Title: Analysis of impact of macroeconomics indicators on CO_2 emissions in India

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Abstract

The energy sector development governs the most of the economic factor growth, however it produces a significant share of global CO_2 emissions. Harmful CO2 emissions and greenhouse gas emissions accelerate global warming. Therefore, more and more countries are adopting a strategy for the transition to carbon-neutral energy. However, energy independence and economic competitiveness are closely linked. Given these facts, we focused on conducting an econometric study of the impact of key macroeconomic indicators on the level of CO2 emissions into the air in the India. The data is considered for the time period 1991-2019 and the major parameters for determining the CO2 emission are GDP, Unemployment rate and Inflation rate. As per data, it is seen that there is a strong correlation between carbon emission and unemployment rate whereas the correlation between GDP and carbon emission is fairly low for India.

Keywords: CO2 emissions, Macroeconomic indicators, India GDP, Unemployment rate, Inflation rate, Econometric study, Energy sector, Global warming, Carbon-neutral energy

1. Introduction

The carbon dioxide emissions are one of the key reasons for global climate change and there is a need to decrease the concentration of CO_2 in environment to avoid the wors effect on climate change [1]. However, the division of this responsibility among nations, regions, and people has long been a source of dispute in international talks. Several economic and regulatory elements have an impact on the degradation of the ecological situation throughout the world.

They operate in various fields, have varying degrees of influence and severity, and operate in those fields. Since the beginning of human habitation and active exploration of the Earth, there has been pollution and resource depletion [2]. Industrial revolutions encouraged the emergence of these factors, which were more pronounced during the times of developing industrial output, urban expansion, and population growth.

The developing world's contribution to the issue of climate change has historically been little, and their per-capita carbon dioxide (CO_2) emissions are much lower than those of the industrialised world. But in the coming two decades, some of them are anticipated to dramatically expand their emissions. With 21% and 16% of the world's population, respectively, China and India will require special consideration in the future for any global CO_2 emission reduction strategy to be successful. A large portion of the reported increase in emissions in developing nations is related to these nations' growing populations, urbanisation, and economic prosperity. The forecasts are meant to show that, in another 25 years, these nations might rank among the top emitters of carbon. Therefore, it is stated that developing countries must take action to ensure that their emissions do not increase as much as expected before they become as big of a problem as the currently industrialised countries. However, it is not acknowledged or seen as significant that these restrictions might restrain the economy of developing countries, leading to severe losses in welfare. The adoption of environmentally friendly technologies is consistent with the Lisbon Agenda and the Sustainable Development Goals [1]. In order to strike a balance between business, the environment, and society, firms pursue technical advancement [2, 3]. A green economy that is actively being developed can successfully reduce carbon dioxide emissions. Economic development influences the total quantity of carbon emissions, but in turn, the amount of carbon emissions reflects the level of economic development. A balanced theoretical and methodological approach is needed to resolve the tension between socioeconomic development and the transition to a low-carbon energy future. This can be done by determining how macroeconomic issues affect CO_2 emissions. The majority of research focuses on understanding how one of the components affects CO_2 emissions, yet the mentioned problems are complicated. It is necessary to examine all economic elements collectively because they all have an impact on a certain outcome [4]. In order to determine additional measures toward de-carbonization that must be ensured in the national economy without impeding its socioeconomic development, it is important to model the interactions between various parameters.

2. Literature Review

With the growth of the global economy, the effects of the economy on the environment are becoming more and more obvious. As a result, numerous researches have attempted to define and evaluate the relation between environment and economic development [5–8]. Using Dennis Meadows' model, researchers looked at how population increase, the expansion of industrial and agricultural production, the use of natural resources, and environmental pollution are related to one another [9]. Jay Forrester's system dynamics methodology was used to create Dennis Meadows' model, which was detailed in the 1972 book "The Limits to Growth." The model's conclusions and Thomas Malthus' beliefs are pretty similar. They were created using the five primary criteria in which earth's population, industrialisation, food production, resource depletion, environmental pollution, and production of food are the top five global issues [10]. The current notion of "sustainable development" was thus established, and the need to transition to zero growth—that is, to decrease output and consumption to mere reproduction—was also supported. Recent years have seen an increase in the visibility of environmental challenges, which motivates politicians to act [11]. It is vital to alter people's cognition and views of society's economic and environmental ideals [12, 13]. Political globalisation is known to have a direct impact on the environment, according to contemporary research, while economic globalisation, which is harmful to the environment, cannot be stated to have such an impact [14,15]. The most frequent reasons of increased CO_2 emissions are free commerce, extensive energy consumption, and rapid urbanisation [16,17]. Numerous studies have demonstrated that rising economic activity results in rising CO_2 emissions [18,19]. Increased energy consumption is necessary for modern manufacturing settings, which directly increases CO_2 emissions [20,21]. In order to strengthen the energy sector, which is the primary contributor to CO_2 emissions, the OECD has identified five key economic sectors: industry, agriculture, transport, services, and other green growth sectors [22]. The transport industry, according to researchers, exhibits the strongest direct link, meaning that as energy consumption in this industry rises, so does the efficiency of CO_2 production [23]. Cement manufacturing, the chemical industry, and ferrous metallurgy are the main sources of CO_2 emissions in the sector. The entire correlation between the dynamics of three major product groups' production and the industry's emissions suggests that a number of essential products are heavily dependent on emissions [24].

