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TOWARDS SUSTAINABLE DEVELOPMENT: ANALYSING RENEWABLE ENERGY, HDI, AND ENVIRONMENTAL IMPLICATIONS IN SELECTED EMERGING COUNTRIES

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Abstract

This paper examines emerging market economies that have significant coal production and strong renewable energy potential. The work, covering the period 1992–2021, provides a detailed analysis of the contribution of renewable energy sources to environmental degradation in these countries. The primary objective is to assess the combined impact of joint policies designed across these countries at the global level. The findings demonstrate that the load capacity curve hypothesis is valid for China, South Africa, and Türkiye. Furthermore, the Human Development Index (HDI) has been found to have a positive long-term environmental impact in these three countries. Conversely, renewable electricity generation in India, South Africa, and Türkiye has been found to benefit the environment, while the opposite is observed in Brazil. The HDI has been found to have a negative environmental impact in India and Russia.

Keywords: Load Capacity Curve Hypothesis, Renewable Energy, HDI, Sustainable Development

JEL Codes: Q56, O13, F53

SÜRDÜRÜLEBİLİR KALKINMAYA DOĞRU: SEÇİLMİŞ YÜKSELEN EKONOMİLERDE YENİLENEBİLİR ENERJİ, İNSANİ GELİŞME ENDEKSİ VE ÇEVRESEL ETKİLERİN ANALİZİ

Öz

Bu çalışma, kömür üretiminde önemli paya sahip olan ve aynı zamanda güçlü yenilenebilir enerji potansiyeli bulunan gelişmekte olan piyasa ekonomilerini incelemektedir. 1992-2021 dönemini kapsayan araştırmada, bu ülkelerde yenilenebilir enerji kaynaklarının çevresel bozulma üzerindeki katkısı detaylı olarak analiz edilmiştir. Temel amaç, söz konusu ülkeler arasında tasarlanacak ortak politikaların küresel düzeyde sağlayacağı birleşik etkiyi değerlendirmektir. Elde edilen bulgular, Çin, Güney Afrika ve Türkiye için yük kapasitesi eğrisi hipotezinin geçerli olduğunu göstermektedir. Ayrıca, bu üç ülkede İnsani Gelişme Endeksi'nin (HDI) uzun vadede çevre üzerinde olumlu bir etkisi olduğu tespit edilmiştir. Öte yandan, Hindistan, Güney Afrika ve Türkiye'deki yenilenebilir kaynaklardan elektrik üretiminin çevreye fayda sağladığı, ancak Brezilya'da tam tersi bir durumun gözlemlendiği sonucuna varılmıştır. HDI'nin çevre üzerindeki etkisinin Hindistan ve Rusya'da olumsuz olduğu belirlenmiştir.

Anahtar Kelimeler: Yük Kapasite Eğrisi Hipotezi, Yenilenebilir Enerji, İGE, Sürdürülebilir Kalkınma

JEL Sınıflaması: Q56, O13, F53

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1. Introduction

One of the most important security and health issues today is to be able to continue our lives in a clean environment. Sustainable resource utilization in a healthier ecosystem is becoming more important day by day. Current technological developments and the increase in environmental awareness include projects that have not yet been realized at the desired level. Countries with high international effectiveness should realise this awareness and ensure that projects are transformed from idea to process. The most important issue to be realized is the efficient use of resources. The sustainable use of underground and aboveground resources and their inclusion in production in a way that does not affect the recycling rate should be determined as the first action move of humanity. Social, economic, and environmental policies, which can be described as the three pillars of sustainability, should be ensured by the action and supervision of leading countries (Moldan et al., 2012; Sternfels, 2021).

The fact that global warming cannot be stopped shows that an urgent action plan should be developed. According to the UNDP (2024a) report, the international community is realizing the need to keep the temperature below 0.2 °C and limit it to 1.5 °C for much more carbon and greenhouse gas emissions compared to pre-industrial periods. After 2019, human-induced warming increased by 0.2 °C per decade. Compared to pre-industrial periods, a two °C increase in global temperature may cause devastating effects. Preventing this change, which may affect the environment, human health, and living standards, strives for a temperature increase (Hendrix et al., 2023; UNDP, 2024a). Building environmental sustainability will be one of the critical policies for the future of humanity. Institutes, norms, and global action projects are important moves that can be developed for this purpose. One of the most important causes of environmental degradation is undoubtedly the need for energy. The increase in the need for energy after industrialization and the creation of new profit areas with the production of machinery have brought along energy diversification. Energy is one of the first areas to be intervened in order to keep up with the need for energy and to prevent environmental disasters. The use of environmentally friendly energy sources and the prevention of environmental degradation caused by fossil fuels are important policy steps that can be taken against global warming (UN-Climate Action, 2024; EPA, 2023).

Environmentally friendly energy diversity has been established as an inevitable R&D field with industrialisation. The increase in trade between countries with the effect of globalization has brought along new solutions searches and needs, such as logistics and the construction of energy fields abroad. Considering that energy is a fixture of today’s national economies, developments in energy can be considered as the main agenda of politicians. On the other hand, we need to achieve this if we want to continue production on a healthier and more habitable planet. We need a level of energy that can meet the insistence on growth, and we need healthy generations that can produce energy. What is necessary to establish this is the establishment of an energy supply chain that can stop and prevent environmental degradation (Chen, 2023; Helo et al., 2024; Biswas, 2023).

The sensitivity of countries and large companies to environmental pollution emerges as an important issue at this stage. Just as politicians prefer 5-10 years of country governance to environmental sustainability in order to collect votes, companies may prefer economic growth and corporate profits at the expense of damaging the ecosystem. According to the IEA (2023) ecological report, carbon emissions continue to increase today. The most environmentally damaging sectors are energy systems that produce and consume fossil fuels. Academic literature has also developed in this field as international platforms have started to declare what needs to be done in order to ensure that global awareness is directed towards this field and that it is not too late to take measures. These developments have enabled companies to take more environmentally friendly measures (S&P Global, 2023; Preston, 2023). Agreements between countries organizations such as COP28, Kyoto Protocol (2011), and Paris Climate Agreement (2015) are joint activities and solution searches in order to prevent the global climate crisis and slow down the temperature. The common agenda of the activities and declarations is to increase renewable energy investments and to set 2030 targets by countries. It is the establishment of a global sense of duty to eliminate the geographical renewable energy disruptions, not only on a country basis, by paying attention to the renewable energy efficiency of the countries. Prioritization of R&D investments is to be made in the field of energy, and attention is drawn to sustainability. Countries have the potential to produce different renewable energy. The reason for this is that different geographical settlements have different sunbathing, heating, wind fields, and underground resources. Insufficiency or lack of underground resources makes it more attractive to utilize renewable resources. Countries need to discover the most efficient energy field that they can produce by supporting R&D through their existing geographical structures (EIA, 2023; Blondeel, 2021).

