Examining Environmental Kuznets Curve for Carbon Dioxide Emission in Bangladesh: A Bootstrap Approach

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Carbon dioxide emissions (CO_2) often hypothesized to follow environmental Kuznets curve model. In the paper, CO_2 were examined according to the Environmental Kuznets Curve Hypothesis in the context of Bangladesh using exploratory data analysis and confirmatory analysis using time series data from 1972 to 2000. Both classical and bootstrap techniques were used to draw inferences on model parameters. This study reveals that Carbon dioxide emission per capita was increasing annually at a constant rate, yet over a 10 year period, there was an increase in both the median level and its numerical variations. This exploratory analysis revealed that an increase of Carbon dioxide emission per capita did not have a self-limiting point linked to increasing GDP per capita in Bangladesh as shown in the Environmental Kuznets Curve. Rather, the situation is explained better by a simple linear time trend model.

JEL Codes: Q5

1. Introduction

The last two decades the world has witnessed unprecedented effects of global warming. The increasing CO_2 in the atmosphere gave rise to warmer global temperature (IPCC. 1996). The main source of CO_2 is fossil fuel, the main power source of automobile and industry that are directly linked with economic growth

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and developments. The causal relationship between economic development and different indicators of environmental quality has been extensively explored in the recent years by the Environmental Kunzets Curve (EKC) models globally, regionally or country wise (Galeotti and Lanza 1999, Kumar and Aggarwal 2003, Martinez-Zarzoso and Bengochea-Morancho 2003, Hayward 2005). Grossman and Krueger (1991) first introduced Environmental Kuznets Curve (EKC) hypothesis for different environmental indicators such as CO_2 emission. The EKC hypothesis stated an inverted *U*-shape relation between various indicators of environmental quality and per capita income. Under this hypothesis, CO_2 emission was usually explained by linear, quadratic or cubic polynomial functions of income per capita.

Numerous panel and cross-country studies provided evidence in favor of EKC in some countries or regions (Grossman and Krueger 1991, Shafik 1994, Holtz-Eakin and Selden 1995). Also there were some evidence against the hypothesis for a number of measures of environmental degradation (Rothman and de Bruyn 1998). Moreover, several limitations of the data, econometric techniques (such as, violation of fundamental assumptions inadequate model diagnostics) cast serious threat to the conclusion validity of EKC models (Shafik 1994, Arrow et al. 1995, Stern et al. 1996, Ekins 2000, Stern 2003). Regarding the EKC model specification, Azomahou *et al.*(2006) showed that that the polynomial functional form of CO_2 emission was not appropriate and per capita GDP was not exogenous, which clearly contradict the existence of an EKC model for CO_2 emissions. Such relationship is not unique regardless of time and place and the relationship dependents on the specific circumstances and their economic policy of the country (Grubb et al.). So the nature of relationship between CO_2 emission and GDP per capita could be different for Bangladesh and was unknown.

The external validity of the reported turning points in the EKC literatures is somehow misleading because, many of the reported turning points for different environmental degradation indicators were at a level greater than the current per capita income of most countries (e.g. $4000-$5000 in Grossman and Krueger (1991), $8709 in Selden and Song (1994), Holtz-Eakin and Selden (1995) infer a turning point of $35,418 whilst Neumayer (2004) cited a range between $55,000 and $90,000 as the turning point). Per capita income of the people of Bangladesh is low and it is $1500 compared with the world-wide income distribution and the economy of Bangladesh has a steady growth (Al-Amin et al. 2007, CIA 2009). What is the nature of the growth- CO_2 emission relationships for Bangladesh? Study on Bangladesh in this regard is important to rationalize CO_2 emission depending on the manageable causes for planning the sustainable development strategy for Bangladesh.

This study aims to explore the scenario of CO_2 emission using time series data and justify the possible existence of EKC for CO_2 emission in Bangladesh. We applied exploratory data analysis techniques and model EKC undertaking the vast diagnostic review to overcome the drawbacks of previous studies. We apply bootstrap techniques to avoid small sample discrepancy and to enjoy the autonomy over the classical normality assumption for testing the hypothesis of the model parameters.

2. Methods

2.1 Data

We used time series record of CO_2 emissions measured in metric tons per person were obtained from the www.unep.org for the period 1972-2000 (29 years), GEO data Portal provided by United Nations Statistics Division. GDP per capita series, measured in thousand constant dollars at 1985 price, are drawn from World Development Indicators 2003 provided by The World Bank.

2.2 Exploratory Data Analysis (EDA)

We explored CO_2 emission and GDP per capita by time series plots in level and first difference, box plots and scatter plots for diagnostic checking. Exploratory data analysis allows the data to guide the analysis, choice of appropriate models and to check outliers in the data that might influence the result unduly (Tukey 1977, Hoaglin et al. 1985).

