Asafu-Adjaye, 2000), (Zachariadis, 2007), (Magazzino, 2018), and (Almozaini, 2019).

2.2. Energy Consumption and Public Debt

Only a few researchers have looked at the effect of government debt on energy usage. Ziaei (2012) investigated the impact of government debt on energy consumption in 15 European countries over the period from 1995 to 2011 using the GMM model. The study reveals that investment, inflation and government debt have positive and significant impacts on energy consumption. Sun and Liu (2020) studied the impact of debt whether private or public on energy consumption in China using annual data over the period from 1996 to 2016 by employing the LMDI model. The study found that private debt per capita had a favorable influence and contributed the most to China's energy consumption. Concerning government debt, it has a detrimental influence on energy use.

Hashemizadeh et al. (2021) used FGLS and PCSE models to investigate the influence of public debt on renewable energy usage in 20 emerging nations from 1990 to 2016. The main findings of the study show that public debt and trade openness have unfavorable significant influences on renewable energy use in eight nations, while they have direct significant impacts in Indonesia and the Republic of Korea. Economic growth, on the other hand, has a favorable and substantial influence on renewable energy use in eleven nations and a significantly negative impact in three countries.

To the best of our knowledge, the study of the linkage between disaggregated energy use and public debt is currently insufficient, and the results obtained are also inconclusive. As a result, further research is required to address the energy-debt nexus argument.

There are no studies that assess the consequences of public debt on renewable and non-renewable energy use. As a result, our research will fill in the gaps in the current literature.

3. DATA, MODEL, AND METHODOLOGY

3.1. Model Specification and Data Sources

As earlier literature paid less attention to the debt-energy consumption nexus, this paper investigates the influence of government debt (PD) on both renewable (Ren) and non-renewable energy (NRE) consumption in OECD countries. There are additionally four control variables: GDP growth rate (GDPG), trade openness (Open) as a percentage of GDP, inflation rate (inf) and population growth rate (popg). Two models have been constructed using previous studies to achieve the main objective of this study.

$$RE = \beta_0 + \beta_1 PD + \beta_2 GDPG + \beta_3 inf + \beta_4 open + \beta_5\ popg + \in_t \quad (1)$$

$$NRE = \propto_0 + \propto_1\ PD + \propto_2\ GDPG + \propto_3\ inf + \propto_4\ open + \propto_5\ popg + \mu_t \quad (2)$$

This study is based on yearly data and covers the period from 1980 to 2020 for 17 OECD countries: Austria, Belgium, Denmark, France, Germany, Spain, Sweden, Switzerland, Greece, Luxembourg, Netherlands, Norway, Iceland, Ireland, Italy, Portugal, United Kingdom, and the US. The sample was chosen based on data availability. There are two main dependent variables, non-renewable energy (NRE) and renewable energy (RE) consumption. Both sources of energy are measured in exajoules, and the data comes from the BP Statistical Review of World Energy. Public Debt (PD) as a percentage of GDP, is the major independent variable, and data is acquired from the Global Debt Database. The data for the control variables (GDP growth rate, trade openness, population growth rate, and inflation rate) is retrieved from the World Development Indicators. Table 1 displays descriptive statistics for the underlying variables.

3.2. Econometric Model

To investigate the influence of government debt on both renewable and nonrenewable energy use, which was introduced in the previous subsection, estimated generalized least squares and quantile regression models are to be used.

3.2.1. Generalized least squares (GLS)

As a first step, the EGLS (Estimated Generalized Least Squares) estimator will be used. When one of the key assumptions of the Gauss-Markov theorem, namely homoscedasticity and the lack of serial correlation, is broken, the Generalized Least Squares approach is employed to cope with the scenario where the OLS estimator is not BLUE (Best Linear Unbiased Estimator). If the other requirements of the Gauss-Markov theorem are fulfilled, the GLS estimator is BLUE. The goal of this paper is to estimate the parameters of a linear-panel model using Generalized Least Squares approaches, which can handle the problems of correlation and heteroscedasticity (Bamati and Raoofi, 2020).

In the beginning, equations (1) and (2) are estimated by the OLS method, and the results indicate that there is an autocorrelation problem. As a result, GLS is needed to eliminate autocorrelations.

3.2.2. Panel quantile regression (PQR)

The bulk of the existing empirical studies on energy consumption determinants assume parameter homogeneity and are based on OLS and instrumental variables (IV) regressions, panel techniques, or matching estimators. Furthermore, supposing that responsiveness across nations is identical may result in findings based on the entire population of countries being over-fitted to a specific subset of interest. In other words, if the data is biased due to heterogeneity, an empirical pattern discovered may have different implications for various groups of nations. As a result, using quantile regression would be preferable (Dufrenot et al., 2010).