2.1 GDP and CO_2 Emissions

Increased GDP and economic activity have resulted in higher energy consumption and, as a result, higher CO_2 emissions [26]. In other words, the deterioration of the environment is being caused by a combination of human activity and the rapid rise of the global economy. According to [44], the proposition that GDP is influenced by greenhouse gas emissions is fairly acceptable theory. The mathematical models of ecological and economic interactions are developed in the works [27–30] in the area of indicators of the economic structure of society, prices, and environmental damage. These models include multiple parameters and are defined by systems of ordinary differential equations; their numerical specification results in tasks involving parameterization (identification).

Measuring of the effects of economic growth on CO_2 emissions was developed by a group of researchers, including Menyah and Wolde-Rufael (2010) [31], Nazirah Wahid et al. (2013) [32], Razak et al. (2013) [33], and Zhou and Li (2011) [34]. In 89 nations from six different regions, including Asia Pacific, Eastern Europe, the Americas, the Middle East and North Africa, Sub-Saharan Africa, and Western Europe, Al-mulali Usama & Sheau-Ting (2014) [35] examined trade, exports, imports, energy consumption, and CO_2 emissions (in the period of 1990–2011). Haug & Ucal (2019) [36] looked at how FDI and international trade affected Turkey's CO_2 emissions. They discovered considerable asymmetries in the relationship between CO_2 per capita emissions and exports, imports, and FDI. Additionally, they found that FDI do not have any statistically significant long-term effects, which supports the results of Mahmood et al [37]. Here we can consider the following hypothesis regarding the impact of GDP on CO_2 emission in India as,

Hypothesis 1 (H1): There is a significant indirect impact of GDP on CO_2 emissions in India.

2.2 Inflation and CO_2 Emissions

All nations are impacted by the inflation rate, and this impact can be either beneficial or bad. "A rise in the price level of a good or service or market basket of commodities and/or services" [38] is one definition for this phrase. It has to do with how much the cost of goods or services has changed or increased by percentage at a particular point in time, usually annually [39]. Increased material costs are correlated with higher inflation rates, and as a result, workers will call for wage increases to offset rising living expenses [40]. While the topic of inflation and its effects on the various nations were examined from many angles, the situation gets considerably more complicated when additional factors are taken into consideration, such as the effect of inflation on CO_2 emissions. This subject has only been the subject of a few research. First off, it is impossible to directly calculate the effect; consequently, researchers employ a variety of indirect approaches to study it. Here we can consider the following hypothesis regarding the impact of inflation rate on CO_2 emission in India as,

Hypothesis 2 (H2): There is a significant indirect impact of inflation on CO_2 emissions in India.

2.3 Unemployment and CO2 Emissions

In the Gulf and Maghreb nations from 1995 to 2013, Mrabet & Jarboui (2017) [41] examined the effects of institutional determinants on the effectiveness of the GDP and CO_2 emissions. For Arabic countries, they demonstrated a favourable impact of inputs like manpower on CO_2 emission efficiency. The capital is a factor in the GDP efficiency of Maghreb nations. Additionally, Liu & Feng (2022) [42] used panel data from 77 nations and regions from 1991 to 2020 to investigate the possible impacts of unemployment on global CO_2 emissions. According to their research, unemployment has a negative impact on CO_2 emissions at the global level, but this is not the case at the regional level. Likewise, from 1991 to 2019, Naqvi et al. (2022) [43] investigated how the generation of renewable energy affected the unemployment rate in European nations. The findings showed that the long-term impact of renewable energy production on unemployment levels in European nations was significant. Here we can consider the following hypothesis regarding the impact of unemployment on CO_2 emission in India,

Hypothesis 3 (H3): There is a significant indirect impact of unemployment on CO_2 emissions in India.

