O.P. Singh *et al*, International Journal of Advances in Agricultural Science and Technology,
Vol.3 Issue.3, May- 2016, pg. 01-13 **ISSN: 2348-1358**
Impact Factor: 6.057

Impact of CO_2 Emission on Economic Growth and Environmental Kuznets Curve, India

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***Abstract:** The major constituent of Green House Gases (GHGs) is attributed to carbon dioxide (CO_2) emission that leads to global warming and climate change. Increasing negative consequences of global warming and climate change had called for more attention and discussion on global environmental issues. In this context, present paper tried to investigate the growth trend of CO_2 emission from agriculture and to test the hypothesis of Environmental Kuznets Curve (EKC) for India over the period of 1971 to 2009. Growth trend analysis suggests that all the sources of GHGs emission from agriculture were showing positive growth trend except N_2O from rice cultivation. The positive relationship was found between CO_2 equivalent GHGs emission from agriculture and agricultural value added (current US$). Growth trend analysis for India's GDP (current US$) and agricultural GDP was growing with a compound growth of 6.70 and 4.53 per cent respectively during the study period. There was positive relationship between per capita GDP (current US $) and CO_2 emission. Agriculture can play an important role in mitigation of GHGs, some agricultural practices can absorb CO_2 from the atmosphere and sequester carbon in the soil. The relationship between per capita GDP (current US $) and CO_2 does not support the hypothesis of Environmental Kuznets Curve (EKC) i.e. inverted U shaped in India context. Economic growth itself cannot replace multilateral policies that seek to reduce the CO_2 emission. Therefore, government should develop and adopt appropriate policies to reduce the CO_2 emission from different sources.*

***Keywords:** "CO_2 emission", "Gross Domestic Product", "Green House Gas", "Environmental Kuznets Curve", "Growth trend"*

1. Introduction

Destructive growth in environmental consequences leads to environmental risk and uncertainties in the future are alarming. The most important risk is probability of climate change due to greenhouse effect caused by harmful gases emission in the atmosphere. The major constituent of Green House Gases (GHGs) is attributed to carbon dioxide (CO_2) emission leading to global warming and climate change (World Bank, 2007). Out of total GHGs emission globally, highest contribution comes from electricity and heat generation (24.6 per cent) followed by land use change (18.2 per cent), transport (13.5 per cent), agriculture (13.5 per cent), industry (10.4 per cent), other fuel consumption (9.0 per cent), fugitive emission (3.9 per cent), waste (3.6 per cent) and 3.4 per cent from industrial process (Baumert *et al*., 2005). India contributes about 5.6 per cent of GHGs to world's total GHGs emission ranking fifth position (Baumert *et al*., 2005). The increasing negative consequences of global warming and climate change had called for more attention and discussion on global environmental issues (Saboori *et al*., 2012). The evidences of global warming are rising in global average air and ocean temperatures, widespread melting of snow and ice and escalating global average sea level. As per report of Intergovernmental Panel on Climate Change (IPPC), the possible increase in global temperature from 1.1 to 6.4^{0}C and rise in sea level from 16.5 to 53.8 cm by 2100 (IPPC, 2007).

Many countries have struggled a lot to achieve economic growth without concurrently witnessing an augmentation in CO_2 emission. However there has been growing concern over the method of "low carbon and green growth" (Hwang and Yoo, 2012). The developing and underdeveloped countries have argued that any restriction on carbon energy would hamper the economic growth and suggested that developed country should raise fund to mitigate global warming because growth in GHGs is the by-product of developed country. Past researchers tried to find out relationship between economic growth and CO_2 emissions and it is widely hypothesised that pollutants and income are tied together in a Kuznets relationship (Shafik and Bandyopadhyay, 1992; Grossman and Krueger, 1995; Stern, 2004a). Starting from a low base, pollutants per capita and income per capita increases together until a certain income level was reached at which growth of the pollutant flattens and then reverses. In this context, present study was an attempt to find the growth trend of CO_2 emission from agriculture and economic growth and to test the hypothesis of Environmental Kuznets Curve (EKC) in Indian context whether it is true or not?

