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Trend of global carbon emissions with special reference to economy, energy, finance, forest, urbanisation and trade openness: an analysis

Unmilan Kalita

Department of Economics, Gauhati University, Guwahati, India.

Abstract

Global warming coupled with a staggering level of greenhouse gas (GHG) emissions has pushed our planet to a brink of irreversibility. Concentration of atmospheric carbon dioxide (CO_2), one of the major GHGs, today is more than ever seen in 3 million years of human history. An elaborate play of multiple factors has led us to this situation so extreme and hazardous. This paper examines the relationship between CO_2 emissions and relevant factors using a multivariate linear and double-log regression model taking economic growth, energy consumption,forestcover, financial development, urbanisation and trade openness as variables across 55 countries with different levels of development. The findings indicate significant causal relationships between the factors, underlining crucial aspects that can majorly benefit climate change research and policymaking. Results emphasize the need to reverse the trend of increasing emissions while moving on to a phase of greener growth and healthier economic practices, based on unconventional energy sources and appropriate policy making.

Keywords : CO_2 emissions, economic growth, energy consumption, urbanisation, regression model

1. Introduction

When Ernest Hemingway celebrated the beauty of nature by writing “the Earth is a fine place and worth fighting for”, he would’ve never imagined the immense criticality of such a thought. Tensofdecades later, forests have turned into deserts,population has grown exponentially and the planet is 1.2^{0}C warmer compared to pre-industrial levels with significant irreversible consequences. Earth is gradually moving from a greenhouse phase to a hothouse phase,where climate in the long term will settle at 4-5^0 C above pre-industrial levels with a sea level rise of 10-60 m globally (Rockstrom, 2019). Simply put, economic development coupled with preservation of the environment is the biggest challenge humanity is facingtoday.

Environmental degradation, as indicated by the D = PAT equation, is caused by the combination of an existing and increasing very large human population (P), continuously increasing economic growth (A) and resource depletion with polluting technology (T) (Chertow, 2001; Huesemann and Huesemann, 2011). Carbon dioxide (CO_2), being a major green house gas (GHG) warming the earth, shares correlation with all the three variables. It now has been equivocally identified as a major pollutant (Edoja, 2016), accounting for more than 75% of GHG emissions (Abbasi and Riaz, 2016).

The present paper examines the impact of economic growth, energy consumption intensity, forest degradation, financial development, trade openness and urbanisation on CO_2 emissions across 55 nations of different levels of development selected on a random sample. To allow comparisons across countries, the statistical tables used are made with data standardized internationally, collected and treated by international agencies such as the World Bank and International Energy Agency (IEA).

2. Literaturereview

Literature in the context of this paper consists of research that spansonly the last three decades. Grossman and Krueger (1995) inferred that to obtain

Corresponding author : unmilan.k@gmail.com

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a high level of growth, a nation would require more inputs to magnify its outputs, leading to a rise in emissions along with waste generated through the process of economic activities. As such, CO_2 level in atmosphere has been rising since industrial revolution (Ayoade, 2003). Aslanidis and Iranzo (2009) undertook a study concerning 77 non-OECD nations concerning impact of per capita income on CO_2emissions. Farhani and Rejeb (2012), Chen and Huang (2014), Heidari *et. al* (2015) and Narayan & Narayan (2010) conducted similar studies. They found variable results, mostly GDP being strongly correlated to CO_2 emissions in the short run. Saidi and Hammami (2015) studied the effec to fenergy consumption on CO_2 emissions, thereby finding a good correlation. Shabaz *et. al* (2017) examined the relationship of trade openness on CO_2 emission finding that trade openness hampers environmental quality which however varies among nations. As such, studies have discussed the relationship between CO_2 emissions and economic growth or CO_2 and trade openness. However, anaggregated study concerning our given variable shasn't been observed to the best of our knowledge. This study intends to close such gaps. The study employs a simplistic approach towards providing a general understanding of the objective in question.

3. Objective

The present paper bears the objective of examining the impact and relationship between CO_2 emissions and other variables as mentioned in the introduction.

