Estimation of Environmental Kuznets Curve in India and China

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Abstract: Intercorrelated economic development and environment is a matter of great discussion far away. Various studies found the different shapes of the relationship between development and the environment by adopting other methods. This study has adopted the least square method to trace out the growth–emission relationship for the period of 1971 to 2014 in the case of India and China. The result shows for the same period of time, growth-emission is associated with an inverted U-shape in India although, in the case of China, a cubic polynomial inverted U-shape relation exists.

Keywords: Kyoto Protocol, Economic Growth, Environment, Long-run relationship, EKC

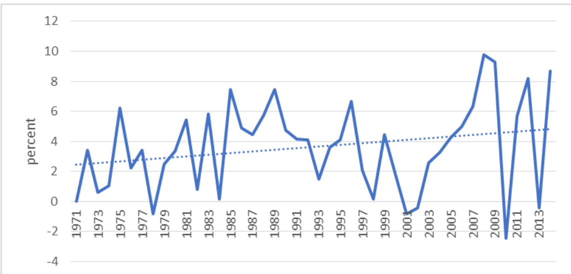
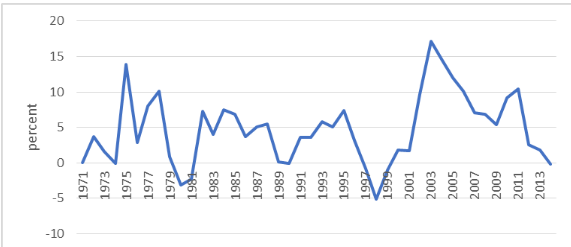
1. Introduction-

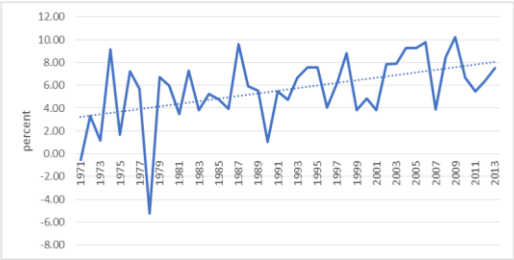
Economic Growth associates all matters either a matter of balanced growth or equal distribution or a matter of corporate social responsibility or a matter of environmental quality. The existence of Growth and environmental relation make restless to everyone rethink the development model. What kind of relationship exists between these two, depending upon their model of development and used input. Economic growth has been boosted by mainly conventional energy mainly which includes coal, oil, and natural gas and the same are the primary source of Greenhouse gases emission and most dominated by carbon emissions. Grossman and Kruger (1995) first try to find out the relationship between income and environmental quality and their finding explains that this relation is an inverted U shape between income and Environmental quality. Followed by Stern DI & et. al. (1996), Panayotou T., Cole MA, Barbier EB (1997) and more development has been done to find out the right and perfect shape of this relation by adding a new form of the equation and including another variable that affects environment quality and carbon emissions. A period of study is essential in the study to find the right shape of this relationship due to national and international efforts to improve environmental quality. Due to the seriousness of the environmental problems, the first serious step started at the international platform in the decade of 1970s earth summit and the second most important step is the Kyoto protocol and agenda 21 aftermath of this, developed and developing countries started to work under "common but different responsibility" to reduce their GHG emission 5.2 percent at 1998 level by 2008. Considering this game-changer step, important to examine the shape of the growth emission relationship under the Environmental Kuznets framework.

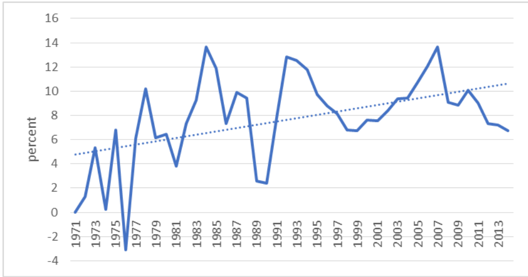
1.1 Trend of Variables:

The annual growth of variables for both countries is presented in table 1.1. Carbon emission and GDP both follow an increasing trend in India and China whereas Fossil fuel energy consumption and Trade openness show a declining trend over time.

