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| RESEARCH ARTICLE

Eco-efficiency and Sustainability: An Analysis for the Philippines

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| ABSTRACT

The aim of this paper was to explore the effect of energy consumption, CO2 emissions, and population growth on the Gross Domestic Product (GDP) in the Philippines. Economic growth reflects the increase in production, consumption, and use of resources which are often associated with poor environmental quality. Many studies show that energy consumption used in production and consumption drives GDP, however, the use of energy leads to environmental degradation and many have concluded that economic growth is unsustainable. It has been perceived that economic growth and environmental goals conflict with each other. Population growth is also often associated with economic growth which affects the environment and the Philippines is one of the fastest urbanizing countries and overcrowded cities. Therefore, there is an urgent need for economic models to be sustainable. The relationship between energy consumption, CO2 emissions, population growth, and GDP was assessed using regression analysis (the OLS regression and CLRM assumptions). Data from the Philippines between 1980–2019 were analyzed. The OLS showed that energy consumption and population growth are both statistically significant; however, the CO2 emissions are insignificant. Moreover, most assumptions of CLRM are met except for the autocorrelation. Based on the results it is recommended that the Philippines should adopt and promote renewable energy sources that are reusable which can reduce CO2 emissions and ensure sustainable economic development of the Philippines. Hence, this study supports the need for a global transition to a green economy in the Philippines.

| KEYWORDS

Energy consumption, CO2 emissions, Population growth, Gross Domestic Product, Green Economy

| ARTICLE INFORMATION

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1. Introduction

1.1. Background of the study

Economic Growth refers to the increase in the quality and quantity of goods and services that the society produces. It is undeniable that every country aims for economic growth for it drives progress, develops opportunities and creates decent jobs for all and improves the standard of living. Yet, It is also undeniable that an increase in production, consumption and use of resources are often associated with poorer environmental quality which many have concluded that economic growth is unsustainable. It has been perceived that economic and environmental goals conflict with each other. Over the last decade, a frequent claim has been that economic models need to make a transition into more sustainable development in order to address climate change, biodiversity losses and other environmental problems while at the same time addressing economic and social challenges.

It is viewed that economic growth depends on the use of energy as production and consumption activities use energy as a basic input and that an increase in energy directly causes growth in GDP. (Barney & Franzi). Although, many studies argue that high use of energy, particularly non-renewable energy leads to environmental degradation because of carbon dioxide emissions.

The Philippines' Gross Domestic Product was worth $394.09 billion in 2021, according to official data from the World Bank. Thus, the GDP value of the Philippines represents 0.29% of the world economy.

According to World Data, the Philippines' total consumption is 78.30 billion kWh of electric energy per year, thus per capita has an average of 705 kWh. It is known that the Philippines can provide itself completely with "self-produced" energy. As such, the rest of the self-produced energy is either exported to other countries and/or unused.

Carbon dioxide emissions in the Philippines were 148 million tonnes in 2021. According to World Data, carbon dioxide emissions in the country increased from 1972 emitting 27.8 million tonnes to 2021 emitting 148 million tonnes, an increase at an average annual rate of 3.70%.

Meanwhile, the population in the Philippines rose to 1.31% by the first couple of months in 2021 which is an increase from the previous year of 109,480,590, according to the Commission on Population and Development (POPCOM).

1.2 Statement of the Problem

The study focused on the increased attention given to energy consumption, population, and increased CO2 emissions in relation to Gross Domestic Product.

Specifically, it aims to answer the following questions below:

1. Is there a statistically significant relationship between Gross Domestic Product and energy consumption in the Philippines?
2. Is there a statistically significant relationship between Gross Domestic Product and carbon dioxide emissions in the Philippines?
3. Is there a statistically significant relationship between Gross Domestic Product and population growth in the Philippines?
4. To what extent do energy consumption, carbon dioxide emissions, and population growth influence Gross Domestic Product?
5. What do these relationships reveal about sustainability in the Philippines?

1.3 Formulation of Hypothesis

<u>Hypothesis 1:</u>

Ho: there is no significant relationship between energy and GDP
H1: there is a significant relationship between energy and GDP

<u>Hypothesis 2:</u>

Ho: there is no significant relationship between CO2 and GDP
H1: there is a significant relationship between CO2 and GDP

<u>Hypothesis 3:</u>

Ho: there is no significant relationship between population and GDP
H1: there is a significant relationship between populations and GDP

1.4 Significance of study

1. For the households: This study provides sufficient information about the impact of energy consumption on economic growth that helps individuals to think of better ways to utilize energy to promote efficiency.

2. For the firms: This paper helps businesses to comprehend the influences of energy, carbon dioxide emissions, and population growth on economic growth in order for them to realize how their activities affect the overall gross domestic product in the Philippines, helping them modify their techniques in production.

3. For institutions and government: This study helps the institutions and the government to comprehend the influences of energy, carbon dioxide emissions, and population growth on economic growth in order to modify the existing policies and proactive planning.

4. For future researchers: The paper will allow future researchers to acknowledge the significance of energy consumption, carbon dioxide emissions, and population growth to gross domestic product and come up with new models to analyze the variables and other determinants further.

1.5 Objective of the study

The researchers aim to determine the degree of the relationship between energy consumption, carbon dioxide emissions, and population growth to the Gross Domestic Product. The study intends to determine the independent variables' impact on the patterns of economic growth in the Philippines.

1.6 Scope and Limitation

As this study is conducted in the context of the Philippines and the dataset used is forty years (from 1980-2019), this may not provide an overall picture of the economic growth. Hence, the findings cannot be generalized and may not suitably reflect the significance of energy consumption, carbon dioxide emissions, and population growth to the gross domestic product in all countries.

The paper is composed of five main sections. Following the introduction, Chapter 2 presents the related studies highlighting the policy, theoretical, and empirical issues. Chapter 3, provides a conceptual framework to highlight the variables. Chapter 4 discusses the results of the paper. Finally, the conclusion and recommendation are given in Chapter 5.

2. Review of Related Literature

Economic growth indicates an increase in real GDP. There are numerous factors affecting economic growth. One of the main factors is our natural resources. Natural resources stimulate economic growth as it is the key input in the manufacturing process (Ibrahim, 2017). Natural resources pertain to the materials from the earth that are utilized to meet human needs and support life. Almost everything we do involves natural resources and is used to produce countless daily products that we consume. Consumption is one of the most vital components of GDP. Thus, with the expansion in output and consumption, we are likely to witness the risk and cost imposed on our environment. Economic growth's environmental impact includes increased energy consumption, carbon dioxide emissions, and population growth. In this case, the researcher would like to review the empirical studies under the three sub-section: the relationship between GDP and energy consumption, GDP and carbon dioxide emissions, and GDP and population growth.

2.1 Economic growth and Energy

Gozgor et al. (2018) explored the effect of energy consumption including renewable and non-renewable energy, on the economic growth of 29 OECD (Organization for Economic Cooperation and Development) countries during the period of 1990 to 2013 by utilizing the ADRL model and PQR (Panel Quantile Regression) estimations. The results show that the use of both renewable and non-renewable energy positively contributes to economic growth. However, energy consumption negatively affects the environment due to greenhouse gas emissions in the atmosphere.