4. Methodology

The study employs a linear regression model and a Cobb-Douglas (double-log) regression model to conduct a cross-sectional analysis.

4.1 Definition of dependentvariable

Carbon dioxide (CO_2) is a colourless, odourless and non-poisonous gas formed by combustion of carbon and in the respiration of living organisms, and is considered a green house gas (OECD, 2013). CO_2 emissions refers to its or its precursors' release into the atmosphere over aspecifiedarea and period of time. CO_2 emissions in metric tons per capita has been taken as the dependentvariable.

4.2 Explanation of chosen explanatory variables:

4.2.1 Economicgrowth:

Gross Domestic Product (GDP) percapita at purchasing power parity (PPP $) is taken as proxyfor the status of economic growth of anation. GDP is defined as the sum of value added by all resident producers plus any product taxes (less subsidies) not included in the valuation of output. GDP per capita is GDP divided by mid-year population. GDPPPP$ implies the data being converted into a common currency which is allowed by PPP$. This makes statistics comparable acrosscountries.

4.2.2 Energyconsumptionintensity

Energy/Electricityconsumption percapita measures this. It is defined as the average kilowatt-hours (kWh) of electrical power consumed per person in a particular country (IEA, 2007).

4.2.3 Forest cover

this has been taken as forest cover as a percentage of land area.

4.2.4 Financial development

Domestic credit provided by financial sector (% of GDP) is taken as a proxy here. This is considered to study the general impact of credit on emission generation of reduction by industrialunits.

4.2.5 Urbanisation

This pertains to the percentage of urban population with respect to the total population of acountry.

4.2.6 Tradeopenness

It is the value of merch an disetrade (exports plus imports) as a % of GDP.

4.3 The Model

4.3.1. Assumptions on the regressionmodel

It is assumed that the explanatory variables wield significant influence on CO_2 emissions of nations. There lationship between the dependent and explanatory variables is assumed to be linear and subject to randomerror. Data for all nations was not readily available. We assume our sample of 55 countries is agood reflection of the over all globalscenario and that variables significant in our model will also apply to other nations aswell. Due to in consistencies with the data, values collected with respect to variables were inconsistent. However, data set is assumed to be appropriate given the unsophisticated nature of the study.

4.3.2 Model specification

4.3.2.1 The Linearmodel

COE = á + â1 (GDP) + â2 (ENR) + â3 (FOR) + â4 (FIN) + â5 (URB) + â6 (TRD) + ………..(i)

where, á is an intercept, â1, â2, â3, â4, â5, â6 are the regression coefficients of the explanatory variables and u is the random error term. The variable abbreviations are elaborated in table-1.

4.3.2.2 The Cobb-Douglas form (double-logmodel)

COE = a $(GDP)^{\hat{a}}1$ $(ENR)^{\hat{a}}2$ $(FOR)^{\hat{a}}3$ $(FIN)^{\hat{a}}4$ $(URB)^{\hat{a}}5$ $(TRD)^{\hat{a}}6$ ………..(ii)

Since the model (ii) is non-linear in the parameters, we log-transform it to obtain a linear regression model as below—

ln (LE) = ln a + â1 ln(GDP) + â2 ln(ENR) + â3 ln(FOR) + â4 ln(FIN) + â5 ln(URB) + â6 ln(TRD) + u……(iii)

= á + â1 ln(GDP) + â2 ln(ENR) + â3 ln(FOR) + â4 ln(FIN) + â5 ln(URB) + â6 ln(TRD) + u …..(iv)

where, á = ln a.

Thus, the model (iv) is linear in the parameters á, â1, â2, â3, â4, â5, â6.This model is also known as a log-log or double-log model.

