CO_2 EMISSIONS FROM PAKISTAN AND INDIA AND THEIR RELATIONSHIP WITH ECONOMIC VARIABLES

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(Received 10th May 2017; accepted 22nd Jul 2017)

Abstract. The rapid increase in CO_2 emissions has been a hot topic for whole world because of their major contribution to greenhouse gases (GHG) which is an ultimate cause of global warming. This study analyses spatially gridded data from EDGAR (Emissions Database for Global Atmospheric Research) and linear relationship using multiple linear regression model between CO_2 emissions and four economic variables (energy use, urban population, gross capital formation and GDP at market prices) for Pakistan and India. Additionally, four major tools (f-test, t-test, time series analysis, and prediction errors) are used for the purpose of investigating linear relationship and efficiency of the model. EDGAR data shows that about 200 teragram CO_2 has been emitted from Indo-Gangatic plain. Analysis revealed that the most effective predictor for both the Pakistan and India is energy use. The value of f-stat and t-stat showed that the economic variables have joint and individual significance for the regression model at $p<0.05$. Time series revealed that CO_2 emissions increased gradually from 1971 to 2011. Error analysis indicated that regression model for Pakistan is more efficient than that of India. New policies can be devised and decisions can be taken on the basis of information given by this paper.
Keywords: *GHG, Energy use, EDGAR, prediction errors*

Introduction

Economic activities have been increased in the world since the last century. These activities not only promoted the countries in economic development but made an immense increase in CO_2 emissions also. Human activities are adding over 29 billion tons of CO_2 to the environment each year (Goodal, 2007). Contribution of CO_2 to the total greenhouse gases (GHG) is reported to be 58.8% (World Bank, 2007). This rapid increase in CO_2 is so dangerous that it can lead to the severe situations like storms, flood, and other environmental calamities. CO_2 emissions have also caused the sea level to rise to 10-20 cm (Mukhtar, 2004).

It has been noted that due to 30% overall increase in CO_2, the global temperature has also risen by 32.54-33.08 °F (Spence, 2005). There are also some other elements which are contributing to the drastic environmental changes i.e. population, transportation, economic growth, energy consumption and industrial activities (Abdullah, 2015).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1504_13011312

Numerous researches have been conducted to study the relationship among these variables, which clearly indicate the importance of the topic for the whole world (Moran and Gonzalez, 2006; Lozano and Gutierrez, 2007; Ang, 2009; Su et al., 2009; Freitas and Kaneko, 2011; Keat et al., 2015). Bi-variate and multi-variate methods have been used by numbers of researchers to study the relationship between CO_2 and economic variables (Abdullah, 2015).

Four variables; CO_2, population, gross domestic product (GDP), and energy consumption, have been used by Lozano and Gutierrez (2007) through a non-parametric frontier approach to investigate the association between these variables for USA. The study finds a positive relationship between the estimated variables. Moran and Gonzalez (2006) used the methods of linear programming to find the major productive linkage between CO_2 emissions and human activities. This study also found a direct relationship between the variables. Freitas and Kaneko (2011) studied the links between CO_2 emissions and economic growth in Brazil. They concluded that energy intensity, economic activity and demographic pressure increase the emissions. Data for more than 50 years was used by Ang (2009) in order to explore the determinants of CO_2 emissions for China. This study reported a negative relationship between CO_2, research intensity, technical transfer and absorptive capacity in china. On the other hand, a positive relationship was found between energy use, high income, trade openness and CO_2 emissions. Numbers of studies have been conducted to test the comparative relationship of CO_2 emissions and economic variables. Su et al. (2009) used the data of China and Singapore to study the relationship of CO_2 emission and trade. The study concluded that in 40 sectors export is positively correlated with carbon emissions. Martinez and Maruotti (2011) applied STIRPAT model for 88 developing countries from 1975 to 2003 in order to investigate the relationship of CO_2 and urbanization, which showed an inverted U shaped relationship of concerned variables, which means positive relationship existed between urbanization and carbon emissions at 10% level. Aqeel and Butt (2001) determined that the energy consumption is the determinant of economic growth for Pakistan. Energy consumption and pollution has positive relationship for both long and short term (Shahbaz et al., 2010). In an analysis, Keat et al. (2015) examined the correlation between petroleum products and CO_2 emissions by using multiple linear regression model. They found high correlation value (R^2 = 0.9544) among the variables. Mohiuddin et al. (2016) found positive relationship of CO_2 emissions with three parameters i.e. energy consumption (EC), GDP, and electricity production from oil, coal and natural gas over Pakistan.