2. Data and analytical tools

Source of data and data use

Present study was based on the secondary data and data was collected from different sources. The data related to the CO_2 emission from agriculture was collected from the FAOSTAT database (FAO, Undated) and data related to GDP, per capita GDP, per capita CO_2 emission, agriculture value added, share of agriculture to India's GDP, etc. was collected from database of World Bank (World Bank, Undated).

Analytical Procedure

Growth trend analysis

The compound growth trend analysis was carried out to estimate the compound growth rate of [a] source-wise GHGs emission equivalent to CO_2 from agriculture during 1990 to 2010; [b] Growth in agricultural value (current US$) added; India's GDP (current UD$); share of agriculture to India's GDP during 1971 to 2012; and [c] growth in India's GDP and CO_2 emission for the period of 1971 to 2009. The compound growth trend was estimated using following algebraic form of the function:

$$Y = a * b^t \qquad (1)$$

Where *Y* is CO_2 emission, *a* is the constant and *b* is the regression coefficient and *t* is the time.

Regression analysis

In order to test whether the value of agricultural output (at current US$) influences the level of CO_2 emission, following model was used:

$$In\ AR = \propto_0 + \propto_1 In\ AY + \mu \qquad (2)$$

Where *In* is the log value, *AR* is the amount of CO_2 emission (in Kg) from agriculture, *AY* is the agriculture value added (in current US$), and μ is the error term.

In order to test whether the income level, influences the level of CO_2 emissions, we used following model:

$$In\ R = \propto_0 + \propto_1 In\ Y + \mu \quad (3)$$

Where *In* is the log value, *R* is the amount of CO_2 emission (in Kt), *Y* is the GDP (in current US$), and μ is the error term.

Environmental Kuznets curve (EKC)

The environmental Kuznets curve (EKC) was estimated to test the hypothesis of EKC in Indian context, because every country has different level of environmental degradation. The model used for the present study was:

$$\varepsilon = f\ (\gamma + \gamma^2 + \gamma^3 + \beta + \mu) \quad (4)$$

Where ε is the per capita CO_2 emission (in metric tonnes); γ is the per capita GDP (current US $); γ^2 is the squired per capita GDP (current US $); γ^3 is the cubic per capita GDP (current US $); β is the per capita energy consumption (Kg in oil equivalent); and μ is the error term.

The description of variables, expected sign, empirical references and source of data is presented in Table 1. Introduction of γ variable was used to verify that if the early stages of economic development trigger the CO_2 emission as suggested by the Stern (2004). The introduction of γ^2 in the model has the objective to corroborate if there is an inverted U shaped curve between per capita income and CO_2 emissions.

The theoretical expectation is that the coefficient that accompanies this variable is negative and significant. At the high level of economic growth changes towards intensive industries as well as a greater social conscience and environmental regulation leads to a gradual decline of CO_2 emission (Stern *et al*., 1996; Panayotou, 1993). The reason of incorporating γ^3 variable in the regression is to check if the CO_2 come back at very high levels of economic growth. If an inverted U shape curve exists, the coefficient of this variable is zero. Otherwise if this coefficient is positive and significant, this means there is an N shaped function concerning per capita income and CO_2 emission. Per capita energy consumption (β) measured in kg oil equivalent was introduced in the equation because if the energy is adopted everywhere and the majority of forms of utilisation free pollutants, it is necessary to add a proxy to evaluate it as suggested by the Agras and Chapman (1999). Theoretically there is positive relationship between energy use and CO_2 emission.

