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MODELLING AND FORECASTING ENERGY CONSUMPTION AND CARBON DIOXIDE EMISSIONS IN INDIA

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Abstract

The study explores to analyze the relationship between carbon dioxide emissions and energy use consumption per capita in India for the time frame, 1970 to 2016. For this purpose, the time series econometric tools are employed to select an appropriate model for forecasting. The predicted values for carbon dioxide emissions as well as energy consumption per capita are computed for 2017 till 2024 respectively. The future trends of these variables for India strongly indicates the upsurge in both emissions and energy consumption. This calls for an urgent action plan by policy makers for sustainability in the near future both at local and global arena.

Keywords:

Carbon dioxide emissions;

Forecasting;

Auto Regressive model;

Sustainability ;

Energy Consumption.

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1. Introduction

India embarked on the adoption of economic reforms in 1991 under the recommendations of International Monetary Fund and Washington Consensus. The reforms comprised of structural and stabilization policies related to liberalization and globalization. The gradual openness of the economy initiated social transformation. The metamorphosis is reflected across the urban and rural spheres of the society. The growing and uprising urbanization as a consequence of rapid dynamism in India have resulted in tripling of energy consumption from 191 million tons of oil equivalent in 1991 to 595 million tons in 2013 at a compounded annual growth rate (CAGR) of 5.3%.

India's energy mix is primarily fossil-fuel driven, with coal accounting for 54.5% followed by oil with a 29.4% share in the total energy consumption in 2013. The existing commitment of reduction from 20% to 25 % during 2005-2020 is further enhanced in the Paris Climate Change Agreement, where India committed to reducing the emissions intensity of its gross domestic product by 33–35% during 2005–2030. The National Action Plan on Climate Change initiated National Missions to make a sincere effort to balance development objectives. However the social, rural and urban commitments fail to meet the target. The issue of global warming, melting of polar ice caps, rising sea levels and subsequent damage to natural eco systems ar the reflections of climate change. The substantial rise in atmospheric concentrations of carbon dioxide , methane , nitrous oxide have gradually made the matters worse.

This purpose of this paper is to explore the relationship between CO_2 emissions and energy use consumption per capita in India. The study aims to predict the future trends of CO_2 emission and energy consumption per capita in India.

For this purpose, the study applies time series econometric methodology for the annual data on CO_2 emissions from 1970 to 2016 in India. The current study forecast the future trends till 2024. The existing literature portays ceretain insights on the trends regarding carbon dioxide emissions and its after effects.

Climate change as a result of global warming has become one of the most important issues in the recent years. Reddy *et al*. (1995) shows that global mean temperature will also rise to 3˚C - 4˚C with doubling of the CO_2 concentration In 2007, the Intergovernmental Panel on Climate Change reported that there would be an estimated rise in the average global temperature between 1.1˚C and 6.4˚C within the next 100 years Lau *et al*. (2009) shows that a meager 2˚C increase in temperature would greatly hamper many ecosystems and would cause an increase in the sea-level that would adversely impact the lives of people living in coastal zones.

The developed countries have a much higher share in global emissions than the developing ones. Nebojsa (1994) studied the perspectives of GHG emission on a regional basis. He stated that the developing countries are responsible for less than 16% of the CO_2 concentration due to their past consumption of fossil energy.

According to International Energy Agency (2018), India emitted 2299 million tones of carbon dioxide , which is even higher than China and United States due to rise in coal consumption.
This motivates the study to focus on the environmental concerns. The quantum growth in GDP is the perennial agenda of the policy makers . However, quality growth should be tailored to cater the needs of sustainable environment. This paper is expected to project the areas of concern.

2. Research Method

a) Data

The study is based on the annual data on carbon dioxide emissions per capita and energy consumption per capita for the time frame, 1970-2016. The data is collected from World Development Indicators, published by World Bank.

Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring. The source refers to Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States. Energy use refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport. The source refers to IEA Statistics.

b) Methodology

This study applies the forecasting technique applied in time-series econometrics. One such forecasting technique is ARIMA model.

ARIMA is one of the most traditional methods of non-stationary time series analysis. In contrast to the regression models, the ARIMA model allows time s to be explained by its past or lagged values and stochastic error terms. The models developed by this approach are usually called ARIMA models because they use a combination of autoregressive (AR), integration (I) - referring to the reverse process of differencing to produce the forecast and moving average (MA) operations.

The ARIMA model is denoted by ARIMA (p , d , q), where "p" stands for the order of the auto regressive process, "d" is the order of the data stationary and "q" is the order of the moving average process.

3. Results and Analysis

The empirical findings are reported and analysed below as per the steps in Box-Jenkins Methodology.