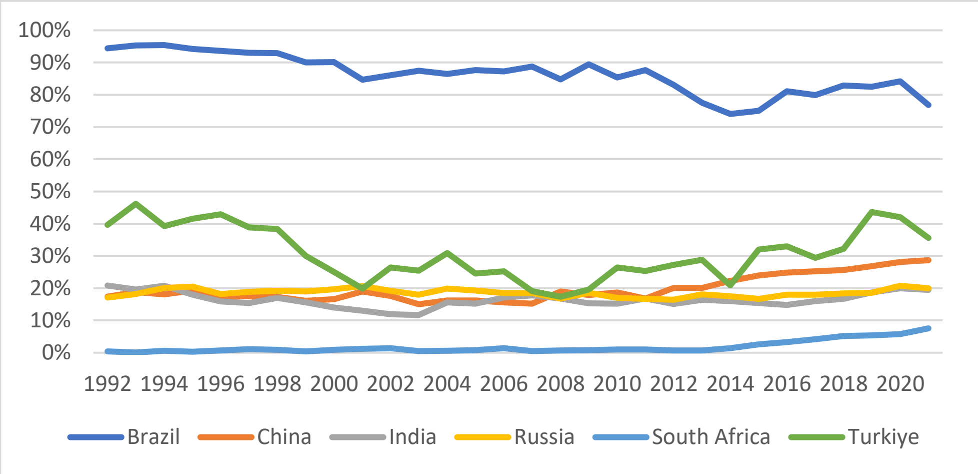
This study consists of the country group consist of Brazil, Russia, India, China, and South Africa (namely BRICS[2]) which aim to challenge the dominance of the Western bloc over the

[2] The BRICS is expanded to 10 countries- Brazil, China, Egypt, Ethiopia, India, Indonesia, Iran, Russian Federation, South Africa, United Arab Emirates in 2025. While this study has been studied, BRICS countries still consist of these five countries - Brazil, Russia, India, China and South Africa (the BRICS). Therefore, when the BRICS countries refers in the text, it refers these 5. (ILO, 2025, “The ILO and the BRICS”)

global financial system by including Türkiye in this group, which constitute approximately 40% of the world population. This group of countries has been analysed due to their energy potential, large capital structures that can influence global capital, geopolitical advantages, and being important actors in the global production chain (Worldometer, 2024; Hooijmaaijers, 2021). The selected emerging countries are Brazil, Russia, India, China, South Africa, and Türkiye. Their different economic structures, geopolitical positions, and capital and labour structures make them worthy subjects of analysis. For example, China started to lose its labour advantage in the 2020s due to the decline in its young population and the increase in labour costs in the manufacturing sector. Even if it is one of the few countries that managed to grow with the impact of COVID-19, China's global impact in future projections is shifting from being the 'workshop of the world' to exporting products containing technology and innovation. Russia is already an anti-Western global player due to its political stance against NATO. Rich in underground resources, Russia is a country that needs to be analysed for its governance structure and economic problems. India hosted the first summit meeting of the BRICS countries. India, which can be described as the silent opponent of the Western bloc, needs to be examined for its population, production potential, energy needs, and global influence. Brazil and Türkiye, two countries with relatively more democratic structures within BRICS countries, are the countries with better diplomacy and transition between the West and the East. Its political structure and its stance against the Western capital system make this country valuable. Türkiye, on the other hand, stands out with its geopolitical position and diversity of renewable energy sources. Its geopolitical structure as a bridge between Europe and Asia makes Türkiye important for both blocs. South Africa, as the African representative in this country group, has developed a financial sector, and rich mineral resources have made it one of the leading countries in Africa (Aydin and Turan, 2020; Ogura, 2020; Chen, 2021).

The countries in the sample group have different amounts of renewable energy production, human development, and gross domestic product. The sample group, which reflects different socio-cultural and economic backgrounds, will show the functioning of a structure that has come together from different parts of the world and is willing to produce economic policy together with a common goal. Changing roles and trends and the functioning of today's economic structure have brought about new searches against the Western bloc. For this reason, these selected country group data allows us to analyse the institutional impact of countries that are important parts of the global economic chain. The fact that China, India, Russia, and South Africa in the sample group are among the top 7 coal-producing countries worldwide makes the renewable energy dimension of the study more meaningful (Worldometer, 2024). Except for Brazil and Türkiye, the amount of energy obtained from renewable sources does not exceed 20% in any of the countries. The global environmental damage caused by China, India, Russia, and South Africa through fossil-based fuel consumption and production is the first contribution of this paper to the literature. The second contribution is the impact that this group of countries can create against environmental degradation by building action plans together. The countries' share of energy consumption from renewables is shown in Figure 1.

Figure 1. Share of electricity from renewables (ER)

