Print ISSN: 2288-4637 / Online ISSN 2288-4645
doi:10.13106/jafeb.2021.vol8.no4.0613

The Relationship Between Income Inequality and Energy Consumption: A Pareto Optimal Approach

Mehmet NAR[1]

Received: December 15, 2020 Revised: March 06, 2021 Accepted: March 15, 2021

Abstract

This paper analyzes the relationship between income distribution and energy consumption from a Pareto optimal approach. For this purpose, the causality relationship between electricity consumption per capita (kWh) with respect to country groups and energy consumption per capita (kg of oil equivalent) along with gross domestic product per capita was analyzed. In addition to this purpose, a Pareto analysis was conducted to determine the countries with the highest per capita national income, how much of the world total energy they consume, and whether the law of power in the energy and electricity markets exists. Finally, the impact of official development assistance provided to low-income countries by high-income countries on the low-income countries' electricity and energy consumption was analyzed. In other words, it was questioned whether pareto redistribution policies serve the purpose or not. The Engle-Granger causality approach was used in the analysis of the causality relationship between variables. Our analysis indicated that, first, the energy data of the country groups may be inadequate in revealing income inequalities. Second, the existence of Pareto law of power and global income inequality can be explained based on energy data. Finally, Pareto optimal redistribution policies to eliminate income inequality remain inadequate in practice.

Keywords: Energy Economy, Income Inequality, Income Distribution, Energy Consumption, Pareto Optimality, Efficiency

JEL Classification Code: O13, Q43, D3, D61

1. Introduction

One of the current issues regarding the economy is income distribution, which is the basic indicator of the distinction between equality and inequality. Fair and balanced distribution of income is also important for the sustainability of individual and social welfare. According to the classical view, inequality in income distribution leads to capital accumulation. Inequality directs a significant part of capital to prosperous individuals with a high marginal propensity to save; thus, capital accumulation increases, and the growth accelerates. According to the modern view, justice or equality in income distribution encourages investment in human capital which accelerates economic growth and reduces income inequality (Byrns & Stone, 1997; Lee, 2019; Ruffin & Gregory, 2000). Studies of income inequality and growth are generally shaped around these two theories. However, the issue that has not yet been completely resolved is the causes of income inequality and conceivable solutions (Hasanov & Izraeli, 2011; Kaynak, 2014).

One of the main reasons for economic inequality is that wages are determined by the market. Information, skills, and educational opportunities that are distributed unevenly are also among the causes of inequality (Nar, 2020a; Stiglitz, 2013). Personal factors also lead to income inequality, as enumerated below. The initial ownership of the goods, that is, the degree that production is possessed by an individual determines the difference in income (Leung, 2015). Innate talent differences play a role in determining wealth among individuals (Messmore, 2012). The gender gap is another factor contributing to income inequality (Jain-Chandra, 2015). Technological development also leads to unemployment and income inequality (Leung, 2015). As a result of financial globalization, foreign direct investments and portfolio investments increase. Technology-intensive foreign capital inflows contribute to the increase in income by increasing the

[1]First Author and Corresponding Author. Associate Professor. Department of Economics, Faculty of Economics and Administrative Sciences, Artvin Coruh University, Turkey [Postal Address: Hopa İktisadi ve İdari Bilimler Fakültesi Sundura Mah. Lise Cad. No:69 08600 Hopa/Artvin, Turkey] Email: 0608mehmet@gmail.com

demand for highly skilled labor and thus wages in this field. Income inequality increases even more for unskilled workers (Freeman, 2010; Lee, 2013; Velde, 2003). Another indicator that reveals inequality of income distribution is energy use rates which can also be used as a criterion of income inequality. Since there is a direct relationship between energy poverty and income inequality, policy makers can obtain an idea about the poverty level in a particular country by assessing the energy access data (Laldjebaev et al., 2016; OECD, 2014).

Inequalities are often discussed and analyzed in terms of income or monetary criteria, but differences in energy access and usage can also reveal income inequalities. Therefore, total energy statistics can be used to identify inequalities in global, regional, and national income distribution (Pachauri & Rao, 2014). The main indicators of the relationship between inequality in income distribution and energy poverty are (a) access to electricity networks and (b) the amount of energy consumed (UN, 2018).

Primary energy sources, sources that can be used directly, are oil, coal, natural gas, solar, wind, nuclear, hydraulic, and biomass. The secondary energy source, sources that can be used after being transformed, include gasoline, diesel oil and diesel fuel from petroleum and electricity from coal and solar energy. In practice, it is easier to reveal income inequalities by considering electricity usage rates compared to energy consumption data (Stern & Cleveland, 2004) because electricity, which is a secondary energy source, is the most easily controlled form of energy that can be used in almost any field. In relation to production, electricity can also be produced in a clean manner by renewable methods such as wind, water, and solar. It is the only type of energy that is open to consumption by all age and income groups and is an indicator of modernity. For this reason, data on electricity consumption is frequently used in research to define income inequalities (Lee, 2020; Liddle, 2012; Maza & Villaverde, 2008).

To this end, this study was structured as follows: (a) the relationship between energy and electricity consumption data and income distribution was analyzed, and the efficiency of energy data was investigated to determine income inequality; (b) the obtained energy data was applied to the Pareto law of power to investigate whether this law is sufficient to explain income inequality; and (c) within the scope of Pareto redistribution policies, whether the assistance provided from rich countries to poor countries have an effect on the energy consumption and income inequality of poor countries was investigated.

2. Literature Review

Analyses of energy consumption generally focus on the causality relationship between energy consumption and economic growth (Payne, 2010). However, few studies examine the relationship between energy consumption and income inequality (Wolde-Rufael, 2006). For example, in the study conducted by Hedenus and Azar (2005), incremental income inequality also increased per capita energy inequality globally. According to Jacobson et al. (2005), the unequal distribution of energy sources causes important social and environmental problems. Using the dynamic panel method, Sonora (2018) concluded that access to energy reduced income inequality and that energy inequality varied according to countries, regions, and economic situations.

