

Co2 Emissions, Coal and Renewables Use in Energy Production, And Their Implications in Gdp Growth

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Abstract.

The purpose of this article is to identify the degree of correlation between variables such as carbon dioxide (CO₂) emissions, coal consumption for energy generation and the use of renewable sources in the energy mix, and the implications of these results on the Gross Domestic Product (GDP). For the development of this research, the review of theoretical approaches and the literature review on the mentioned concepts were used; as well as the degree of quantitative correlation of the variables described, through data analysis and regression. Among the main findings, stands out the high degree of positive correlation between CO₂ emissions and GDP growth; the positive correlation of energy generation based on the use of coal, with CO₂ emissions; as well as the urgent need to stimulate the energy (use and generation) transition towards renewable sources, in order to reduce polluting emissions, protect the environment and promote the improvement of quality of life.

Keywords: Sustainable Development, Environment and Growth, Alternative Energy Sources, Demand and Supply.

1. Introduction

The purpose of this study is to analyze variables related to CO₂ emissions, coal consumption for energy production, and the use of renewable sources as input to generate energy, as well as the implications of these variables on the growth of the Gross Domestic Product (GDP) of countries.

It is relevant to connect these variables with prospects for growth or decrease in GDP, in this way, it can be better conceived if the economic growth of the countries is positively or negatively related to polluting or clean energy production, recognizing that the Energy is a vital input for the economic sectors of nations.

This article analyzes the leading countries in the mentioned variables, as well as the evolution in the last 10 years in the behavior of said variables, and their correlation. The research development is divided into four segments: 1. Overview of CO₂ emissions from energy generation, 2. Analysis of the use of coal as a global energy source, 3. Need for the energy transition towards renewable sources, and 4. Results of relation of the mentioned variables, with the variations of the GDP of the observed countries.

2. Methods

For the development of this study, two processes were followed: a qualitative one, which consisted of reviewing the literature, obtaining research input from recognized information repositories such as "Science Direct", "Web Science" and "Scopus databases"; With these bibliographic platforms, it was possible to build three of the four sections of the "Result" section of this study, it was possible to understand what the researchers and certain international analysis centers state, in terms of CO₂ emissions, use of coal for production energy, as well as the prospects and importance of renewable energy.

The second methodological approach of this research was developed through quantitative data analysis, for this purpose, the Regression tool was used to analyze the mentioned variables and their implication in the variation of GDP. In order to develop the data analysis, figures and information from the 2020 Global Energy Statistical Yearbook (Enerdata, 2020), were used, a source from which data related to CO₂ emissions, coal consumption for energy, and percentage of renewable sources for electricity production globally. On the other hand, the figures referring to GDP were obtained from the World Bank data platform (World Bank, 2020). The quantitative component includes data for the four large variables mentioned, for 41 countries, which are those that coincide in the tables and records of Enerdata as well as the World Bank.

3. Results

3.1 Overview of CO₂ emissions

Energy is one of the main pillars for the development and economic growth of any country, consequently, it is directly related to industrialization, population growth and the improvement of the quality of life (Sahir & Qureshi, 2007); It is precisely the uncontrolled industrialization that is affecting the health of the planet due to high emissions of carbon dioxide (CO₂). The demand for energy is related to the development and growth of economies to supply the needs of their economic markets.

Carbon dioxide emissions are one of the major pollution factors on the planet, exacerbating the phenomenon of the greenhouse effect thanks to oil, gas, coal, among other energizing elements (Albiman et al., 2015), meaning a high impact not only in the environment, but also in the economy of the planet; This is how it is understood that both aspects have to be managed in a positive and intelligent way.

Climate change is one of the main problems facing society today; Global pollution is accelerating disproportionately, at such a speed and with such a lack of consciousness, that it seems that there is another planet to go to, once, Planet Earth deteriorates to the maximum. The damage that pollution caused by bad production and consumption practices causes the planet is practically irreversible. Additionally, the main economic activities carried out by the most powerful countries are not friendly to the health of the planet. A sustainable bet on this scenario could be that developed countries significantly reduce their CO₂ emissions (Halkos & Bampatsou, 2019).