The trend of carbon dioxide emissions is rising alarmingly in South Asian countries (i.e. India, Pakistan, Bangladesh, Sri Lanka and Nepal) (Sarker et al., 2013). Due to rapid increase in urbanization and industrialization, Pakistan and India are experiencing high amounts of greenhouse gases and air pollutants. Several studies, employing different techniques such as satellite and ground based remote sensing, and *in situ* measurements, have been conducted to monitor greenhouse gases and air pollutants over the sub-continent (Ali et al., 2014; Tariq and Ali, 2015; Tariq et al., 2015; Tariq et al., 2016; Ul-haq, 2014; Ul-Haq, 2015a; 2015b; 2015c; 2015d; Badarinath, 2009). Ang (2009) focused on China, a growing economy, and found that an increase in energy use and trade intensity contributes to higher CO_2 emissions in china. However, in this paper an effort has been made to find the relationship of CO_2 emissions with four economic variables (energy use, urban population, gross capital formation and GDP at market price) over two south Asian countries. Only those economic variables have been

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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considered that are significant ($p<0.05$) determinant of CO_2 emissions in both Pakistan and India. To the best of our knowledge no study has so far been conducted to estimate linear relationship between CO_2 emissions and economic indicators of energy use, urban population, gross capital formation, and GDP at market price for Pakistan and India. The focus of this study is to investigate the relationship between CO_2 emission and the four economic variables for Pakistan and India.

Materials and Methods

Datasets

To investigate spatial distribution of CO_2 emissions we used total CO_2 emissions from EDGAR (Emissions Database for Global Atmospheric Research) version 4.2 data over Pakistan and India during the period 1970-2008. EDGER is a globally gridded database of anthropogenic emissions of greenhouse gases and air pollutants from all the sectors. Same type of economic variables was taken for both the countries for the purpose of easy comparison. Data of CO_2 emissions and four economic variables (energy use, urban population, gross capital formation and GDP at market prices) is sourced from the world data indicator (World Bank, 2016). Data of all the variables were obtained from 1971 to 2011 for both the countries.

Linear relationship of predictors and response variables

Multiple linear regression (MLR) model is used to study linear relationships between the variables. To get interdependencies for a given dataset, the model is widely used to describe the link between the response and predictor variables (Keat et al., 2015). Multiple regressions analysis is most common tool being used in the field of sciences for understanding the results (Courville et al., 2001; Nimon et al., 2010; Zientek et al., 2008).

MLR model is called linear because it forms a straight line when plotted over graph. The functional form of Simple Linear Regression (SLR) is usually written as follows:

$$Y = m + bX \quad \text{(Eq.1)}$$

where Y is a dependent or response variable for a selected value of X. m represents the Y-intercept and b is a slope of the line. The above equation shows the relationship between one response and one predictor variable. However, there may be a situation in which we need to investigate the relationship of one response variable with multiple predictors. For such kind of relationship MLR model can be used. MLR model is used when we have to study the relationship between one response and several predictors. In MLR model the additional predictor variables (denoted by X1, X2, X3, …., and so on) are used to study the relationship between a dependent and multi independent variables. The general form of MLR equation is:

$$Y = \mathrm{m} + \mathrm{n1X1} + \mathrm{n2X2} + \mathrm{n3X3} + \cdots..\mathrm{nkXk} \quad \text{(Eq.2)}$$

where m is the Y-intercept and k is any positive integer which is used to represent numbers of predictors in MLR equation. “n_k” is the slope of Y i.e a unit change in n_k with the corresponding change in Y.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1504_13011312

Analysis and Results

In order to understand the spatial distribution of CO_2 emissions, we have plotted total CO_2 emissions (see *Figure 1*) from EDGAR data over Pakistan and India during the period 1970-2008. It can be observed from the *Figure 1* that high amounts (about 200 terra gram) of CO_2 have been emitted from Indo-gangatic plain (in north and north eastern parts of India) during the period 1970 to 2008. These high emissions are due to rapidly growing urbanization, industrialization, economic activities and biomass burning. It can further be noted that north eastern parts of Pakistan and almost entire India have emitted almost 20 terra gram of CO_2 in the period from 1970 to 2008.