According to the study conducted by the UN (2018), inequalities in energy use increase income inequalities between rural and urban areas. In addition, productivity is limited, life opportunities are precluded, and institutional growth and employment decrease while poverty increases. The use of alternative insecure energy sources also causes serious problems for health. In some regions, for example, in sub-Saharan Africa and South Asia where people have limited energy sources, the situation is much worse than in areas with easily available energy sources. Scott (2013) concluded that there was a strong correlation between per capita gross national income and per capita energy consumption. Accordingly, the energy consumption of low-income countries is extremely low. In order for these countries to achieve their human development goals and achieve economic development, they need to increase their energy consumption. According to the analysis results, 77% of the total primary energy supply in these countries consists of renewable energy sources (most of them are biomass such as wood or charcoal), and 23% are fossil fuels.

In the study by UNDP (2017), attention was drawn to energy inequality at the national level. There is, for example, a direct relationship between energy poverty and low income in Moldova. According to the research carried out by the International Energy Agency (IEA, 2016), in a country where the income distribution is not equal, energy inequalities are more important because high rates and degree of energy poverty eliminates the necessary conditions for individual well-being and life sustainability such as cooking, heating, health, and access to education. Considering that 1.2 billion people still have no access to electricity today, access to energy is an important determinant of individual welfare as well as economic welfare. According to Oswald et al. (2020), there was a significant relationship between per capita energy consumption and income level. In addition, inequality in the final energy distribution also restrained sustainable development. The findings showed that the energy demands of high-income individuals will increase more concerning energy-intensive goods in the coming period.

Ritchie and Rose (2020) investigated trends in energy consumption per capita and examined, not only electricity consumption, but also all dimensions of energy. First, the average energy consumption per capita is constantly increasing. Between 1980 and 2018, average consumption increased by 45 percent. Second, this increase in per capita energy consumption partially explains income inequality between countries and regions. In a study by Oswald et al. (2020), a significant relationship was found between per capita energy consumption and income level. According to Lawrence et al. (2013), fossil fuels are the main cause of extensive disparities in world energy consumption, and one way to overcome this problem is to edge the global economy towards renewable energy, specifically solar, wind, water energy.

Besides the studies that reveal the causality relationship between energy inequality and income inequality, there are also studies showing that there is no causal relationship between these variables. For example, Payne and Taylor (2010) claimed that there is no Granger causality relationship between the increase in energy consumption and real gross domestic product (GDP) in the study they conducted on the USA using annual data between 1957 and 2006. Mahalingam and Orman (2018) examined the relationship between energy consumption and national income in all states in the USA and concluded that there was no causal relationship between energy consumption and national income in any states except for two. Faisal et al. (2016) examined the causality relationship between energy and electricity consumption and national income by using data from the 1990 to 2011 period. In their study carried out using the VAR model, no causal relationship was found between electricity and energy consumption and national income in Russia.

Mutascu (2016) examined the relationship between energy consumption and GDP based on data from 1970 to 2012 specific to G7 countries. According to the findings, a causality relationship could not be determined for England and Italy. Therefore, it is not possible to conclude whether the findings obtained from this research support the findings of particular studies because there are too many variables that affect national income per capita and electricity, and energy consumption are merely two of them. Additionally, different findings are obtained in diverse studies. In this study, a single-track causality relationship was determined in the countries with upper middle-income level from per capita electricity consumption to per capita national income. No causality relationship was found between per capita energy consumption and national income in any country group.

3. Research Methodology

One of the biggest problems of the world today is undoubtedly the development gap between high-income countries and low-income countries, a difference that leads to income inequality. Although there are many reasons for differences between countries' gross national products, energy consumption and electricity consumption are key. The high energy consumption of high-income countries enables more production, which increases the gross national product. In contrast, since electricity and energy consumption in the low-income countries are insufficient for the needs of the population, production remains low, resulting in low GNP. In this context, this study aimed to investigate the causal relationship between per capita electricity consumption (kw/h) and per capita energy consumption (oil equivalent) and gross national product per capita by country groups. In addition, in this study, a Pareto analysis was conducted to determine the existence of a law of power in the energy and electricity markets to determine how much total energy and electricity are consumed by the countries with the highest per capita national income. Thus, in this study, an attempt is made to determine if income inequalities are based on the existence of a law of power. Finally, the impact of official development assistance from high-income countries to low-income countries on the electricity and energy consumption of low-income countries were examined. In this manner, the question of whether Pareto optimal redistribution policies are effective in reducing energy inequalities was examined.

4. Data Set

Country groups rather than countries were used in the study. The electricity and energy consumption per capita and national income per capita for the 1980 to 2018 period in the five country groups, namely, low income, lower middle income, middle income, upper middle income, and high income were compiled from the World Development Report and World Bank data to create a data set. Table 1 shows the variables used in the study.

Since the purpose of this study is to determine the causal relationship between electricity and energy consumption and per capita national income within each country group, time-series analysis techniques and not panel data analysis were used. The aim of the study also required a separate analysis of the relationship between per capita electricity and energy consumption and per capita national income. In this context, the Engle-Granger causality approach was used in the analysis of the causality relationship between two variables (one dependent and one independent variable). In this approach, first, two variables with the same level of stationary are subjected to least squares regression, and then the stationarity of the remains is examined. If the remnants of the regression are stationary at the level value, the two examined variables are considered to be cointegrated. The Granger causality of two variables, which are considered to have a cointegration relationship, can be examined. The causality relationship between official development assistance from high-income countries to low-income countries and electricity and energy consumption of the low-income group of countries were examined in the same way.