2.3 Confirmatory Analysis

We have considered the basic EKC model as follows;

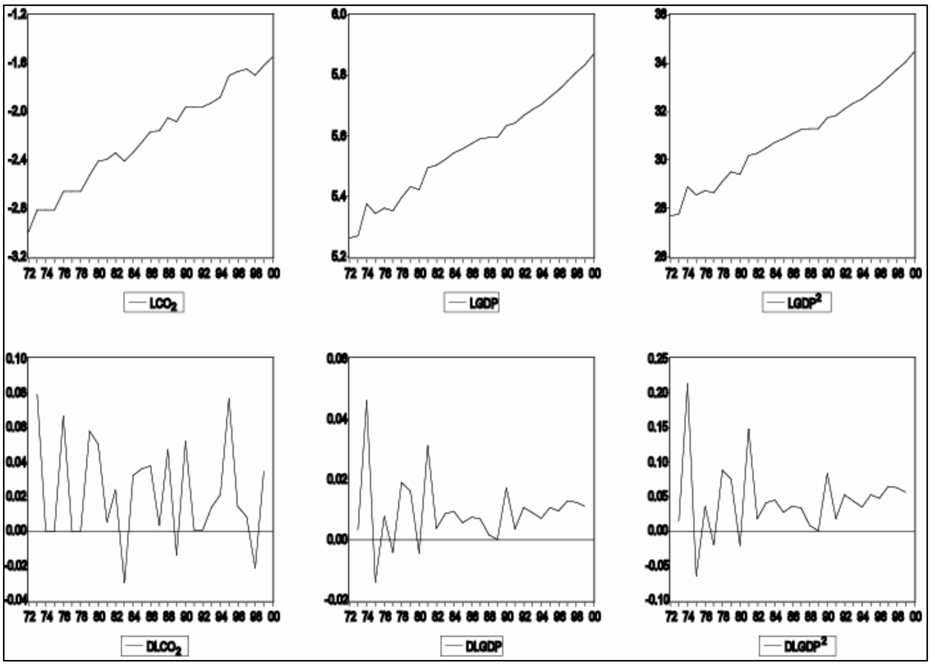
$$CO_{2t} = \alpha + \delta t + \beta_1 GDP_t + \beta_2 GDP^2_t + \varepsilon_t \qquad (1)$$

where CO_{2t} is CO_2 emission per capita at time t, GDP_t is GDP per capita at time t, $t = 1,2, \ldots ,T$, t is the time variable. The random disturbances ε_t are assumed to be in Gaussian distribution. Non-zero α constant term allows the fixed part of CO_2 emission for Bangladesh. δ, β_1 and β_2 are the coefficients of time, GDP and squared GDP per capita respectively that accounted for the share of contribution of the variables to CO_2 emission per capita in Bangladesh. We applied ordinary least square (OLS) method to estimate the parameters. We applied diagnostic tools to assess the model. The sample autocorrelation function and Ljung and Box (*L-B*) statistic of the estimated residuals were used to study whether there were any autocorrelation left in the residuals. Assumption of normality of the residuals were tested using histogram, normal probability plot (Weisberg 1980, Liu and Hudak 1986) and with formal tests; rescaled moment test (Imon 2003) and Jarque-Bera test (Jarque and Bera 1987). Goldfeld-Quandt test (Goldfeld and Quandt 1972) and Breusch-Pagan test (Breusch and Pagan 1979) were used to check the heteroscedasticity of the residuals. Condition number and condition index (CI) were used to check multicollinearity and its' strength. Outlier was checked by running time series plot, box plot and standardized residual plot and normal probability plot.

Hypothesis tests and confidence intervals based on asymptotic theory could be seriously misleading for small sample size and bootstrap could be a possible solution of such small sample discrepancy (Davidson and MacKinnon 1992, 2002). We used bootstrap method to validate the inferences drawn by classical approach. By model based bootstrap we resample from original data to create replica of datasets and estimate the parameters of interest. We used model based bootstrap to estimate the EKC model parameters and classically estimated model is used for bootstrapping regression. Regarding the critical region of hypothesis testing by bootstrap, we use confidence region approach described by Beran (1984, 1986, 1988). 9999 replicates are taken to draw the empirical sampling distribution of estimates for each hypothesis tests.