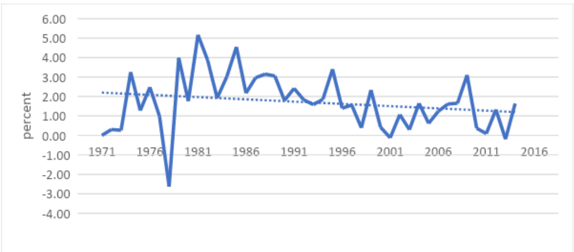
Table 1.1 Annual growth of carbon emission

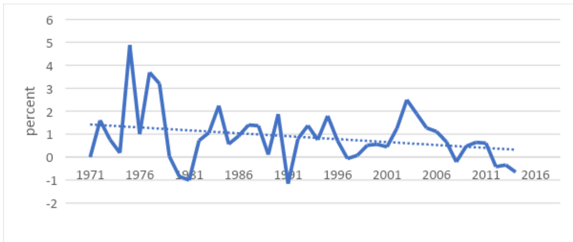
India 	China 
Annual growth of GDP	



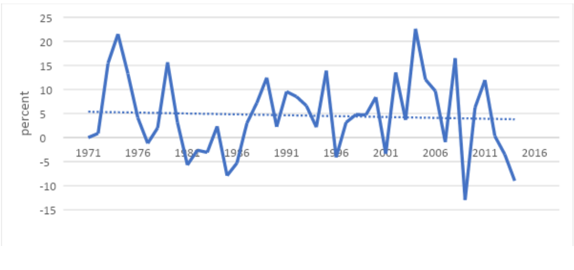


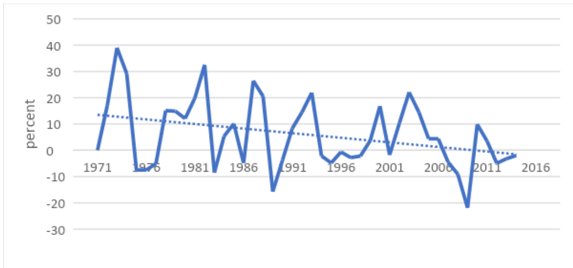
Annual Growth of Fossil fuel consumption





Annual Growth of Trade Openness





Source: Author calculation based on WDI data

2. Theoretical framework and empirical literature

2.1 Genies of Environmental Kuznets Curve

The fundamental theory of the environmental Kuznets curve was first developed and studied by Grossman and Krueger (1995)and specifies an inverted U-shaped relationship between income and environmental pollution. EKC comprises three stages and the first stage elaborates on economic growth and environment deterioration relation but after a certain level of growth or “turning point” of economic growth (highest point of the curve), environmental degradation starts to reduce.

Figure 1 Environmental Kuznets Curve

Source- Grossman and Krueger (1995)

2.2 Empirical literature

From Grossman and Kruger's analysis on the environment- income relation to nowadays there are many developments have been noticed in literature by the inclusion of other variables and simple to econometrical tools applications to examine this relation. Grossman and Kruger have extended the Kuznets (growth -inequality relationship) curve into Environmental Kuznets Curve by adding Income and Environmental quality variables. On the basis of available literature, there is three / four stream of research which has focused on testing the Environmental Kuznets curve. The first stream examines the relationship between carbon emission, and economic growth with additional variable energy consumption [25][16][17][13][19][29][2][10]. Make available the understanding of unidirectional and bidirectional relations of carbon emission, energy consumption, and economic growth in different regions. Carbon emission, energy consumption, and economic growth relation exist in the short run [11] and in long run, both[11][20][6][21] Tiwari & Kumar (2011) observed the connection between energy consumption, economic growth, and CO_2 emissions in India. Applied the Granger approach in the VAR framework and found that energy consumption, population, and capital Granger-cause economic growth but economic growth, not Granger causes energy consumption, population, and capital. Applied IRFs and VDs analysis outcome shows that CO_2 emissions positively influence energy use and capital but do not have the same impact on population and GDP. Moreover, Energy consumption has a constructive effect on CO_2 emissions and GDP but is negative on capital and population. This study advises policymakers to reduce fossil fuel dependency and energy generation, better to move in the direction of renewable energy sources. Wang, Zhou, Zhou, & Wang (2011) analyzed the nexus of energy consumption, real economic output, and carbon dioxide emissions specialized in China. Covered 28 provinces in China based on panel data for the period 1995 to 2007. Applied panel cointegration and panel vector error correction methods and summarized that these variables cointegrated with each by bidirectional causality. Thereby result supports that energy consumption and economic growth elongated causes of CO_2 emission and the same CO_2 emission and economic growth reasons for energy consumption. The study indicated that proper policy is required to control the country's economic growth at the cost of environmental loss in the long run. Wang, Fang, Guan, & Ma (2014) investigated the association between urbanization, energy consumption, and CO_2 emission in the 30 Chinese provinces for the period 1995-2011. The used panel data model in this study and resulted that per capita CO_2 emissions imbalances exist across the region in the country. These three variables are associated bidirectional in the long run and the significance of which was discovered to vary between provinces as a result of the scale of their respective economies and concluded that two-way positive causal relationship exists between energy consumption and CO_2 emission as well as energy consumption and urbanization and a one-way positive causal relationship exists from urbanization to energy consumption. This study also shows that the country per capita and total CO_2 emission increase pattern and potentiality of the reduction underdeveloped three scenarios. Zhao (2018) investigated the impact of GDP, fossil fuel energy consumption, energy consumption intensity, and economic structure on SO_2 emission in the Chinese province; it focused on the SO_2 emission to calculate the environmental degradation and relation to other essential factors. Moreover, Fang (2018) checked the impacts of economic growth, and trade openness on the environment in 261 cities in people and public China (PRC) for the measure of environmental Kuznets curve used an SO_2 emission from the industry. CO_2 emission and economic growth relation in the EKC framework have been checked by Dong (2018) with additional variables like fossil fuels consumption, nuclear energy, and renewable energy, and Jalil (2009) analyzed the causal relationship between income, energy consumption, foreign trade and carbon emission for 1975 to 2005. Hang (2011) studied the economic scale, technology, income, and population from 1980 to 2006 While Xu (2017) analyzed the carbon emission due to fossil fuel energy consumption from economic growth in China. Zhang (2009) used energy consumption, economic growth, and carbon emission.