Excessive use of fossil fuels destroys our environment. According to the study, the use of renewable energy emits low GHG. More countries are trying to use more renewable resources to reduce emitting carbon dioxide. Bhuiyan et al. (2022) utilized a systematic literature review in examining the relationship between renewable energy consumption and economic growth in both developed and developing countries. In 46 articles reviewed from 2016-2021, It is found that using renewable energy is not a barrier to economic growth for both developing and developed countries. Moreover, it is also found that there is a lack of significance in using renewable energy (threshold level) on economic growth for developed countries.

In the study conducted by Esen and Bayrak (2017), it is found that energy consumption supports economic growth in net energy-importing countries as it is a crucial indicator of economic development by supporting basic humanitarian needs. The findings of the study indicate a positive relationship between energy consumption and economic growth in the long run as the import dependence of the country decreases. Moreover, when the income level of the country increases, the effect of energy consumption on GDP decreases. This means that it is necessary to use energy efficiently.

Kasperowicz and Streimikiene (2016) utilized the panel data approach to examine the relationship between economic growth and energy consumption in V4 and 14 EU countries from 1995-2012. The estimated result indicates that energy consumption is positively related to GDP. Energy consumption was viewed as a pro-growth variable which means that an increase in the utilization of energy will lead to an increase in economic growth, revealing 1% increase in energy consumption will give a 0.19% increase in V4 countries and 0.066% in EU countries. This signifies that V4 countries are more dependent on energy for economic growth. The empirical results also show that European countries are energy-dependent when it comes to economic growth.
Bhat et al. (2022) applied the domino theory to analyze the effect of energy consumption and economic growth on environmental quality in G20 countries from 1990 to 2014. The empirical results imply a significant and positive relationship between economic growth and energy consumption. Urbanization leads to increased use of non-renewable energy that will increase the cost of the quality of the environment. Moreover, the elasticity coefficient of renewable energy is significant and negative which means

increased use of renewable energy will improve environmental quality. Panel causality result also shows the causality among the variables in both the short run and long run. Hence, the study recommended a decrease in the use of non-renewable energy and the use of renewable energy as a substitute to reduce carbon emissions.

2.2 Economic Growth and CO2 emission

Carbon dioxide is recognized as one of the most dominant GHG (Green House Gases) in the atmosphere (Olubusoye and Musa, 2020). Although carbon is one of the vital components of life, an excessive release of carbon has negative effects on the environment's quality. The release of GHG in the atmosphere is associated with economics and activities (Hallegate et al., 2016). Olubusoye and Musa analyzed the ECK (Environmental Kuznets Curve) hypothesis in African countries combined into 3 income groups from 1980-2016 by utilizing the ARDL model, Mean Group (MG), and the Pool Mean Group Model. In their study, the results signify that the number of carbon emissions rises as economic growth increases in 79% of countries in Africa, while in a few countries in Africa (21%), it is observed that economic growth will lead to lower carbon emissions. This means that only 21% of the sample is statistically significant with the ECK hypothesis. The results show that the turning point has not been reached in most countries in Africa which requires the necessity to develop adequate policies and technology to create a turning point in carbon emissions as economic growth rises.

Sun et al. (2022) stated that the development of the economy is primarily dependent on fossil fuels, and as an outcome, poor quality of air has brought negative effects on people's daily lives. Their study emphasizes green growth level as a constant variable to examine the relationship between carbon dioxide emissions and economic growth in Nanjing city. Sun et al. utilized the ECK algorithm and VEC model in analyzing the data gathered from 1993-2018. The result shows that the ECK curve of Nanjing city indicates an N-shape which means that the hypothesis in the original ECK will not be consistent in the long run, thus, implying a positive relationship between economic growth and carbon dioxide emissions.

Caporale et al. (2021) applied fractional integration and cointegration approach in examining the relationship between the logarithms of CO2 emissions and real GDP in China. China's economic growth relied mainly on fossil fuels that release carbon dioxide which makes China the largest carbon dioxide emitter in the world (IEA, 2020). The results of the study show that there is a long-run equilibrium relationship between the GDP and carbon dioxide in first differences which signifies the urgent need to create environmental policies aimed at reducing carbon dioxide emissions during periods of economic growth.

Rahman et al. (2020) utilized the panel cointegration extended neoclassical economic growth model to examine the long-run and short-run effects of carbon dioxide emissions, population density, and trade openness to economic growth in five South Asian countries for the period of 1990-2017. The results imply that carbon dioxide emissions and population density are positively and statistically significant to economic growth in the long run while trade openness shows a negative result. The result also indicates that there is a bidirectional link between carbon dioxide emissions and economic growth both in the short run and long run. The study concludes that an increase in carbon dioxide emissions contributes to economic growth as it increases industrial production. As an outcome, an increase in carbon dioxide emissions increases the cost of the quality of the environment. Therefore, it is necessary to create smart policies to obtain suitable alternative solutions for minimizing carbon dioxide emissions.

Environmental degradation and climate change deliver the status of a sustainable economy (Ozili, 2020). The negative impacts of climate change lead to an adverse effect on well-being and human livelihoods. Carbon dioxide emissions resulting from human activity become the key factor of climate change. The progression of demand at different stages in economic development requires the necessity to create a suitable solution for environmental problems such as sustainability. Cigu et al. (2022) examined the relationship between economic growth and carbon dioxide emissions in 27 EU member states by utilizing the qualitative sequential approach and quantitative methods including DOLS (Dynamic Ordinary Least Squares) for the period 2000-2017. The results signify that there is a cointegrating relationship between economic growth and carbon dioxide emissions across all EU member states in the long run. The DOLS result also shows a significant relationship between economic growth and carbon dioxide, revealing a 1% change in GDP leads to a 0.072 change in CO2 emissions. The study also signifies that an increase in income leads to an increased demand for environmental protection. However, it is found that economic growth only diminishes climate vulnerability in EU countries with the correct type of growth. Thus, the researcher concluded that policymakers must be careful and aware of the effects of using energy in achieving growth in correlation with the appropriate methods aimed to reduce environmental problems and climate risk management.

2.3 Economic Growth, CO2 Emissions, and Energy Consumption

According to the study conducted by Tong et al. (2020), GHG carbon dioxide resulting from the burning of fossil fuels and transportation is a major contributor to global warming and climate change problems. Tong et al. analyzed the causal relationship between economic growth, energy consumption, and carbon dioxide emissions in E7 countries using the ARDL bound test. The result shows that in the short run, there is a presence of granger causality from energy consumption to carbon dioxide emissions and economic growth across all E7 countries except Indonesia. Short-run granger causality was also identified from carbon dioxide emissions to energy consumption across all E7 countries. The result also shows that there is a cointegration between economic growth, energy consumption, and CO2 emissions for Brazil, and India but not for Turkey, Mexico, Indonesia, and the People's Republic of China. Overall, the study confirms the need for E7 countries to move away from fossil fuel consumption and focus on alternative technologies and promote the use of clean energy to reduce negative circumstances such as pollution. Failing to do this will also fail one of the most significant SDGs by the United Nation which is reaching net zero emissions by 2030.

Another study utilized the ARDL approach. Khan et al. (2020) examined the relationship between energy consumption, economic growth, and carbon dioxide emissions in Pakistan using time series data from 1965-2015. According to their study, it is mostly the developing countries that are facing environmental degradation caused by non-renewable energy consumption and Pakistan's rapid economic growth caused by land cutting and deforestation. The estimated results indicate energy consumption and economic growth lead to an increase in carbon dioxide emissions both in the short run and long run. Based on the results, it is recommended for Pakistan's policymakers develop and adopts renewable energy for its reusable feature that could help minimize emitting carbon dioxide in the atmosphere and also guarantee economic sustainability in Pakistan.