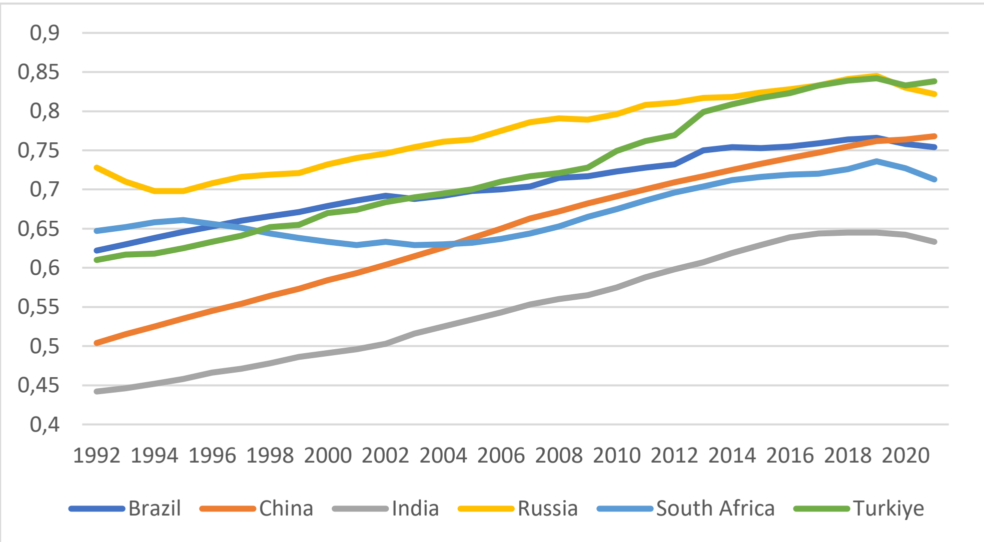


Source: Author's drawing with Microsoft Excel based on the World Bank Data

Considering renewable energy investments, it can be said that Brazil is the renewable energy pioneer of this country group. Brazil has established a hydropower-based energy production network with its renewable hydropower plants by utilizing a natural resource such as the Amazon River. The decline in the share of energy consumption from renewables is due to the increase in industrialization and household consumption. Russia is one of the countries with the world's largest wind energy potential. India is a country with high solar energy potential, where increasing energy demand can be met with solar energy. China is one of the world's leading countries in solar and wind energy. South Africa is a country with high solar energy potential but less than the others. However, since renewable energy investments in Russia, China, India, and South Africa are insufficient or not at a level to meet the increase in demand, the proportion of renewable energy has not increased. As coal-producing countries, they cannot utilize their potential. In Türkiye, solar and wind energy investments have not been able to provide the desired level of renewable energy production. As of 2021, 76.8% of electricity in Brazil, 28.7% in China, 19.4% in India, 20% in Russia, 7.56% in South Africa, and 35.6% in Türkiye is obtained from renewable sources (da Silva et al., 2016; Kudelin and Kutcherov, 2021; Kumar et al, 2023; Tian et al, 2023; Jain and Jain, 2017; Soylu et al, 2024).

The economic size and the fact that it includes countries with large energy needs, such as Russia and China, show the importance of the findings of the study. The use of electricity obtained from renewable resources in the study will enable us to measure how environmentally sensitive developed countries with high renewable potential are while maintaining their economic growth with fossil fuels. In the literature, many studies have been conducted on these countries. Studies such as Uzlu (2024), Shi et al. (2024), Samour et al. (2023), and Yıldırım et al. (2019) have examined the environmental impacts of the source and consumption of energy. The common result of the studies is the environmental impact of energy obtained from renewable sources in selected countries. Renewable resources make nature more liveable and increase sustainability in both energy and health issues. In this study, the proportion of electrical energy, which is generally used by households and industry, derived from renewable sources is analysed, and this ratio has reinforced its meaning with the inclusion of human development in the dataset. Human consciousness, which is the basic element of households and production, was chosen as a variable in this study. The environmental awareness of people according to the level of having a quality standard of living in the human development index (HDI), which includes the parameters of a long and healthy life, knowledge, and a decent standard of living, will be analysed with the findings of this study. This will also contribute to the scarcity of articles in the literature on HDI-based environmental awareness. HDI data of the countries in the sample group are shown in Figure 2.

Figure 2. HDI data of Selected Countries



Source: Author’s drawing with Microsoft Excel based on the World Bank Data

As seen in Figure 2, India has the lowest HDI among the sample group. As of the end of 2021, Türkiye has the highest HDI. In HDI data, below 0.55 is defined as low human development, 0.55-0.699 as medium human development, 0.7-0.799 as high human development, and 0.8 and above as very high human development. In light of this information, Türkiye and Russia are at 'very high,' Brazil, China, and South Africa are at 'high', and India is at 'medium' human development level with end-2021 data. The contribution of the study to the literature is seen here with one more feature. In an analysis with countries from all human development levels, an energy-based analysis has been made with environmental awareness. Considering that household access to electricity is limited in countries with very large populations, such as India, and around 300 million people do not have access to electricity, the energy side of this analysis is unique (Agrawal et al., 2020).

The common point of the studies on environmental degradation is to mitigate the environmental degradation of countries that cannot even give up growth. When defining environmental damage, attention is paid to how sustainably we use the resources available in nature. Ecological footprint data, which analyses how many worlds are needed for a country with the underground resources it uses and enables us to analyse the sustainable use of resources, is one of the main data sets used in these analyses. In addition to the ecological footprint data, there is biocapacity data, which has the same parameters as the ecological footprint, including the resources offered to us in nature that we can use. This data shows us the forms of life and resources that we use in the world and prevent their sustainability. With the ratio of these two data, the load capacity factor (LCF) data was created with the interpretation made by Siche et al. (2010). LCF is a dataset that includes what we demand from nature and the resources that nature supplies (offers) to us. Its theoretical formulation is found by dividing biocapacity by ecological footprint. The critical threshold of LCF data is 1. If the LCF is less than 1, the use and destruction of nature exceeds the sustainable development of biocapacity. Therefore, the utilisation of resources threatens natural life and resource sustainability. If the LCF is equal to 1, resource utilization is equal to the destruction of nature. The sustainability of living life remains at the same level. In addition, the ecological balance can continue in its current state. If the LCF is less than 1, it shows that the use of natural resources causes environmental destruction and that a sustainable environment and resource supply are not possible.

Since economic growth and GDP stability are the main policy agenda of countries, the ecological damage of GDP growth should be examined. One of the parameters that can be used to analyse this damage is the LCF data, which shows the damage to biodiversity caused by the natural resources used in the growth and formation of GDP. LCF is affected by the change in GDP, and countries' ambition for economic growth may cause them to be insensitive to the destruction of nature. For this reason, the Load Capacity Curve (LCC) hypothesis, which hypothesizes the environmental destruction of the economic political agenda, is constructed. The LCC hypothesis can be proved or disproved by analysing the relationship between GDP and LCF. The LCC curve is a parabolic curve with a positive coefficient. According to the hypothesis, as the development (or growth) in GDP increases, LCF decreases up to a threshold point, thus, environmental degradation increases. However, after this threshold point, the increase in GDP will lead to an increase in LCF and an increase in sustainability and diversity in nature. It is possible for biocapacity, one of the components of LCF, to increase more than the ecological footprint by exceeding this threshold point. When analysing this, pure data and the square of GDP are taken. In this way, a linear and negative relationship between GDP and LCF should be observed in the pure data, with a decrease in LCF while GDP increases. In the square of GDP, due to its positive parabolic structure, a positive relationship between GDP and LCF should be observed.