In this section, panel quantile regression will be used to verify the validity and reliability of the results by estimating the parameters at various points along with the (conditional) energy consumption. Koenker and Bassett (1978) were the first to propose the panel quantile regression. The key benefit of employing the PQR is that it helps to reduce outlier biases, and the panel quantile regression is more reliable than ordinary least squares estimators when the residual components are not distributed normally (Gozgor et al., 2018). More importantly, the repercussions of public debt, GDP growth rate, population growth rate, trade openness, and inflation rate may vary depending on the extent of energy usage.

Many empirical studies employ quantile regression analysis, where the variables may have varied (or differing) impacts at various points in the conditional distribution of the dependent

Table 1: Variables' descriptive statistics

	GDPG	INF	NRE	PD	POPG	REN	Open
Mean	2.056673	3.652950	8.370473	64.57497	0.537504	0.205101	86.73432
Median	2.134453	2.291701	2.072249	58.53426	0.476504	0.022630	68.66328
Maximum	25.17625	27.21275	95.31857	211.2147	2.890960	5.709858	380.1042
Minimum	−10.82289	−5.213920	0.104818	4.063845	−1.853715	0.000000	16.60391
Std. Dev.	2.753817	4.333871	19.47829	33.49581	0.505680	0.586522	57.66317
Skewness	0.104347	2.338171	3.626772	0.940056	0.820413	5.847098	2.220583
Kurtosis	12.94235	9.528172	14.87708	4.203347	5.913316	43.95693	9.193049
Jarque-Bera	2863.801	1867.384	5608.619	144.2955	323.7459	52536.91	1681.837
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	1429.388	2538.801	5817.479	44879.61	373.5650	142.5449	60280.35
Sum Sq. Dev.	5262.954	13035.01	263306.4	778646.9	177.4646	238.7417	2307578.
Observations	695	695	695	695	695	695	695

variable. These heterogeneous effects have been shown to provide important information that can't be identified using traditional mean regression approaches like the ordinary least-squares (OLS) method. PQR may also be used to investigate the non-linear effects of regressors on a dependent variable (Albulescu et al., 2019).

Given a set of independent variables $X_{it,}$ illustrated in equations (1) and (2), the conditional distribution of the dependent variable can be written as the t^{th} quantile (0< t <1), such that:

$$Q_\tau(NRE_{it}) = \propto_0 + \propto_\tau X_{it} + \propto_t \mu_{it} \quad (3)$$

$$Q_\tau(RE_{it}) = \beta_0 + \beta_\tau X_{it} + \beta_t \mu_{it} \quad (4)$$

4. RESULTS

It can be concluded from Table 2 that, according to the GLS model, in column (1), the influence of public debt on renewable energy use is favorable and statistically significant. This indicates that the debt incurred by the public sector of the group of countries under consideration is geared toward investments in renewable energy sources. This result is consistent with that of Florea, Maria, Puiu, Manta, and Berceanu (2021). It has been shown that the GDP growth rate has a statistically significant negative influence on the utilization of renewable energy, as found by Giraud and Kahraman (2014) and Matei (2018), reflecting either a deficiency of investment in renewable energy or the presence of an undeveloped energy sector in some of these countries.

The results also indicate that population growth has a favorable and considerable influence on renewable energy consumption. Inflation and trade openness, on the other hand, have major negative effects on renewable energy usage. The ability of countries under consideration to import advanced technology is enabled by trade openness. The use of advanced techniques reduces the energy intensity. The economic consequences of deploying sophisticated technologies include using less energy and producing more output, which is referred to as the technique effect (Shahbaz et al., 2014).

The quantile regression results represented in columns (2), (3) and (4) give clarification and/or support for the results of the generalized least squares (GLS) model. The panel quantile regression findings are really intriguing. Table 2 shows that public debt has a more favorable impact on renewable energy usage in the higher quantiles. According to the quantile regression estimates at the 25^{th} quantile, public debt and population growth rate have no significant influence on renewable energy use. In terms of the 50^{th} and 75^{th} quantiles, the findings are comparable to those of the GLS model. In general, the GLS and quantile regression analysis indicate that overall public debt plays an important role in increasing renewable energy consumption in OECD member nations.