Table-1 : Description of variables and expected signs of coefficients

	Variable name	Variable description	Expected impact
1	COE	CO_2 emissions per capita (Mt)	——
2	GDP	GDP (PPP $)	Positive
3	ENR	Energy consumption per capita (kWh)	Positive
4	FOR	Forest cover as % of total land area	Negative
5	FIN	Domestic credit to private sector (% ofGDP)	Negative
6	URB	Urban population as a % of totalpopulation	Positive
7	TRD	Trade as a % of GDP	Positive

4.3 Materials and Methods

● *Secondary research & data collection:* The models undertaken were estimated using international cross-sectional data of 55 countries. The basic criterion for choice was their relevant data being readily available. Data has been obtained from the World Bank, IRENA, IEA, OECD and United Nations websites, the links to which have been mentioned in the references. Datasets pertain to the year 2018, except that of forest cover which is for 2014. It is to be noted that estimates that are found through secondary research often understate the actual problems & statistics related to the study.

● *Model* : Two linear models were separately used for the analysis - a linear regression model (i) and a double-log regression model (iv).

● *Software:* To perform the analysis, statistical software IBM SPSS v23.0 & Microsoft Excel, 2016 wereused.

1. Result and discussion

The significance of variables in the present study, after regression analysis, has been reported inTable-2. Estimated coefficients of GDP, ENR, FOR, FIN, URB and TRD in both the models have expected signs. The estimated ENR, FOR and URB variables turned out to be statistically significant in the linear model while all the explanatory variables, except TRD, has turned out to be significant in the double-logmodel.

Table-2 : Results of regression analysis

SL. No.	Linear model		Double Log model	
	Variables	Estimated Coefficients (standard error) {p value}	Variables	Estimated coefficients (standard error) {p value}
1.	Constant	1.607 (1.289) {0.219}	Constant	0.00*** (11.669) {0.000}
2.	GDP	2.928 (0.00) {0.397}	ln GDP	0.494*** (4.052) {0.000}
3.	ENR	0.001*** (0.542) {0.00}	ln ENR	0.247** (2.296) {0.026}
4.	FOR	- 0.040** (0.158) {0.020}	ln FOR	- 0.110* (-1.985) {0.053}
5.	FIN	0.007 (0.063) {0.443}	ln FIN	0.165** (0.102) {0.017}
6.	URB	0.065*** (0.263) {0.009}	ln URB	0.766** (2.360) {0.022}
7.	TRD	0.005 (0.049) {0.565}	ln TRD	0.182 (0.061) {0.228}
	R^2 **F** **df**	0.809 33.825*** 6	R^2 **F** **df**	0.894 67.352*** 6

Note:

- Figures within ( ) and { } indicate standard error (SE) and p (sig) valuesrespectively.
- ***, ** and * indicate that the estimated coefficients and test statistic are statistically significant at 1, 5 and 10 percent levelsrespectively.

The estimated linear model can explain 80.9% variations in COE in the study. Although the goodness of fit is moderately high, only 3 variables out of 6 exert significance with respect to CO_2 emissions. A few discrepancies may also exist within the data set. On the other hand, the double-log model explains 89.4% of the variations. Following are some of the most important inferences that can be drawn from the results obtained during our study:

- The ENR variable is highly significant and the coefficient is positive in both models. This invariably underlines the prevalent concept that energy consumption and CO_2 emission are positively related. Thus, greater the energy consumption on an individual level, more is the emission of CO_2 into the atmosphere. Generation of electricity at present comprises basically of thermal power plants that use coal and fossil fuels to meet energy demand. Factually, sources of electricity include coal and peat (38.3%), natural gas (23.1%), hydroelectric 16.6 (%), nuclear power (10.4%),oil(3.7%) and renewable energy (5.3%) and waste (2.3%). Evidently a greater proportion of electricity is generated by conventional sources which in turn form the greatest source of CO_2generation.

