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Environmental Kuznets Curve for CO2and NOx emissions: A Case Study of India.

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Abstract
The causal relationship between economic growth, environmental consumption and degradation has been a subject of debate for last few decades. In this regard, the inverted U-shaped Environmental Kuznets curve (EKC) demonstrates (pollution-income relationship) that initially the environmental degradation and pollution surpass the level of income per capita; however this trend reverses since at the higher income levels economic growth initiates environmental improvement due to technological change that allows cleaner input to be used in the production of goods and services. This debate is reminiscent of the one that resulted from the Club of Rome Report (Meadows et al 1972).Unresponsive regarding environmental protection and endeavour to speed up economic growth had not only kept environmental considerations as secondary objectives in policy making in these countries but also threatened their sustainable future. This paper reviews the empirical studies that have examined the relationship between environmental degradation and economic growth. It also underlines other econometric and methodological problems with estimates of the EKC. Based on secondary data with reference to India, an empirical econometric model is tested to analyze the relationship between NOx, CO2 (in per capita metric tones) and GDP(per capita). The implications for environmental policy with particular reference to a developing country like India are addressed.

Key Words: CO2, Environmental Kuznets curve (EKC); Economic growth; Environmental degradation; GDP per-capita; India,NOx.

JEL classification: N50, O13, Q00, Q20, Q50.

1. Introduction

The increasing pace of growth and extreme pressure of population has led to an increase threat of global warming and climate change .The carbon dioxide (CO2) emission is considered as the main cause to the Green House Gases (GHGs).It is responsible at least 60% to the cause of global warming. Since 1990, the linkage between emission and economic growth has been studied extensively as global warming is raising the concern of environmental degradation. In order to reduce the emission of GHGs, there have been several international attempts of which the Kyoto protocol agreement is the most notable one. The Kyoto Protocol, signed in 1997, is a protocol to the United Nations Framework Convention on Climate Change (UNFCCC) and the important feature of this protocol is to reduce the collective emissions of GHGs of 39 industrialized countries and European Union by 5.2 percent from 1990 level during the period of 2008-2012.In 2015, the historic United Nations Climate Change Conference was held in Paris. It was an opportunity to put the world on course to meet the climate

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change challenge and to construct a new model of growth that is safe, durable and beneficial to all. The reconciliation of economic growth with environmental sustainability is a major concern in the environment economy debate because the growth theory has majorly ignored environment. On the other hand it was also argued that growth is also a precondition for environmental improvement (Bhagwati, 1993).According to Beckerman (1992) "the strong correlation between incomes and extent to which environmental protection measures are adopted demonstrates that, in the longer run, the surest way to improve your environment is to become rich". Studies by Georgescu-Roegen (1971) have claimed that there exists a trade-off between economic growth and environmental sustainability. In this context, there have been a lot of empirical studies regarding the trade-off that exists between environmental degradation and economic growth. Studies have put forth the hypothesis that there exist an inverted–U-shaped relationship between per capita income and indicators of environmental degradation. According to this inverted U shape relationship between different pollutants and per capita income in different countries which is also called the "Environmental Kuznets Curve"(EKC),environmental degradation first increases with the per capita income and then after a turning point it decreases as per capita income increases. There are few explanations for the inverted U shape of EKC;

a)Scale Effect: Scale of production implies expanding production at given factor-input ratios, output mix, and state of technology. It is normally assumed that a 1% increase in scale results in a 1% increase in emissions. In short, as economy expands there is increase in environmental degradation.

b). Composition Effect: Economies move from subsistence to more material and intensive patterns of agriculture towards industrialization and then to service sector. This development path is the result of capital accumulation and knowledge based economies. Study by (Ekins 1997) suggests that the i) composition effect adds to the scale effect that is it leads to environmental damage at a faster rate than income ii) the composition effect acts against but does not fully counteract the scale effect.

c). Displacement effect: Economies undergo displacement effect in which there is an increased demand of environmental quality as a result of increased income.