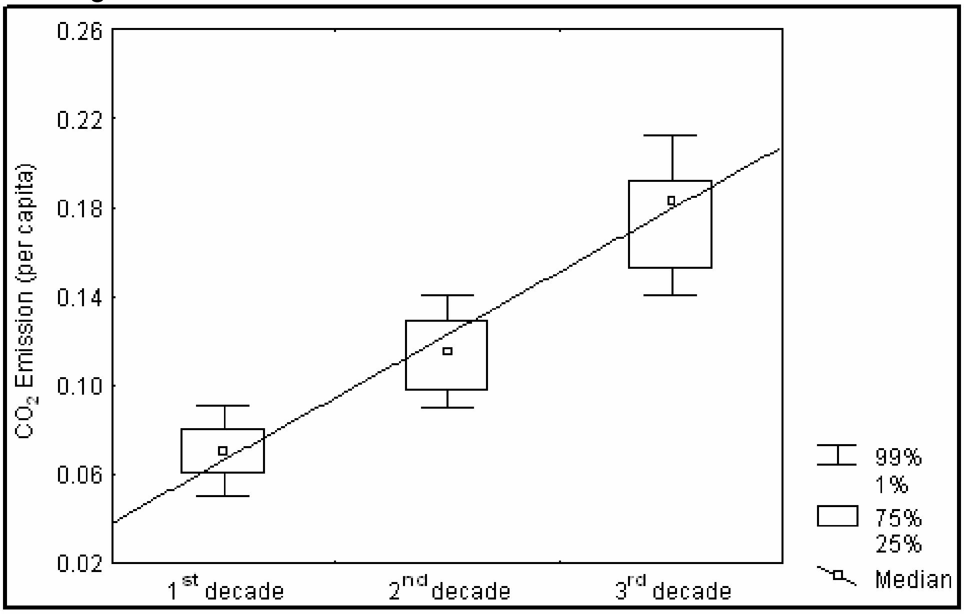
3. Results

Figure 1. Graphical presentation of untransformed CO_2 emission per capita, GDP per capita, and the first differenced log transformed variables.



CO_2 emission per capita, GDP per capita and it's square have strong increasing trend The first difference from it's lag is able to remove trend The mean of the differenced CO_2 emission was likely nonzero (Fig 1) which implies CO_2 emission per capita is increasing and the rate of increase is likely constant over time. The trend of GDP per capita is not completely removed by differencing rather there was an increasing trend in the rate of change in GDP indicates acceleration.

Figure 2. Decadal box plot of CO_2 emission per capita (unit: thousand metric tons) in Bangladesh



Both median emission and variation of emission have been increased in consecutive decades (figure 2). We found an increasing decadal trend of CO_2 emission. We did not observe any value abruptly fluctuated from the majority.

We fitted basic EKC model described by equation 1. From box plot we found that the variance of CO_2 emission per capita was dependent on time. We took the logarithm of the variables and these log transformed variables were used for analysis.

Table 1. Results of EKC model parameter estimations and hypothesis testing by classical and bootstrap methods and diagnostic statistics

Coefficients	Estimates	SE	*t*-value	*Pr*>|*t*|
Intercept	-9.1393	4.4872	-2.0367	0.0524
Trend	0.0221	0.0041	5.3347*	0.0000
β_1	6.6297	3.6850	1.7991	0.0841
β_1	-1.3946	0.7670	-1.8183	0.0810
Test statistics	*F*: 604.4	*R-M*: 0.6995	*G-Q*: 0.4204	*J-B*: 0.5221
p-values	0.00	0.352	0.433	0.770
RSE: 0.0224	R^2: 0.9864	*D-W* Stat: 1.805	*k*: 1996.87	*CI*: 3987472

*Significant at 5% level at bootstrap test.

The model explained about 98.64% variability of CO_2 emission. The *F*-statistic implies that the overall regression is highly significant. *t*-statistics suggests that the intercept is significant at 5% level and the trend is highly significant. The slop term β_1 and β_2 are significant at 10% level. Thus the model as a whole has satisfactory explanatory power. The diagnostic test for normality of the residuals shows that residual may be normally distributed. The *D-W* statistics shows that residuals are most likely serially correlated.
Diagnostic tests suggested that there was no unexplained serial correlation left by the model. The Goldfeld-Quandt (*G-Q*) test suggested that the error is homoscedastic. The histogram and normal probability plot of the residuals showed that the residuals might be non-normal but the RM test and J-B test suggested the normality of the residuals. The value of condition number *k=1996.87* and condition index *CI = 3987472* are very high compared to the standard *k* = 1000 and the CI = 30 respectively. This suggests the presence of severe multicollinearity.