Zhang and Zou (2020) used data from 30 regions in China from 2000 to 2017, establishing a spatial Durbin model to examine the dynamic relationship and spatial spillover among economic growth, energy consumption, and carbon dioxide emissions. The results show that carbon dioxide emissions can improve when there is an increase in economic growth and a reduction in carbon dioxide will not significantly affect economic growth. It is found that energy consumption and carbon dioxide emissions are interrelated which means that there is a negative spatial spillover impact on carbon dioxide emissions of the cities and provinces in China.

Ang (2017) examined the causal relationship among carbon dioxide emissions, energy consumption, and GDP (Economic Growth) in France utilizing a vector error-correlation and cointegration approach. The findings present strong evidence for the existence of a relationship among the variables in the long run. The causality results also support the argument that economic growth carries influences the increasing energy consumption and pollutant emissions in the long run. It also signifies a unidirectional causality from energy consumption to economic growth in the short run.

Energy consumption generates economic activities. Thus, economic growth contributes to increasing pollutant emissions. Therefore, switching to renewable energy is necessary to minimize environmental deterioration. Shaari et al. (2020) employed the ADRL model to examine how economic growth and energy consumption contribute to CO2 emissions in chosen countries by per capita income. The findings indicate that using renewable energy could decrease CO2 emissions in the long run. Results also show that economic growth and population growth could lead to more risk to the environment due to higher carbon emissions. Contrarily, it is found that in the short run, higher overall renewable energy consumption and population can help minimize pollutant emissions.

2.4 Economic Growth and Population Growth

Carbon dioxide emission resulting in the degradation of the environment is one of the significant issues many countries are facing and the population is one of the main factors in carbon dioxide emissions. Burhan et al. (2020) investigated the impact of population growth and economic growth on carbon emissions in Afghanistan. The researchers employed the IPAT model for the analysis. The data were tested for multicollinearity and normality with the assistance of the Durbin-Watson test of multicollinearity, skewness, and kurtosis. The data shows no collinearity. The findings of the study indicate that GDP and population growth have a positive relationship, revealing a 1% increase in population leads to an increase of 0.32 in carbon dioxide emission. Furthermore, a 1% change in economic growth will cause a 2.354% change in the amount of carbon dioxide emission.

It has been a growing concern about the negative effects of carbon emissions, energy consumption, and economic growth on the environment. The concern occurs commonly and severely in ASEAN countries. It is found that greenhouse gas emissions in the atmosphere can threaten the well-being of an individual both at a regional level and country level. The region has now been experiencing environmental pressure due to population growth. Duc Vo and Anh Vo (2021) utilized the advanced panel vector autoregressive model and Granger non-causality test to examine the relationship between population, energy consumption, CO2 emissions, and economic growth. The findings of the study show that renewable energy utilization is relative to population growth and leads to pollutant emissions. The result of the study also shows that there is a presence of bidirectional Granger causality in each pair among economic growth, energy consumption, and CO2 emissions. Thus, the study concluded that there is a need to moderate population growth and lengthen the utilization of renewable energy in achieving sustainable economic growth in the ASEAN region.

Another study that examines the nexus among economic and population growth, carbon dioxide emission, and renewable energy over the period 1990-2014 using common correlated effects mean group (CCEMG) shows that population and economic growth is statistically significant to carbon dioxide emission which means that as the two variables increases, carbon dioxide emission increases. Furthermore, using renewable energy can help in minimizing carbon dioxide emissions.

Meanwhile, according to Zhang et al. (2017), the demand for energy due to the growing population is on the rise. This is essential to keep pace with the rapid transformations in global economies. Thus, energy is essential to human lives and to the social, economic, and environmental development of the global economy. It is likely impossible to produce, deliver, or use mainstream commodities without consuming energy. Hence, Yildirim (2017) observed that insufficient energy would negatively impact the performance of different sectors of the economy. As such, the need for economic growth has led to environmental degradation, which is often a resultant effect of development and industrialization in both developed and developing countries. The economic growth of any country is dependent on different factors, which may impose negative impacts on the environment such as environmental pollution, and climate change. Also, the rapid increase in population growth in many countries such as the Philippines has fast-tracked economic growth with the resultant effect of an increase in energy consumption. Hence, the main issue that many countries are facing is the level of CO2 in the environment which is increasing significantly due to energy consumption and economic growth.

2.5 Synthesis

Out of all the related studies gathered for economic growth and energy, it is found that energy consumption is positively related to GDP. However, excessive use of energy, particularly non-renewable energy, negatively affects the environment.

On the other hand, from the related studies gathered for economic growth and CO2 emissions, it is found that carbon dioxide and economic growth have a positive relationship although some of the studies gathered show carbon dioxide is dependent on economic growth. Studies also claimed that there is an urgent need to create environmental policies aimed at reducing carbon dioxide emissions.

The result from the gathered related studies indicates that population growth and GDP have a positive relationship, although a study shows that population growth is related to energy consumption and carbon dioxide emissions.
From the studies gathered for the three independent variables, the result shows that economic growth and energy, economic growth and carbon dioxide, and economic growth and population are positively related. The studies also recommended reforming policies to decrease the negative effects of energy consumption, carbon dioxide emissions and population growth on the environment. Although, it is also seen that the three independent variables correlate with each other.

2.6 Theoretical Framework

2.6.1 Environmental Kuznets Curve Theory

The Environmental Kuznets Curve (EKC) is a hypothesized relationship between various environmental degradation indicators and income per capita. In the early stages of economic growth degradation and the increase of pollution, but beyond some level of income per capita (which will vary for different indicators) the trend reverses so that at high-income levels economic growth leads to improvement of the environment (Mishra, 2020).

The green economy aims to achieve economic growth as well as development without an adverse effect on the environment. Hence, the EKC hypothesis explains the relationship between economic activity and environmental degradation. Moreover, the OECD defined green growth as "fostering economic growth, and development, while ensuring that the natural assets continue to provide the resources, as well as, environmental services on which our well-being relies."

The EKC illustrates that as a country develops its industry, environmental degradation increases accordingly, and starts decreasing after reaching a certain level of economic progress. Thus, it implicitly suggests that environmental damage is unavoidable in the first phase of economic development in a country. Hence, there are suggested several reasons for the inversion of pollution patterns (Mishra, 2020). First, the turning point for pollution is the result of more progressive communities placing greater value on a cleaner environment and putting into place institutional, and non-institutional measures to affect this. Second, pollution increases, in the early phase of a country's industrialization, due to rudimentary, inefficient, and pollution-generating industries. Hence, when industrialization starts to achieve more advanced levels until it is sufficiently advanced, the pollution will stop increasing. Moreover, service industries will gain prominence causing a further reduction in pollution.