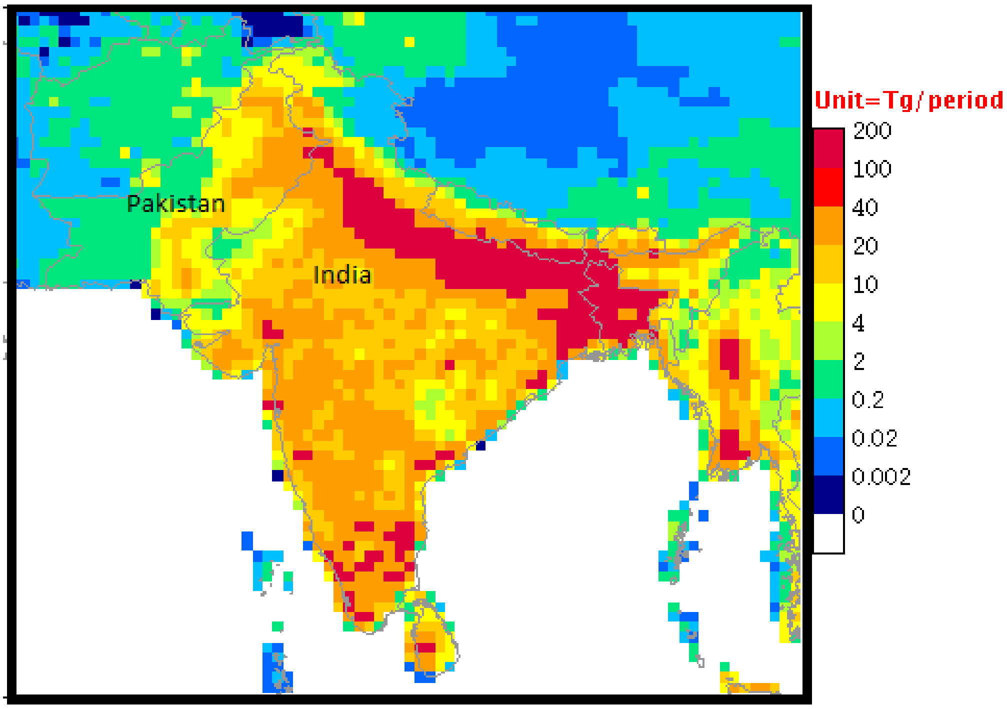

Figure 1. *Spatial distribution of total CO_2 emissions over Pakistan and India in the period 1970-2008.*

Data of CO_2 emissions and economic variables of two developing countries i.e Pakistan and India have been taken for the purpose of studying the linear relationship among them. Data for CO_2 emissions and economic variables have been considered for the period 1971 to 2011 for both the countries. Same type of economic variables was taken for both the countries for the purpose of easy comparison. Data for both dependent and independent variables have been taken from the official website of World Bank (World Bank, 2016). Predictors for Pakistan as well as for India data are energy use, urban population, gross capital formation, GDP at market prices, which are represented as E1, U1, C1, and G1 respectively for Pakistan, whereas the variables for India data are denoted by E2, U2, C2, and G2 respectively. CO_2 emission is a dependent variable which is denoted by Y1 for Pakistan and by Y2 for India. For study purpose the analysis section is divided into four parts which are explained below.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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Excluded predictors

The four predictors that were considered for regression analysis for both India and Pakistan have been shown in the *Tables 1 and 2*. Tables show all the predictors with their corresponding t-values and p-values for Pakistan and India. Regression coefficient analysis shows that all predictors for Pakistan are significant and therefore included in full model because they are significant at 95% level because probability of acceptance is defined at $p<0.05$.