Table 1: Variables Used in the Study

Variable	Explanation
L_ELECTRICITY	Per capita electricity consumption of low income countries
L_ENERGY	Per capita energy consumption of low income countries
L_GDP	GDP per capita of low income countries
LM_ELECTRICITY	Per capita electricity consumption of lower middle income countries
LM_ENERGY	Per capita energy consumption of lower middle income countries
LM_GDP	GDP per capita of lower middle income countries
M_ELECTRICITY	Per capita electricity consumption of middle income countries
M_ENERGY	Per capita energy consumption of middle income countries
M_GDP	GDP per capita of middle-income countries
UM_ELECTRICITY	Per capita electricity consumption of upper middle income countries
UM_ENERGY	Per capita energy consumption of upper middle income countries
UM_GDP	GDP per capita of upper middle income countries
H_ELECTRICITY	Per capita electricity consumption of high income countries
H_ENERGY	Per capita energy consumption of high income countries
H_GDP	GDP per capita of high-income countries
ODA	Official development assistance from high income countries to low income countries

One other aim of the study is to reveal the existence of the law of power in the electricity and energy markets. The law of power, also called the Pareto analysis, is known as the 80/20 rule. Thus, in this study, the question of whether 80% of the total energy and electricity consumed is indeed consumed by the high-income group was examined.

5. Findings

5.1. Causality Relationship Between Per Capita GDP and Per Capita Energy and Per Capita Electricity Consumption by Country Groups

The initial aim of the study was to determine the causality relationship between per capita national income and electricity and energy consumption. In determining this relationship, the stationarity of the series was firstly examined with the help of unit root tests. In Table 2, the findings of Phillips Perron and Augmented Dickey Fuller Unit Root tests carried out to investigate the stationarity of the variables used in the study are presented.

As can be seen in Table 2, not all variables used in the study are non-stationary at level value. On the other hand, when their first differences are taken, all series become stationary.

It was observed that all of the series used in the study became stationary when the first differences were taken. Therefore, all series were determined to be equally stable. For this reason, it was decided to use the Engle-Granger cointegration and Granger causality approach in the cointegration and causality analysis.

The Engle-Granger cointegration test requires the two variables to be subjected to least squares regression, the creation of residues as a result of the regression, and the series obtained from these residues to be stationary at the level. In Table 3, the findings for the unit root tests of the error terms obtained from a total of 10 least squares regressions performed to determine the effect of per capita electricity and per capita energy consumption on national income per person separately for each country group may be seen. It was determined that the error terms obtained from each regression were stationary in the level value; therefore, there was a cointegration relationship between the examined variables.

Determining the cointegration relationship between the variables made it possible to examine causality between the variables. The findings of the Granger causality analysis of per capita electricity consumption and per capita energy consumption with national income per capita, separately for all country groups may be seen in Table 4. Accordingly, a single-way causal relationship from per capita electricity consumption to per capita national income in the upper middle-income group was accepted at a 10% significance level ($p = 0.0686 < 0.10$).

Table 2: Unit Root Tests*

	t	*p*		*t*	*p*
Phillips-Perron (PP) Unit Root Test					
L_ELECTRICITY	0.2295	0.7475	d(L_ELECTRICITY)	−6.1926	0.0000
L_ENERGY	0.2101	0.7418	d(L_ENERGY)	−5.9980	0.0000
L_GDP	2.6997	0.9977	d(L_GDP)	−3.3984	0.0012
LM_ELECTRICITY	3.1776	0.9994	d(LM_ELECTRICITY)	−4.3786	0.0001
LM_ENERGY	1.7682	0.9795	d(LM_ENERGY)	−5.7441	0.0000
LM_GDP	3.2391	0.9995	d(LM_GDP)	−2.9099	0.0048
M_ELECTRICITY	2.8678	0.9985	d(M_ELECTRICITY)	−5.7025	0.0000
M_ENERGY	2.4705	0.9960	d(M_ENERGY)	−5.3406	0.0000
M_GDP	3.0818	0.9992	d(M_GDP)	−2.9269	0.0046
UM_ELECTRICITY	2.8822	0.9986	d(UM_ELECTRICITY)	−5.4099	0.0000
UM_ENERGY	2.3722	0.9948	d(UM_ENERGY)	−5.2203	0.0000
UM_GDP	3.0692	0.9992	d(UM_GDP)	−2.9566	0.0042
H_ELECTRICITY	2.4054	0.9952	d(H_ELECTRICITY)	−5.5907	0.0000
H_ENERGY	0.2428	0.7513	d(H_ENERGY)	−5.5603	0.0000
H_GDP	3.2673	0.9995	d(H_GDP)	−3.4922	0.0009
ODA	2.4397	0.9956	d(ODA)	−3.4881	0.0009
Augmented Dickey-Fuller Unit Root Test (ADF)					
L_ELECTRICITY	0.2117	0.7423	d(L_ELECTRICITY)	−6.1928	0.0000
L_ENERGY	0.1318	0.7183	d(L_ENERGY)	−5.9871	0.0000
L_GDP	3.5051	0.9998	d(L_GDP)	−3.4603	0.0010
LM_ELECTRICITY	3.2916	0.9995	d(LM_ELECTRICITY)	−4.3756	0.0001
LM_ENERGY	1.4820	0.9634	d(LM_ENERGY)	−5.7441	0.0000
LM_GDP	2.0972	0.9900	d(LM_GDP)	−1.0679	0.2526
M_ELECTRICITY	3.6511	0.9998	d(M_ELECTRICITY)	−1.9812	0.0468
M_ENERGY	2.2420	0.9929	d(M_ENERGY)	−5.3390	0.0000
M_GDP	2.0529	0.9890	d(M_GDP)	−2.9846	0.0039
UM_ELECTRICITY	2.4211	0.9954	d(UM_ELECTRICITY)	−5.2942	0.0000
UM_ENERGY	2.3605	0.9947	d(UM_ENERGY)	−5.1774	0.0000
UM_GDP	2.0788	0.9896	d(UM_GDP)	−3.0080	0.0037
H_ELECTRICITY	2.5782	0.9969	d(H_ELECTRICITY)	−5.3549	0.0000
H_ENERGY	0.2963	0.7664	d(H_ENERGY)	−5.5501	0.0000
H_GDP	3.6570	0.9998	d(H_GDP)	−3.5339	0.0008
ODA	1.3735	0.9549	d(ODA)	−3.4881	0.0009

*Level Value; Without Trend & Constant.