3. Results and discussion

Green house gas emission from agriculture

Green House Gas (GHG) emission from agricultural activities accounts for about 15 per cent of global GHGs emissions. The methane emission from livestock accounts for about 27 per cent of total GHGs emission from agriculture, which is the by-product of normal digestive process of cattle and other livestock. The major sources of GHGs emission from agriculture are methane (CH_4), nitrous oxide (N_2O) emission from the use of nitrogenous fertilizer and the CO_2 emission from burning of fuel which is used for mechanical power to perform different agricultural activities. The major sources of CH_4 emission are enteric fermentation, manure management, rice cultivation under standing water and burning of crop residues, whereas major sources of

N_2O emission are manure management, application of synthetic fertilizer, manure application to agricultural field, manure left on pasture land, crop residues, organic farming and burning of crop residues.

In India, total CO_2 equivalent emission from different sources of agriculture was 4821.30 million tonnes in 1990 and it was increased to the level of 6091.02 million tonnes by the year 2010 registering a compound growth rate of 1.05 per cent per annum during the same period of time (Table 2). In 1990, out of total CO_2 equivalent emission, the lion share comes from the enteric fermentation in the form of methane (CH_4) i.e. 51.12 per cent and the share was reduced to 49.41 per cent by the year 2010. In 1990, CO_2 equivalent emission from enteric fermentation was 2464.5 million tonnes and it declined to the level of 49.41 per cent by the year 2010. Growth trend analysis suggests that it was growing with a compound growth rate of 0.80 per cent per annum respectively.

The CO_2 equivalent emission from rice cultivation was 946.26 million tonnes in 1971and it reduced to the level of 819.09 million tonnes by the year 2010. The growth trend analysis suggests that it was shrinking with a compound growth rate of -0.16 per cent per annum during the same period of time. The reduction in CO_2 equivalent emission from paddy field may be due to adoption of alternate wait and dry paddy cultivation, system of rice intensification (SRI) etc. The CO_2 equivalent emission from synthetic fertiliser was 488.33 million tonnes in 1990 and it was increased to the level of 1068.22 million tonnes in 2010 registering a compound growth rate of 3.33 per cent per annum. Augmentation in CO_2 equivalent emission from synthesis fertilizer was due to increase in use of chemical fertilizer. In 1990, CO_2 equivalent emission from manure left on pasture was 539.58 million tonnes and it was increased to 710.38 million tonnes by the year 2010 growing with a compound growth rate of 1.17 per cent per annum during the same period of time (Table 2).

The CO_2 equivalent emission from manure applied to soil in India was 23.15 million tonnes and it was increased to 33.69 million tonnes by the year 2010 registering a compound growth rate of 1.64 per cent per annum. In case of manure management, CO_2 equivalent emission was 181.31 million tonnes in 1990 and it was increased to 246.51 million tonnes by the year 2010 and it was growing with a compound growth rate of 1.36 per cent per annum during the same period of time. The growth trend analysis for CO_2 equivalent emission from crop residue suggests that it was growing with a compound growth rate of 1.01 per cent per annum during the study period. Whereas in case of burning of crop residue, the CO_2 equivalent emission was 26.46 million tonnes in 1990 and it was augmented to the level of 27.01 million tonnes by the year 2010. Increase in the CO_2 emission from burning of crop residue was due to large scale adoption of mechanical power for harvesting paddy and wheat crops and farmers are burning crop residue in the field to manage the crop residue.

Agriculture can play an important role in mitigating CO_2, CH_4 and N_2O. Agricultural plants absorb CO_2 from the atmosphere to develop plant tissues. Some agricultural practices absorb CO_2 from the atmosphere and sequester carbon in the soil for long period. Methane (CH_4) from paddy can be reduced in substantial amount by the adoption of agronomic practices like alternate wet and dry of paddy field, System of Rice Intensification (SRI) etc. Farmers are also adopting resource conservation technologies (RCTs) to minimisation of the tillage practices, crop residue management, leaf colour chart for application of nitrogenous fertiliser etc. which leads to reduction of CO_2 emission from agriculture.