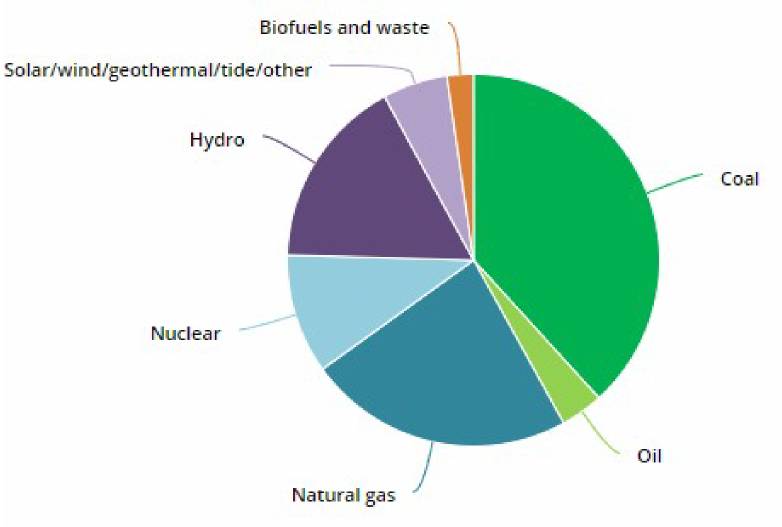

Fig. 1 : Sources of global energy production

Source : Electricity Statistics, IEA

In 2018, CO_2 emissions from global energy rose to 33.1 Gt CO_2 by 1.7% from last year (IEA, 2019). Emissions from all fossil fuels have increased along with the power sector accounting for almost two-thirds of the growth. Use of coal sources have increased in Asia with China and India along with USA accounting for nearly 85% net increase inemissions.

Therefore, as the results succesfully establish, there is a positive and highly significant relationship between global energy consumption and CO_2 emissions.

- The coefficient for GDP is positive in both models. However, the value is highly significant in the double-log model only. Such a result substantiates the assumption that economic growth has a direct relationship with CO_2 emissions. Historically, CO_2 emissions have been driven by economic growth. This is the most fundamental proposition continually proven by economists worldwide.

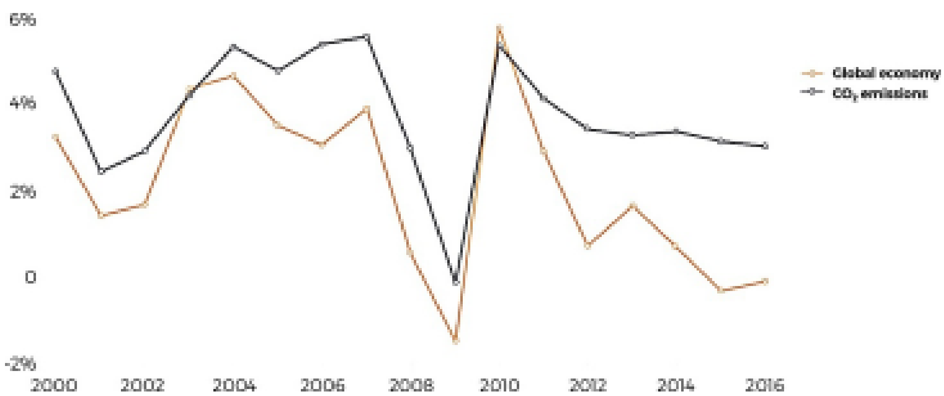

Fig. 2 : CO_2 emissions and global economy growth rates

Source : World Energy Outlook, 2018

Figure- 2 appropriately depicts this positive relationship. Economic growth induces expansion of industries which are in turn fossil fuel-intensive. This leads to a vicious process of emitting GHGs indiscriminately, that accumulate in the atmosphere. Notably, CO_2 has a longer lifetime than most other GHGs. Also, economic growth aligns itself with deforestation, desertification, extraction of fossil fuels and unsustainable land use. These activities undeniably contribute to CO_2 emissions. Hence, the double-log model successfully captures this relationship in our study.