Table 3: Unit Root Tests of Error Terms*

Country Group	Regression		Error Term	PP		ADF	
	Dependent V.	Independent V.		*t*	*p*	*t*	*p*
Low income	L_GDP	L_ENERGY	ε	−4.1414	0.0001	−4.1479	0.0001
	L_GDP	L_ELECTRICITY	ε	−15.0820	0.0000	−4.1285	0.0001
Lower middle income	LM_GDP	LM_ENERGY	ε	−3.5708	0.0007	−3.5462	0.0008
	LM_GDP	LM_ELECTRICITY	ε	−10.5654	0.0000	−3.5746	0.0000
Middle income	M_GDP	M_ENERGY	ε	−9.5590	0.0000	−3.9007	0.0003
	M_GDP	M_ELECTRICITY	ε	−3.3154	0.0015	−3.4002	0.0000
Upper middle income	UM_GDP	UM_ENERGY	ε	−4.2094	0.0001	−4.1541	0.0001
	UM_GDP	UM_ELECTRICITY	ε	−4.1551	0.0001	−4.1014	0.0001
High income	H_GDP	H_ENERGY	ε	−4.8014	0.0000	−4.7697	0.0000
	H_GDP	H_ELECTRICITY	ε	−5.4322	0.0000	−5.4322	0.0000

*Level Value; Without Trend & Constant.

Table 4: Causality Relationship between Per Capita Electricity and Energy Consumption and Per Capita GDP in Terms of Country Groups

Country Group	Granger Causality Relationship	*F*	*p*
Low income	L_GDP is not the Granger causality of L_ELECTRICITY	2.3400	0.1126
	L_ELECTRICITY is not the Granger causality of L_GDP	0.5265	0.5957
	L_GDP is not the Granger causality of L_ENERGY	0.7859	0.4643
	L_ENERGY is not the Granger causality of L_GDP	0.8997	0.4167
Lower middle income	LM_GDP is not the Granger causality of LM_ELECTRICITY	0.7537	0.4788
	LM_ELECTRICITY is not the Granger causality of LM_GDP	1.6618	0.2057
	LM_GDP is not the Granger causality of LM_ENERGY	0.3589	0.7012
	LM_ENERGY is not the Granger causality of LM_GDP	1.8351	0.1760
Middle income	M_GDP is not the Granger causality of M_ELECTRICITY	0.0967	0.9081
	M_ELECTRICITY is not the Granger causality of M_GDP	1.6910	0.2004
	M_GDP is not the Granger causality of M_ENERGY	0.5692	0.5716
	M_ENERGY is not the Granger causality of M_GDP	1.1471	0.3303
Upper middle income	UM_GDP is not the Granger causality of UM_ELECTRICITY	0.1738	0.8412
	UM_ELECTRICITY is not the Granger causality of UM_GDP	2.9176	0.0686
	UM_GDP is not the Granger causality of UM_ENERGY	0.3403	0.7141
	UM_ENERGY is not the Granger causality of UM_GDP	1.6488	0.2082
High income	H_GDP is not the Granger causality of H ELECTRICITY	1.2763	0.2929
	H_ELECTRICITY is not the Granger causality of H_GDP	1.1591	0.3266
	H_GDP is not the Granger causality of H_ENERGY	2.0657	0.1433
	H_ENERGY is not the Granger causality of H_GDP	0.5380	0.5891

According to Galvin (2020), the existence of a single-way causality relationship in the upper middle-income group from per capita electricity consumption to per capita national income may have resulted from the increase in per capita electricity consumption in the middle-income countries. In addition, there is a decrease in per capita consumption in developed countries, but there is still a vast global inequality in both energy and electricity consumption. The average US citizen still consumes more than ten times the energy consumed by a citizen of India, four to five times more than a citizen of Brazil, and three times more than a citizen of China. While energy (electricity) consumption and population have stabilized to a great extent in developed countries, the increase in global consumption in developing countries such as China and India may explain this situation (Lawrence et al., 2013).

In other country groups, the causality relationship between per capita electricity and energy consumption and per capita national income could not be determined ($p > 0.05$). This may be due to models that take only electricity and energy consumption per capita into account although there are many variables that affect national income per capita. Furthermore, country groups rather than countries were used in the study. According to Oswald et al. (2020), it is easier to reveal differences or inequalities in country comparisons because household values take into account the subjective conditions and characteristics of the countries because heterogeneities are evident both in the quantities of energy used, the types of energy predominantly used, and the levels of access to these across countries and populations. In addition, energy needs (e.g., heating/cooling energy demands) differ according to the climatic conditions in the countries and their natural resources. These differences mostly explain the differences in income, production, and consumption activities and lifestyles. However, since the energy data for the country groups are homogenous general data, they may be inadequate for determining income inequalities (Pachauri & Rao, 2014).

In this case, it may be possible to reach the solution by associating the energy data with the concept of Pareto optimality because this concept can offer appropriate solutions in many conceivable fields from income inequality to energy, health to housing, quality of life to democracy, and crime rates to state theories (Nar & Nar, 2019).

5.2. Pareto Optimal Analysis of Per Capita National Income, Per Capita Energy, and Per Capita Electricity Consumption

Pareto optimality or the efficiency concept is based on the work of the Italian economist Vilfredo Pareto (1848–1923) and is a concept used in efficiency and income distribution related studies. Pareto optimality is the situation in which it is not possible to enhance the welfare of a person without reducing the welfare of another person in the society (Figure 1). In this case, scarce resources are also allocated effectively. Pareto optimal income distributions are discussed in detail by Hochman and Rodgers (1969).