Growth of agricultural value added and GDP

India's GDP (Gross Domestic Product at current price US$), agricultural value added (current US$) and contribution of agriculture to India's GDP (per cent) is presented in Figure 1. It was observed from Figure 1 that, there was two growth sub-periods between 1971 to 2012 viz., (a) period-I (1971 to 2000) and (b) period-II (2001 to 2012). India's GDP was 68.53 billion US$ in 1971 and it was increased to 1841.72 billion

US$ by the year 2012 and it has increased with a compound growth rate of 6.70 per cent per annum during same period of time. The sub-period wise analysis suggests that it was growing with a compound growth rate of 6.2 and 13.1 per cent during period-I and period-II respectively. The higher growth during second period may be due to the benefit of economic liberalisation started and higher growth in agricultural value added.

Per capita GDP in India at current price was US$ 120.70 in 1971 and it was augmenting with a compound growth rate of 5.10 per cent per annum touched to US$ 1489.24 by the year 2012. The sub-period-wise compound growth trend analysis suggests that it was growing with compound growth rate of 4.10 and 11.80 per cent per annum during period-I and period-II respectively. The value added from agriculture at current price was 25.56 billion US$ in 1971 and it was increased to 303.31 billion US$ by the year 2012 registering a compound growth rate of 4.53 per cent per annum during the study period. The sub-period-wise analysis suggests that it was growing with a compound growth rate of 4.40 and 11.20 per cent per annum for period-I and period-II respectively.

The contribution of agriculture to India's total GDP was 40.28 per cent in 1971 and it was declined to the level of 17.39 per cent by the year 2012. In the stages of economic development, during the initial stage, government allocate larger quantity of available resources for the development of primary sector i.e. agriculture and smaller quantity for secondary and tertiary sector. After development of primary sector, government starts to develop secondary and tertiary sector. As a result, in the initial stage of economic development, the contribution of primary sector to GDP was more and thereafter it starts declining. The compound growth rate of decline in contribution of agriculture to India's GDP was -2.19 per cent per annum.

Relationship between CO_2 emission and economic growth

The effects of economic growth on natural and environmental resources have become central question and the concern over environment prevention is rising. Per capita GDP and CO_2 emission are moving towards same direction (Figure 2). In 1970, per capita GDP in India was 120.70 US $ (at current price) and it was increased to the level of 1147.24 US $ by the year 2009. The growth trend analysis suggests that per capita GDP in the country was growing with a compound growth rate of 4.70 per cent per annum. Growth in per capita GDP was lower during 1971 to 2000, but it was more than double during 2001 to 2009 (Figure 2).

In 1971, per capita CO_2 emission was 0.36 tonnes and it was increased to the level of 1.66 tonnes by the year 2009 and it was growing with a compound growth rate of 3.80 per cent per annum during the same period of time.

Table 3 represents the econometric results, obtained from the log linear OLS technique. Amount of total CO_2 emission was regressed on India's GDP measured in current US $. The coefficient of multiple determination (R^2) was found to be 0.947 suggests that the CO_2 emission in the country was explained 94.5 per cent by the GDP measured in current US $. The beta coefficient for GDP was found to be 0.838 and it was significant at one per cent level of significance. This means increase in one per cent CO_2 emission will enhance the India's GDP by 0.838 per cent.

Relationship between CO_2 emission and agricultural output

Is CO_2 emission has any impact on agricultural value added (current US $)? Table 4 represents the regression output. The coefficient of multiple determination (R^2) suggests that the dependent variable was explained by 94 per cent. The analysis suggests that there was positive correlation between CO_2 emission and agricultural value added (in current US $). One per cent increases in CO_2 emission from the agriculture, increases the agricultural value of output by 0.170 per cent.