Against this backdrop, the objective of the present study is to analyze the relationship between CO_2/NO2 (per capita metric tons) and GDP (per capita) for India .The paper reviews EKC literature, background history, conceptual insights.. It also underlines other econometric problems with estimates of the EKC, and re-evaluates several empirical studies.

2. Origin of Environmental Kuznets Curve

In the sixty seventh annual meeting of American Economic Association in December 1954, Simon Kuznets delivered presidential address entitled ,"Economic Growth and Income Inequality ".He suggested that as per capita income increases , income inequality also increases at first and then after some turning point starts declining. This relationship between per capita income and income inequality can be represented by bell shaped curve known as Kuznets Curve.In1990's Kuznets curve took a new form of relationship. The study of Grossman and Krueger's in 1991, for per capita income and environmental degradation shows the same inverted U shape relationship as original Kuznets curve. Latter, this inverted U shaped relationship was supported by studies of World Bank 1992 Development Report (Shafik and Bandyopadhyay, 1992) and ILO discussion paper (Panayotou, 1993). Now Environmental Kuznets curve has become a vehicle for describing the relationship between income and environmental quality (Dinda, 2004).

3. Environmental Kuznets Curve : A Debate

The study by Grossman and Krueger (1991) emphasizes the various sources of environmental impact from a greater openness to trade namely the scale effect, composition effect and displacement effect. According to his study the scale effect refers to the impact of economic growth on the environment. The major finding of the study was that the level of pollutants were rising with per capita income at low levels of income ,as expected ,but to fall with per capita income giving rise to an inverted U shaped relationship between economic growth and environmental degradation. Studies by Selden and Song (1994) and Grossman (1995) found similar findings that there exists an inverted U-shaped relationship between economic growth and indicators of environmental degradation. Stokey (1995) explains the EKC phenomenon in terms of changes in the marginal utility of consumption at different levels of per capita income. Dasgupta et al (2002) gives conventional explanation of EKC: “In the first stage of industrialization, pollution grows rapidly because people are more interested in jobs and income than clean air and water, communities are too poor to pay for abatement and environmental regulation is correspondingly weak. The balance shifts as income rises, leading industrial sectors become cleaner, people value the environment more highly, and regulatory institutions become more effective. Along the curve, pollution levels off in the middle income range and then falls toward pre industrial levels in wealthy societies”.

However some studies had more ambiguous results, implying that EKC may not hold at all times and for all pollutants (e.g. Shafik,1994).It has been observed that EKC has been attacked on both empirical and methodological grounds (e.g. Stern and Common ,2001;Dasgupta et al,2002;Perman and Stern 2003).There were four types of contributions to the EKC literature between 1991 and 1998 :estimation of the basic EKCs, studies of the theoretical determinants of the EKC, studies of the empirical determinants and critique of EKCs” (Stern 1998).Estimation of basic EKCs refer to “studies whose main aim is to estimate the relationship between environmental indicators and growth rate” (Stern, 1998). .Concluding studies have shown that EKC does not necessarily apply to all indicators of environmental degradation. Studies of the theoretical determinants of the EKC “have built on the heuristic theory of the EKC to mathematically relate plausible assumptions about technology and preferences to the shape of the time path of environmental impacts”(Stern 1998).These include studies of Lopez (1994), Selden and Song (1995),John and Pecchenino (1994), John et al. (1995),McConnell (1997) and Stokey (1998). Studies of the empirical determinants of the EKC have focused on examining possible determinants of the EKC relationship (Stern 1998).Conditioning variables include trade (e.g. Rock ,1996;Rothman ,1998),political freedom (e.g.Torras and Boyce ,1998),density of economic activity (e.g. Kaufman et al 1998) and economic structure (e.g.Suri and Chapman ,1998;Rock 1996). Stern study (1998) identified some major critiques related to EKC namely the assumption that changes in trade relationships associated with development have no effect on environmental quality ,econometric problems ,ambient concentrations versus emissions ;asymptotic behaviour etc.