Once the relationship between LCF and GDP is proven, the other steps of the analysis can be carried out. The relationship between renewable energy and environmental degradation should be analysed. Renewable energy investments are directly related to the level of development and economic prosperity of countries (Evans, 2024). When the increase in GDP reaches a certain level of prosperity, it supports environmental investments and increases renewable energy investments (Pata et al., 2023). Based on this hypothesis, the relationship between renewable energy and environmental destruction should be analysed in conjunction with the conservation hypothesis. According to the conservation hypothesis, the use of renewable energy will cause less environmental damage in the production and use of appliances than the use of fossil fuels. Therefore, the widespread use of renewable energy by countries that have reached a certain level of economic growth will lead to a decrease in environmental destruction (Hawken, 2015; von Weizsacker, 2013). In this study, the conservation hypothesis between renewable energy and environmental destruction will be analysed.

Electricity obtained from renewable sources enables the development of more efficient energy policies with energy awareness. Environmentally conscious individuals use renewable energy sources and prefer fuels that are less harmful to nature (Hao, 2022; Hashemizadeh & Ju, 2021). Therefore, individuals' environmental awareness and avoiding energy types that may harm the environment have a positive impact on nature. The relationship between the human development index (HDI) and the LCF, which we use as a parameter showing the destruction of nature, is explained by the 'Energy Ladder' Hypothesis, which represents socio-economic development and transition to environmentally friendly energy types (Waweru, 2022). According to the hypothesis, the energy used in households and production has changed with the socio-economic development of humanity. In the hypothesis, which analyses the history of humanity's energy use under three sub-headings, 'primitive fuels' are the energy obtained by people using 'agricultural waste, animal waste, firewood'. With the effect of scientific developments, these fuels are replaced by the second phase called 'transition fuels'. In this phase, 'charcoal, kerosene, and coal' are used. In this period, when humanity meets mass production, the needs are produced with coal and its derivatives that cause intense air pollution. In the period, which is the closest stage of socio-economic development to our age, 'Advanced Fuels' were used. In this phase, socio-economic development is possible with mass production, and the change in welfare is realized with more environmentally friendly energy types. The energy types used in this phase are 'LPG, electricity, and biofuels'. The electricity used by the population can be obtained from these fuels, and energy needs can be met from these sources.

In this paper, the gross domestic product represents the livelihood opportunities of people, the share of electricity represents the type of energy they use to build their livelihoods, and the human development index represents their awareness of the types of energy they use to build these livelihoods. The impact of all these variables on the sustainability of our planet will be measured by the ratio of biocapacity and ecological footprint data. The sample group includes leading coal-producing countries such as Russia, China, and South Africa, as well as countries with a very high level of renewable electricity production, such as Brazil. There is a country like Türkiye that is not utilising its potential and a coal-producing country like India, whose human development is lower than that of others. The validity of the LCC hypotheses in the selected country group, which covers a wide range of cultures and political ideologies, will be analysed in three steps. The questions to be answered in the study and these questions are as follows:

- Is there a positive relationship between GDP and LCF and a negative relationship between GDP^2 and LCF as predicted by the LCC hypothesis? (SDG 8 and 12)
- Is there a positive relationship between ER and LCF, as predicted by the conservation hypothesis? (SDG 7 and 13)
- Is there a positive relationship between HDI and LCF, as predicted by the Energy Ladder hypothesis? (SDG 4)

In this study, the relationship between the variables will be explained with Sustainable Development Goals, which are global common solution proposals. The relationship between GDP and LCF is related to SDG 8 and SDG 12. The ability of countries to build a sustainable economic policy with responsible consumption and production in the growth policy that can be created through economic growth with a Decent work plan will be answered in the first question. Even if economic growth negatively affects LCF in the current plan, the proof of its long-term positive change will show that a decent work environment and growth can be achieved through responsible production and consumption. The relationship between ER and LCF is related to SDG 7 and SDG 13. It will show the extent to which affordable and clean energy meets household demand, how much electricity is generated from renewable sources, and how action is taken against the global climate crisis. The fact that electricity, which has an important place in the use of households and businesses, is obtained from renewable sources will show us how sustainable energy and climate policy can be developed as a result of sustainable energy policies and the abandonment of fossil energy consumption, which is one of the factors that cause the most damage to the environment. The relationship between HDI and LCF is related to SDG 4. It will show how effective the educational activities, awareness-raising seminars, and conferences developed to raise environmental awareness are in society. It will show the quality education plan that raises the level of awareness and the sustainable environmental action of the countries.

The expected results of the study vary due to the presence of coal-producing countries and various potential energy production capabilities. However, technological developments and international organizations that will positively affect the common sustainability plan and environmental awareness allow the findings to be expressed more clearly. It is expected that the LCC hypothesis will be proved by the null relationship between GDP and LCF and the positive relationship between GDP and LCF, the conservation hypothesis will be proved by the positive relationship between ER and LCF, and the Energy Ladder hypothesis will be supported by the proof of the positive relationship between HDI and LCF. The increasing number of analyses made with LCF day by day and the developments in the academic literature with the SDG theme, where sustainability is at the forefront, make it possible to develop clear policies with more decisive steps to the global climate crisis. This study will increase the diversity of the HDI data, which is rarely used in the literature without showing human development. In addition to the Brazil, Russia, India, China and countries, which are included in many different studies, Türkiye, which connects Asia and Europe due to its geopolitical location, has renewable potential and political relations with the East-West bloc, will be added to the BRICS countries, which are established only against the Western bloc in the literature, and it has been examined how the BRICS, which is a partner in global policies, can create an impact. In order to close the gap in the literature, the effect of the East will be shown in the construction of a global action plan instead of the East-West bloc.

The paper consists of an introduction section and a total of five chapters. After the introduction, studies analysing the relationship between GDP, ER, HDI, and LCF in the literature will be reviewed. The methodology, sample group, time period analysed, and empirical results of the studies will be shown in this section with the help of a table. In the third section, the data used in the study and the sources from which they are obtained will be explained, and the empirical equation created to test the hypotheses in the study will be explained. In the fourth section, the econometric method used in the study will be presented. With the help of figures and formulations, the empirical method used in the study and its results will be explained. In the fifth section, the sustainability plans proved by the study will be explained with the findings, and policy recommendations will be made with the assumption that developing policies together may lead to more qualified environmental gains. As a result of the study, country, and group-based policy recommendations will be analysed by blending them with SDG plans.