On the other hand, when analyzing the situation in developing countries (middle income), the long-term result in the relationship between CO₂ emissions, Gross Domestic Product (GDP), and Foreign Direct Investment (FDI), has shown a positive relationship between energy production and CO₂ emissions, energy production activities in these countries are characterized by a high rate of use of technology, but also by the use of obsolete tools, becoming an inefficient method and unregulated for power generation activities, adding the lack of infrastructure and lack of capital for these operations (Danlami et al., 2019).

It is impossible to cover topics related to energy generation, without ignoring its implication in the economy, in social and environmental aspects. Many emerging market countries face the inadequate use of energy supplies, which satisfy energy demand, and at the same time, try to combat problems related to environmental sustainability (Bhat, 2018), aspects that must be considered when considering they try to achieve the objectives to become more competitive countries.

To exemplify how the development of a nation implies transformation in energy and CO₂ emissions, the case of Saudi Arabia is presented, as a developed country, in recent decades there has been a dramatic growth in energy consumption and emissions of CO₂, this due to

the also increasing consumption of energy for activities such as transport, industry, etc. (Algarini, 2020).

For its part, China is the largest emitter of CO₂, showing rapid growth during the last six years (BP, 2019), negatively affecting the environment and being one of the factors that position it as the most polluting country in the world; Despite this scenario, China begins to implement strategies to reduce its CO₂ emissions, which are not strong enough to achieve this mission, painting a bleak outlook for a healthy environment for the rest of the world.

Studies have shown that agriculture in China should undergo changes to achieve a reduction in CO₂ emissions in the future. The Chinese government must regulate the agricultural sector and its production practices since this is one of the most polluting sectors in the country. Some of the proposed measures are: promote organic agriculture, use environmentally friendly technologies, responsibly use pesticides and fertilizers; All this in order to reduce the level of pollution that the country recently faces, as well as reducing CO₂ emissions (Doğan, 2019).

Due to climate change, all agricultural production activities will be significantly affected in the following years; It is known that some areas will experience a decrease in crop production, while other areas will see an increase in production (Ejemeyovwi et al., 2018).. If agricultural production is well managed, the result can be clearly positive in environmental and productive matters. The CO₂ emissions produced by the agricultural sector come mainly from the burning of fossil fuels to generate energy for production (Mota et al., 2010).

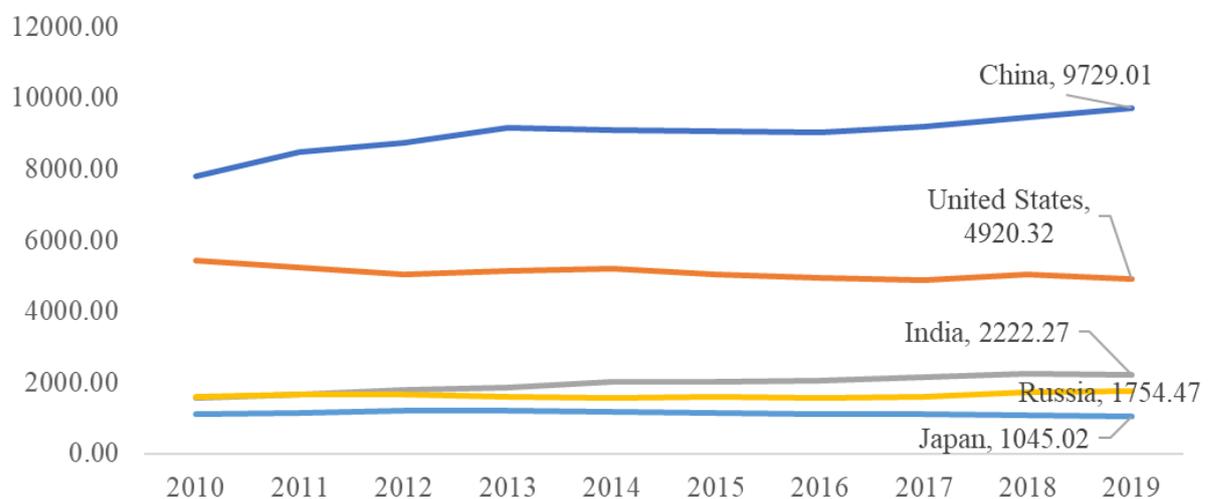
Developed countries have caused the highest amount of pollution and CO₂ emissions, this, because of the strengthening of these economies; These nations are the main responsible for the present situation regarding pollution and global warming. Developed nations should lead the alternatives in favor of the environment, society and the global economy; Instead, these states are exclusively interested in economic growth, while ignoring the negative problems and procedures of current manufacturing techniques (Muhammad & Saad, 2018); This situation generates more pollution, with fewer opportunities to reverse the damage that is being caused.