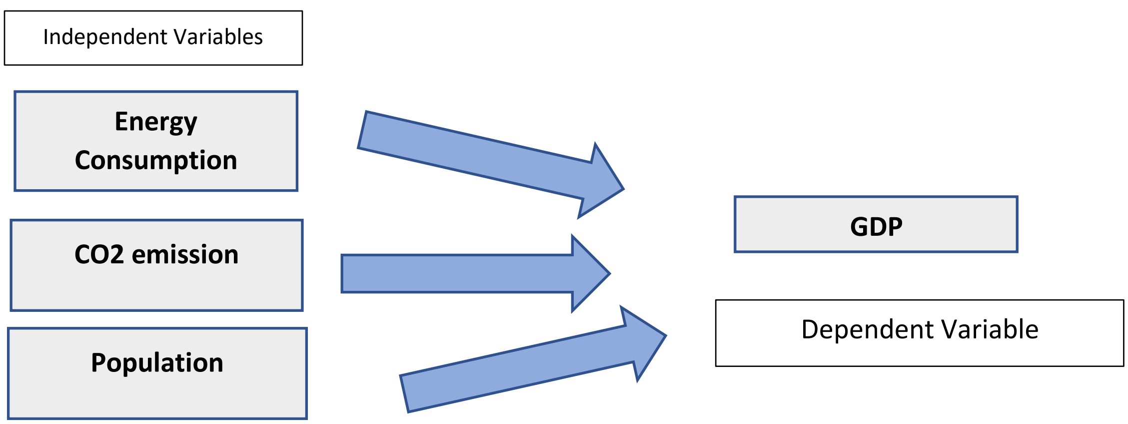
The relationship between environmental degradation and economic activities is not only direct but can also be indirect through the form of trade. According to Mishra (2020), some economists believe that free trade brings economic growth and that economic growth, in turn, helps to protect the environment from damage through raised incomes.

2.6.2 Demographic Transition Theory

The demographic transition theory can be modified by incorporating environmental dimensions and rethinking the relationships between demographic processes as well as development as they interact with environmental changes. The theory recognizes that population, development, and environment are inseparable and assumes a dynamic relationship between the three in which changes in each can induce changes in the other two. In general, according to Mishra (1995), the theory hypothesizes a slow increase in overall environmental degradation with the onset of demographic transition. After some time, with the growth of population in conjunction with growth in human consumption as well as the growth in environmentally destructive technology and industry, the rate of overall environmental degradation starts increasing rapidly beyond some critical point. Thus, this abrupt change is expected because of the stress on the ecosystem generated by the three factors that can keep building up for some time.

Most communities and/or societies undergo a transition in environmental degradation level along with the demographic transition. According to Mishra (1995), transition in environmental degradation can be divided into three (3) broad phases: pre-transition, transition, and post-transition. Thus, environmental degradation in a community and/or society moves from a relatively stable state at some low level in the pre-transition phase to another relatively stable state, most likely at some higher level, in the post-transition phase. With these, the transition phase can be subdivided into two (2) phases: deterioration and improvement (Mishra, 1995). Starting off with a relatively low stable state in the pre-transition phase, overall environmental degradation first deteriorates till a certain point and then gradually improves until it stabilizes the environmental transition. During the deterioration phase, the environment first deteriorates rather slowly before reaching a certain critical point, depending on the resource base, population pressure, and institutional structure in a community and/or society, beyond which the environment deteriorates rapidly until it peaks and eventually enters the improvement phase.

2.6.3 Conceptual Framework



To understand the basic structure of relationships between population, development, and environment, a conceptual framework in the form of a box and arrow diagram has been presented. The GDP is seen as directly affected by energy consumption, CO2 emissions, and population growth. Hence, this framework differentiates the characteristics of population and environment from their processes and shows underlying links between population, economic development, and environment.

3. Methodology

3.1 Data Description

This study uses annual time-series data spanning from 1980 to 2019, which totals 40 observations. The data were collected from the Philippine Statistics Authority for the constant GDP, BP Statistical Review of World Energy, and International data from the U.S. Energy Information Administration (EIA) for energy consumption, Statista for the population, and Global Carbon Project for CO2 emissions.

From the literature review, the researchers identified factors that theoretically affect the GDP. These factors include energy consumption, population, and CO2 emission. Thus, these variables are taken into account in this study. The following variables used are listed as follows:

Variable	**Proxied by**	**Unit**
GDP	Constant GDP	Peso
Energy	Primary Energy Consumption	Terawatt-hours (TWh)
Population	Population Growth	Number of individuals
CO2 Emission	Annual CO2 Emissions	tonne

3.2 Descriptive Statistics

Table 1. Descriptive Statistics

Variable	**Count**	**Mean**	**Std. Deviation**	**Minimum**	**Maximum**
GDP	40	8.47E+06	4.29E+06	4.15E+06	1.94E+07
ENERGY	40	283.73	117.28	133	560
POPULATION	40	77.316	18.553	47.36	108.12
CO2	40	68.269	31.221	27.9	146.61

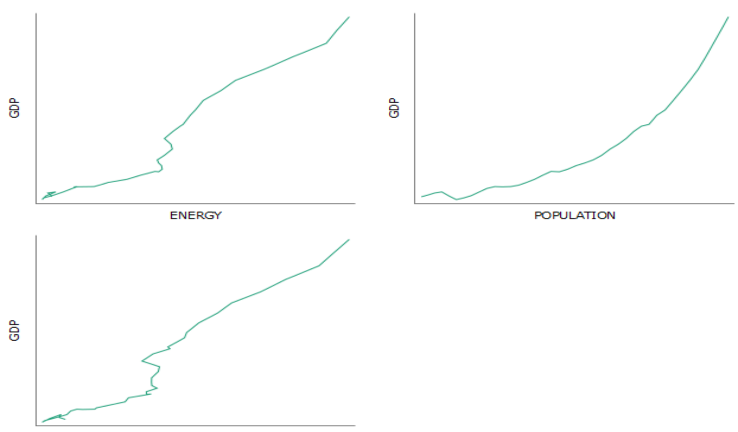


Figure 1. Graph of the dependent and independent variables

```
Correlation Coefficients, using the observations 1980 - 2019
5% critical value (two-tailed) = 0.3120 for n = 40

         GDP        ENERGY   POPULATION          CO2
      1.0000        0.9612       0.9274       0.9696  GDP
                    1.0000       0.9543       0.9960  ENERGY
                                 1.0000       0.9358  POPULATION
                                              1.0000  CO2
```

Figure 2. Correlation Matrix

Table 1 presents the descriptive statistics of the data set. From 1980 to 2019, the average constant GDP is 8,472,300 pesos. It reached a low of 4,153,148 pesos in 1985 and reached its peak in 2019 at 1,938,2751 pesos. Energy consumption on average is at 283.73 TWh for the years covered in the study. The lowest was 133 TWh in 1985 and the highest was 560 TWh in 2019. On average, the population growth covers 77.316 million people, with a minimum of 47.36 million people in 1980 and a maximum of 108.12 million people in 2019. Thus, CO2 emissions averaged 68.269 million t in the given years, reaching a minimum of 27.9 million t in

1985 and a maximum of 146.61 million t in 2019. Interestingly, constant GDP, energy consumption, and CO2 emissions reached low during 1985 when the Philippines dealt with domestic, natural, and external crises; it is the last year of the economic recession coinciding with the end of the Marcos regime era. Surprisingly, all of the variables reached their peak in 2019 before the COVID-19 pandemic.

Given the values of the coefficient in figure 2, there is a fairly strong positive relationship between the variables which can be shown in figure 1.

3.3 Methodology

The method of Ordinary Least Squares (OLS) regression was used in this study. The OLS evaluates the relationship between dependent and independent variables, which is done by minimizing the residual sum of squares. This method also determines whether a variable significantly affects the dependent variable as denoted by the p-values accompanying the beta coefficients of the respective variables. Since the study aims to assess the significant relationship between the variables constant GDP, energy consumption, population growth, and CO2 emissions, the OLS method is an apt methodological choice for the study.