3. Methodology

There are two primary categories of relationships in scientific and applied economic research: functional (determinate) and correlation (stochastic). At the level of functional dependency, phenomena exhibit harsh mechanical causality and dynamic regularity, which are described mathematically. Correlation is a relationship when each value of the argument has multiple values of the function and there is no discernible relationship between the argument and the function. Econometric regression models [44], which enable quantifying the current regularity of socioeconomic processes and phenomena [45, 46], are used to describe it. The one-way stochastic reliance of a single random variable (dependent variable) on a number of different random variables (independent variables) is known as a regression model [47].

The research technique employed in our article includes the following key stages in order to verify the hypotheses and examine how macroeconomic indices affect CO2 emissions in India:

Stage 1: Selection of indicators and sampling for modelling.

The authors selected the following indicators: dependent variable—the amount of CO2 emissions into the air (CO2)—and independent variables—gross domestic product (GDP), inflation rate (INFLATION), and unemployment rate (UNEMPLOYMENT). The sample of statistics is formed from all the available values of the annual indicators for the period 1991–2019 (Table 1).

The required data was collected and compiled from different online resources as mentioned below:

1. CO2 emission data:

European Environment Agency (EEA)- Emissions Database for Global Atmospheric Research (https://edgar.jrc.ec.europa.eu/) dataset name: EDGARv5.0_FT2019

2. Macroeconomics indicators: World Bank- Free and open access to global development data (https://data.worldbank.org/indicator/)

Stage 2: Graphic display of indicators and analysis of their dynamics for the period for the period 1991–2019.

Stage 3: Formation of a correlation matrix to assess the relationship between indicators.

Stage 4: Construction of a regression equation.

$$y = b_0 + \sum_{r=1}^{n} b_r x_r$$

Where y is the dependent variable, b are the parameter (coefficient) of regression (b_0 is considered as intercept in the regression model), x is the factor of influence (independent variables) and n is the number of factors in the regression model.

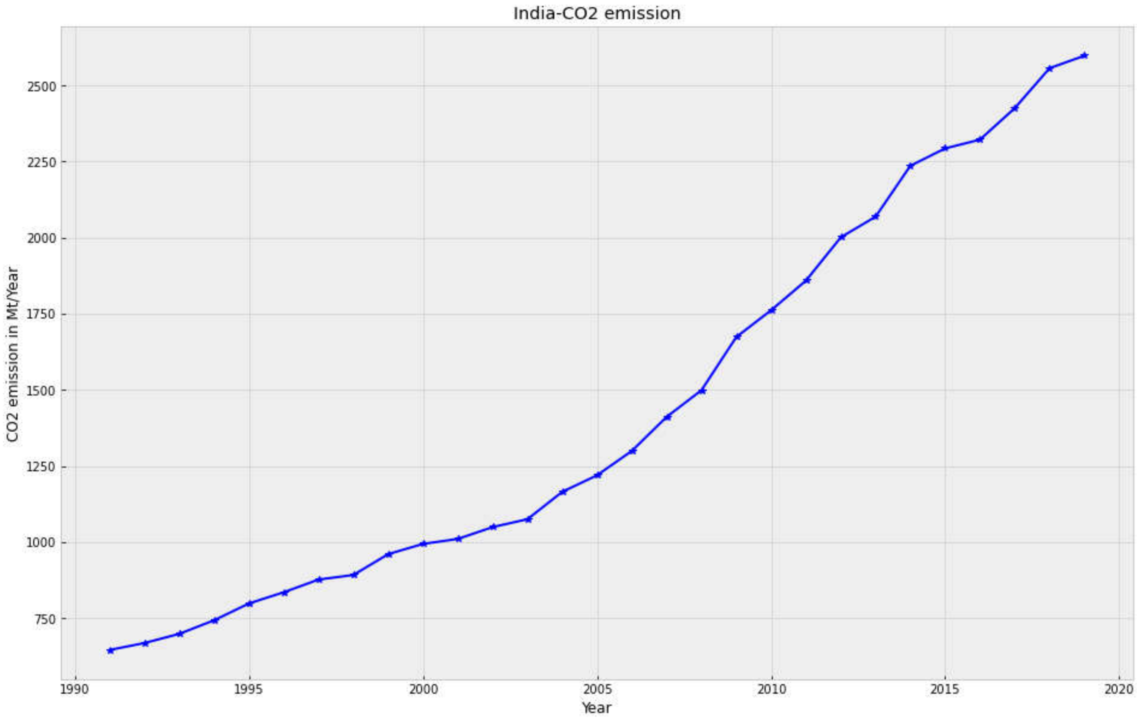
Stage 5. Estimation of the parameters of econometric models using the method of least squares. Checks the quality of constructed econometric models using the coefficient of determination and Fisher's criterion