2. Literature Review

One of the constant parameters in studies on environmental economics is energy. Since obtaining energy from renewable sources is one of the main factors in order to prevent environmental degradation, studies examining environmental destruction are included in the literature. In order to determine the numerical equivalent of environmental degradation, the amount of greenhouse gases and CO_2 are first used in studies. In such studies, air pollution temperature increases caused by carbon dioxide emissions have become the subject of studies. These studies were developed, and a wider environmental destruction data and ecological footprint, including CO_2, are created. With the ecological footprint, 'carbon footprint, built-up land, forest, cropland & pasture, fisheries' are added to the data, and parameters such as construction as well as the resources demanded and consumed by humans from nature were included in the analyses as an element that destroys natural life. In addition to the ecological footprint, which indicates what we demand from nature, the resources that nature can offer us should also be included in the analysis here. Biocapacity represents the productivity of the ecological existence of a land. LCF, which is widely used in today's studies, is invented and used by proportioning these two data.

In the previous research, ecological footprint data showing environmental damage will be included in the literature by using it instead of the dependent variable in the literature. In addition, since there are very few studies with HDI data in the literature, the human capital index are added to the literature as a parameter representing human development. The scarcity of analyses with HDI data, which includes a wider dataset, income levels in people's welfare, the contribution of adults to the economy, and health status, is a particularly important parameter for our sample group, which includes human development at all levels. However, the human capital index will also be included in the study. In this study, while analysing the literature, studies examining the ecological impact of each parameter will be classified as a sub-heading. What countries do to establish ecological awareness and sustainability will be examined between economic size and LCF (GDP, LCF), between energy from renewable resources and LCF (ER, LCF), and between the level of development of the country's people and LCF (HDI, LCF). Studies including three or more variables from GDP, ER, HDI, and LCF are analysed in the last part of the literature.

Table 1. Literature summary

Authors	Sample Group	Time	Method	Results
The Literature Investigates the Relationship between GDP - ED				
Caglar et al. (2023)	BRICS	1990-2018	CUP-FM and CUP-BC	GDP ↑ ED
Yavuz et al (2023)	Türkiye	1982-2022	AARDL	GDP ↑ ED
Balsalobre-Lorente (2024)	G20 Countries	1997-2018	FMOLS	GDP ↑ ED
Feng et al (2024)	E-7 Countries	1996-2019	Panel Quantile Regression	GDP ↑ ED
Jin et al. (2024)	G-7 Countries	1995-2022	MMQR	GDP ↑ ED
The Literature Investigates the Relationship between ER - ED				
Liu et al (2022)	South Africa	1990-2018	ARDL Bound Test	ER ↓ ED
Alola et al (2023)	India	1965-2018	DyARDL	ER ↓ ED
Hakkak et al (2023)	Russian Federation	1992-2018	ARDL	ER ↓ ED
Usman et al (2024)	China	1970-2018	DyARDL	ER ↓ ED
Fang et al (2024)	South Africa	1990-2018	DyARDL	ER ↓ ED
Xie et al (2024)	China	1990-2021	NARDL	ER ↓ ED
The Literature Investigates the Relationship between HDI – ED				
Pata and Ertugrul (2023)	India	1988-2018	AARDL	HC ↓ ED
Aydin et al. (2023)	Most Paper Recovering 10 Countries	1991-2017	AMG and CCE	HDI ↛ ED
Li, Siying et al (2024)	BRICS	1995-2021	CS-ARDL, AMG, CCEMG	Education ↓ ED
Qing et al. (2024)	G20 Countries	2000-2020	MMQR and AMG	HDI ↓ ED
Gu et al (2024)	BRICS	1992-2020	DOLS, FE-OLS, MMQR	HC ↑ ED

Table 1. Literature summary (Continue)

Authors	Sample Group	Time	Method	Results
The literature Investigates the Relationship between more than two variables				
Ayad (2023)	G-7 Countries	1970-2019	Pooled Mean Group ARDL	HC ↓ ED, ER ↓ ED
Aytun et al (2024)	19 Middle Income Countries	1980-2016	CS-ARDL	GDP ↑ ED, HC ↓ ED
Li, Sheng et al (2024)	BRICS	1990-2018	CS-ARDL	ER ↓ ED, GDP ↑ ED
Chien (2024)	China	1981-2018	QARDL	GDP ↑ ED, ER ↓ ED
Leitão (2024)	G-7 Countries	1990-2019	FMOLS, DOLS, ARDL	HC ↓ ED, ER ↓ ED
Inuwa et al (2024)	India	1970-2017	DyARDL	ER ↓ ED, GDP ↑ ED
Çamkaya and Karaaslan (2024)	USA	1965-2018	Augmented ARDL	ER ↛ ED, GDP ↑ ED, HC ↓ ED

ER: Renewable Energy consumption or production, **GDP:** Gross Domestic Product, **HDI:** Human Development Index, **HC:** Human Capital, **↛:** No Causality, No Relationship, **→:** There is a relationship or causality, **↑:** Increases, **↓:** Decreases, **ED**: Environmental Deterioration, **DHC:** Dumitrescu-Hurlin Panel Causality Test, **ARDL**: Autoregressive Distributed Lag, **AARDL:** Augmented ARDL, **DyARDL**: Dynamic ARDL, **CS-ARDL**: Cross-Sectional ARDL, **NARDL:** Non-linear ARDL, **QARDL:** Quantile ARDL, **OLS:** Ordinary Least Squares, **FMOLS:** Fully Modified OLS, **DOLS:** Dynamic OLS, **FE-OLS:** Fixed-Effects OLS, **MMQR:** Method of Moments Quantile Regression, **AMG:** Augmented Mean Group, **CCEMG:** Common Correlated Effects Mean Group, **GMM:** Generalized Method of Moment

3. Data and Model

The study analyses the selected emerging countries (Brazil, Russia, India, China, South Africa, and Türkiye) for the period 1992-2021. The dataset consists of electricity from renewable sources (ER), gross domestic product (GDP), human development index (HDI), and load capacity factor (LCF). The 'e' logarithm of the data is taken during the analysis, and the analysis is continued with the ln-based dataset for each data set. The dependent variable in the study is the LCF data representing environmental degradation. The independent variables are GDP, GDP squared, ER, and HDI. In the study, the long-run effect of ER, HDI, and GDP on LCF is analysed. This relationship will show us the environmental impact of the economic development of electrical energy from renewable sources through conscious people in the long run. The squaring of the GDP data tests whether the negative impact of changes in GDP on the environment can be reversed in the long run. The reason why LCF data is used to measure environmental destruction is that it includes not only the parameters that destroy nature but also biocapacity and environmental wealth. LCF data consists of ecological footprint, which is what is demanded from nature, and biocapacity, which is what nature can offer us. The description and sources of the dataset are shown in Table 2.