Zhan J. (2016) analyzed the existence of the Kuznets curve in China between rural economic growth and income distribution inequality among rural residents and then based on the provincial panel data, adopted fixed effect and random effect models to analyze the relationship The results show the existence of Kuznets curve in rural economic development in China. There is an inverted U-shaped relationship between rural economic growth and income inequality among rural residents. And economic growth of most provinces has not yet reached the inflection point to reduce income inequality degree.

Very few pieces of literature are available which has conducted this study in the time frame and by using the least square method to estimate Environmental Kuznets Curve with the inclusion of fossil fuel and trade openness variable. Moreover, this study has tested the emission-growth-fossil fuel-trade openness long-run relationship. Additionally, compared the result to explain the differences between EKC shapes in India and China.

2.3 Objectives of Study

1. To examine the relationship between carbon emission, fossil fuel energy consumption, trade openness, and economic growth in India and China.
2. To test the Environmental Kuznets Curve hypothesis in India and China.

2.4 Hypothesis

1. There is a significant relationship between carbon emission, fossil fuel energy consumption, trade openness, and economic growth in India and China..
2. Environmental Kuznets Curve hypothesis exists in India and China.

3. Data and Methodology-

Before the estimation of economic growth and carbon emission relation in the Environmental Kuznets Curve framework, we performed the Unit Root test, to check the variables' stationary nature. Non-stationary time series used in the model can give spurious regression results. The present study has applied Augmented Dicky Fuller (ADF) and Phillip-Parron (PP) tests for the stationary test. VAR-based Johansen cointegration test (1991, 1995) performed using a Group object or an estimated Var object.

To estimate the effect of economic growth on carbon emission in the case of India and China, we employed the least square method to test the turning point (Environmental Kuznets curve) Followed by the method of Mor (2014), who tested the turning point by using the least square method. We test the growth-emission relationship with the following equation.

Emission Model specification -

$$CO_2 = \beta_0 + \beta_1 Y_t + \beta_2 Y_t^2 + \beta_3 Y_t^3 + \varepsilon_t$$

Here, CO_2 is the dependent variable, stands for per capita carbon emission, Y is the independent variable, stands for per capita income, Y^2 stands for the square of per capita income, t stands for time index, ε normally distributed error term, β's stand for parameters to estimate. Calculated the first turning point of carbon emission and economic growth using the formula: (-β1/2* β2). CO_2 is measured in carbon emissions in metric tons per capita and used as a proxy of Environmental Quality and GDP constant at 2010 US$ used as a proxy of economic growth. For the analysis work used EViews 7 software.
This study includes two high-growth economies- India and China. Data have been taken from published data of World Development Indicators (WDI). The selection of the study period is primarily determined by the as a milestone decade in the environmental world due to the seriousness and international effort about environment quality and the second limitation related to the use of the 1971-2014 data span is the availability of data for each country.