This study aims to assess the relationship between energy consumption, population growth, and CO2 emissions with the constant GDP. In order to test this, the constant GDP was used as a proxy for GDP. The specific use of the GDP was based on the availability and consistency of the data.

With these, the following econometric model is specified:

$$GDPi = \beta 0 + \beta 1ENERGY + \beta 2POPULATION + \beta 3CO2 + \xi i$$

> where GDP represents the peso constant GDP; ENERGY is the primary energy consumption; POPULATION is the population growth; CO2 is the annual CO2 emissions; B0, B1, B2, and B3 are the beta coefficients for the aforementioned variables, respectively; ξ is the error term.

To assess whether the assumptions of CLRM are met, the following diagnostic tests were employed: Variance Inflation Factor for multicollinearity, Breusch-Pagan test for heteroscedasticity, Breusch-Godfrey test for autocorrelation, Jarque-Bera test for normality and normality of error terms, Ramsey RESET test to gauge whether the model is correctly specified, and Augmented Dickey-Fuller for unit root test.

Gretl was used for data cleaning and econometric tests.

4. Results and Discussions

4.1 Initial Results

As mentioned, the study aims to evaluate the relationship between the constant GDP and its determinants. More specifically, the study assessed the relationship between variable constant GDP with three independent variables namely, energy consumption, population growth, and CO2 emissions. In order to test this, OLS regression was used. Figure 3. Presents the initial results from the OLS regression.

Dependent variable: GDP

	coefficient	std. error	t-ratio	p-value	
const	−3.29638e+06	982788	−3.354	0.0019	***
ENERGY	−74210.7	19441.1	−3.817	0.0005	***
POPULATION	121195	31077.3	3.900	0.0004	***
CO2	343552	61913.7	5.549	2.79e−06	***

Mean dependent var	8472340	S.D. dependent var	4292441
Sum squared resid	2.90e+13	S.E. of regression	897714.7
R-squared	0.959626	Adjusted R-squared	0.956261
F(3, 36)	285.2181	P-value(F)	3.89e−25
Log-likelihood	−602.9546	Akaike criterion	1213.909
Schwarz criterion	1220.665	Hannan-Quinn	1216.352
rho	0.685921	Durbin-Watson	0.635218

Figure 3. Initial Regression estimates

Based on the results, the initial regression produced an R-squared of 0.9596. This means that 95.96% of the variability in the constant GDP is explained by the independent variables. This value is extremely high and means that the model is well constructed. With this, it can be said that the independent variables from the model are sufficient in explaining the variations of constant GDP.

In terms of the beta coefficient, all three independent variables are statistically significant, with their p-values less than the level of significance. This implies that a one-unit increase in energy consumption leads to a decrease of 74,210.7 pesos in constant GDP. On the other hand, a one-unit increase in population growth and CO2 emission leads to an increase in constant GDP by 121,195 pesos and 343,552 pesos, respectively. Moreover, Durbin-Watson shows there is a positive autocorrelation of the data.

4.2 Diagnostic Tests

In order to determine whether the results of CLRM are met and whether these regression results are correct, the results from the diagnostic tests are presented below.

4.3 Variance Inflation Factor for multicollinearity

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Variance Inflation Factors
Minimum possible value = 1.0
Values > 10.0 may indicate a collinearity problem

     ENERGY  251.575
 POPULATION   16.089
        CO2  180.828
```

Figure 4. Results from the VIF

To check for multicollinearity in the model, the Variance Inflation Factor (VIF) test was conducted. A VIF value of greater than 10 implies that a certain variable causes multicollinearity.

Results from the VIF test show that all variables have a VIF value of greater than 10. This means multicollinearity exists.

4.4 Breusch-Pagan test for heteroscedasticity

```
Breusch-Pagan test for heteroskedasticity
OLS, using observations 1980-2019 (T = 40)
Dependent variable: scaled uhat^2

               coefficient   std. error   t-ratio   p-value
  ---------------------------------------------------------
  const         2.05509      1.26658       1.623    0.1134
  ENERGY        0.0414163    0.0250550     1.653    0.1070
  POPULATION   -0.0475263    0.0400513    -1.187    0.2431
  CO2          -0.133757     0.0797920    -1.676    0.1023

  Explained sum of squares = 4.69901

Test statistic: LM = 2.349503,
with p-value = P(Chi-square(3) > 2.349503) = 0.503104
```

Figure 5. Results from Breusch-Pagan test

The Breusch-Pagan test was employed to assess possible heteroscedasticity in the model. The null hypothesis of the test states that the data are homoscedastic and the data has equal spread or variance. A p-value greater than 0.05 would mean that the null hypothesis of homoscedasticity is accepted. Contrarily, a p-value less than 0.05 implies that the data is heteroscedastic.

In this case, the p-value is 0.50 which is greater than the level of significance, 0.05. This means that the null hypothesis of homoscedasticity is accepted and that heteroscedasticity is not present in the model.

4.5 Breusch-Godfrey test for autocorrelation

```
Breusch-Godfrey test for autocorrelation up to order 2
OLS, using observations 1980-2019 (T = 40)
Dependent variable: uhat

                coefficient     std. error     t-ratio   p-value
  --------------------------------------------------------------
  const          457303         639168          0.7155   0.4792
  ENERGY          45144.9        14212.1        3.177    0.0032   ***
  POPULATION     -45521.0        21201.9       -2.147    0.0390   **
  CO2           -142419          45133.1       -3.156    0.0033   ***
  uhat_1              0.598060       0.148530   4.027    0.0003   ***
  uhat_2              0.360536       0.155357   2.321    0.0264   **

  Unadjusted R-squared = 0.604967

Test statistic: LMF = 26.034352,
with p-value = P(F(2,34) > 26.0344) = 1.39e-007

Alternative statistic: TR^2 = 24.198670,
with p-value = P(Chi-square(2) > 24.1987) = 5.56e-006

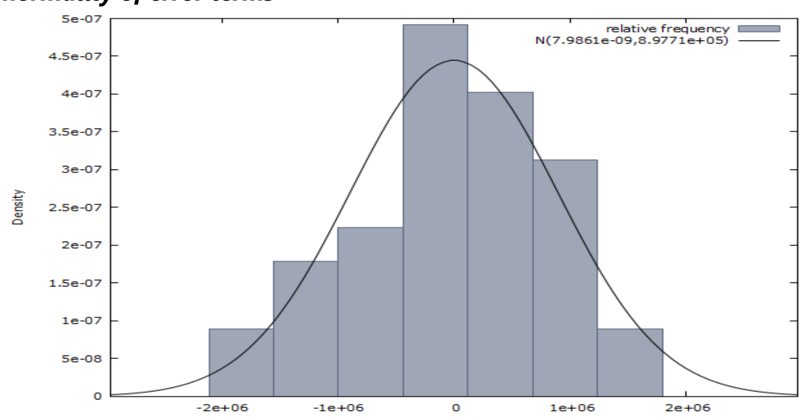
Ljung-Box Q' = 33.4766,
with p-value = P(Chi-square(2) > 33.4766) = 5.38e-008
```

Figure 6. Results from the Breusch-Godfrey test

The Breusch-Godfrey test was used in order to detect autocorrelation. The data are said to be autocorrelated with one another when the p-value yielded from the test is less than 0.05. A p-value greater than 0.05 would mean that the null hypothesis of no autocorrelation is rejected.

For the test, the default lag of 2 was used. The p-value yielded from the test is 0.000000139, which is less than 0.05. This implies that autocorrelation is present in the model.

4.6 Jarque-Bera test for normality of error terms




```
Frequency distribution for residual, obs 1-40
number of bins = 7, mean = 7.98609e-009, sd = 897715

       interval          midpt    frequency    rel.     cum.