Table 1: Parameter values used in the regression model

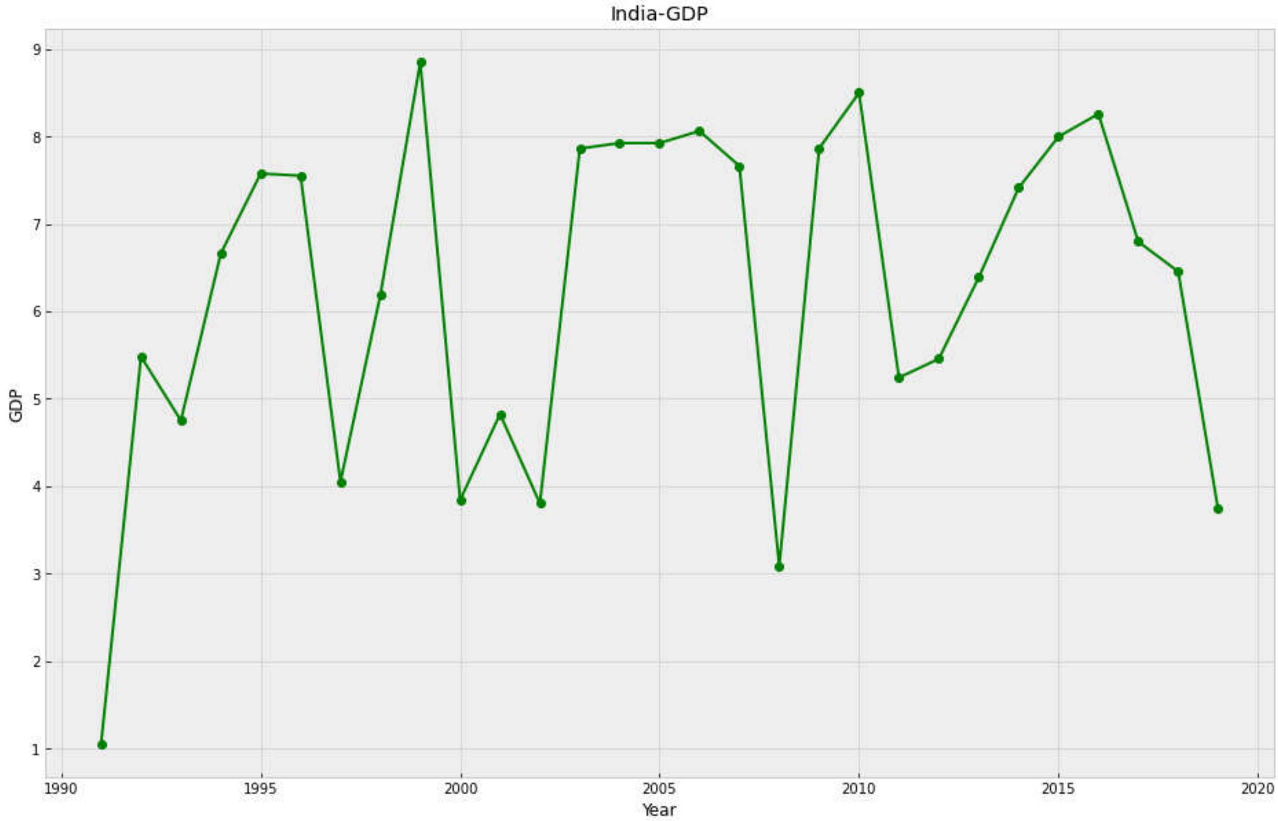
Year	India-CO2	India-GDP	Inflation, %	Unemployment
1991	645.64	1.056831	13.75182	5.599
1992	668.44	5.482396	8.965152	5.727
1993	698.52	4.750776	9.861783	5.691
1994	743.14	6.658924	9.980045	5.739
1995	798.35	7.574492	9.062702	5.755
1996	835.14	7.549522	7.575018	5.74
1997	876.87	4.049821	6.476271	5.613
1998	891.88	6.184416	8.010168	5.666
1999	960.39	8.845756	3.068396	5.736
2000	993.97	3.840991	3.64497	5.561
2001	1010.29	4.823966	3.215616	5.576
2002	1049.16	3.803975	3.715684	5.53
2003	1075.07	7.860381	3.867798	5.643
2004	1164.98	7.922937	5.725413	5.629
2005	1219.35	7.923431	5.621903	5.613
2006	1299.5	8.060733	8.400938	5.601
2007	1411.22	7.660815	6.944418	5.572
2008	1498.8	3.086698	9.19397	5.414
2009	1673.47	7.861889	7.040365	5.544
2010	1761.4	8.497585	10.52603	5.546
2011	1858.61	5.241315	8.73358	5.426
2012	2000.84	5.456389	7.934386	5.414
2013	2068.6	6.386106	6.186504	5.424
2014	2235.92	7.410228	3.331757	5.436
2015	2292.96	7.996254	2.279588	5.435
2016	2321.8	8.256306	3.237975	5.423
2017	2425.42	6.795383	3.969258	5.358
2018	2556.55	6.453851	3.88424	5.33
2019	2597.36	3.737919	2.390749	5.27