Environmental Kuznets curve

Simon Kuznets (1955) suggested that as per capita income increases, income inequality also increases at first but then after turning point starts to decline. The inverted U-shaped relationship between per capita income and income inequality can be represented by bell-shaped curve, this popular phenomenon is known as the Kuznets Curve. A similar relationship was observed by different researchers between per capita income and environmental degradation in the early 1990s in different parts of world (Grossman and Krueger, 1991; Shafik and Bandyopadhyay, 1992; Panayotou, 1993). The Environmental Kuznets Curve (EKC) proposes that indicator of environmental degradation first rise, and then fall with rising income per capita (Stern, 2004). Many past researchers used cross-section or panel data techniques to estimate the relationship between per capita income and various environmental indicators for a group of countries (Grossman and Krueger, 1991; Shafik and Bandyopadhyay, 1992; Panayotou, 1993; Roca *et al*., 2001; Shafik, 1994; Holtz-Eakin and Selden, 1995; Bruyn *et al*., 1998).

Later researchers focused on individual country's analysis to test the relationship between economic growth and environmental pollution (Bruyn *et al*., 1998; Roca *et al*., 2001; Lindmark, 2002; Fried and Getzner, 2003; Egli, 2004; Akbostanci *et al*., 2009; Fodha and Zaghdoud, 2010; He and Richard, 2010; Saboori *et al*., 2012). However, the empirical evidence in support of positive, negative or an inverted U-shaped relationship between environmental degradation and economic growth has not been conclusive yet in both the panel and time series data based analysis.

The econometric results were obtained for CO_2 emission per capita (ε) were regressed on GDP per capita in current US $ (Υ), squired per capita GDP in current US $ (Υ^2), cubic per capita GDP in current US $ (Υ^3), and per capita energy consumption in kg oil equivalent (χ) by OLS using time series data and result were presented in Table 5.

For the OLS model, all estimated coefficient values reveal significant at one per cent level of significance. The coefficient of multiple determination was found to be 0.998 suggests that all the independent variables incorporated in the model were influenced dependent variable (per capita CO_2 emission) by 99.80 per cent. From the model it is clear that explanatory variables influenced the amount of CO_2 emission per capita. These variables are GDP per capita and per capita energy consumption. The coefficient of γ (per capita GDP at current US $) showed the expected positive sign as suggested by the Grossman and Krueger (1991); Selden and Song (1994) and Kaufmann *et al*, (1998). In the early stage of economic development triggered the augmentation of CO_2 emission in Indian condition also (Stern, 2004).

The regression coefficient of γ^2 (squired per capita GDP at current US $) was found to be negative and significant as suggested by Grossman and Krueger (1991), Selden and Song (1994), Kaufmann *et al*. (1998). The basic region behind the negative sign of γ^2 is that at higher level of economic growth leads to intensive industries as well as a grater social conscience and environmental regulation leads to a gradual decline of CO_2 emission (Stern *et al*., 1996; Panayotou, 1993).

The regression coefficient for γ^3 (cubic per capita GDP at current US $) variable were found to be more than zero means absence of inverted U shaped of the environmental Kuznets curve. The regression coefficient was positive, significant and more than zero suggests that there is N shaped environmental Kuznets curve of income per capita and CO_2 emission per capita in India (Grossman and Krueger, 1991; Moomaw and Unruh, 1997; Arraes *et al*., 2006; and Maddison, 2006).

The coefficient of the variable β (energy consumption per capita in oil equivalent) was positive and highly significant as theoretically expected as suggested by Cole *et al*. (1997) and stern (2002). If energy consumption increased along with increase in economic development, despite of regular advancement in the energetic efficiency, it is not surprising that the same thing takes place with CO_2 emissions (Cole *et al*., 1997).

From the above discussion it is clear that beside greater GDP per capita causes more CO_2 emissions and a country with high CO_2 emissions might results greater GDP per capita. By extending the model including the cubic form of GDP per capita concludes that continuous income increase does not guarantee the continuous improvement of environment quality, provides that the relationship between Environment Kuznets curve (EKC) and CO_2 emissions is just temporary, because an N shaped EKC was found. This means that the relationship between income and CO_2 emissions is not automatic and thereby possibilities for designing public policies and international agreement accrue as a form of promoting the environmental improvement, as suggested by Grossman and Krueger (1994) and Stern (2004).