Regarding the utilization of non-renewable energy, it can be noticed from the results of the GLS model, illustrated in Table 3, that public debt has a major detrimental influence on nonrenewable energy use. When the government debt increases, it is expected that long-term interest rates will rise, and hence investment and consumption will decrease. Consequently, non-renewable energy consumption will decrease, and production will decrease as well. GDP growth rate and population growth rate have significant positive impacts on non-renewable energy consumption. Finally, inflation and trade openness have significant negative impacts on the use of non-renewable energy.

Table 2: Results of the Estimation of the EGLS and Quantile Regression Models for Renewable Energy Consumption

	EGLS (1)	Quantile regression		
		0.25 (2)	0.5 (3)	0.75 (4)
C	0.120403*	1.859701*	3.557820*	14.68386*
PD	0.001402*	0.008044	0.043742*	0.054343*
GDPG	−0.003876*	−0.133933	−0.479526*	−0.945584*
POPG	0.031477*	1.060680	2.199021**	15.84622*
Open	−0.000568*	−0.011291**	−0.017632*	−0.118069*
INF	−0.006430*	−0.151395*	−0.314326*	−1.207971*
R-squared	73.11%	-	-	-

**Significant at 5%, *Significant at 1%

Table 3: Results of the estimation of the EGLS and Quantile regression models for non-renewable energy consumption

	EGLS (1)	Quantile regression		
		0.25 (2)	0.5 (3)	0.75 (4)
C	11.69472*	2.157124*	4.916381*	13.18071*
PD	−0.005049*	−0.000514	0.008495	−0.019081*
GDPG	0.064359*	0.002431	−0.01477	0.076979
POPG	2.450302*	0.448526	1.64597*	4.32358*
Open	−0.069355*	−0.011791*	−0.029832*	−0.067520*
INF	−0.114411*	0.058883*	−.165379*	−0.351290*
R-squared	89.3%			

**Significant at 5%, *Significant at 1%

According to the quantile regression estimates at the 25^{th} quantile, public debt has a negative insignificant impact, while at the 50^{th} quantile, the impact is positive and insignificant, and finally, with respect to the 75^{th} quantile, public debt has an adverse and minor influence on the usage of nonrenewable energy. The coefficient of GDP growth rate is positive for the 25^{th} and 75^{th} quantiles and significant for the 75^{th} quantile only. It is negative and insignificant for the 50^{th} quantile. The population growth rate has a positive coefficient for the three quantiles, but it is relevant only for the 50^{th} and 75^{th} quantiles. The coefficient of trade openness is negative and significant for all quantiles. Finally, the inflation rate has a negative and significant coefficient for the 50^{th} and 75^{th} quantile and positive and significant for the 25^{th} quantile. It can be noticed from Table 3 that all variables have more favorable impacts on renewable energy usage in the higher quantiles.

5. CONCLUSION AND POLICY RECOMMENDATIONS

In many countries, the rapid economic expansion raises the need for energy, coupled with the fact that increased energy usage at the expense of environmental quality has become a major concern for these economies. Many countries have faced substantial issues because of global warming and climate change. These growing concerns have driven several developed and emerging countries to seek an alternate energy source to fulfill their overall energy demands while also dealing with the threat posed by the effects of global warming and rising carbon emissions. Renewables play an important role in reducing carbon emissions, ensuring the security of the supply of energy, and achieving economic progress.

Furthermore, the move from nonrenewable to renewable sources entails financial obligations, which many governments borrow to fulfill this requirement. As a result, the goal of this research is to look at the link between public debt and renewable and nonrenewable energy usage. To accomplish this goal, GLS and quantile regression models have been employed for a set of 17 OECD countries for the period 1980-2020.

The key findings of this study indicate that public debt has a positive effect on renewable energy usage while having a devastating impact on the utilization of non-renewable energy. The country’s growth rate has a negative influence on renewable energy while having a good impact on non-renewable energy consumption. The inflation rate and trade openness have negative and significant impacts on energy consumption, whether renewable or non-renewable. Finally, with respect to the population growth rate, it has a favorable and considerable influence on both renewable and non-renewable energy use.

A number of policy recommendations have been made as a result of the current findings. Policymakers should take the advantage of directing public debt to encourage using and investing in the renewable energy sector and try to substitute renewable energy for non-renewable energy. To encourage the use of renewable energy, the government debt should be allocated to renewable energy investment projects. Furthermore, the government should remove legal and regulatory barriers to private sector participation in renewable energy project development. Private investment can be used to lower the countries’ governmental debt.

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