4. Results & discussion

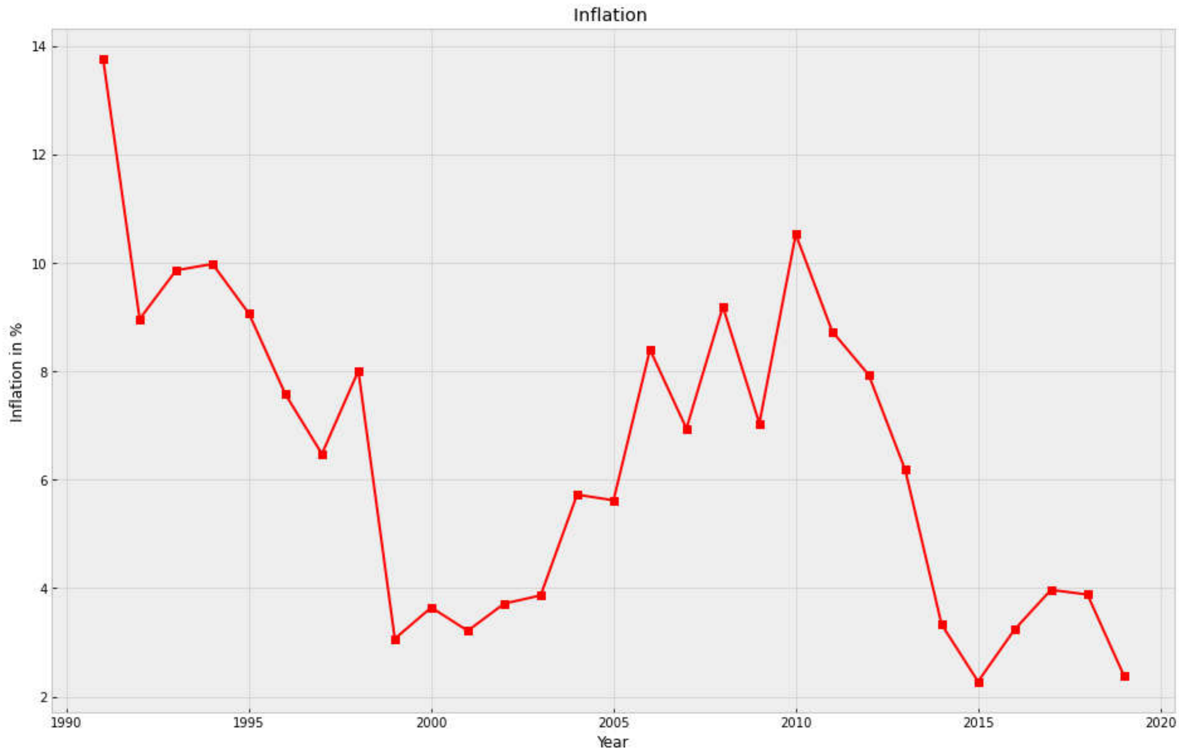
The graphical representation of the dynamics of changes in CO2 emissions and the macroeconomic indicators of India is shown in Figure 1.