            < -1.558e+006 -1.837e+006     2      5.00%    5.00% *
 -1.558e+006 - -9.984e+005 -1.278e+006     4     10.00%   15.00% ***
 -9.984e+005 - -4.392e+005 -7.188e+005     5     12.50%   27.50% ****
 -4.392e+005 -  1.200e+005 -1.596e+005    11     27.50%   55.00% *********
  1.200e+005 -  6.792e+005  3.996e+005     9     22.50%   77.50% ********
  6.792e+005 -  1.238e+006  9.588e+005     7     17.50%   95.00% ******
           >=  1.238e+006  1.518e+006     2      5.00%  100.00% *

Test for null hypothesis of normal distribution:
Chi-square(2) = 2.694 with p-value 0.26001
```

Figure 7. Results from Jarque-Bera normality of residuals test

The Jarque-Bera test gauges whether the error terms are normal. Like the preceding tests, a p-value of greater than 0.05 is desirable since the null hypothesis states that the error terms are normally distributed.

The figure above shows a normally distributed histogram of residuals. Moreover, the p-value obtained is greater than 0.05, which means that the residuals are normally distributed.

4.7 Ramsey RESET test

```
RESET test for specification (squares and cubes)
Test statistic: F = 52.286379,
with p-value = P(F(2,34) > 52.2864) = 4.23e-011

RESET test for specification (squares only)
Test statistic: F = 86.516617,
with p-value = P(F(1,35) > 86.5166) = 5.45e-011

RESET test for specification (cubes only)
Test statistic: F = 61.922341,
with p-value = P(F(1,35) > 61.9223) = 3e-009
```

Figure 8. Results from Ramsey RESET test

The Ramsey RESET test was employed to assess whether the model was correctly specified. Like the previous test, a p-value greater than the level of significance is desirable because it means that there is no problem with the data or the model.

In this case, however, the p-value yielded is lower than 0.05. This means that the model is incorrectly specified and that necessary re-specifications are needed in order to amend the issue.

4.8 Normality Test

Table 2. Results from Jarque-Bera normality test

Normality Test	
Jarque-Bera test	
	p-value
GDP	0.0245829
ENERGY	0.259348
POPULATION	0.276919
CO2	0.0876175

The null hypothesis of the Jarque-Bera test is a joint hypothesis of the skewness being zero and the excess kurtosis being zero. As shown above, the independent variables have a p-value >0.05, which implies that the data are consistent with having skewness and excess kurtosis zero. However, the dependent variable has a p-value less than 0.05 which suggests that the observed data is inconsistent with the assumption that the null hypothesis is true.

4.9 Augmented Dickey-Fuller Test

Table 3. Results from Augmented Dickey-Fuller test

Augmented Dickey-Fuller Test		
	with constant	**with constant and trend**
	p-values	
GDP	1	1
ENERGY	0.998	0.9191
POPULATION	0.05948	0.5722
CO2	1	0.9987

In the ADF test in which the null hypothesis assumes the presence of a unit root, the p-value obtained should be less than the significance level of 0.05 in order to reject the null hypothesis.

The data above shows that both with constant and with constant and trend the p-values of the data are greater than 0.05 which indicates that the data is non-stationary.

4.10 Model re-specification

Based on the diagnostic tests, the model suffers from multicollinearity, autocorrelation, misspecification, and the presence of unit root after failing the Variance Inflation Factor, Breusch-Godfrey test, Ramsey RESET test, and Augmented Dickey-Fuller test. Since key assumptions of the CLRM are violated, the results from the regression cannot be fully relied upon.

To amend the mentioned issues, the following treatments were adopted: Taking into account these changes, the econometric model is re-specified. For autocorrelation, the lagged values of the independent variables were included in population and CO2 with a direct relationship in the OLS with the dependent variable, as well as, using the first difference in the dependent variable. In addition, the first-difference estimator is used in independent variables with the highest multicollinearity data. Moreover, the independent variable (population) was converted to a logarithm in order to account for multicollinearity and misspecification.

Taking into account the changes, the econometric model is re-specified as:

$$d\_GDPi = \beta0+\beta1\_d\_ENERGY+\beta2\_l\_POPULATION\_2+\beta3\_d\_CO2\_2+\xi i$$

4.11 Diagnostic tests after re-specification

To assess whether the issues are resolved, the diagnostic tests were re-run.

4.12 Normality test

Table 4. Results from Jarque-Bera normality test after re-specification

Normality Test	
Jarque-Bera test	
	p-value
d_GDP	0.449565
d_ENERGY	0.149988
l_POPULATION_2	0.264736
d_CO2_2	0.903753

The Jarque-Bera test shows that all the variables have a p-value greater than 0.05, which implies that the data are all consistent with having skewness and excess kurtosis zero.

4.13 Augmented Dickey-Fuller test

Table 5. Results from Augmented Dickey-Fuller test after re-specification

Augmented Dickey-Fuller Test		
	with constant	**with constant and trend**
	p-values	

d_GDP	0.8802	0.01708
d_ENERGY	0.0193	0.02484
l_POPULATION_2	0.03226	0.848
d_CO2_2	0.1202	0.0002736

The data above shows that all the variables with constant and trend have p-values lower than 0.05 which indicates that the data is stationary. In addition, only energy and population have lower 0.05 p-values in both tests.

4.14 Variance Inflation Factor for multicollinearity

```
Variance Inflation Factors
Minimum possible value = 1.0
Values > 10.0 may indicate a collinearity problem

      d_ENERGY    1.304
l_POPULATION_2    1.379
        d_CO2_2    1.393
```

Figure 9. Results from the VIF after re-specification

Results from the VIF test show that all variables have a VIF value of less than 10. This means that multicollinearity doesn't exist.

4.15 Ramsey RESET test

```
RESET test for specification (squares and cubes)
Test statistic: F = 1.316878,
with p-value = P(F(2,31) > 1.31688) = 0.283

RESET test for specification (squares only)
Test statistic: F = 2.668909,
with p-value = P(F(1,32) > 2.66891) = 0.112

RESET test for specification (cubes only)
Test statistic: F = 2.655758,
with p-value = P(F(1,32) > 2.65576) = 0.113
```

Figure 10. Results from Ramsey RESET test after re-specification

Results from the Ramsey RESET test reveal that the p-value yielded is greater than 0.05. This means that the model is correctly specified.

4.16 Condensed results from other tests

```
LM test for autocorrelation up to order 2 -
  Null hypothesis: no autocorrelation
  Test statistic: LMF = 1.19147
  with p-value = P(F(2, 31) > 1.19147) = 0.317304

Breusch-Pagan test for heteroskedasticity -
  Null hypothesis: heteroskedasticity not present
  Test statistic: LM = 0.636997
  with p-value = P(Chi-square(3) > 0.636997) = 0.887913