Table 1. *Predictors for Pakistan data*

Model	t-value	Sig(p-value)
Energy Use (E1)	5.043451516	1.31549E-05
Urban Population (U1)	2.706522425	0.010328845
Gross capital formation (C1)	-2.570265226	0.014445252
GDP at market price (G1)	6.4717461	1.63514E-07

Table 2. *Predictors for India data:*

Model	t-value	Sig(p-value)
Energy Use (E2)	6.122963685	4.76218E-07
Urban Population (U2)	3.311246823	0.002120419
Gross capital formation (C2)	-0.977359963	0.334913416
GDP at market price (G2)	1.287407878	0.206167702

Table 2 shows that predictors E2 and U2 are significant only because their significance value (p-value) is less than 0.05 whereas predictors C2 and G2 are insignificant because their significance value (p-value) is more than 0.05. Thus, the predictors C2 and G2 should be excluded from the model of India.

Analysis of variance

After exclusion of insignificant predictors, the selected variables were used to model CO_2 using MLR technique. *Tables 3 and Table 4* show summary results for the MLR model for Pakistan and India data respectively.

Table 3. *MLR test for Pakistan data*

Regression Statistics	
Multiple R	0.997723762
R Square	0.995452705
Adjusted R Square	0.99494745
Standard Error	3376.590289
Observations	41

From the regression statistics of Pakistan, value of R^2 and adjusted R^2 is found to be 0.995452705 and 0.99494745 respectively pointing towards the fact that about 99%

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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variation in CO_2 emission is explained by energy use, urban population, gross capital formation and GDP at market price for Pakistan. This analysis of variance shows that the P-value for the F-test statistics is 3.47144E-47, which is providing strong evidence to reject the null hypothesis. The *Table 4* shows the MLR model for India data.

Table 4. *MLR test for India data*

Regression Statistics	
Multiple R	0.998204755
R Square	0.996412733
Adjusted R Square	0.99622393
Standard Error	33354.1464
Observations	41

ANOVA (Analysis of Variance)

	Df*	**SS****	**MS*****	**F******	**Significance F**
Regression	2	1.17E+13	5.87E+12	5277.51	3.47E-47
Residual	38	42274965109	1112499082		
Total	40	1.17E+13			

** stands for Degrees of freedom, ** Sum of squares, *** Mean square, **** F statistics*

From the regression statistics of India data, the value of R^2 and adjusted R^2 is found to be 0.996412733 and 0.99622393 respectively indicating that about 99% variation in CO_2 emission is explained by energy use, and urban population for India. ANOVA indicates that the p-value for F-test statistics is 3.47144E-47, which is strong evidence against the null hypothesis. It is also indicated by ANOVA that degree of freedom is 2, indicating minimum number of independent variables for complete system. Sum of square is found to be 1.17×10^{13} which is showing deviation from mean. The ratio of sum of square to the relevant degree of freedom called mean square and is found to be 5.87×10^{12}. It is clear from the above discussion that there exists a linear relation between predictors and CO_2 emission.

Multiple regression equations

Regression coefficients for all the predictors for Pakistan are given in *Table 5*. From the above table it is clear that p-value and coefficients are against rejection region having p-value less than 0.05. It is providing a strong evidence for rejecting then null hypothesis. These results indicate that these four economic variables are good predictors for CO_2 emissions for Pakistan.

Table 5. *Regression coefficients for Pakistan*

	Coefficients	**Standard Error**	**t Stat**	**P-value**	**Lower 95%**	**Upper 95%**
Intercept	-63984.7977	8847.997555	-7.23155689	1.63498E-08	-81929.3683	-46040.227
Energy use	262.5086441	52.04940372	5.04345152	1.31549E-05	156.947561	368.069727
Urban Population	0.001005508	0.000371513	2.70652243	0.01032885	0.00025205	0.00175897