Some of the recent studies include the empirical analysis of the relationship between income and pollution by assuming a common structure of all countries by Eugenio Figueroa B and Roberto Pasten C. The study uses the Random Coefficient Model proposed by Swami (1970) and empirically estimates EKCs for sulphur dioxide with specific turning points from a sample of 73 high and low income countries. The study suggests that regulatory processes resembling market mechanisms could induce the empirical emergence of EKCs. A Bayesian estimator is used in order to test the EKC hypothesis country by country. In order to check for a heterogeneous rather than a common structure, the study tested for variable slopes instead of constant slopes to analyze the EKC for SO_2 emissions. Results show that for some countries the EKC hypothesis is robust but for other countries it is not. For homogenous developed countries, there is strong evidence of an overall EKC. At country level, for most of the OECD members and for most of the members of the developed world the EKC hypothesis is robust. However a few members of the OECD and a few members of the developed world do not display an EKC. At country-specific level, 17 out of 28countries strongly support the EKC hypothesis, and 11 out of 28 countries do not support the EKC hypothesis.

With reference to India the study by Pradyut Ranjan Jena (2009) analyzed the determinants of environmental productivities and finds Environmental Kuznets Curve type relationship existence between environmental productivity and income. The study relies on state–level industry data of sulphur dioxide, nitrogen dioxide, and suspended particular matter over the period 1991–2003 in the analysis of environmental management because it influences the cost of alternative production and pollution abatement technologies. The production function analysis is used to measure productivity change in a joint production model, with the help of a vector of market and nonmarket outputs (see Kumar (2006) for the literature). This approach uses the Luenberger productivity index, which is the dual to the profit function and does not require the choice of an input–output orientation (Chambers et al., 1996). This study uses two datasets, viz, market input/output, TFP_{Market}, and environmental input/output, TFP_{Joint}, considering the maximum expansion of good outputs and contraction of bad outputs. The total factor productivity (TFP) associated with environmental outputs, TFP_{Env} or environmental productivity, is then calculated as:

$$TFP_{Env} = TFP_{Joint} - TFP_{Market}$$

Where TFP is Luenberger indices, which gives the difference of the two models. The TFP indicates not only the change in technology, but also the effect of management–level changes in institutions, including environmental regulations. Results of the study shows that overall environmental productivities decrease over time, the existing environmental management is not sufficient to bring sustainable development in the country. The environmental productivities, in general, decline more in high–income states in comparison to the low–income states. Panel analysis results show that a combined effect of income on environmental productivity is negative which removes the confusion why productivity has declined faster in developed states than their underdeveloped counterparts. The study therefore, concludes that the ongoing pace of industrialization should be met with an effective environmental management to free from untoward consequences in India.

4. Data and EKC Model

CO2, NOx as well as GDP data was collected from World Bank Database. In this study we have tested the EKC hypothesis for CO2 emissions from the time period 1960 to 2011 while the EKC hypothesis for NOx was tested from the time period 1970 to 2012(due to lack of data availability). After checking for the stationary of the time series data (separately for CO2, NO2, GDP) using Augmented Dickey Fuller test, we conducted quadratic and cubic regression to construct an EKC equation thereafter. Since the β test statistic was coming out to be insignificant we have shown the cubic regression model result in the estimation and results section.

The quadratic form is the traditional one used in most EKC studies, defined as:

$\mathbf{Y_t = \beta_0 + \beta_1 X_t + \beta_2 X_t^2 + U_t}$,...**(**1)

The EKC hypothesis holds if $\beta_1>0$ and $\beta_2 <0$, and both are statistically significant. Therefore a turning point and an inverse U –shaped relation could exist. With these observations, there exist a linkage between CO2/NOx emissions and GDP. The turning point where the EKC changes its curvature is estimated by taking out the first derivative and equating the same to zero.