Table 2. The dataset and sources used in the study

Variable	Definition	Source
RNW	Share of primary electricity generated by renewables	ourworldindata.org
GDP	Gross Domestic Product (constant 2015 US$)	worldbank.org
HDI	Human Development Index	hdr.undp.org
LCF	Load Capacity Factor (Biocapacity/Ecological Footprint)	footprintnetwork.org

Source: Created by the author

The dataset analyses the selected emerging countries; Brazil, Russia, India, China, South Africa, and Türkiye. A very diverse group of countries with different human development data, underground resources, fossil fuel reserves, and solar and wind energy capacity are analysed. In the sample group, which includes countries that have lagged behind in realizing their renewable energy potential, the ratio of electrical energy used by households and small businesses to total energy, GDP amounts in constant 2015 US$, human development indices in medium, high, and very high classes add value to the analysis as a study that should be included in the literature. The different reactions of countries to environmental policies, the fact that India, a country with rising garbage mountains such as Ghazipur, Okhla, and Bhalswa, and countries that are relatively close to Europe such as China and Russia are included in the sample group increases the importance of the study (Owid, 2022; WB - GDP, 2023; GFN - EF & Biocapacity, 2022; UNDP - HDI, 2024b). The equation created for the analysis in the study is as follows:

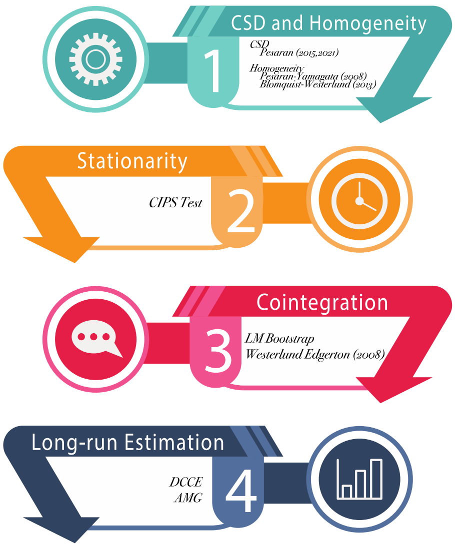
$$lnlcf_{it} = \beta_0 + \beta_1 lnhdi_{it} + \beta_2 lner_{it} + \beta_3 lngdp_{it} + \beta_4 lngdp_{it}^{\ 2} + \varepsilon_{it} \qquad (1)$$

In equation 1, ε_{it} represents the error term, β_1, β_2, β_3, and β_4 represent lnhdi, lner, lngdp, lngdp2 coefficients, respectively.

4. Methodology and Empirical Results

In order to analyse the relationship between the independent variables and the dependent variable in the studies, the procedures that test the suitability of the data for analysis should be applied first. Since the developments in countries that have the effect of globalization affect the socio-economic situation of other countries, this effect should be analysed first. The first test in the analysis is the cross-sectional dependence (CSD) test. The second test is to analyse the measurability of the individual results of the countries analysed. The homogeneity test should be run to understand the significance of the countries' analyses together or individually. Thirdly, data shocks should be analysed. It is likely that the shocks that have unexpected effects due to the impact of major events with global impact (such as COVID-19) may cause shocks in the countries' dataset, making the analysis impossible. For this reason, the stationarity test should be performed in the third step. If the stationarity of the data at the level or first differences can be proved, the analysis can be performed. If this condition is met, a co-integration test, which tests the possibility of making long-run forecasts, should be performed. If the existence of cointegrated behaviour between the variables is proved, a numerical estimation of the long-run relationship can be made. In this way, it can be proved to what extent the changes in the independent variables affect the dependent variable. The test steps used in this study are shown in Figure 3.

Figure 3. The Steps of Empirical Analysis



Source: Author's edit with Adobe Illustrator, Original file downloaded from www.freepik.com

Pesaran's (2015, 2021) weak CSD test is used to test horizontal cross-section dependence. In the test, despite the H0 hypothesis stating the existence of weak CSD, the alternative hypothesis accepts the existence of strong CSD. According to the test results, the H0 hypothesis is rejected with a p-value of 0.000 for each variable. The test results prove that there is strong CSD in the panel dataset. In the homogeneity test, which shows whether the coefficient estimates of the countries should be made individually or as a group and proves the possibility of individual analyses of the countries, two different analyses were run. Firstly, Pesaran-Yamagata (2008) and Blomquist-Westerlund (2013) tests were run to increase the reliability of the test. In both tests, the H_0 hypothesis, which states that homogeneity prevails in the dataset and that individual results cannot be analysed, is rejected. After determining that the dataset has strong CSD and heterogeneity, as shown in Table 3, it is necessary to test the data sensitivity of the analysis.

Table 3. CSD, Stationarity, and Slope Homogeneity Test Results

	CSD		CIPS Stationarity		
Variables	Statistics	P-value	I(0)	I(1)	
lnlcf	11.37*	0.000	-1.6	-3.215^x	
lngdp	20.38*	0.000	-1.903	-3.831^x	
$lngdp^2$	20.38*	0.000	-1.936	-3.76^x	
lnrnw	2.56**	0.011	-2.186	-3.816^x	
lnhdi	19.53*	0.000	-2.009	-3.037^x	
Slope Homogeneity					
Pesaran-Yamagata (2008)			Blomquist-Westerlund (2013)		
$\hat{\Delta}$	10.287*	0.000	$\hat{\Delta}_{hac}$	4.146*	0.000
$\hat{\Delta}_{adj}$	11.501*	0.000	$\hat{\Delta}_{adj,hac}$	4.635*	0.000

*, **: Means strong cross-section dependence at 1%, 5% confidence level, respectively
x: p-value <0.01. The analysis employed a model with constant terms.
For the CIPS analysis, the critical values are -2.57, -2.33, and -2.21 for 1%, 5%, and 10%, respectively.
Source: Author's estimation with Stata