4. Conclusion

The major sources of GHGs release from agriculture are CH_4, N_2O and CO_2. The growth trend analysis suggests that all the sources of GHGs from agriculture were registered positive growth trend except N_2O from rice cultivation. The diminishing trend in N_2O emission from agriculture field may be due to adoption of improved cultural practices like short duration of standing water in paddy field, alternate wet and dry paddy field, conservation agriculture and system of rice intensification (SRI) etc. The positive correlation was observed between GHGs equivalent CO_2 emission from agriculture and agricultural value added (current US$). Growth trend analysis for India's GDP (at current US$) and agricultural GDP was growing with a compound growth of 6.70 and 4.53 per cent respectively during the study period. But contribution of agriculture to India's GDP was gradually declining over the period of time. It is due to larger contribution comes from the secondary and tertiary sectors. There was positive relationship between per capita GDP (at current US $) and per capita CO_2 emission.

Agriculture can play an important role in mitigating GHGs viz., CO_2, CH_4 and N_2O. Agricultural plants absorb CO_2 from the atmosphere for use in developing plant tissues. Some agricultural practices absorb CO_2 from the atmosphere and sequester carbon in the soil for long period. Methane (CH_4) from paddy can reduce in substantial amount by the adoption of agronomic practices like alternate wet and dry of paddy field, System of Rice Intensification (SRI) etc. The relationship between per capita GDP (current US $) and CO_2 emission does not support the hypothesis of Environmental Kuznets Curve (EKC) i.e. inverted U shaped for India, but it may be N shaped. The economic growth itself cannot replace multilateral policies that seek to reduce the CO_2 emission. Therefore, government should develop and adopt appropriate policies to reduce the CO_2 emission from different sources.

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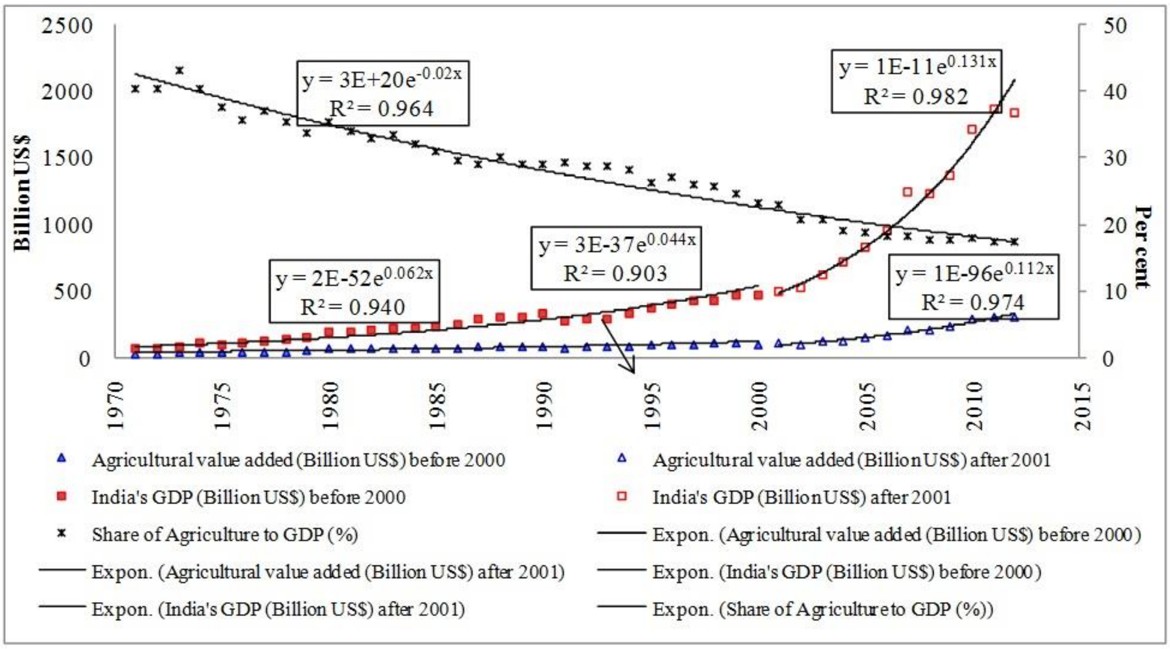