In Figure 1, while the vertical axis shows the income distribution in a society with individuals A and B, the horizontal axis indicates the amount of the total income ($\overline{y}$). The peak points indicate the ones who get the highest share of income distribution. As it moves downward, the shares which the individuals receive from the income decreases. Finally, at the bottom point, the majorities in which there are the poorest people take place. The initial distribution in the Pareto income distribution is data. Due to different reasons (legacy, talent etc.), the shares which individuals receive from income show a difference. It is assumed that at the point of $\overline{y}/2$, income is distributed between A and B equally. All black points (every median) equals optimal value. Until these points are reached, the income is distributed effectively. In this way, it is possible to increase one individual's welfare without decreasing it for another. However, after any of these points are reached, the welfare of A or B can be increased by decreasing the other's welfare. On the other hand, it is difficult to adopt this efficiency model developed by Pareto for resource distribution to income distribution. Since it is impossible to increase one person's welfare without decreasing another's, as Bundschuh (2012) stated, it is not possible to reach optimal Pareto distribution without the existence of redistribution policies of the government or voluntary contributions by individuals. As Pareto emphasizes, the income struggle in the real world is essentially the domination of the minority over the majority (Arnold, 2015; Boccara, 2010; Leach, 2004; Nar, 2020b; Warr, 1982).

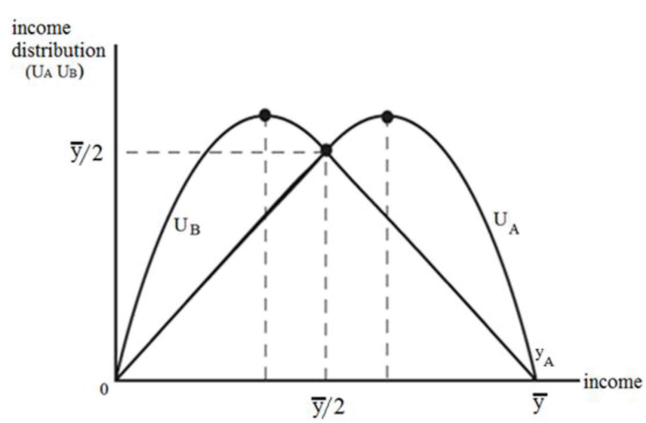

Figure 1: Pareto Optimal Income Distribution
Source: (Leach, 2004)

Pareto optimal income distribution is best known as the 80/20 rule, meaning that 20% of the population controls 80% of the income. Vilfredo Pareto (1897) drew attention to inequality in income distribution or wealth. The rich segment, which constituted 20% of the population in Italy, also held 80% of the land. This rule, which Pareto found by chance over land ownership, is called the law of power. In terms of income distribution, this rule can be said to be valid today (Boccara, 2010; Bodley, 2013). Studies on the law of power have increased significantly in the past half century. According to research, it is possible to find this rule at work in all areas of life. For example, 20% of manufactured products make up 80% of sales, 20% of sales provide 80% of profit, 20% of drivers cause 80% of accidents, we wear 20% of our clothes in 80% of our life-time, and 20% of criminals are responsible for 80% of crimes (Boccara, 2010; Koch, 2014). The law of power is the subject of research in many sciences, particularly in economics and sociology. This approach in which Vilfredo Pareto explained the distribution of wealth or income with the law of power continues to be have current applicability. Studies on the law of power indicate that the free market mechanism tends to distribute wealth or income according to the 80–20 rule when left *motu proprio*. The richest 20% of the world today receives 82% of the world's income while the poorest 20% receive only 1.4%. This explicitly reveals the existence of the law of power (Small, 2011; Vogli, 2013).

In order to examine the law of power in the energy and electricity market, the electricity consumption per capita and energy consumption per capita in the data set were listed from large to small. Then, the cumulative sums and cumulative percentages were calculated, and a Pareto chart was created. As seen in Figure 2, the country group that is in the highest income group in per capita energy consumption consumes 60% of the total energy.

The same analysis was carried out for electricity consumption, and, as seen in Figure 3, it was determined that 70% of the total electricity consumed was consumed by the countries in the highest income group.

It is possible to list some of the studies that support the results of our analysis as follows. Lawrence et al. (2013) reached the conclusion that the countries in the highest income group consume two-thirds of the energy produced and pointed out the existence of the law of power. The findings of Oswald et al. (2020) also point to the existence of the law of power. Another study demonstrates that global income inequality is closely related to inequalities in global energy use. The poorest 40% of the world's population uses only 10% of global income and final energy. Countries in the high-income group (the richest) possess two-thirds of the global income and final energy. However, inequalities in electricity usage are much more evident.