To analyse the stationarity of the series, Pesaran's (2007) CIPS test, which is sensitive to CSD and gives qualified results, is used. In the CIPS test, the test must first be estimated as in equation 2, and then the statistic in equation 3 must be calculated.

$$\Delta Y_{i,t} = \alpha_i + \beta_i Y_{i,t-1} + \delta_i \bar{Y}_{t-1} + \gamma_i \bar{Y}_t + \varepsilon_{i,t} \qquad (2)$$

$$CIPS = \frac{1}{N}\sum_{i=1}^{N} CADF_i \qquad (3)$$

In equation 3, the cross-sectionally augmented Dickey-Fuller statistics is represented by $CADF_i$. The CIPS statistic is obtained by averaging the $CADF_i$ Statistics. In the test, the H_0 hypothesis states that the series has unit root, and the alternative hypothesis states stationarity. The stationarity test results of the dataset are shown in Table 2. According to the test results, each variable is unit rooted at level and stationary at first difference. This result shows that the long-run relationship can be analysed in the sample group.

In the third step of the analysis, Westerlund and Edgerton's (2007) LM bootstrap and Westerlund and Edgerton's (2008) structural break co-integration tests were run for the significance of the long-run relationship between the independent variables and LCF. In the LM co-integration analysis, the H_0 hypothesis accepts the existence of a co-integration relationship. The equation of the test is as follows:

$$LM_N^{+} = \frac{1}{NT^2}\sum_{i=1}^{N}\sum_{t=1}^{T}\widehat{w}_i^{-2}\, s_{it}^{2} \tag{4}$$

In equation 4, $\widehat{w}_i^{2}$ represents the error terms' long-term variances, s_{it}^{2} represents error terms' partial sums. Westerlund and Edgerton (2008) developed a model that can cope with structural breaks and allows us to analyse the long-run relationship. In this model, a new test including $LM\varphi$ and $LM\tau$ statistics, which accepts the absence of co-integration in the H_0 hypothesis, are created.

$$\Delta\hat{S}_{it} = constant + \varphi_i\hat{S}_{it-1} + \sum_{j=1}^{pi}\varphi_{ij}\Delta\hat{S}_{it-1} + error \tag{5}$$

$$LM\varphi(i) = T\hat{\varphi}_i\left(\frac{\widehat{w}_i}{\hat{\sigma}_i}\right) \quad , \quad LM\tau(i) = \frac{\hat{\varphi}_i}{Se(\hat{\varphi}_i)} \tag{6}$$

In equation 5 and 6, $\hat{\varphi}_i$ represents the least squares estimate, $\hat{\sigma}_i$ represents the estimated standard errors. The results obtained from both tests show the existence of long-run co-movement and long-run co-integration between the independent variables in equation 5, as seen in Table 4.

Table 4. Findings of the Co-integration Tests

LM bootstrap			**Westerlund and Edgerton (2008)**		
	Statistics	***Probability***		***Statistics***	***Probability***
Constant	1.410	1.000	$LM\tau$	-7.699	0.000*
Constant + trend	4.461	0.999	$LM\varphi$	-2.772	0.003*

*: Means rejection of H0 hypothesis at p-value<0.01
Source: Author's estimation with Stata

After the proof of co-integration, both panel-wide and country-specific coefficient estimation results should be analysed in a heterogeneous dataset. In the estimation of the coefficients, the AMG estimator developed by Eberhardt and Teal (2010) and the DCCE estimator developed by Chudik and Pesaran (2015) were run for the results for the whole panel. DCCE estimator is used for country-specific results. According to the panel results, there is no long-run relationship between any independent variable and LCF.

Table 5. Panel and Country-specific Long-run Estimation Results

Panel Results				
	DCCE		AMG	
Variables	Coefficients	p-value	Coefficients	p-value
lner	0.0535	0.732	0.0277	0.676
lnhdi	8.3955	0.148	-0.4810	0.408
lngdp	-220.58	0.449	5.1718	0.460
lngdp2	4.1150	0.447	-0.1187	0.423
Country-Specific Results				
Countries	lner	lnhdi	lngdp	$lngdp^2$
Brazil	-0.548*** (0.051)	1.3620 (0.528)	171.12* (0.009)	-3.102* (0.008)
China	0.0276 (0.765)	23.888* (0.002)	-115.89* (0.000)	1.998 (0.000)
India	0.3412*** (0.000)	-4.8178* (0.000)	-1.4906 (0.864)	0.036 (0.818)
Russia	-0.1710 (0.209)	-4.0232* (0.008)	299.25* (0.000)	-5.403* (0.000)
South Africa	0.5314* (0.000)	28.001* (0.000)	-1645.3* (0.000)	30.607* (0.000)
Turkiye	0.1405* (0.008)	5.962* (0.001)	-31.15*** (0.055)	0.5546*** (0.064)

Note: *, **, *** represents significancy at 1%, 5%, and 10% respectively
Note: Results in brackets are p-values.
Source: Author's estimation with Stata

As shown in Table 5, when we look at the panel results, it is seen that none of the independent variables have a long-run relationship with the dependent variable. The results obtained from the AMG test were not satisfactory, and the results were obtained with the DCCE, which includes a newer technique. The lack of a long-run relationship between the independent variables and the dependent variable was reinforced. The results of Pesaran-Yamagata (2008) and Blomquist-Westerlund (2013) tests show that the panel is a heterogeneous panel. For this reason, country-specific results were also analysed. In the panel dataset, the countries where each independent variable is significant are Türkiye and South Africa. The results of the analyses for the variables are as follows: i) electricity from renewable sources reduces environmental degradation in India, South Africa, and Türkiye. The conservation hypothesis is valid in these three countries. ii) The increase in the human development index increases environmental degradation in India and Russia. It decreases in China, South Africa, and Türkiye. The 'Energy Ladder' hypothesis is supported in these three countries. iii) An increase in GDP decreases LCF in China, South Africa, and Türkiye, and increases it in Brazil and Russia. iv) An increase in the square of GDP increases LCF in China, South Africa, and

Türkiye, but increases it in Brazil and Russia. The LCC hypothesis is valid in China, South Africa, and Türkiye. It is invalid in Brazil and Russia.