One of the smartest bets to achieve the reduction of pollution and CO₂ emissions can come from the transition to energy with renewable sources, however, this transition seems to generate less economic interest, since it requires greater economic capacity, in contrast to the energy produced with non-renewable sources; creating little awareness and interest on the part of potential investors of this type of strategic turn (Muhammad & Saad, 2018). However, more frequently, there are studies that show that by making the energy transition to cleaner sources appropriately carried out, countries would generate more benefits in the economy; Not making the energy transition means that the world will not be sustainable not only environmentally or socially, but also from an economic perspective (Bhat, 2018).

Next, Figure 1 shows the evolution of metric tons of CO₂ emissions in the last 10 years, for the five countries that lead figures in this concept. It is evident that China, while leading

CO2 emissions, with a wide advantage over the second country (United States), shows a worrying growing trend. For its part, United States, the second country in terms of emissions of metric tons of CO2, fortunately has decreased its emissions over the last 10 years. The list of the five most CO2 emitting countries is complemented by India, Russia and Japan, with India being the only one of these three countries, which shows a slight upward trend.

Figure 1: Evolution of CO2 Emissions (metric tons) product of fuel combustion (2010 - 2019).



Source: Compiled by authors, based on information from the Enerdata YearBook 2019.

3.2 Implications of the use of coal as an energy source

Coal is one of the most used energy sources in the world, being the main factor that allowed the industrial revolution. The countries that we know today as industrialized, were pioneers in the nineteenth century in extractive coal mining, and used this mineral as a primary source of energy generation (Yilmaz & Uslu, 2007).

Coal is usually the only alternative to meet the growing demand for low-cost energy. 55% of the world's coal is used by developed countries, with trends that coal consumption increases to 2.2 billion tons by 2025 (Balat & Ayar, 2004). This panorama does not only represent effects on the environment, but on long economic scales; Industries that have coal as their main source of energy will become more dependent on this mineral, which is highly polluting (Jiang et al., 2019).

There is a need for the development of different alternatives to produce energy with renewable sources, to reduce the consumption of coal; Clean and smart energies can be used, but in the imaginary the conception appears that they are expensive and of low production, which implies that they are not the best answer to satisfy the economies that consume energy in large quantities.

Contrary to what experts assert about the production of coal, as well as the safety of using this material for energy production in more than 50 countries, the production of coal has decreased considerably since 2016 (N. Wang et al., 2018).

Contrary to the aforementioned scenario, and taking as a reference for the analysis of coal consumption and production, the case of India can be analyzed, which is the second largest exporter of this mineral, India has increased its coal production among the years 2017 and 2018, also highlighting in the global figures for coal import and export (BP, 2019).

There are more than 50 countries that extract coal, which means that there is a large reserve of the mineral, thus guaranteeing its use for many more years. Coal is a non-renewable source of energy, making it a powerful engine of CO₂ emission, this is one of the reasons why countries such as Austria, Canada and the United Kingdom, seek other sources to produce energy (Rokhim et al., 2018).

The second largest economy in the world, China, argues that coal is a reliable source for producing energy; Additionally, the cost of energy in the energy field is low in contrast to other materials that also act as a motor for energy production (Jiang et al., 2019), which makes coal an attractive option.