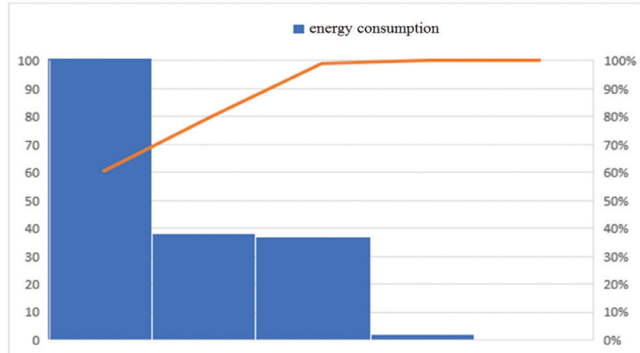

Figure 2: Pareto Chart of Per Capita Energy Consumption

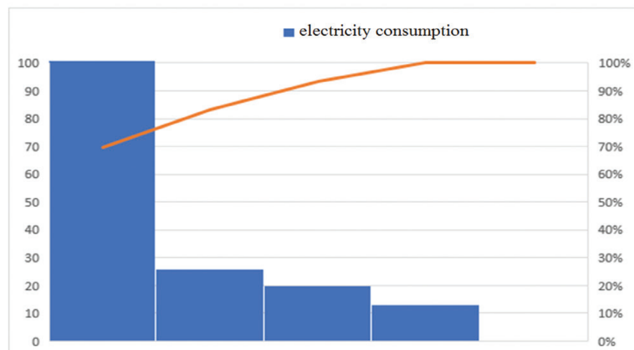

Figure 3: Pareto Chart of Total Electricity Consumption

Approximately one fifth of the world's population does not have access to electricity. The richest 20 percent on a global scale consumes close to 80 percent of global electricity. This situation is a literal demonstration of the existence of the law of power. Inequalities in the distribution of modern fuels lead low-income countries to become more dependent on energy based on biomass fuels (plant, algae, animal waste, etc.) (Pachauri & Rao, 2014).

Today, rich countries make up about 15–20% of the world population while they possess 81% of the world income. According to data from *The Economist*, approximately one billion people have been freed from chronic poverty in the past two decades, certainly a positive trend. However, the poorest 20 percent of the world's population uses only a quarter (1/4) of global resources, unlike the richest 20 percent. Considering this major wealth inequality, the richest 20% consumes approximately 80% of the world's resources. Social and economic injustice causes great wealth inequalities. According to a similar study, the privileged part of the world population (17%) consumes most of the world resources (80%). Approximately five billion people have to live on only the remaining 20%. The 1.9 trillion-dollar wealth of 500 billionaires in the world is more than the income of the world's 170 poorest countries (Begg et al., 2008; World Centric, 2020). According to the research carried out by the International Energy Agency, the richest 20% consumes 80% of the world resources. According to a similar study conducted by Oxfam, income and wealth inequality has tended to increase rapidly since the 1980s. 82% of the global wealth created in 2017 is in the hands of high-income groups, and inequality is the determining power of our time (IEA, 2016; Oswald et al., 2020). Bundschuh explains in his study that the basic truth underlying the wealth of industrialized countries is based on the use of nuclear and fossil energy resources. In such a world, wealth is built only on the poverty created. According to Bundschuh, "80% of all traditional energy sources are consumed by only 20% of humanity." In other words, 20% of wealthy people use 80% of global financial resources. Therefore, the unjust distribution in energy consumption is in complete correlation with the distribution of poverty and wealth in the world (Bundschuh, 2012).

All these statements point to the existence of Pareto income distribution or the law of power. The simple argument put forward by Vilfredo Pareto decades ago is a law that can be used to explain income inequalities today. However, another result is that income distributions that are unequal are not Pareto-optimal. In other words, in today's world, where resources are scarce, it is possible to increase the welfare of some only at the expense of the welfare of others. In such a world, wealth can only be built on the poverty created. For this reason, Pareto-optimal redistribution policies for relatively poor people are considered important in reducing income inequality.

Pareto optimal redistribution policies suggest solutions for reducing income inequalities. Redistribution policies make the Pareto principle operable and provide transitivity. The main idea is that the transfer of resources from the rich to the poor through income transfers of the states or with voluntary contributions will reduce global income inequality and increase the wellbeing of everyone. But in the real world, is income transferred from the rich to the poor through governments and voluntary donations or is there enough assistance to move the economy into Pareto optimal distribution?

5.3. Causality Relationship between Per Capita Electricity and Energy Consumption of Low-income Countries and Development Assistance Provided to Low-income Countries

In practice, most of the aid from rich countries to poor countries is in the form of official development assistance, either through international organizations (World Bank, UN) or directly by governments of rich countries. In addition, voluntary monetary transfers, donations and grants made by individuals, bilateral and multilateral non-governmental organizations, and charities are evaluated within this scope. However, it is seen that analysis is made based on data regarding official development assistance because voluntary aid other than governments is extremely small scale. In addition, such aid usually consists of transfers for small projects, too insignificant to be included in the calculations (Hale et al., 2013; Keeling & Ridout, 2002).

In this study, the causal relationship between the official development aid provided from the high-income countries to the low-income countries with the same method and the electricity and energy consumption of the low-income countries were also examined. The question is asked as to whether development assistance has an impact on the energy/electricity consumption of the poor countries on income inequality, in other words, whether Pareto redistribution policies work or not. Table 5 shows the findings of the unit root tests of the error terms of the least squares regression performed to reveal the impact of development assistance on the per capita electricity consumption and per capita energy consumption of low-income countries. Accordingly, there is a cointegration relationship between development assistance and per capita electricity and energy consumption of low-income countries.

The findings of the Granger causality analysis examined after determining the cointegration relationship are shown in Table 6. Accordingly, there is no Granger causality between development assistance and low-income countries' per capita electricity and energy consumption ($p > 0.05$).

Table 5: Unit Root Tests of Error Terms*

Country Group	Regression		Error Term	PP		ADF	
	Dependent Variable	Independent Variable		*t*	*p*	*t*	*p*
Low income	L_ELECTRICITY	ODA	ε	−6.2993	0.0000	−6.2998	0.0000
	L_ENERGY	ODA	ε	−6.2692	0.0000	−6.1825	0.0000

*Level Value; Without Trend & Constant.

Table 6: Causality Relationship Between Per Capita Electricity and Energy Consumption of Low-Income Countries and Development Assistance to Low-Income Countries

Granger Causality Relationship	*F*	*p*
ODA is not the Granger causality of L_ENERGY	1.4552	0.2484
L_ENERGY is not the Granger causality of ODA	0.3184	0.7295
ODA is not the Granger causality of L_ELECTRICITY	0.1535	0.8583
L_ELECTRICITY is not the Granger causality of ODA	1.4940	0.2397

This shows us that Pareto optimal redistribution policies remain extremely limited, and it is very difficult or even impossible to prevent global income inequality through voluntary aid because aid from rich countries to poor countries through governments and voluntary organizations is too small to be compared to the wealth of countries. In addition, the process of money transfer is extremely slow in government assistance from rich countries to poor countries. Aid provided by international organizations including the United Nations are extremely insufficient transfers (Hale et al., 2013; Little & Clifford, 2017; Warr, 1982).