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1504_13011312

Gross capital formation	-877.477516	341.3957077	-2.57026523	0.01444525	-1569.8601	-185.09493
GDP at market prices	2.65923E-07	4.10898E-08	6.4717461	1.63514E-07	1.82589E-07	3.4926E-07

The regression equation given below shows that E1 is the best predictor for CO_2 emission in Pakistan. MLR equation for above regression coefficient for Pakistan data is given in equation 3.

$$Y1=63984.79+262.50\ E1+ 0.0010\ U1-877.47\ C1 +0.00000026\ G \qquad (Eq.3)$$

Table 6. *Regression coefficients for India*

	Coefficients	**Standard Error**	**t Stat**	**P-value**	**Lower 95%**	**Upper 95%**
Intercept	-1346910.76	44694.4021	-30.136006	3.8908E-28	-1437389.9	-1256431.7
Energy use	5110.86089	323.755895	15.7861555	2.8098E-18	4455.45136	5766.2704
Urban population	0.00130128	0.00033639	3.86840378	0.00041641	0.00062030	0.0019822

It can be seen from the *Table 6* that p-value for energy use and urban population for India data is less than 0.05, which is a clear indication that these two variables are significant for India. Thus, we can reject the null hypothesis. Therefore we can conclude that the better predictors for CO_2 emissions for India are energy use and urban population. MLR equation of India for above regression coefficients are given in equation 4.

$$Y2 = 1346910.76 + 5110.86\ E2 + 0.0013\ U2 \qquad (Eq.4)$$

The above equation is showing that E2 is the best predictor for CO_2 emission in India. The value of f-stat and t-stat showed that the economic variables have joint and individual significance for the regression model at $p<0.05$. It can be noted from the regression equations for Pakistan and India that the best predictor against CO_2 emissions is energy use. Our findings are partially consistent with the findings of Wang et al. (2011, 2016) and Ang (2008).

For comparison, the time series data of actual and modeled CO_2 emissions have been plotted together in *Figure 2*. It can be noted from the *Figure 2(a)* that CO_2 increased gradually from 1971 to 2011 over Pakistan. It can further be observed from the figure that actual and modeled CO_2 over Pakistan show a similar pattern indicating the efficiency of regression model. The values of actual CO_2 emissions ranged from 18929 to 163452 while modeled values of CO_2 emissions ranged from 15103.50 to 173441.50. The mean value of actual CO_2 emissions was found to be 77446.32 while mean value of modeled CO_2 emissions is found to be 77446.33 which are very close to each other. It is noted from the *Figure 2(b)* that CO_2 emissions are increasing steadily from 1971 to 2011 for India. Similar pattern of actual and modeled CO_2 is observed which indicates the competence of regression model. The mean value of actual CO_2 emission for India was found to be 849817.23 while mean value of modeled CO_2 emissions is found to be 849817.21. The lowest and highest modeled CO_2 values are 172859 and 2096057

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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respectively. The minimum and maximum values of actual CO_2 emissions are 205869 and 74344 respectively. It can also be observed from *Figures 2a* and *2b* that actual and modeled CO_2 emissions of India (2074344) are greater than the corresponding CO_2 emissions of Pakistan