- The coefficient of FOR is negative in both models and also significant. This clearly proves that a decline in forest cover will result in more CO_2 emissions. Global forest cover is dwindling day by day with tropical countries struggling to curb emissions. Deforestation not only indicates population rise but also rise in deployment of plantation crops like soy and oil palm. Rising issues of food securityplays a huge role here. Wetlands contain a substantial amount of CO_2 and bringing them under cultivation leads to its release. Forest cover is so crucial that restoring and improving forestry practices could remove 7 billion metric tons of CO_2 annually, similar to eliminating 1.5 billion cars- more than all the cars in the world today (WRI, 2017). For instance, if robustly aligned and expanded, Indonesia's forest moratorium could help it avoid 427 million metric tons of CO_2 emissions by 2030 (WRI, 2017).
- The FIN coefficient has surprisingly turned out positive with a significant presencein the double-log model. This contradicts the underlying objective in the study that greater credit to private sector enables them to employ better technologies and sustainable practices, thereby reducing CO_2 emissions. Credit incentives for private sector is a cruciala spect of climate-conducive policy making. As such, there should be a resulting negative correlation between CO_2 emissions and credit. The result arrived possibly indicates discrepancies in the dataset or vagueness of the proxy variable to represent the intended idea. The models should be reformulated to avoid remove this defect.
- Urbanisation coefficient indicates a positive relationship with CO_2 emissions while also being statistically significant in both models. This is a result of substantial importance in accordance with literature. Urban areas are highly energy intensive (industrial manufacturing, transportation, etc) and are mainly fossil fuel-driven. This factor is majorly significant in case of developing and less developed nations. For instance, an industrialised China heavily relying on coal-fired power to day emitsmore CO_2 than USA and European Union combined. Making things even grim, Asia's average annual growth rate of CO_2 emissions is nearly triple the global average. Urbanisation in this unabated growth is a major by-product.

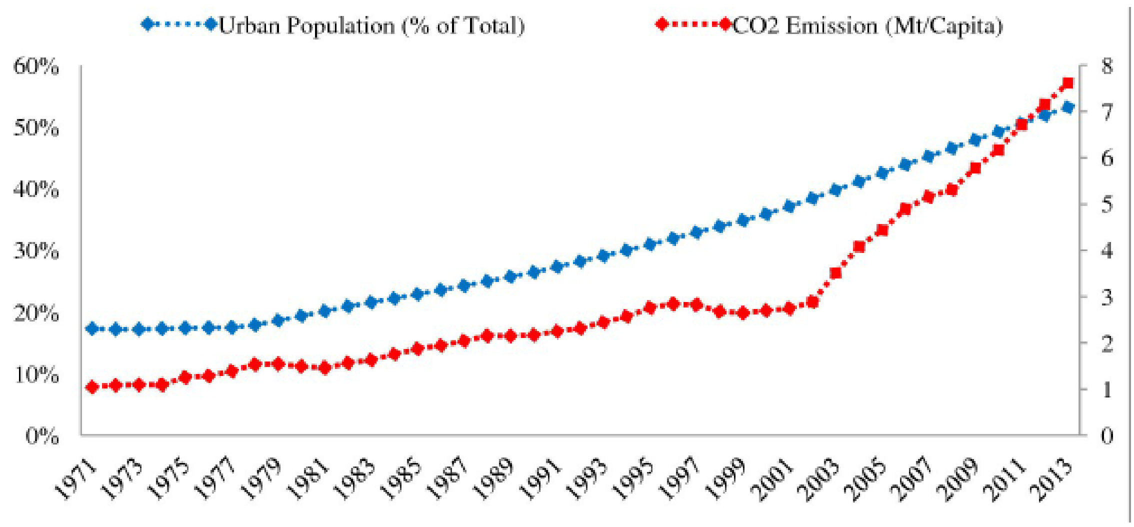

Fig. 3: Trends in China's rate of urbanisation and its CO2 emissions

Source: Forbes Magazine, July, 2018.

Undeniably, there's a positive trend between both the variables in the model which is successfully shown.

- The coefficient for TRD has turned out positive as expected but doesn't show any significant impact on CO_2 emissions. This is in line with the environment- development debate wherein a section believes trade openness to be a significant driver of CO_2 emissions while the other denies it unanimously. The underlying notion of including this variable was just to check whether trade and CO_2emissions have a working relationship and if it is strong enough. As expected, there is a positive correlation between both, albeit a weak one.