Figure 1: India's GDP, agricultural value added and share of agriculture to GDP

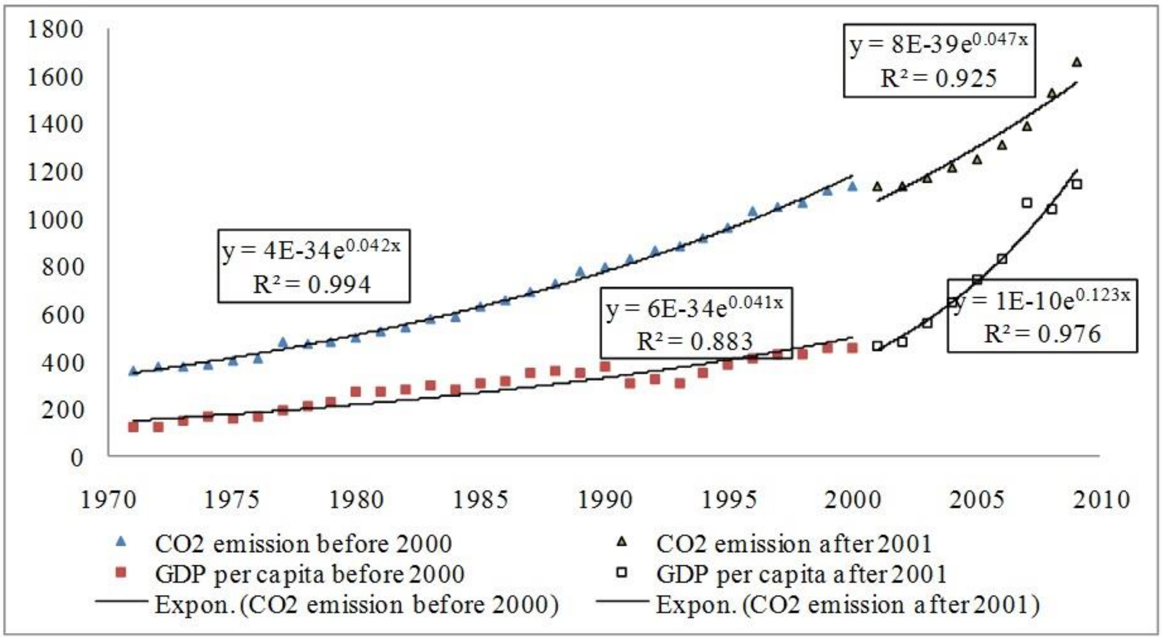

Figure 2: Growth in per capita GDP and CO_2 emission, India

Table 1: Description of variables

Variable	Description	Expected sign	Empirical references	Source of data
ε	Per capita Co_2 emission		Agras and Chapman (1999), Cole *et al*. (1997) Dijikgraaf and Vollebergh (2001)	World Bank
γ	GDP per capita	+	Grossman and Krueger (1991), Selden and Song (1994), Kaufmann *et al*. (1998)	World Bank
γ^2	Squired GDP per capita	-	Grossman and Krueger (1991), Selden and Song (1994), Kaufmann *et al*. (1998)	World Bank
γ^3	Cubic GDP per capita	*	Grossman and Krueger (1991), Moomaw and Unruh (1997), Arraes *et al*. (2006), Maddison (2006)	World Bank
β	Per capita energy consumption (in kg oil equivalent)	+	Cole *et al*. (1997), Stern (2002)	US Energy Information Administration