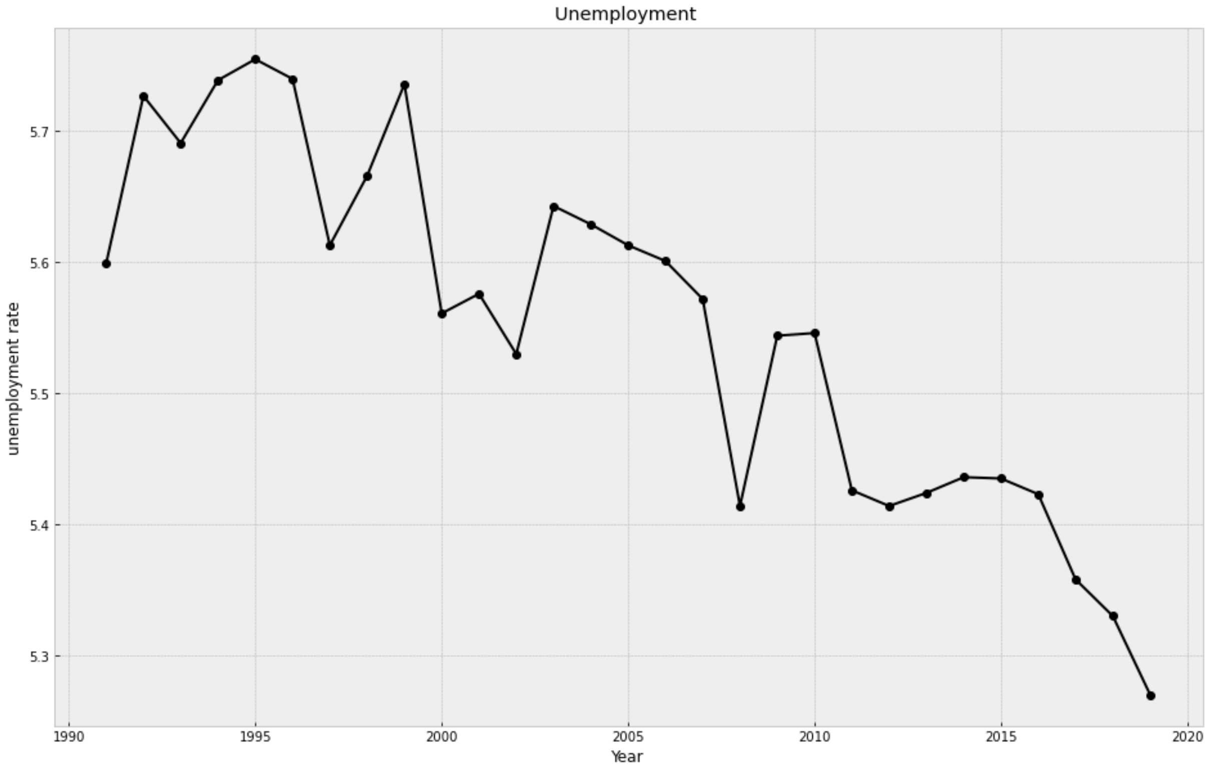
(a)


India-GDP
GDP
Year
1990
1995
2000
2005
2010
2015
2020
1
2
3
4
5
6
7
8
9

(b)


Inflation
Inflation in %
Year
1990
1995
2000
2005
2010
2015
2020
2
4
6
8
10
12
14

(c)



(d)

Fig 1: Graphical representation of the dynamics of changes in CO2 emissions and the macroeconomic indicators of India

The matrix graph of the correlations between indicators is given in Figure 2.