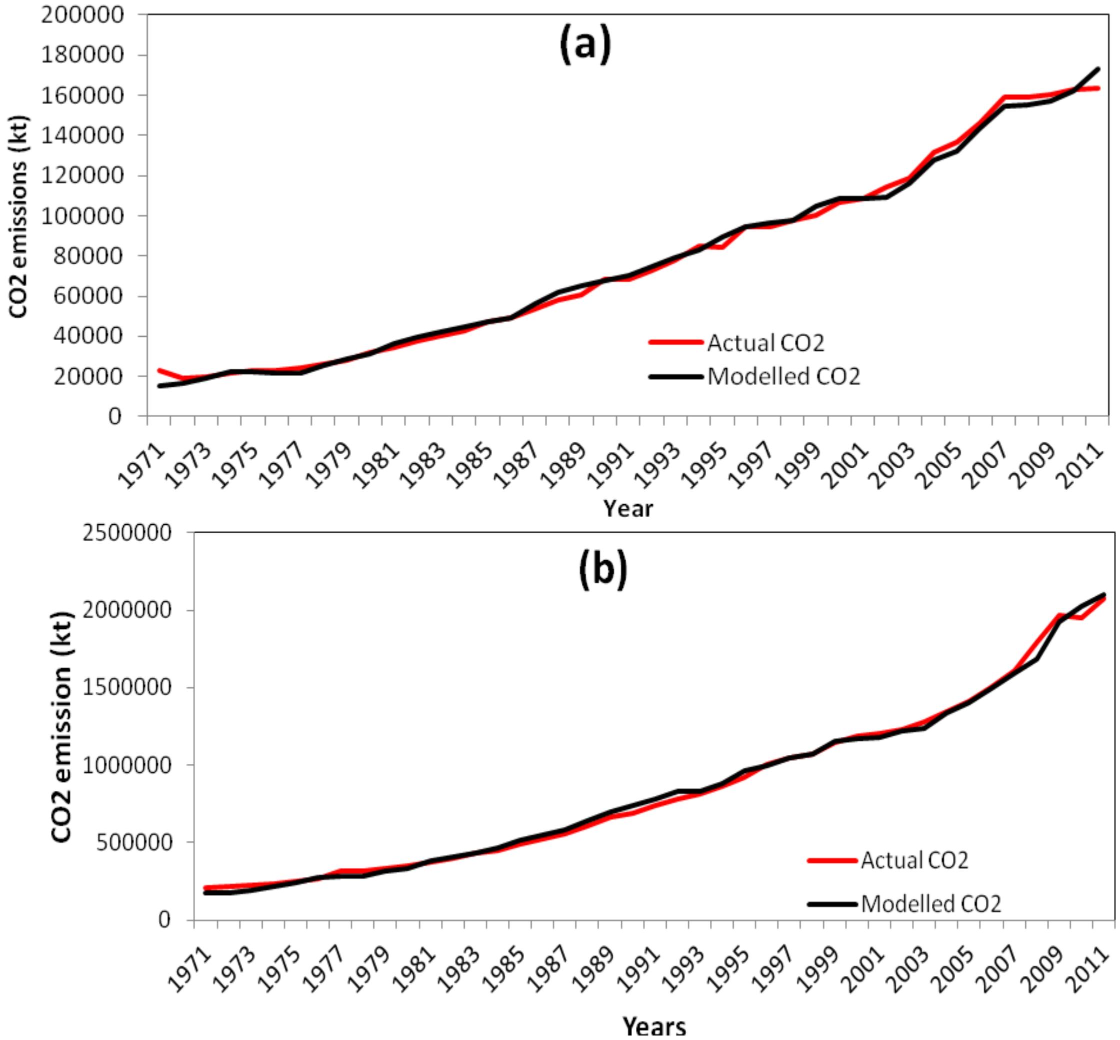

Figure 2. *Time series of modeled and actual CO_2 emissions over (a) Pakistan and (b) India*

Prediction errors

Performance of predictors in the regression model can be measured using two techniques known as MAE (Mean Absolute Error) and RMSE (Rout mean square error). These measures are used to show that how predicted values are performing against the actual values. The difference of actual value and predicted values is called prediction error or deviation error. Equations used to measure predicted error are given below:

$$MAE = \frac{1}{n}\sum_{t=1}^{n} \left| \frac{At - Pt}{At} \right| \quad \text{(Eq.5)}$$

APPLIED ECOLOGY AND ENVIRONMENTAL RESEARCH 15(4):1301-1312.
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$$RMSE = \sqrt{\frac{1}{n} \sum_{t=1}^{n} (At - Pt)^2} \qquad \text{(Eq.6)}$$

In equations 5 and 6 *At* is representing the actual value, *Pt* is representing predicted value and *n* is representing to the maximum numbers of values in a selected model. *Table 7* is showing the error results of both Pakistan and India model.