Mathematically it is given by $\mathbf{Y^* = - \beta_1/2\, \beta_2}$

In this case, environmental pressure increases at initial growth stages but at a decelerating rate, up to a threshold. However, after this phase, growth allows improvements in the environmental state. If $\beta_1<0$ and $\beta_2>0$, a U shaped pattern is observed, which is particularly bad for sustainable development assumptions.

The cubic form of EKC is given by:

$\mathbf{Y_T = \beta_0 + \beta_1 X_t + \beta_2 X_{t2} + \beta_3 X^3_t + Ut}$.................................... **(2)**

The equation describes a relationship with two potential turning points. Indeed if $\beta 1>0$, $\beta_2< 0$ and $\beta_3>0$, we have an N –shaped function. After an initial EKC like phase, environmental pressure begins to rise again thereafter. But only one inflection point could exist (an increasing or decreasing relationship). The inflection point is found in the same way by putting second derivative equal to zero and is solved for income i.e.

$Y^0 = - \beta_2/3\, \beta_3$

5. Econometric Specifications and Results

The descriptive statistics has been shown in Appendix. We have tested the null hypothesis that EKC does not holds in case of India against the alternative that the relationship does hold in the country .After running the cubic regression in EVIEWS software we obtained relationship between GDP and CO2 /NOx emissions in the initial phase, the results of which are shown below. The study runs the cubic and quadratic regression because it was originally used by Grossman and Krueger (1994) in their path breaking study. This section shows the model results and briefly summarizes the major findings.

5.1Unit Root Test Results:

5.1.1Augmented Dickey Fuller Test Results for CO2

Null Hypothesis: D(CO2) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.740520	0.0000
Test critical values:	1% level	-4.152511	
	5% level	-3.502373	
	10% level	-3.180699	

*MacKinnon (1996) one-sided p-values.

5.1.2 Augmented Dickey Fuller Test Results for GDP

Null Hypothesis: D(GDP) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-9.004709	0.0000
Test critical values:	1% level	-4.152511	
	5% level	-3.502373	
	10% level	-3.180699	

*MacKinnon (1996) one-sided p-values.

5.1.3 Augmented Dickey Fuller Test for NO x

Null Hypothesis: D(NITOGEN) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.479661	0.0000
Test critical values:	1% level	-3.600987	
	5% level	-2.935001	
	10% level	-2.605836	

*MacKinnon (1996) one-sided p-values.

As it can be clearly seen from the above tables ,the Augmented Dickey Fuller test clearly states that all the variables are integrated of order one i.e all the series taken up in the analysis is I(1).The p-value is less than .05 which clearly states that we do not reject the null hypothesis and conclude that the series is stationary on first difference. Also since the series is integrated of order one we can conclude that there exists a long term relationship between GDP and CO2 /NOx. We now conduct simple cubic OLS since the quadratic model proved to be inconclusive regarding the shape of EKC since the betas were insignificant.

5.2 Regression Results

5.2.1Cubic Model for CO2

Dependent Variable: CO2
Method: Least Squares
Date: 10/15/16 Time: 15:16
Sample (adjusted): 1960 2011
Included observations: 52 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.405960	0.024982	16.25012	0.0000
GDP	5.36E-07	5.25E-08	10.20918	0.0000
GDP^2	-1.00E-13	1.81E-14	-5.510450	0.0000
GDP^3	6.42E-21	1.52E-21	4.211233	0.0001

R-squared	0.912244	Mean dependent var	0.749812
Adjusted R-squared	0.906759	S.D. dependent var	0.403332
S.E. of regression	0.123159	Akaike info criterion	-1.276879
Sum squared resid	0.728069	Schwarz criterion	-1.126784
Log likelihood	37.19886	Hannan-Quinn criter.	-1.219336
F-statistic	166.3232	Durbin-Watson stat	1.312553
Prob(F-statistic)	0.000000		