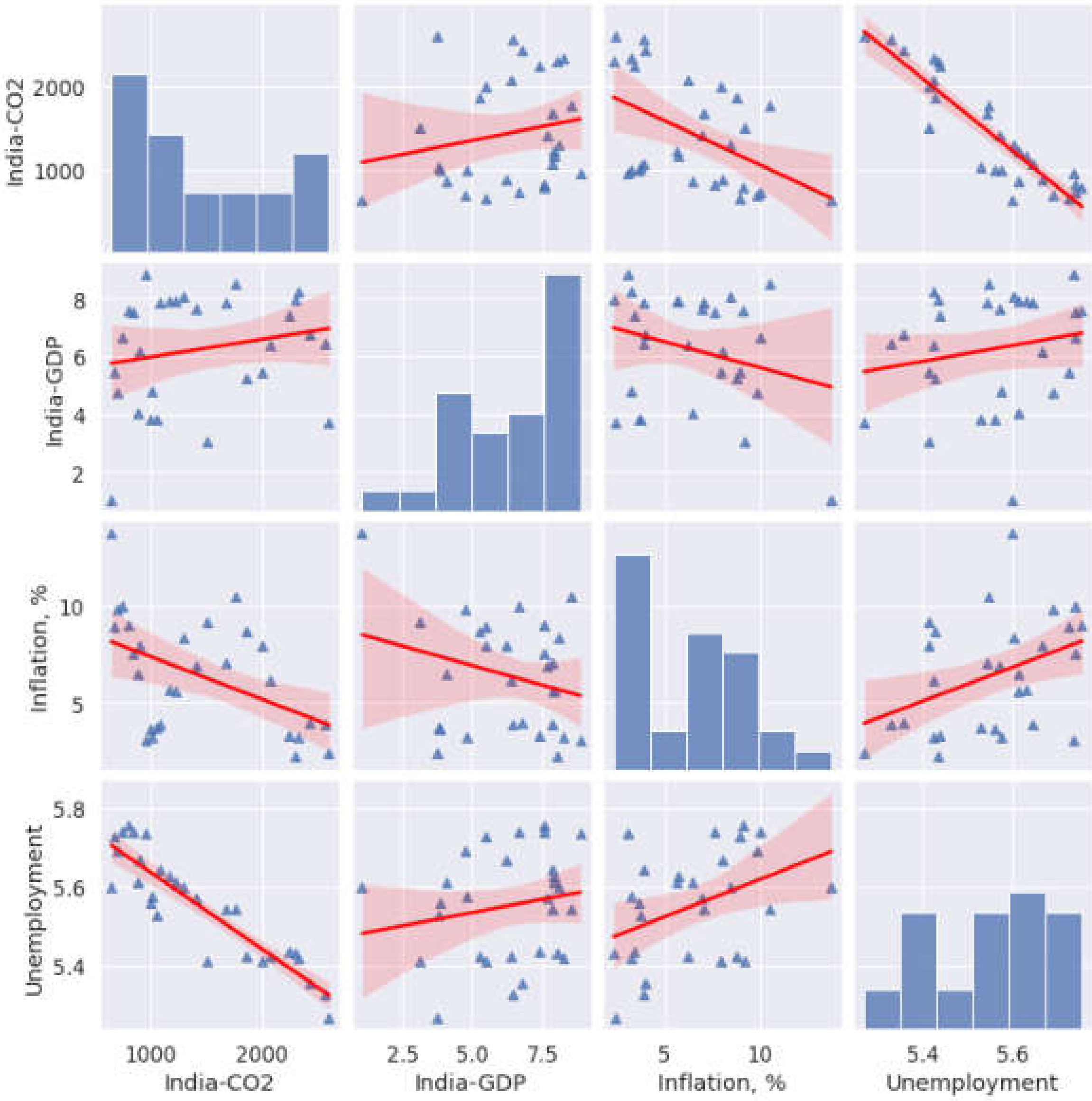


Fig 2: The matrix graph of the correlations between indicators

The formation of a correlation matrix allowed obtaining the following results, as shown in Figure 3:

1. Correlation between CO2 emission and GDP in India is 0.20
2. Correlation between CO2 emission and Inflation rate in India is -0.48
3. Correlation between CO2 emission and Unemployment rate in India is -0.91