The study developed by (J. Wang et al., 2011), argues that China is the global leader in two scenarios, both in production and consumption of energy whose source is coal; The sector that most consumes Chinese coal is industrial, with 95% use of the mineral in the Asian country. However, it is valid to note that since 2016, the consumption of coal in the world has decreased, which would suggest that the days of coal as a power generator are about to end; But the truth is that China continues to be a large producer since 1985 (N. Wang et al., 2018); The reduction in global coal consumption, and the conservative coal consumption trends in China, generate uncertainty about those industries and jobs that depend on the mineral (Riker, 2012).

For the coal exporting countries, the global decrease in coal consumption triggers a series of effects as shown (Rokhim et al., 2018), fall in coal prices, impact on the balance of payments since it is reduced the export budget, generated by the fall in exports and a decrease in demand, a powerful effect, lies in the effects on employment in the coal-producing country.

The analysis of the implications on the environment and in the social sphere, produced by coal-based generation, makes us rethink whether the energy obtained through the combustion of coal is effectively profitable from the economic point of view; These considerations are those made by countries such as China and India (Jin & Kim, 2018), countries in which the figures regarding coal consumption show a decrease, reflecting migrations of energy generation towards more environmentally friendly sources, less CO₂ generators.

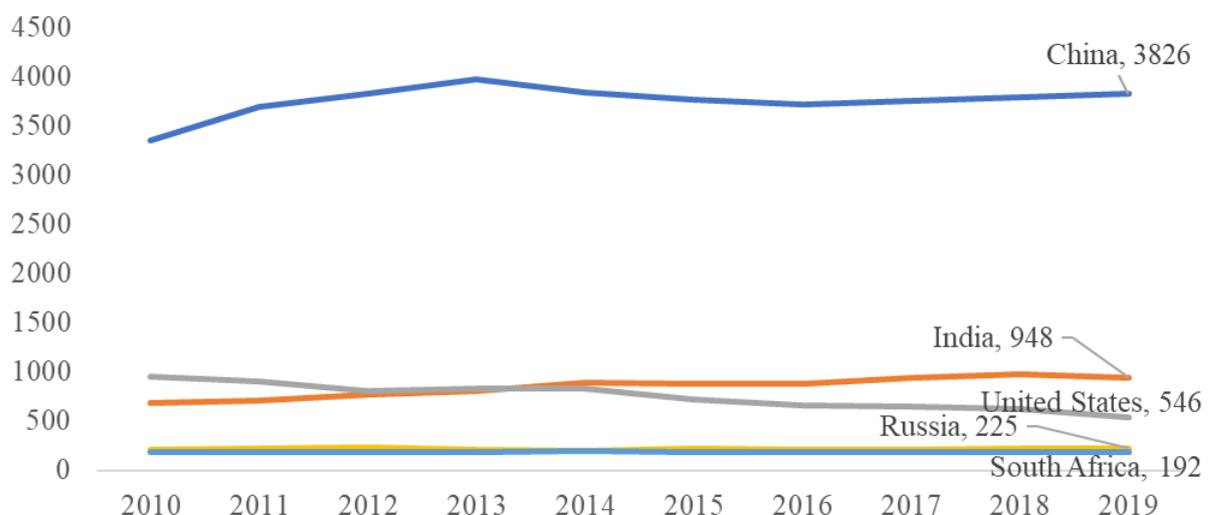
The following figure shows the evolution in the last 10 years in relation to the domestic consumption of coal for energy production, for the case of the five countries that lead this concept. As in the variable of CO₂ emissions, in the case of the use of coal, China leads the

list, with a wide advantage over the second country (India), for this variable, China presents a stable behavior in the last 10 years. This is largely explained by the Chinese substitution of coal for natural gas and other renewable alternatives for power generation.

On the other hand, in Figure 2, India ranks second, with a growing trend in domestic consumption of coal for power generation; On the contrary, United States, which occupies the third place, presents a clearly decreasing trend in this matter, in 2013 India surpassed the United States as the second country with the highest domestic consumption of coal to generate national energy.