4 Results and Discussion-

ADF test result presented in tables 4.1.1 & 4.1.2, shows that for all four variables at the level, we can't reject the null hypothesis of contains unit root because the p-value is more than 5 percent and the estimated test value is higher than the critical value At first difference, CO_2, FE, TO and GDP found stationary this infers that CO_2, FE, TO and GDP series are stationary and integrated of order one I (1). In the Phillip Perron test, the same outcome finds that all four variables are stationary at 1st difference and integrated of order one I (1). The result shows the p-value is more than 5 percent and the estimated test value is higher than the critical value. Based on this, the unit root test performs again on the first difference of these variables. At first difference, FE and TO were found to be stationary while CO_2 and GDP have a unit root. CO_2 and GDP become stationary at the 2^{nd} difference; this infers that FE and TO series are stationary and integrated of order one I (1) and similar outcomes were found after performing the Phillip Perron test.
For the long-run association, the Johansen cointegration test run and with the help of the Vector Autoregression (VAR) model selected the appropriate lag length for the model. Based on Schwarz criteria and Akaike information criteria number of lags has been selected for the model. Table 4.4.3 presents the VAR lag selection result and shows that according to AIC and SC, two lags are suggested for the model. The test result is presented in table 4.2.1 and includes trace statistics and maximum statistics, both tests indicate the evidence of a cointegration equation among the variables. Cointegration trace statistics reject the null hypothesis of no cointegration between the variables, trace statistics of 62.06677 exceeds 95 percent critical value 47.85613. So, the null hypothesis of no cointegration is rejected at 5 percent level of confidence, which confirms the presence of one cointegration equation at 5 percent significance level, which means there exists a long-run relationship among the variables.

Johansen's cointegration test result is presented in table 4.2.2. The test includes trace statistics and maximum, and according to the trace test, there is evidence of at least one cointegration equation among the variables. For FE and TO cointegration trace statistics reject the null hypothesis of no cointegration between the variables, and trace statistics of 16.27397 exceeds the 95 percent critical value of 15.49471. So, the null hypothesis of no cointegration is rejected, which confirms the presence of 1 cointegration equation at a 5 percent significance level, which means there exists a long-run relationship among the variables.

Table 4.1.1 Unit root test-(India)

ADF			PP	
Variables	**Test value (level form)**	**Test value (1^{st} differenced form)**	**Test value (level form)**	**Test value (1^{st} differenced form)**
CO_2	0.512846	-6.657575***	0.691765	-6.71333***
FE	-1.084654	-5.734732***	-1.48926	-5.78189***
TO	-1.581036	-6.457561***	-1.55155	-6.45756***
Y	2.887736	-5.110690***	4.290555	-5.09087***

*, **, *** indicates significant at 10% level, 5% level & 1% level respectively

Table 4.1.2 Result of Augmented Dicky Fuller test (China)

ADF				PP		
Variables	**Test value (level form)**	**Test value (1^{st} differenced)**	**Test value (2^{nd} differenced)**	**Test value (level form)**	**Test value (1^{st} differenced form)**	**Test value (2^{nd} differenced)**

CO_2	-1.9512	-2.28317	-5.93518***	-0.29207	-2.28317	-5.91847***
FE	-2.53258	-4.99391***	-9.94826***	-1.78735	-4.99391***	-12.7619***
TO	-2.46783	-4.67007***	-6.86952***	-1.91182	-4.64108***	-15.9072***
Y	0.921152	-1.95017	-6.26687***	4.757667	-1.961	-6.59733***

*, **, *** indicates significance at 10% level, 5% level & 1% level respectively

Table 4.2.1 Johansen cointegration test result (India)

Null hypothesis	Alternative hypothesis	Eigenvalues	λ_{trace} rank value	Critical values 5%	p- values
H_0: r=0	H_1: r>0	0.637439	62.06677	47.85613	0.0014
H_0: r≤1	H_1: r>1	0.221368	19.45511	29.79707	0.4606
H_0: r≤2	H_1: r>2	0.183547	8.945995	15.49471	0.3704
H_0: r≤3	H_1: r>3	0.010162	0.429007	3.841466	0.5125
		Eigenvalues	λ_{max} rank values		
H_0: r=0	H_1: r>0	0.637439	42.61166	27.58434	0.0003
H_0: r≤1	H_1: r>1	0.221368	10.50911	21.13162	0.6959
H_0: r≤2	H_1: r>2	0.183547	8.516988	14.2646	0.3286
H_0: r≤3	H_1: r>3	0.010162	0.429007	3.841466	0.5125

Note: included endogenous variables are CO_2, FE, TO & Y

*, **, *** indicates significance at 10% level, 5% level & 1% level respectively

Table 4.2.2 Johansen cointegration test result(China)

Null hypothesis	**Alternative hypothesis**	**Eigenvalues**	**λ_{trace} rank value**	**Critical values 5%**	**p- values**
H_0: r=0	H_1: r>0	0.285958	16.27397	15.49471	0.0381
H_0: r≤1	H_1: r>1	0.058342	2.46463	3.841466	0.1164