6. Discussion and Conclusion

The problem of economic inequality has increased rapidly over the past thirty years, including in developed countries. The effects of inequality are intense in areas such as energy, health, shelter, crime rates, and social cohesion; and threaten even the existence of democracies. The problem of income inequality, which reaches extreme levels particularly in low-income countries, also eliminates the opportunity to access goods and services such as food, shelter, roads, clean water, sewerage, health, and education (Galvin, 2020; Lee, 2020). This is even more evident in energy and electricity consumption. Depending on income inequality, electricity and energy usage rates also differ disproportionately. The lack of adequate, reliable, and affordable access to modern energy also limits production, institutional growth, and employment. Moreover, energy inequality negatively affects human health and well-being and contributes to chronic poverty. Therefore, energy inequalities can be seen as a reflection of income inequalities. For example, in some countries, fewer than half of all health facilities have access to electricity, and access levels are lower in rural areas. In sub-Saharan Africa, just 35% of primary schools have electricity access, compared to 48% in South Asia and 93% in Latin America. Energy income inequality is even more pronounced, given that one fifth of the world's population does not have access to electricity (Pachauri & Rao, 2014; UNDP, 2017) because no consumption category is strictly devoted to energy (Oswald et al., 2020).

This study addressed the relationship between income inequality and energy consumption with a Pareto-optimal approach. Country data was analyzed by dividing it into five categories, low-income, lower middle-income, middle-income, upper middle-income, and high-income countries. Then, the causal relationship between each income group, per capita electricity and energy consumption, and per capita national income was investigated. In this way, an analysis was conducted on how effective energy data are in explaining global income inequality.

The first conclusion of the analysis was that the energy data of country groups are insufficient to reveal income inequalities. The findings show that there is a single-way causality relationship between per capita electricity consumption and per capita national income only in countries at the upper middle-income level. This may be due to the fact that most of the growth in electricity consumption per capita in the last 30 to 40 years has increased in middle-income countries. In other country groups, the causality relationship between per capita electricity and energy consumption and per capita national income could not be determined ($p > 0.05$). This result may be said to arise from models taking per capita electricity and energy consumption into consideration although there are numerous variables effecting per capita national income.

In the second aspect of this study, the existence of the Pareto law of power was investigated with reference to the energy data. For this purpose, firstly, Pareto optimality, Pareto optimal income distribution, and Pareto optimal redistribution policies was explained. Then, a Pareto analysis was performed based on energy data, and based on this data, the existence of the Pareto law of power and global income inequality could be explained. The realization that high-income countries consume 60% of total energy and 70% of total electricity supports the existence of the Pareto law of power, in accordance with similar studies.

In the third aspect of this study, it became clear that Pareto optimal redistribution policies fail to reduce global income inequality. The absence of a causal relationship between development assistance and per capita electricity and energy consumption of low-income countries supports this conclusion.

References

Arnold, B. C. (2015). *Pareto distributions*. London, UK: Chapman and Hall/CRC Press.

Begg, D., Fischer, S., & Dornbusch, R. (2008). *Economics.* New York, NY: McGraw-Hill.

Boccara, N. (2010). *Modeling complex systems*. Berlin, Germany: Springer.

Bodley, J. (2013). *The Small nation solution: How the world's smallest nations can solve the world's biggest problems.* Lanham, MD: AltaMira Press.

Bundschuh, J. (2012). *Sustainable energy developments*. London, UK: CRC Press.

Byrns, R. T., & Stone, G. W. (1997). *Economics*. Boston, MA: Addison Wesley.

Faisal, F., Tursoy, T., & Reşatoğlu, N. (2016). Energy consumption, electricity and GDP causality: The case of Russia, 1990–2011. *Procedia Economics and Finance*, *39*(1), 653–659.

Freeman, R. (2010). Does inequality increase economic output. In: *Controversies about inequality*. Stanford, CA: Stanford University Press.

Galvin, R. (2020). Recent increases in inequality in developed countries. In: R. Galvin (ed), *Inequality and energy*. Cambridge, MA: Academic Press.

Hale, T., Held, D., & Young, K. (2013). *Gridlock: Why global cooperation is failing when we need it most*. Hoboken, NJ: John Wiley & Sons.

Hasanov, F., & Izraeli, O. (2011). Income inequality, economic growth, and the distribution of income gains: Evidence from the U.S. states. *Journal of Regional Science, 51*(3), 518–539.

Hedenus, F., & Azar, C. (2005). Estimates of trends in global income and resource inequalities. *Ecological Economics, 55*(3), 351–364.

Hochman, H., & Rodgers, J. D. (1969). Pareto optimal redistribution. *The American Economic Review, 59*(4), 542–557.

IEA (International Energy Agency). (2016). *World Energy Outlook*. International Energy Agency.

Jacobson, A., Milman, A., & Kammen, D. (2005). Letting the (energy) Gini out of the bottle: Lorenz curves of cumulative electricity consumption and Gini coefficients as metrics of energy distribution and equity. *Energy Policy*, *33*(1), 1825–1832.

Jain-Chandra, S. (2015). *Why Gender and Income Inequality are linked*. World Economic Forum. Retrieved June 30, 2020, from https://www.weforum.org/agenda/2015/10/why-gender-and-income-inequality-are-linked/

Kaynak, M. (2014). *Development economics*. Ankara, Turkey: Gazi Bookstore.

Keeling, W., & Ridout, M. (2002). *People, places and themes*. Portsmouth, NH: Oxford Heinemann.