Russia and South Africa finalize the list of five countries; countries that present stable behavior, with almost imperceptible variations, in the levels of coal consumption to generate energy in these territories.

Figure 2: Evolution of coal consumption in combustion for energy production (2010 - 2019).



Source: Compiled by authors, based on information from the Enerdata YearBook 2019.

3.3 Importance of energy transition towards renewable sources

Returning to the premise on the relevance and leadership of China in the production and consumption of coal as an energy source, (Avrin, 2018) expresses that the challenge facing the Asian country in its search to reduce emissions by 80% of CO₂ by 2050, will imply the transition from energy sources towards clean and renewable alternatives; This change could mean an increase in the cost of power generation by approximately 30% in an unrestricted scenario.

Despite the perceptions about the increase in energy costs in the case of the transition to renewable sources, (Gomez Echeverri, 2018) indicates that investment towards clean energy generation worldwide presents figures with a positive trend, which allows determine that there is financial willingness to support the transition, therefore financing disappears as an obstacle towards this end.

The foregoing does not go against the reality of the high costs of advancing projects towards economic transition, especially for private entities; That is why, it becomes a vital support, that governments, laboratories and universities, support with studies, research and financing, to reduce the cost of technologies for the generation of renewable energy (Fersi & Chtourou, 2018), In this way, competitive energy would be created, technological development in the clean energy sector, the environment benefits by reducing CO2 emissions, and the economy becomes healthier.

To reinforce the idea about the relevance of the integration of the triple helix (State - Universities - Private Sector), the study by (Adeniyi & Adewuyi, 2019) exposes that the exports of West African countries are not competitive, one of the reasons for this assertion is that there is insufficient support from the public sector in the provision of energy in the industries and infrastructure that support exports, making it difficult to generate energy by the export sector alone.

Decisions on the economic transition should not be based exclusively on the cost of energy generation of the two alternatives (non-renewable energy vs. renewable energy), the study by (Young & Bistline, 2018) indicates that there are determining considerations that incline the balance towards the production of renewable energy, such as: the reduction of CO2 emissions, job creation, development of a new branch in the energy industry, technological advances, among others.

The energy transition requires technological and innovative development in the countries, which is why the practical management of resources and how they are used in favor of energy generation must be rethought (Avrin, 2018), it is a challenge for China as well as for the rest of the planet.

CO2 emissions by China show a notable increase, when comparing the figures of 2017 and 2018, these emissions are largely the responsibility of energy based on non-renewable sources. It is this panorama that allowed studies such as those of (Jackson et al., 2018) to justify the explosive increase in the use of natural gas as an energy source in China, as part of the state strategy to reduce the Asian giant's CO2 emissions, this is because natural gas is much less polluting than coal.

Maintaining the current model of producing energy, based on minerals such as coal, allows to reaffirm the worrying panorama regarding the future of the planet's climate: dry regions will become drier, territories throughout the planet will suffer more and more devastating hurricanes, earthquakes, fires, floods, among other phenomena (Kofanova, 2018); One of the smart strategies to avoid this situation lies in the global reduction of Greenhouse Gas (GHG)

emissions, as well as CO₂ emissions. There are global proposals that represent international pacts, such as the Paris Agreement, an initiative that seeks not to exceed the temperature of the planet at levels of 2 ° C, which is a difficult challenge to achieve taking into account the speed of pollution and emissions; Companies and countries must work hard to become net-zero in emissions, during the second half of the century (Gomez Echeverri, 2018).

To achieve pacts such as the Paris Agreement, as well as to seek the reduction of CO₂ emissions, there are strategies such as the storage of electrical energy, which has the potential to reduce CO₂ emissions if it meets two conditions: if it induces investments towards renewable energies, and if it supports increasing the factor capacity of existing renewable energies (Bilich et al., 2019); For example, the Swiss case stands out, where energy efficiency improves thanks to the transition from fossil-source energy to carbon-free energy, but the potential for renewable energy generation is not enough in Switzerland to meet the demand for electricity (Babonneau et al., 2018), therefore, the energy storage tactic can considerably help Switzerland in its quest to achieve the goal of transition to renewable energy and meet energy demand.