Table 7. *Errors for Pakistan and India model*

Model	MAE	RMSE
Pakistan data	0.00676	3164.0088
India data	4.99452	2694012.884

It is quite clear from the above table the model of Pakistan has less error than the model of India. This means that regression model of Pakistan is more efficient than that of India. Pakistan is a populous country and the use of petroleum and natural gas is increasing with the increase in population. A considerable amount of carbon is being emitted from natural gas consumption for electricity use (Alam et al., 2007). Less efficiency of regression model of India is might be due to the fact that predictors considered in this study for India are not enough for prediction of CO_2 emissions. Use of other variables may produce better results for India and is recommended for future research. Furthermore, the prediction of CO_2 emissions in this study may not be consistent with the research conducted at sectoral level data. The use of sectoral data is outside the scope of this study and left for upcoming research.

Per-capita energy consumption (kW h) values of India and Pakistan are 644 and 457 respectively. Higher value of per-capita energy consumption (kW h) for India indicates fast economic growth of India as per-capita energy consumption is proportional to economic growth of a country. India has electricity generation of 1193.48 TW h with 17% share from renewable energy sources while Pakistan has electricity generation of 97.796 TW h having 36% share from renewable energy sources (Ahmad et al., 2016). Contribution of coal in electricity production is much higher in India as compared to Pakistan. India is 3^{rd} largest emitter of CO_2. For both countries solar energy is a good choice as it is cleanest energy source and can help in sustainable economic growth. The overall approximate solar energy potential of India and Pakistan are 5000 trillion kW h and 2900 GW h respectively (Ahmad et al., 2016). Due to poor political infrastructure and the lack of research and development centers, Pakistan had been unable to promote sustainable development goals (Ang, 2008). However, presently Pakistan is paying serious attention towards the use of solar energy and in this regard several projects are underway such as Quaid-e-Azam solar energy park of 1000 MW capacity in Bahawalpur, 300 MW solar plant in Quetta and 3000 solar home systems in Tharparkar (Ahmad et al., 2016). Moreover, twenty two projects with the capacity of 772.99 MW are being installed in the country. Similarly, India has also started solar energy projects such as National Solar Mission (NSM) for installation of 22 GW. During 2015–16, 827.22 MW of solar energy was added to the system that enhanced the installed capacity up to 4579.24 MW (Ministry of New and Renewable Energy India, 2015). Other clean renewable energy sources such as wind, hydro and geothermal are also being installed in both the countries.

APPLIED ECOLOGY AND ENVIRONMENTAL RESEARCH 15(4):1301-1312.
http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1504_13011312

Conclusions

In this paper, the multiple linear regression model has been used to investigate the relationship between CO_2 and economic variables for Pakistan and India. The time series of CO_2 emissions for Pakistan and India showed an increasing trend over time especially from 2004 to 2011. Out of the four selected predictors (energy use, urban population, gross capital formation and GDP at market price) only two predictors, energy use and urban population were found to be significant ($p<0.05$) for India, however all the four variables were found to be significant ($p<0.05$) for Pakistan for the prediction of CO_2 emissions. CO_2 emission model for Pakistan showed that four economic variables (E1, U1, C1 and G1) are contributing 99% of the CO_2 emissions in Pakistan. On the other hand, CO_2 emission model for India showed that out of four variables (E2, U2, C2, and G2) only two variables (E2 and G2) are contributing 99% of the CO_2 emissions in India. The regression equation indicated that energy use is the most effective predictor for both Pakistan and India for CO_2 emission. Results from the error of prediction indicated that regression model for Pakistan is more efficient than that of India. Thus, predictors on CO_2 emissions for India are not enough to be considered in prediction of CO_2 emissions. The prediction of CO_2 emissions in this study may not be consistent with the research conducted at sectoral level data. The use of sectoral data is outside the scope of this study and left for upcoming research. Spatially gridded data from EDGER shows that about 200 terra gram CO_2 has been emitted from Indo-Gangatic plain (in north and north eastern parts of India) over the period 1970 to 2008. The results suggest the use of renewable energy resources to reduce the CO_2 emissions. There is a need to enhance the use of clean energy for both countries for sustainable development. On the basis of the information given in this paper new policies can be devised and decisions can be taken.

Acknowledgements. We are grateful to World Bank and EDGAR for providing the data used in this study.

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