To estimate the model, firstly, the stationarity properties of each variable need to be explored. The following table reports the findings :

Table 1. Unit Root Test Results

Tests ***Variables***	***Augmented Dicky Fuller Test***		***Phillips-Perron Test***	
	At Levels (p-value)	***At First Differences (p-value)***	***At Levels (p-value)***	***At First Differences (p-value)***
CO_2 Emissions	*-0.24 (0.99)*	*-5.26 (0.00)*	*-0.54 (0.00)*	*-5.43 (0.00)*
Energy Consumption per capita	*-0.32 (0.54)*	*-5.47 (0.00)*	*-0.48 (0.84)*	*-6.75 (0.00)*

The above table shows that both the variables are level non-stationary but they are first difference stationary. They are integrated of order one. Secondly, the selection of the model is based on the order of auto regressive moving average structure (ARMA). However, both the variables are integrated of order one .

Hence, the appropriate modeling will be Auto Regressive Integrated Moving Average (ARIMA).

The order of AR or MA process will be selected on the basis of minimum Akaike Information Criterion or Schwartz Information Criterion in case of the variable, carbon-dioxide emissions, as stated in the table below :

Table 2. Selection of the Model for estimating CO2 Emissions

Order of ARIMA process	**Schwatrz Criterion(SIC)**	**Akaike Information Criterion**
ARIMA(1,1,0)	-3.65	-3.73
ARIMA(0,1,1)	-3.66	-3.74
ARIMA(1,1,1)	**-3.82**	**-3.94**
ARIMA(2,1,0)	-3.67	-3.75
ARIMA (0,1,2)	-3.70	-3.78
ARIMA(2,1,1)	-3.58	-3.71
ARIMA(2,1,2)	-3.63	-3.76
ARIMA(3,1,0)	-3.54	-3.58
ARIMA(3,1,2)	-3.67	-3.72
ARIMA(0,1,3)	-3.62	-3.66
ARIMA(3,1,3)	-3.48	-3.76

The above table confirms the acceptance of ARIMA(1,1,1) due to the minimum values of SIC and AIC criterion. The study is further extended to check the residual diagnostics.

The residuals confirm the absence of serial correlation or autocorrelation in errors. The F-statistic is 0.313 (p-value = 0.45). Moreover the result confirms the absence of heteroscedasticity .

In the similar manner, the appropriate estimation model is decided on the basis of selection criterion for the variable, energy consumption per capita.

Table 3. Selection of the Model for estimating Energy use consumption per capita

Order of ARIMA process	**Schwatrz Criterion(SIC)**	**Akaike Information Criterion**
ARIMA(1,1,0)	7.02	7.10
ARIMA(0,1,1)	7.11	7.19
ARIMA(1,1,1)	**6.78**	**6.90**
ARIMA(2,1,0)	6.86	6.94
ARIMA (0,1,2)	6.93	7.01
ARIMA(2,1,1)	6.97	7.11
ARIMA(2,1,2)	6.90	7.03
ARIMA(3,1,0)	6.94	7.02
ARIMA(3,1,2)	6.97	7.09
ARIMA(0,1,3)	6.85	7.12
ARIMA(3,1,3)	6.92	7.05

The above table confirms that the selected model is ARIMA(1,1,1), where both SIC and AIC are minimum among the other values. The residuals confirm the absence of serial correlation or autocorrelation in errors. The F- statistic is 0.313 (p-value = 0.45). Moreover the result confirms the absence of heteroscedasticity .In case of carbon-dioxide emissions, the forecasted values are computed based on the dynamic forecast method. In the similar manner, the forecasted values are computed for energy use consumption per capita.

Table 4. Forecasted values of CO_2 Emissions and Energy use consumption per capita

Variables / ***Year***	***Carbon dioxide Emissions (metric tons per capita)***	***Energy use consumption per capita (kg of oil equivalent per capita)***
2017	*1.97*	*660.53*
2018	*2.03*	*670.69*
2019	*2.09*	*680.85*
2020	*2.16*	*691.02*
2021	*2.22*	*701.18*
2022	*2.29*	*711.35*
2023	*2.36*	*721.52*
2024	*2.43*	*731.69*

The above findings strongly reveal that the level of carbon dioxide emissions and energy consumption levels are on an increasing trend. This is an alarming issue for India in the near future. Despite having the potential of high impressive growth in GDP, the policy makers should focus on environmental concerns. The trends in forecast can be represented in the following figures .