5.2.2 Cubic Model for NOx

Dependent Variable: NITOGEN
Method: Least Squares
Date: 10/15/16 Time: 15:35
Sample (adjusted): 1970 2012
Included observations: 43 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	111939.4	5538.658	20.21057	0.0000
GDP1	0.075334	0.009006	8.364484	0.0000
GDP1^2	-1.51E-08	2.68E-09	-5.657933	0.0000
GDP1^3	9.09E-16	1.97E-16	4.621002	0.0000

R-squared	0.817013	Mean dependent var	165735.2
Adjusted R-squared	0.802937	S.D. dependent var	49763.25
S.E. of regression	22090.79	Akaike info criterion	22.93212
Sum squared resid	1.90E+10	Schwarz criterion	23.09595
Log likelihood	-489.0405	Hannan-Quinn criter.	22.99253
F-statistic	58.04325	Durbin-Watson stat	0.923211
Prob(F-statistic)	0.000000		

The results clearly show that there is existence of an N-shaped EKC for CO2 since $\beta_1>0$, $\beta_2<0$ and $\beta_3>0$ and all are statistically significant. In the above table 5.2.1 (for CO2) the value of $\beta_1 = 5.36$ $\beta_2 = -1.000$ while the value of $\beta_3 = 6.42E$ the t values of all variable including intercept are greater than 2(absolute term), which means we reject the null hypothesis that GDP has no impact on CO2. In an alternate way probability of all variable including intercept are less than 0.05 that means we reject the null hypothesis at 5% level of significance. Thus ,for India there exists an inverse N shaped relationship between GDP and CO2 emission. R^2 value of about 91% that shows a good fit and states that 91% of the variation in CO2 emission is explained by GDP. From these results we can say that as GDP increase CO2 emission also increase but as the economy grows further CO2 emissions fall and then increases further. Hence an inverted U -shape exists and CO2 emissions rise again. Similarly in case of NOx , the N shaped EKC exists since $\beta_1>0$, $\beta_2<0$ and $\beta_3>0$ and all are statistically significant. Therefore a turning point and an inverse U –shaped relation could exist for some point of time and NOx emissions increase after it passes the stage of inverted U shaped EKC .In the table 5.2.2 the value of $\beta_1=5.36$, $\beta_2= -1.5$ and $\beta_3= 9.09$, the t values of all variable including intercept are greater than 2(absolute term), which means we reject the null hypothesis that GDP has no impact on NOx. In an alternate way probability of all variable including intercept are less than 0.05 that means we reject the null hypothesis at 5% level of significance. Thus , for India there exists an N shaped relationship between GDP and NOx emission. R^2 value of about 81% hat shows a good fit and states that 81% of the variation in NO2 emission is explained by GDP. From these results we can say that as GDP increase NOx emission also increase but as the economy grows further NOx emissions fall. However this fall in emission is not sustained and there is a further increase in NOx emissions . Hence an N -shape EKC exists for NOx in case of India.

Conclusions

The study clearly shows that there is existence of an N shaped EKC for NOx and CO2 emissions. For a developing nation, GDP growth is enabled by electricity consumption. Subsequent to Bhopal Gas disaster in 1984, regulatory frameworks relating to environmental protection experienced an unprecedented shock. At that time, India started to take environmental protection policies more seriously. The shift from traditional production technologies to green technologies over the period of time ,improved efficiency of coal fired power plants in reducing carbon intensity and CO2 emissions has resulted in better performance for India. Moreover, strict environmental policies followed by municipal government in cities for NO2 emissions has resulted in reduction in emission level as well as improved energy efficiency. However , given the fact that as GDP is increasing further this decline in the emission level is not sustained .The economy witnesses a further increase in these emission levels and the tunnelling through the inverted U shaped EKC for a developing country like India is only temporary. This study demands more stringent environment policies like carbon tax, command and control measures etc.

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