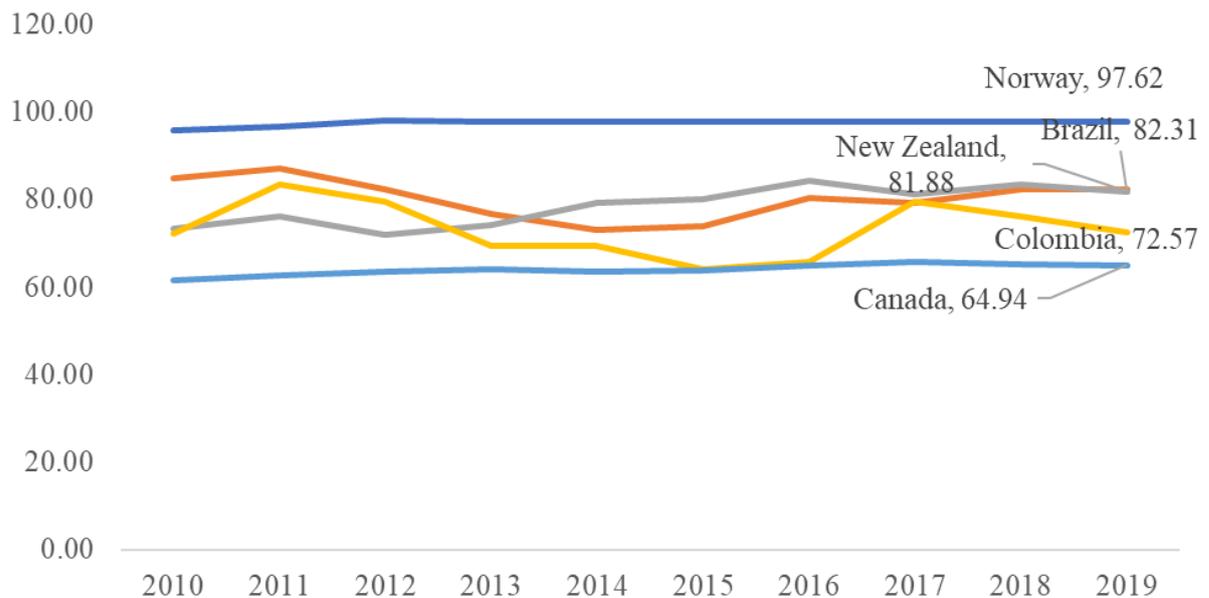
More methods allow us to understand the need for an energy transition towards renewables; In the case of Bangkok, after applying the Application of Multicriteria Methods, it was determined that the increase in pollution in the city is due to a strong dependence on energy on fossil fuels (Ali et al., 2017), the same study, showed that there is no inclusion of renewable sources in the energy mix of the City. In this way, the importance of energy generation through renewable sources is confirmed, if dependence on fossil sources is to be reduced by at least 25% by 2050 (Ali et al., 2017).

The reduction of emissions becomes a challenge for the countries, but if the governments go much further in their national strategies, develop policies for the development and production of clean energy, and promote responsible consumption, the peak of CO₂ emissions by 2030 or earlier (Khanna et al., 2019).

Efforts to widely develop clean energy must become a real commitment on the part of developed countries, which cannot deny their responsibility for current levels of CO₂ emissions, nor can they delay the implementation of real and ambitious policies for energy emission mitigation (Alcaraz et al., 2018). Preventing environmental degradation does not depend on just one country, but involves all states, all industries, all international organizations, all contributions are important (Kofanova, 2018).

Next, it is indicated in Figure 3, information regarding the evolution of the percentage of renewable sources used for power generation, in the last 10 years, by the five countries that lead this variable. The outlook shows stable behavior when comparing the situation in 2010 with the 2019 figures, although during the 10 years of observation there was variation in the figures, mainly for Brazil, New Zealand and Colombia, the positions in 2019 are maintained in the following order: Norway, Brazil, New Zealand, Colombia and Canada.