Table 2: Compound growth rate of CO_2 equivalent emission from agriculture

Sources of CO_2 equivalent emission	Name of GHG emission	CGR (per cent per annum)	R^2
1. Enteric Fermentation	CH_4	0.80	0.851
2. Manure Management	CH_4 and N_2O	1.36	0.981
3. Rice Cultivation	CH_4	-0.16	0.052
4. Synthetic Fertilizer	N_2O	3.33	0.923
5. Manure applied to soil	N_2O	1.64	0.945
6. Manure left on pasture	N_2O	1.17	0.910
7. Crop residues	N_2O	1.01	0.779
8. Burning crop residue	CH_4	0.48	0.528
9. Total GHG emission from Agriculture		1.05	0.916

CGR: Compound growth rate

Table 3: Impact of economic growth on CO_2 emission

Regression coefficients	Un-standardized "b" coefficient	Std. Error	"t" Value	Sig.
Constant " α_0 "	-3.802	0.370	-10.282	0.000
Gross Domestic Product (in current US $) " $\alpha_1 Y$"	0.838	0.032	26.005	0.000
F Value	676.253			0.000
R^2	0.947			

Table 4: Relationship between CO_2 emission and agricultural value output

Particulars	Unstandardized "b" coefficient	Std. Error	"t" Value	Sig.
Constant " $\propto_0$ "	7.853	0.109	72.348	0.000
Agriculture value added (in current US $) " $\propto_1 AY$"	0.170	0.010	17.289	0.000
F Value	298.926	-	-	0.000
R^2	0.940	-	-	-

Table 5: Environmental Kuznets curve regression (OLS)

Coefficients	"b" coefficient	Std. Error	t Value	Sig.
ε (Per capita CO_2 emission) "a constant"	-0.944	0.32	-29.770	0.000
γ (Per capita GDP at current US $)	8.954×10^{-04}	0.000	5.548	0.000
γ^2 (squire per capita GDP at current US $)	-1.674×10^{-06}	0.000	-6.095	0.000
γ^3 (Cubic per capita GDP at current US $)	8.481×10^{-10}	0.000	5.537	0.000
β (per capita energy consumption in kg oil equivalent)	4.417×10^{-03}	0.000	32.511	0.000
R^2	0.998			
F-value	3673.388			
Standard Error of Estimate	$1.800 \times 10\text{-}^{02}$			

A Brief Author Biography

Dr. O. P. Singh did his Ph. D. in Agricultural Economics and has twenty years of rich experience of working with NGOs, academic and research institutions in the area of natural resource management and economics. Presently, Dr. Singh is working as Assistant Professor at Department of Agricultural Economics, Institute of Agricultural Sciences, Banaras Hindu University (BHU), Varanasi. His earlier assignments include research work at Institute of Rural Management, Anand (IRMA), India Natural Resources Economics and Management (INREM) Foundation, Anand and International Water Management Institute (IWMI), India Project Office. Dr. Singh has more than 150 publications including articles in national and international journals, books, book chapters, monographs etc. Dr. Singh also recipient of Dr. SR Sen biennial award for his book "Groundwater Management in India: Physical, Institutional and Policy Alternative".

Dr. P. K. Singh did his Ph. D. in Agricultural Economics from Banaras Hindu University, Varanasi, Uttar Pradesh. Dr. Singh has more than 10 years experience of teaching and research. Presently Dr. Singh is working as Assistant Professor in Department of Agricultural Economics, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. Dr. Singh has more than 10 publications including research articles in national and international journals, book chapters and conference papers. Dr Singh is also involved in a research project on "Network project on market intelligence funded by ICAR, New Delhi".

Prof. Rakesh Singh is Ph. D. in Agricultural Economics and has more than 27 years of professional experience in research, teaching and extension in the field of agricultural economics and policy analysis. He is currently working as Professor, Department of Agricultural Economics, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. Prior to joining at BHU, Dr. Singh served at IIM, Ahmedabad, VBS Poorvanchal University, World Bank Aided Diversified Agriculture Support Project. He has more than 50 publications to his credit including book chapters, national and international journal articles and conference papers. He is also the member of various professional bodies.