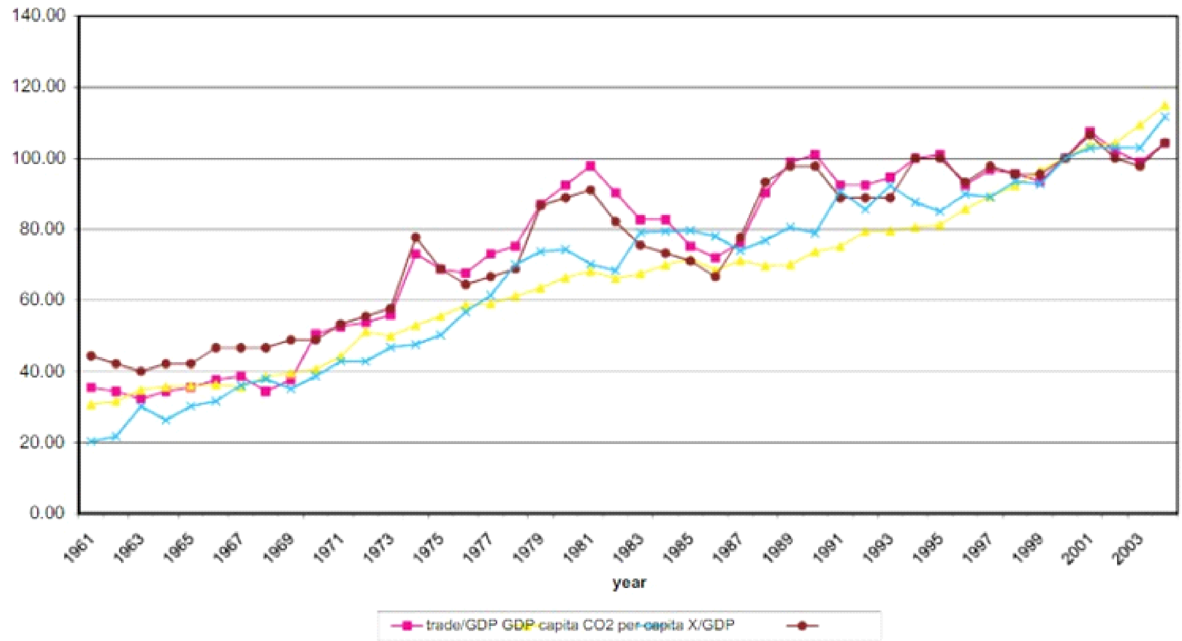

Fig. 4 : Relationship between international trade and CO_2 emissions

Source: World Development Indicators, World Bank

Figure- 4 represents the relationship on a global level. A positive and a strong trend can be witnessed. As such, our model has remained unsuccessful in indicating the significant influence trade openness inflicts upon CO_2 emissions. The model needs to be further revised to study this relationship.

- The intercept term is statistically insignificant in the linear model implying that it has no such impact upon the dependent variable. Relevant variables have thus been accounted for in the model. However, the constant is highly significant in the double- log model. As such, the model needs to be reformulated so that existing discrepancies can be removed and relevant variables are accounted for.

Finally, to ensure that the goodness of fit of the models are not due entirely to the number of factors we chose to use and to verify mentioned discrepancies, the regression models must be refined and speculated on.

1. Conclusion

A recent PNAS publication by interdisciplinary Earth scientists concluded that the problem of climate change may be far worse than what we have been thinking (Steffen et al, 2018). It warns that even if GHG emissions are reduced heavily in line with below 2^0 C goal of Paris Summit (COP21), the phenomenon of *hothouse earth* seems inevitable. To avoid this, humanity must reduce emissions to net zero by 2050. Such a scenario is unrealistic. CO_2emissions or GHGs in totality are an inevitable side-effect of development. What is more crucial, is to acknowledge the risks and move on to sustainable and greener technologies. As our study implies, the answer lies in greener economic growth, greater energy consumption from sustainable sources, improving forestry practices, incentivising investment in greener technology and strengthening international cooperation. This will certainly result in a sustainable urban society and healthier trade practices conducive to well-being of our environment and ensure existence of humanity as we know.

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