Figure 3: Evolution of the percentage of electricity produced by renewable sources (2010 - 2019).



Source: Compiled by authors, based on information from the Enerdata YearBook 2019.

3.4 Statistical results in the relationship of variables.

Once the concepts had been studied from a theoretical perspective, the variables were analyzed as shown in Table 1: Coal consumption (metric tons), CO2 emissions (metric tons of CO2), and GDP (US \$ at current prices), through the Regression tool, obtaining the following results:

Table 1: Relationship between variables, correlation coefficients and significance.

Relationship of Variables	Coefficient of Determination R ²	Function	Significance
Relationship between Coal Consumption and CO2 Emissions	0,883314679	CO2 Emissions = 258,81 + 2,57 (Mt Coal)	Yes
Relationship between CO2 emissions and GDP	0,693593816	GDP = 491726705819.602 + 1955750742.2 (MtCO2)	Yes
Relationship between coal consumption and GDP	0,38235066	GDP = 1181901504814.38 + 397403 (Mt Coal Consumption)	Yes

Relationship between the use of renewables to generate energy and GDP	0,002782143	GDP = 2117123 - 8444066324 (% in Renewables)	No
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Source: Compiled by authors.

The figures can be interpreted, with respect to the relationship of the variables to each other, as follows:

- There is a high correlation between the use of coal to generate energy, with the emission levels of metric tons of CO₂. The coefficient of determination is 88.33% between these two variables. The results after performing the data analysis, with the regression tool, showed that the model presents significance.
- There is a high correlation between the emission of metric tons of CO₂ and GDP growth. The determination coefficient is 69.36% between these two variables. The results after performing the data analysis, with the regression tool, showed that the model presents significance.
- There is little correlation between the consumption of metric tons of coal for power generation and GDP growth. The coefficient of determination is 38.23% between these two variables. However, the results after performing the data analysis, with the regression tool, showed that the model presents significance.
- There is very little correlation between the use of renewable energies for the production of electricity and GDP growth. The coefficient of determination is extremely low, being approximately 0.2% between these two variables. Likewise, the results after performing the data analysis, with the regression tool, showed that the model does not present significance.

4. Discussion

The theoretical framework and the discussion of the aforementioned authors, allows to show that there are social and environmental challenges that invite the reduction of CO₂ emissions, all over the world; in the same way, the general invitation is to dramatically reduce the use of fossil sources -such as coal- to produce energy, and thus, support the concept of reducing CO₂ emissions. In the same sense, the considerations in a broad sense, invite to stimulate the energy transition towards the use of renewable sources, which favor a healthy environment, improve the quality of life; This transition encourages innovation in countries that carry out this type of action.

The theoretical results confirm the close relationship between the use of coal as an energy generator, with CO₂ emissions in the countries; as well as the direct relationship between CO₂ emissions and GDP growth. This panorama is worrying, since although the scientific community makes arguments about the need to move energy towards renewable sources, the

data indicate that those countries that emit the most CO₂ - using fossil sources for energy generation - are those that obtain the most levels of economic growth.

5. Conclusion

The results of this study reaffirm the widely accepted conception in a practical sense: those economies with more robust production devices, which consume more energy, are the ones that grow the most when measuring GDP. There are high levels of correlation between the use of coal to produce energy and the CO₂ emissions of these countries, as well as the following panorama is directly related: those countries that emit the most CO₂ are those with the highest levels of GDP.

It is important that more arguments are developed that invite the energy transition towards clean alternatives, and the urgent reduction of CO₂, through adding environmental variables to the GDP estimate, it is essential not to measure GDP growth only with purely economic variables, This must be urgently promoted, otherwise a false belief of growth will continue to be created.

This study exposes two realities: the need to promote sustainable growth; and at the same time, it shows that those nations that emit the most CO₂ when generating energy are the states with the highest levels of GDP. For future research, it is intended to argue with economic models, the negative impact on growth, to continue with current production dynamics not very friendly to the environment; as well as arguing how GDP is affected by adding environmental and social variables, in terms of economic development..

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