Figure 1 : Forecast Trend for CO2 Emissions

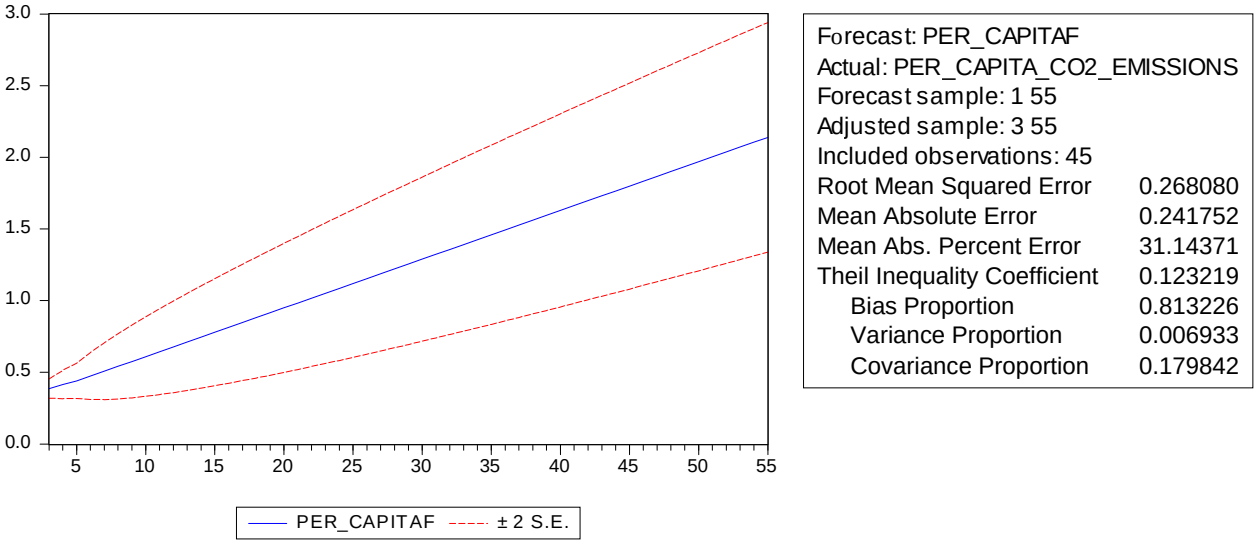
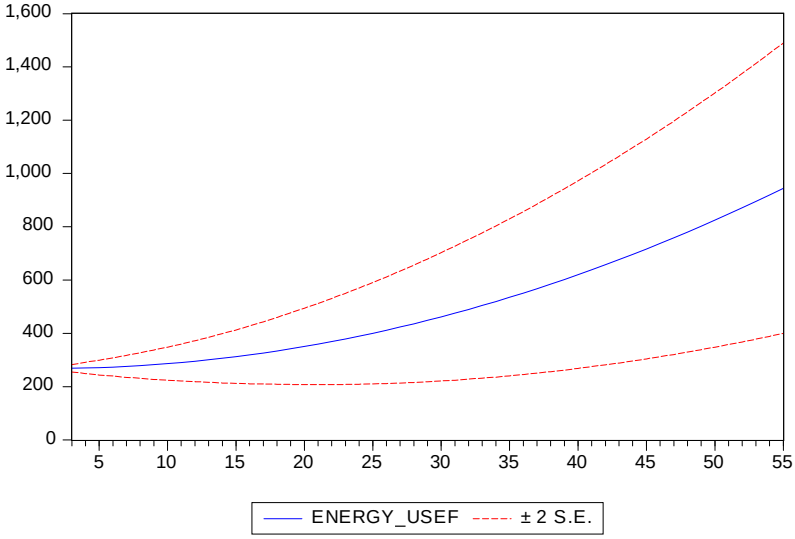


Figure 2 :Forecast Trend for Energy use consumption per capita



Forecast: ENERGY_USEF	
Actual: ENERGY_USE__PER_CAPITA	
Forecast sample: 1 55	
Adjusted sample: 3 55	
Included observations: 43	
Root Mean Squared Error	52.56388
Mean Absolute Error	37.25006
Mean Abs. Percent Error	8.081702
Theil Inequality Coefficient	0.061929
Bias Proportion	0.482076
Variance Proportion	0.416843
Covariance Proportion	0.101081

4. Conclusion

The study infers that for India, the level of both the concerned variables are on the rising trend. This paper aimed to model the emission of carbon dioxide during 1970 to 2016 in India by Autoregressive Integrated Moving Average (ARIMA) approach. On basis of results obtained, it is concluded that ARIMA (1,1,1) model having minimum value of all measures of selection criteria was found to be the appropriate model amongst all for predicting the carbon dioxide emission in India. The model showed a good performance in case of explaining variability in the data series and, it's predicting ability.

Using the model, ARIMA(1,1,1) for energy use consumption per capita, the forecasted values are computed. The prediction trends confirm the upward movement in the values.

The policy makers must be proactive in devising strategies for reduction in CO2 emissions in the near future. The forecasted values call for an urgent action plan.

References

[1] Reddy, V.R., Reddy, K.R. and Acock, B., "Carbondioxide and Temperature Interactions on Stem Extension, Node Initiation and Fruiting in Cotton", *Agricul-ture, Ecosystems* & *Environment,* vol. 55, pp. 17-28, 1995.

[2] Lau, L.C., Tan, K.T., Lee, K.T. and Mohamed, A.R., "A Comparative Study of the Energy Policies in Japan and Malaysia in Fulfilling Their Nations Obligations towards the Kyoto Protocol", *Energy Policy*, vol. 37, pp. 4771-4780, 2009.

[3] Nebojsa, N., "Energy Strategies for Mitigating Global Change. Technology Responses to Global Environmental Challenges", *OECD/IEA,* Paris, pp. 449-459, 1994.

[4] IEA, "Climate Change Indicators in the United States: Global Greenhouse Gas Emissions", 2018.

[5] World Development Indicators, World Bank.