The study supports the studies of Feng et al. (2024) and Caglar et al. (2023) on the relationship between GDP and environmental degradation. Caglar et al. (2023) are similar to this study in terms of including BRICS countries and reinforcing the results. The results of Alola et al. (2024) for India, Usman et al. (2024) for China, and Hakkak et al. (2023) for Russia support the reliability of the results of this study. In the articles examining the effect of HDI on environmental damage, Pata et al. (2023), examining India and Qing et al. (2024) examining each country in the sample in this study support the results of this study. Inuwa et al. (2024) for India, Li Sheng (2024) for BRICS and Caglar et al. (2024) for Türkiye reinforce the reliability of the results of this study. The study represents a content that provides a more reliable analysis of the global impact by examining Türkiye, which can follow policies closer to the East in terms of policy in order to analyse the more western oriented side of the BRICS countries; with this group of countries and aims to close the HDI-based gap in the literature in this way.

5. Conclusion and Policy Recommendations

Global warming is one of the most important ecological problems today. The growth and energy policies of countries that contribute positively to global warming and that do not take into account the future of our planet enable us to approach the threshold of irreversible warming. The most effective policies that countries can put forward to improve their sensitivity are policies that prioritize energy and human development. 'Long and healthy life' and 'knowledge' parameters should be adopted by politicians as a duty to citizens. Conscious people's consumption, production, and political preferences will leave a cleaner, liveable ecosystem as a legacy to the next generation after them. Sustainable development awareness will develop with the scientific and cultural heritage to be transferred from generation to generation. A society with developed environmental awareness will ensure that politicians develop policies in this direction with the demand for the use of renewable resources, the construction of sustainable growth and development, and development in prosperity instead of growth. The promises of politicians will be shaped by this change in consciousness, and the development of more environmentally friendly policies will be possible.

In this study, the environmental sustainability of selected emerging countries is tested. The LCC hypothesis for sustainability was analysed, and the LCF variable was determined to be an independent variable. The LCF variable, which includes biocapacity and ecological footprint, is a variable that is widely used today to show environmental sustainability because it includes what we demand from nature and what nature can supply us. As an independent variable, countries with the highest coal production, such as China, Russia, South Africa, and Brazil, one of the leading countries in the world in terms of energy from renewable sources, are included. A sample group that includes the potential of India, where a part of the population does not even have hygienic toilet facilities in their homes, and Türkiye, which is surrounded by seas on three sides, has rivers and places with high sunshine hours, reveals the originality of the study.

According to the findings of the study, none of the coefficients representing the sample group are significant. In country-specific results, contrary to the expected relationship between variables supported by the hypotheses, results were obtained. These results should be analysed on a country-by-country basis. The reason why ER reduces the LCF in Brazil may be the environmental damage that new plants may cause. In 2021, the share of electricity from renewable sources in total electricity generation in the country is 76.8%. In addition, the increase in renewable energy sources may cause a decrease in LCF as it may affect the diversity of living organisms. Wind turbines may affect poultry habitats, and solar panels located on green lands or seas may affect the insolation time of soil or water and prevent new species diversity. The change in the flow direction of water with the construction of hydroelectric power plants may affect the diversity of living organisms that may occur in lake and river beds and may cause a decrease in biodiversity.

The negative impact of HDI on the environment in India and Russia may be due to their indifference to global environmental destruction. The fact that India has mountains of garbage within the borders of the country rather than its global duties and the lack of toilets and bathrooms in some houses may cause people to be indifferent to the global climate catastrophe. In Russia, the suspension of global duties that started with the occupation of Crimea may have made people indifferent to the environmental disaster. Although these two countries are very important countries in terms of economic and global impact, they see that activities such as COP28 are being carried out and pay less attention to the global climate crisis than other countries due to the fulfilment of other countries' homework. Since the HDI data includes welfare and income, it may show that the increase in welfare and income levels and the increase in consumption in these two countries may be biased towards increasing environmental damage. The resource consumption in Brazil and Russia, the inadequacy of environmental policies, especially in Russia, and the development of consumption culture in these countries show the positive effect of GDP development in the short term and the negative effect in the long term.

The long-term relationship from HDI to LCF for environmental sustainability is evident for China, South Africa, and Türkiye. The Climate Action Network (CAN), which operates in China, South Africa, and Türkiye, supports civil society organizations to raise public awareness of the climate crisis. As supporters and advocates of this network, these three countries fulfil the requirement that education should include environmental awareness (CAN, 2024). In China, the China Youth Climate Action Network has also been established, and efforts have been made to ensure that young people are raised with this awareness and that environmental duties are acquired at a young age (CYCAN, 2024). It is not a coincidence that these three countries have results that support the LCC hypothesis and the relationship from the human development index to the LCF. Although they are the countries that produce the most coal, China and South Africa have made positive contributions to long-term ecological sustainability by ensuring human development and that the demands of the people include environmental sensitivity. It is recognized in these three countries that sustainable development goals can be realized in this way. Other countries should prioritize human development, and policies should focus on renewable energy resources and environment-based human development. Climate crisis studies, where global policies are important, will be possible only if each country fulfils its own homework.

Studies inspired by this study can analyse different country groups. However, the human development factor should not be overlooked. Increasing the number of studies that include HDI data reflecting welfare and conscious consumption will be an important reference point for studies inspired by this study. In addition, studies to be conducted with panel data covering countries such as Russia, China, South Africa, and India, which contribute a lot to global environmental pollution with coal production, will provide qualified publications in the literature. Analysing the environmental policies of countries that can sustain their GDP with pollution by selecting them as a sample within a country group will be an important example of how a solution can be created by developing common policies with other countries.

Abbreviations

UN: United Nations, **UNDP:** United Nations Development Programme, **EPA**: United States Environmental Protection Agency, **EIA**: Energy Information Administration, **ER:** Electricity form Renewables, **HDI:** Human Development Index, **GDP:** Gross Domestic Product, **HDR**: Human Development Reports, **LCF**: Load Capacity Factor (Biocapacity / Ecological Footprint), **CAN:** Climate Action Network, **CYCAN:** China Youth Climate Action Network, **ED**: Environmental Destruction, **OWiD:** Our World in Data, **EF**: Ecological Footprint, **GFN:** Global Footprint Network, **WB:** World Bank, **DV:** Dependent Variable, **GDP^2:** Square of Gross Domestic Product, **SDG:** Sustainable Development Goal

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