Test for normality of residual -
  Null hypothesis: error is normally distributed
  Test statistic: Chi-square(2) = 1.92467
  with p-value = 0.382001
```

Figure 11. Condensed results

The other diagnostic tests show that all the assumptions of CLRM are met. The Jarque-Bera produced a p-value greater than 0.05. The Breusch-Pagan test reveals that the model is still homoscedastic, and the LM test shows that autocorrelation is not present in the model.

With the assumptions of the CLRM now met, the estimates of the respecified regression model are shown below:

```
Dependent variable: d_GDP

                    coefficient     std. error   t-ratio   p-value
  ----------------------------------------------------------------
  const              -4.37251e+06   571142       -7.656    8.19e-09 ***
  d_ENERGY         9160.91            2296.20     3.990    0.0003   ***
  l_POPULATION_2      1.07659e+06   135444        7.949    3.62e-09 ***
  d_CO2_2          8923.94            7415.88     1.203    0.2374

Mean dependent var   396633.4   S.D. dependent var   375408.7
Sum squared resid    8.56e+11   S.E. of regression   161077.4
R-squared            0.831239   Adjusted R-squared   0.815897
F(3, 33)             54.18098   P-value(F)           7.64e-13
Log-likelihood      -494.0008   Akaike criterion     996.0016
Schwarz criterion    1002.445   Hannan-Quinn         998.2733
rho                  0.251233   Durbin-Watson        1.425706