Bootstrap test result suggested that $\hat{\beta}_1$ and $\hat{\beta}_2$ are not a rare value under the null hypothesis hence the null hypotheses $\beta_1 = 0$, $\beta_2 = 0$ might be accepted. The $\hat{\alpha}$ obtained by classical estimation method is a rare value under the null hypothesis and the hypothesis $\alpha = 0$ may be rejected at 5% level of significance. The trend coefficient is highly significant and the histogram of the bootstrapped estimates of trend coefficient under H_0 does not contain the classically estimated value $\hat{\delta}$. Thus, bootstrap test procedure supports the classical test result more clearly. Hypothesis test result suggests that GDP per capita and squared GDP per capita should be removed from the model.

4. Discussion

This paper investigated the trends of CO_2 emission per capita and the existence of EKC for CO_2 emissions per capita of Bangladesh by analyzing secondary time series data. Study showed that CO_2 emission was increasing in consecutive decades in more instable fashion. In every ten year, the median level of CO_2 emission and variation of emission both were increasing, which is alarming. It was strictly increasing rather converges to a certain limit with the growing GDP per capita in Bangladesh. We observed acceleration in GDP growth on or later 1990, but we did not observe any impact of this acceleration on CO_2 emission. However, conclusion based on such a small sample is difficult.

From the EKC model study we found that GDP per capita or squared GDP did not contribute significantly to explain CO_2 emission per capita. Both classical and bootstrap approach suggested that GDP and it's square should be removed from the model. The multicolliniarity test result also suggests that GDP per capita and it's square jointly should not be used as covariate. Removing GDP per capita and its square, the model becomes simply a time trend model, which implies that we did not have any limiting point for CO_2 emission with respect to the increase for GDP per capita for Bangladesh rather CO_2 emission is a function of time which is not some manageable cause. Better interpretation of the model is that, possibly there might have some important variables that were not incorporated in the model.

Study revealed that on or before 1990, the rate of change of GDP per capita was fixed and on or later 1990s the rate was increasing. This rapid growth of GDP might be reasonable as it may be the impact of trade liberalization (Al-Amin et al. 2007). The analysis presented above suggests that an increase in economic growth was not inevitably associated with increase in emissions. Even no effect was observed after the rapid increase of GDP per capita in Bangladesh. From our study it was observed that CO_2 emission is not likely a polynomial function of GDP per capita. The finding suggests the outcomes of Azomahou *et al.* (2006) and Grubb *et al.* (2006).

In the majority of the countries with economies in transition considered the growth of GDP per capita associates with growth in emission per capita, but the amplitude of the growth can vary significantly and depends on other factors specific to each economy. Recall the economic change after 1990 the result of trade liberalization both exports and imports activities increase in Bangladesh directly or indirectly affecting the energy use and various air emissions. Al-Amin et al (2007) showed that the CO_2 emission was highest in the industry (192.7 tones) sector followed by services (5.43 tones) and agriculture (2.95 tones) sector using coal which are largely motivated by exports liberalization. Although these sectors might have some direct impact on the GDP per capita of Bangladesh, the growth of GDP does not reflect the change in emission of CO_2. This might happen due to static assumptions of technological change, energy consumption and use of natural resources, the relative percentage of industry to agriculture with regards to total economic output are the possible regulatory forces of CO_2 emission in Bangladesh. These results suggest that income convergence alone may not be sufficient to induce convergence of pollutant emissions which is one of the main concerns of Bulte *et al.* (2007).

Following the literature on this relationship, we just considered the CO_2 emission per capita and GDP per capita as a proxy variable of per capita income. We did not consider the possible determinants for CO_2 emissions, like technological change, energy prices, etc. which might include in the study. A number of points can be made in support of our choice. The first, obvious one, concerns data limitations, the second point concerns the lack of existing studies and finally and more importantly, we are not concerned here with obtaining best predictions for CO_2 emission next years, rather the relationship and shape of relationship (if exists) with GDP per capita. Moreover the impacts of determinants, which are correlated with GDP, would capture the effect of GDP per capita. The results of our study will not enable us to make precise policy prescriptions rather that would intervene convincingly in the long debate on the existence of EKCs and its implication in Bangladesh.

Based on energy consumption pattern the total projected in 2070 CO_2 emission in Bangladesh will be 293,260 Giga gram with a current growth rate of 6.34% per year (Azad et al. 2006). Our study reveals that increasing CO_2 emission per capita is not directly linked with GDP per capita though GDP is directly linked with energy consumption. Murthy *et al.* (2006) showed that CO_2 emission reduction imposes costs in terms of lower GDP and higher poverty. So to reduce the cumulative emission of CO_2 in Bangladesh the scientists and policy makers should take more care for clean or environment friendly energy production as well as appropriate technology and adapt some policies regarding the reduction of CO_2 emission rather to increase the income per capita only.

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