		Eigenvalues	λ_{max} rank values		
H_0: r=0	H_1: r>0	0.285958	13.80934	14.2646	0.0589
H_0: r≤1	H_1: r>1	0.058342	2.46463	3.841466	0.1164

Note: Included endogenous variables are FE & TO
*, **, *** indicates significant at 10% level, 5% level & 1% level respectively

The test of Environmental Kuznets Curve, checked relationships between carbon emissions and economic growth. As a proxy of environmental degradation per capita carbon emissions and as a proxy of economic growth, per capita GDP has been used. A cubic emission model has been applied to test the inverted U shape relationship.With the help of β1 and β2 values only estimated the first turning point. The empirical recognition of an Environmental Kuznets Curve or inverted U-shape relationship is based on the estimations of regression parameters more promptly coefficient signs and their statistical significance. In the case of the Environmental Kuznets Curve, the curve would be confirming it under the following signs + for β1 and – for β2 for an inverted U shape.

Table 4.3.1 presents the result of the Environmental Kuznets Curve regression result for India. Estimation presents statistically significant parameters with the probability value. The table shows that the estimation of β1 is positive, whereas the estimate of β2 is negative. The findings confirm that in India carbon emission and economic growth are linked as an inverted U shape means Environmental Kuznets Curve relation exists in the country from 1971 to 2014 and the results are in line with Pao, 2010. Pao (2010) examined the relationships between pollutant emissions, energy consumption, and output for a panel of BRIC countries over the period 1971–2005, except for Russia (1990–2005). In long run, energy consumption has a positive and statistically significant impact on emissions, while real output shows the inverted U-shape pattern associated with the Environmental Kuznets Curve hypothesis.

Also, found the existence of an inverted U-shaped Environmental Kuznets Curve hypothesis with the turning point occurring at US$ 6.39 E+02 for India and in the long run as per capita gross domestic product is correlated positively with carbon dioxide emissions per capita, and square of per capita gross domestic product is correlated negatively with carbon dioxide emissions per capita. Table 4.3.2 presents the result of the Environmental Kuznets Curve regression for China. Estimation presents statistically significant parameters with the probability value. The table shows that estimates of β1 and β2 are positive, the findings confirm that in China, carbon emission and economic growth are not linked as an inverted U shape in the country from 1971 to 2014 time period.

Table 4.3.1 Estimation of EKC(India)

Coefficients	Coefficient	t statistics
β_0	-0.69456	-8.07286***
β_1	0.004002	11.74119***
β_2	-3.13E-06	-7.83646***
β_3	9.73E-10	6.902169***
R^2	0.990434	
F-Statistics	1380.489	
EKC shape	Inverted U-shape (with Y and Y^2)	
Turning point	US$ 639.2971	

Table 4.3.2 Estimation of EKC (China)

Coefficients	Coefficient	t statistics
β_0	1.172419	11.63138*
β_1	0.000894	4.621837***
β_2	1.55E-07	1.863581*
β_3	-2.03E-11	-2.13644**
R^2	0.985586	
F-Statistics	911.7211	

5 Conclusions and Recommendations

This study has conducted regression model to find out the relationship between environmental quality and economic growth in case of India & China. Empirical evidence from regression suggests that carbon emission and economic growth are linked as an inverted

U- shape in the case of India and in China, not related as an inverted U -shape, although a cubic polynomial inverted U-shape relation exists in China**.** The linear regression validates these findings that India has a trend of improvement in Environmental Quality after reaching the highest level of growth during this period while in the case of China, the Environmental curve has a trend to improve and then again environment deteriorates during this time period**.** In both countries, there is a trend of environmental quality deterioration with economic growth. Development is highly related to environmental degradation after the action at the international level to control and minimize the growth at the cost of environmental quality. After fourteen years of Kyoto protocol commitment and guidelines, there has not been seen a more downward trend in environmental deterioration. India and China both are higher growth economies and in the phase of to be developing into developed nations, their conventional energy-based development has deteriorated the environment, therefore, there is a need to think about green development for India and China to achieve sustainable and climate goals**.** The positive relation between a Better Environment and economic growth can be more suitable and sustainable for the economy compared to the negative relation between Environmental quality and economic growth. Environmental deterioration generates many new climate challenges likewise more frequent and severe modes and occurred socio-economic losses. The existence of EKC shows negative and then positive both relations between environmental quality and Income, which relation we have found in this study in the case of India while in the case of China, cubic polynomial U-turn shows negative, positive and then again negative emission-growth relation, the existence of this type of cycle in emission-growth relation does not assure about the permanent improvement in environmental quality after reaching peak point of this relation. This tends to more R&D and adoption of non-conventional energy to achieve the sustainable environmental goal.

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