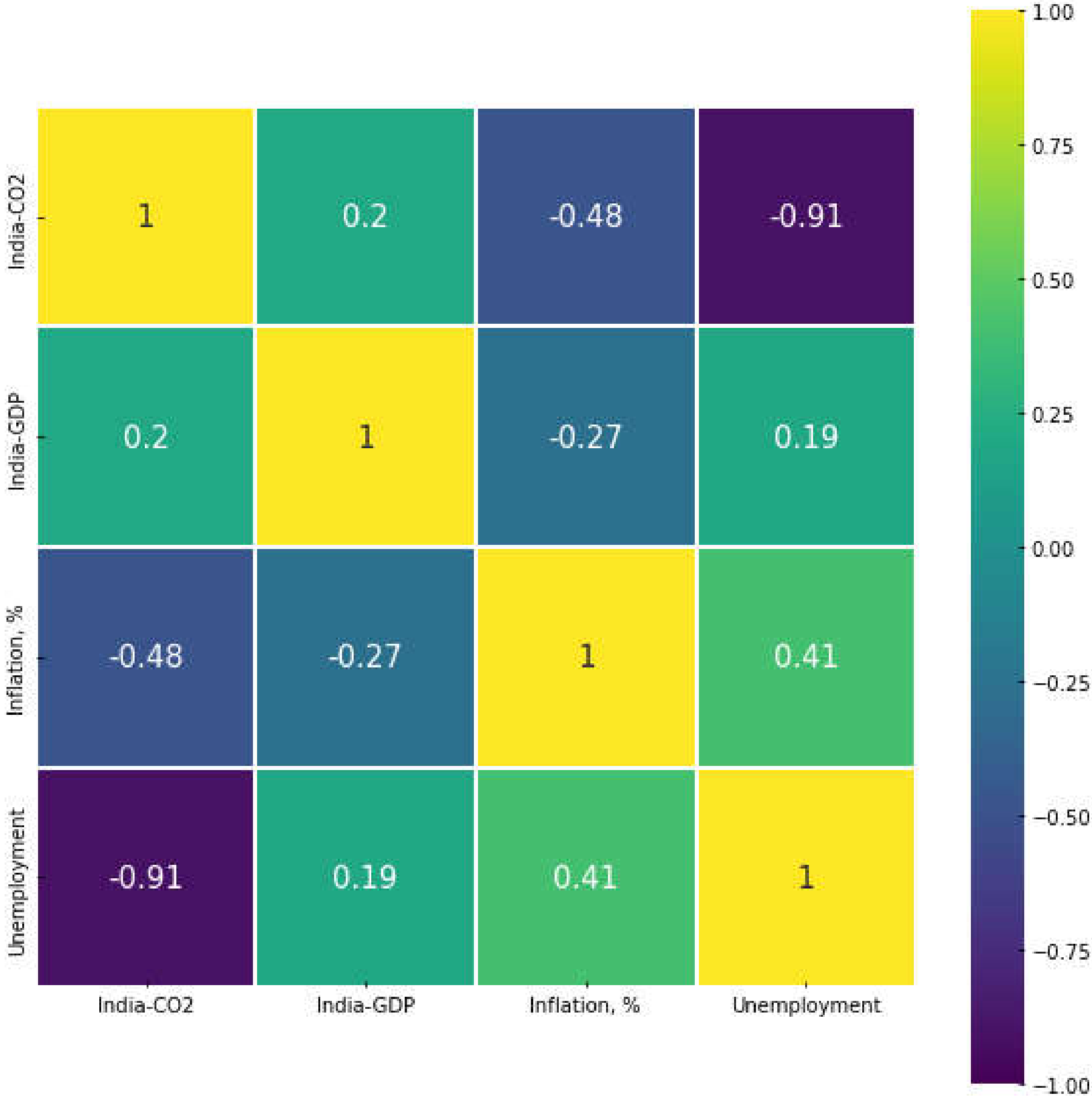


Fig 3: The correlation values between different indicators

The following empirical multiple regression equation can be obtained:

CO2 = 26657.82 + 131.42 GDP +7.103 INFLATION – 4698.97 UNEMPLOYMENT

Using the empirical relation, the actual and predicted CO2 emission can be represented as shown in Figure 4.

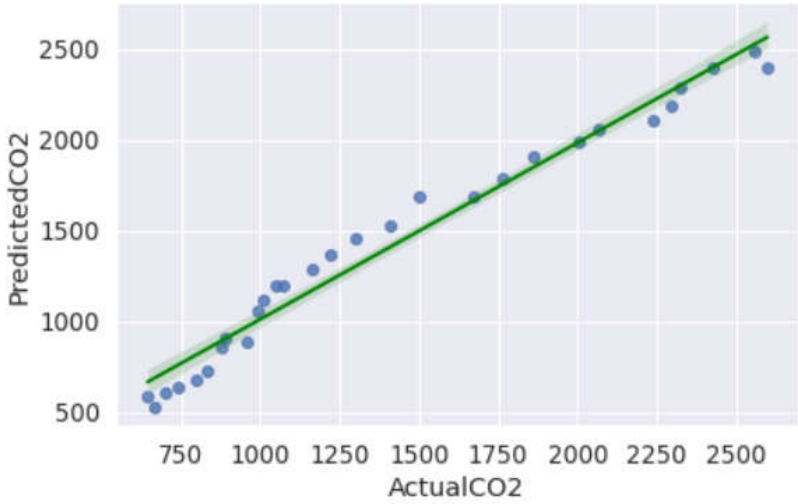


Fig 4: The actual and predicted CO2 emission

The predicted CO2 emission using the regression model has following characteristics:

$R^2 = 0.97$

Mean Absolute error = 88.86

Mean Square Error = 10822.17

Root mean Square Error = 104.029

F-test = 1.0282

p-value = 0.4709

The residual error of the proposed regression model is shown in Figure 5.

Fig 5: Residual error plot

Using the sample data and the analysis we can state that:

a) The Correlation between CO2 emission and GDP in India is comparatively low (0.2) hence hypothesis 1 (H1) is not so much recommended.

b) Correlation between CO2 emission and Inflation rate in India is -0.48. Hence hypothesis 2(H2) can be accepted fairly.

c) Hypothesis 3(H3) shows a strong recommendation as the correlation between CO2 emission and Unemployment rate in India is -0.91

The empirical multiple regression model can be acceptable (R^2 = 0.97, F-test = 1.0282 p-value = 0.4709).

5. Conclusion

In this paper, we have evaluated the relation between CO_2 emission and other socio-economic variable for India. The data is considered for the time period 1991-2019 and the major parameters for determining the CO2 emission are GDP, Unemployment rate and Inflation rate. As per data, it is seen that there is a strong correlation between carbon emission and unemployment rate whereas the correlation between GDP and carbon emission is fairly low for India. The multiple regression equation is considered to model the CO2 emission using the independent variables like GDP, unemployment rate and inflation rate; and the estimated CO2 emission shows satisfactory results in confirmation of the proposed regression model.

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