Excluding the constant, p-value was highest for variable 10 (d_CO2_2)
```

Figure 12. Respecified Regression estimates

The R-squared produced in the regression is 0.83, which is extremely high. This means that 83% of the variability in the dependent variable is explained by the independent variables. For the beta coefficients, energy consumption, and population growth are both statistically significant. This signifies that a one-unit increase in energy consumption and population growth increases the constant GDP by 9160.91 pesos and 1,076,590 pesos, respectively. Contrarily, CO2 emissions are now insignificant after re-specification. Moreover, there is a slightly positive autocorrelation because of the Durbin-Watson which is an improvement from the OLS in figure 3.

5. Summary, Conclusion, and Recommendation

5.1 Summary

The data on energy consumption shows an increasing linear trend from 1980 to 2019. Thus, an increasing linear trend is observed over time. The high demand for electricity for both households and manufacturing and processing industries are the main drivers of the escalating emissions. This is consistent with econometric propositions, which indicate that energy consumption increases proportionally with economic growth. Growing industrial and domestic energy demands necessitated the Philippines to enhance its power generation capacity by expanding energy-related power stations. Notably, there is increasing pressure for renewable green energy sources in the Philippines and for independent power producers to supplement the power utility. This emerging trend is widening the energy mix for the Philippines to include hydro, wind, and solar energy. While the shift to green and cleaner energy sources is gaining momentum in the country, the CO2 emission levels will predictably remain relatively high in the foreseeable future due to the high dependence on energy for power generation. Henceforth, a stringent regulatory system is much needed to curtail the high CO2 emissions levels observed in this study, given the devastating impacts of global warming and climate change that are already ravaging the world.

For population growth, the data shows that there is a significant relationship between the constant GDP. Moreover, population growth plays an important role in overall economic growth, though, the evolution of the population in the Philippines will continue to be the country's concern.

Hence, the green economy is suited because it provides a practical as well as flexible approach for achieving concrete, measurable progress across its environmental and economic pillars while taking into account the social consequences of greening the growth dynamic of the economy in the Philippines. In addition, the focus of green economy strategies is ensuring that natural assets (wealth, health, and well-being) can deliver their full economic potential on a sustainable basis.

5.2 Conclusion

Green economy, as well as green growth, need to be fostered as both of them are needed for sustainable development in the Philippines. Thus, political, social, and economic aspects of sustainability need to be considered for achieving green growth and a green economy. In order to prevent environmental disasters there's a need to radically reduce toxic emissions as well as the consumption of non-renewable resources. As such this poses an enormous challenge to the financial and the real economy. It requires keeping in mind the EKC Model Mechanism and reforming further to develop the global economic, and governance system, and restructure incentive systems. Also, the demographic transition theory makes a useful contribution to the dynamic nature of interactions between population, development, and environment.

5.3 Recommendation

For the household sector, efficiency labeling can be improved to cover more electricity-consuming devices at home. Various instruments such as tiered pricing may also help to incentivize the selection of efficient devices and efficient behavior. Also, increased adoption of more efficient household appliances may reduce power demand, whereas wider use of electric vehicles will increase it, particularly during charging. Meanwhile, increased deployment of renewables may facilitate technology learning curves that reduce costs of the application, operations, as well as, maintenance. Substitution of gas for coal depends on the development of transport infrastructures, and more sustainable transport often depends on the improved patterns of spatial development. As such, strong intersectional coordination in the communities is much needed to ensure that synergies in low-carbon strategies are exploited.

For the businesses, apply non-technological changes and innovation such as new business models, work patterns, city planning and/or transportation arrangements. Thus, interventions to overcome market barriers to the widespread use of renewables need to be undertaken.

For the institutions and the government, educating the people in energy conservation. Also, adopting forward-looking and proactive planning in working to achieve sustainable patterns of consumption and production and to reduce the impacts of human activities on the environment, it is important to recognize that plausible future trajectories of the population in the Philippines lie within a relatively narrow range, especially in the short or long term. Estimated results indicated that energy consumption and population growth are the main cause of economic growth so it is recommended to revise policy related to economic growth in the Philippines for controlling environmental degradations. Non-renewable sources of energy are used as a fuel and for industrial production as well as household energy consumption in the Philippines so it is recommended to adopt such energy sources that cause minimum environmental degradation. To control environmental degradation in the long run, the policymakers should adopt environmental innovation measures more, especially to increase energy efficiency through (1) energy consumption restructuring, (2) promoting social awareness of the advantages of a low-carbon economy and of environmental protection, and (3) ensuring the implementation of environmental protection compliance and legislation. Hence, this type of "green growth" offers new opportunities for entrepreneurship.

The current study attempt to investigate the literature for the last four decades in the domain of economic growth, energy consumption, population, and carbon emission, but it still has limitations that future researchers can address to draw more reliable and concrete conclusions. Future studies have to form appropriate analyzing methods that define the way to report the decision of the study. Earlier studies have used a large number of indicators related to this topic, such as energy intensity, renewable energy, energy efficiency, etc., however, this study addresses a few of the factors that have a direct impact on economic growth and carbon emission.

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Appendices

Appendix A: Constant GDP

Major Industries

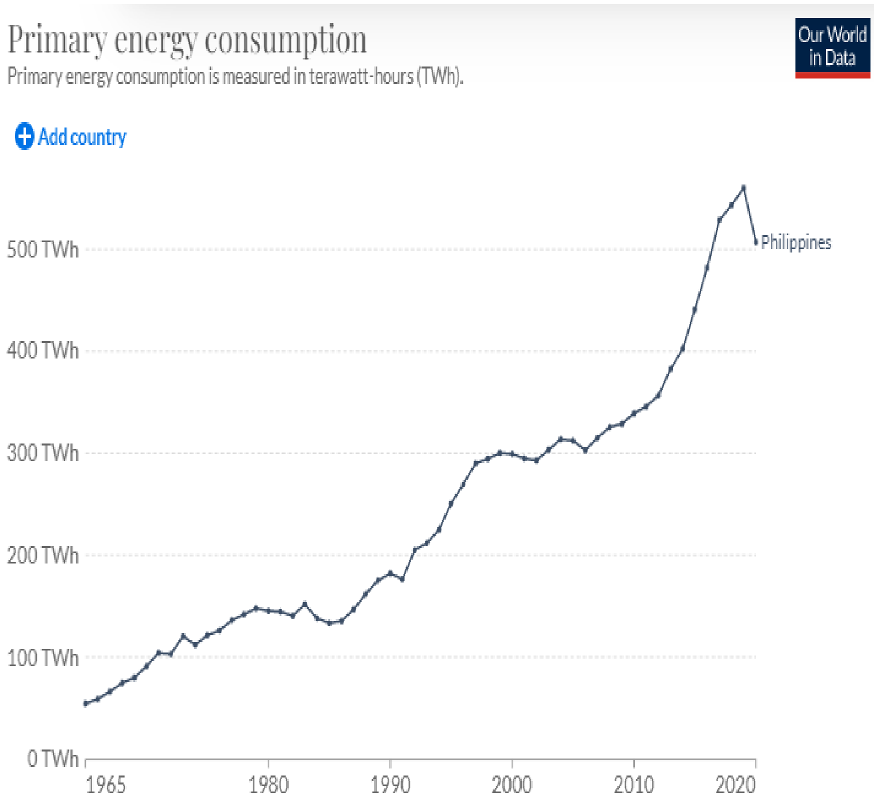
- Agriculture, Forestry and Fishing
- Industry
- Services

Gross Domestic Product	
1980	4,389,222
1981	4,539,430
1982	4,707,317
1983	4,796,612
1984	4,458,961
1985	4,153,148
1986	4,298,952
1987	4,486,464
1988	4,786,920
1989	5,082,939
1990	5,239,629
1991	5,216,764
1992	5,238,551
1993	5,352,850
1994	5,586,966
1995	5,845,376
1996	6,187,935
1997	6,508,867
1998	6,475,405
1999	6,692,102
2000	6,985,383

2001	7,198,384
2002	7,465,894
2003	7,845,677
2004	8,361,078
2005	8,774,325
2006	9,240,804
2007	9,843,239
2008	10,270,878
2009	10,419,633
2010	11,183,861
2011	11,615,360
2012	12,416,466
2013	13,254,644
2014	14,096,047
2015	14,990,907
2016	16,062,676
2017	17,175,978
2018	18,265,190
2019	19,382,751

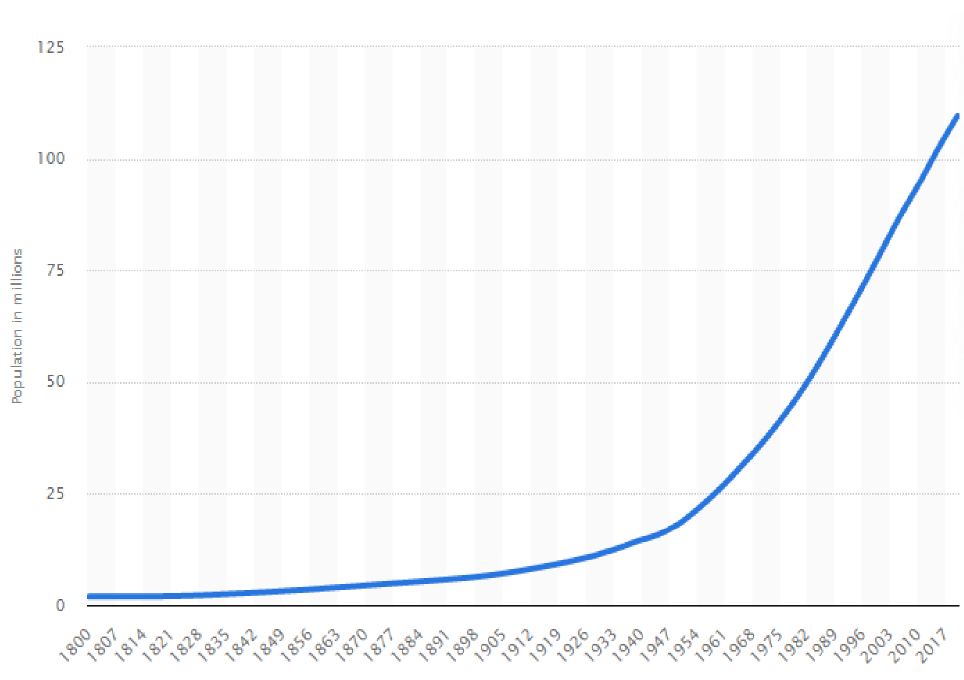
Source: Philippine Statistics Authority

Appendix B: Energy Consumption



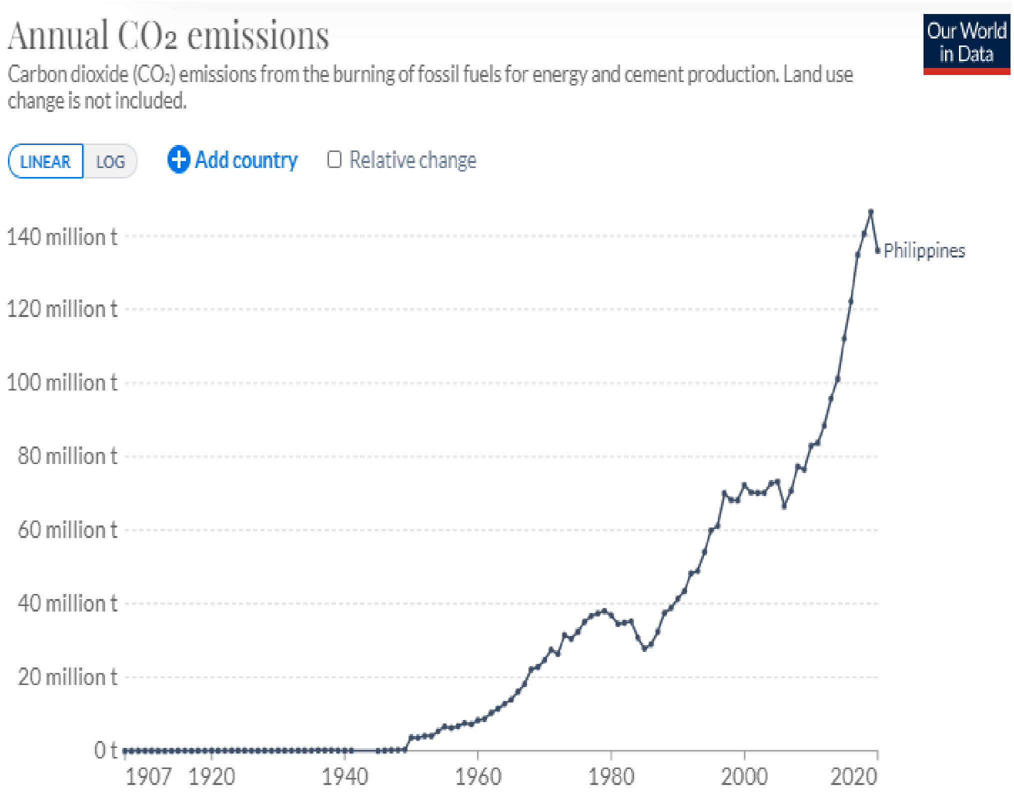
Source: BP Statistical Review of World Energy and EIA

Appendix C: Population



Source: Statista

Appendix D: CO2 Emissions



Source: Global Carbon Project