Koch, R. (2014). *The 80/20 principle and 92 other powerful laws of nature: The science of success*. Boston, MA: Nicholas Brealey Publishing.

Laldjebaev, M., Sovacool, B., & Kassam, K. (2016). Energy security, poverty and sovereignty: Complex interlinkages and compelling implications. In: L. Guruswamy., & E. Nevile (Eds.), *International energy and poverty*. London, UK: Routledge.

Lawrence, S., Liu, Q., & Yakovenko, V. (2013). Global inequality in energy consumption from 1980 to 2010. *Entropy, 15*(1), 5565–5579.

Leach, J. (2004). *A Course in public economics.* Cambridge, UK: Cambridge University Press.

Lee, J. W. (2013). The contribution of foreign direct investment to clean energy use, carbon emissions and economic growth. *Energy Policy*, *55*(1), 483–489.

Lee, J. W. (2019). Long-run dynamics of renewable energy consumption on carbon emissions and economic growth in the European Union. *International Journal of Sustainable Development &World Ecology, 26*(1), 69–78.

Lee, J. W. (2020). Big data strategies for government, society and policy-making. *Journal of Asian Finance, Economics and Business, 7*(7), 475–487. https://doi.org/10.13106/jafeb.2020.vol7.no7.475

Leung, M. (2015). *The causes of economic inequality*. SPI Series on Inequality. Retrieved July 16, 2020, from https://sevenpillarsinstitute.org/causes-economic-inequality

Liddle, B. (2012). The importance of energy quality in energy intensive manufacturing: Evidence from panel cointegration and panel FMOLS. *Energy Economics*, *34*(6), 1819–1825.

Little, I. M., & Clifford, J. M. (2017). *International aid: The flow of public resources from rich to poor countries.* New York, NY: Routledge.

Mahalingam, W., & Orman, H. (2018). GDP and energy consumption: A panel analysis of the US. *Applied Energy*, *213*(C), 208–218.

Maza, A., & Villaverde, J. (2008). The world per capita electricity consumption distribution: Signs of convergence? *Energy Policy*, *36*(1), 4255–4261.

Messmore, R. (2012). Justice, inequality, and the poor. *National Affairs*, *10*(1), 108–120.

Mutascu, M. (2016). A bootstrap panel granger causality analysis of energy consumption and economic growth in the G7 countries. *Renewable and Sustainable Energy Reviews*, *63*(C), 166–171.

Nar, M. (2020a). The size of the public economy and its economic efficiency problem. *Research in World Economy*, *11*(6), 234–246.

Nar, M. (2020b). *Public economics: Theory, politics and practice.* Extended and updated 2nd edition. Ankara,Turkey: Nobel Academic Publishing.

Nar, M., & Nar, M. Ş. (2019). An updated assessment of the OECD's quality of life index. *Problemy Ekorozwoju–Problems oF Sustainable Development*, *4*(1),7–18.

OECD. (2014). *Focus on inequality and growth. Directorate for Employment.* Labour and Social Affairs. https://www.oecd.org/social/Focus-Inequality-and-Growth-2014.pdf

Oswald, Y., Owen, A., & Steinberger, J. (2020). Large inequality in international and intra national energy footprints between income groups and across consumption categories. *Nature Energy*, *5*(1), 231–239.

Pachauri, S., & Rao, N. (2014). *Energy inequality*. Policy Note for International Institute Applied Systems Analysis. https://iiasa.ac.at/web/home/research/alg/energy-inequality

Payne, J. E. (2010). A survey of the electricity consumption growth literature. *Applied Energy*, *87*(1), 723–731.

Payne, J. E., & Taylor, J. P. (2010). Nuclear energy consumption and economic growth in the U.S: an empirical note. *Energy Sources, Part B: Economics, Planning and Policy*, *5*(3), 301–307.

Ritchie, H., & Roser, M. (2020). *Energy*. Retrieved Apr 16, 2020, from https://ourworldindata.org/energy

Ruffin, R. J., & Gregory, P. R. (2000). *Principles of macroeconomics*. Boston, MA: Addison-Wesley.

Scott, A. (2013). Energy and low-carbon competitiveness: The case of low-income countries. *Working Paper 367*. https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/8300.pdf

Small, M. (2011). *Dynamics of biological systems.* London, UK: Chapman and Hall.

Sonora, R. (2018). A panel analysis of income inequality and energy use. *MPRA Paper No. 92171*. https://mpra.ub.uni-muenchen.de/92171/1/MPRA_paper_92171.pdf

Stern, D. I., & Cleveland, C. C. (2004). Energy and economic growth. *Rensselaer Working Papers in Economics.* https://www.researchgate.net/publication/24125107

Stiglitz, J. E. (2013). *The price of inequality: How today's divided society endangers our future*. New York: W.W. Norton & Company.

UN. (2018). *Interlinkages among energy, poverty and inequalities*. United Nations Department of Economic and Social Affairs. https://sustainabledevelopment.un.org/content/documents/17480PB_8_Draft.pdf

UNDP. (2017). *National human development report 2015/2016: Inequalities*. United Nations Development Programme. http://hdr.undp.org/sites/default/files/reports/2757/raport_en_nhdr.pdf

Velde, D. W. (2003). Foreign direct investment and income inequality in Latin America: Experiences and policy implications. *Working Paper*. https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/1928.pdf

Vogli, R. D. (2013). *Progress or collapse: The crises of market greed*. London, UK: Routledge.

Warr, P. (1982). Pareto optimal redistribution and private charity. *Journal of Public Economic 19*(1), 131–38.

Wolde-Rufael, Y. (2006). Electricity consumption and economic growth: A time series experience for 17 African countries. *Energy Policy*, *34*(1), 1106–1114.

World Centric. (2020, Feb 2). *Social & economic injustice*. http:www.worldcentric.org/conscious-living/social-and-economic-injustice