Global observation of EKC hypothesis for CO_2, SOx and NOx emission: a policy understanding for climate change mitigation in Bangladesh

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ABSTRACT

Environmental Kuznets Curve (EKC) hypothesis is critical to understanding the developmental path of a nation in relation to its environment. How the effects of economic development processes dictate environmental changes can be found through the study of EKC. To understand the EKC phenomena for climate change, this study was undertaken by reviewing the available literature. As CO_2, SOx and NOx are the significant greenhouse gases (GHG) responsible for global warming, thus leading to climate change, the study focused on those GHGs for EKC consideration. With an understanding of the different EKC trajectories, an attempt was made to determine the implications for the economic development of Bangladesh in regards to the EKC. It was shown that EKC for CO_2 was following a monotonous straight line in most cases. SOx were shown to follow the full trajectory of the EKC in most situations and NOx was shown the hope only for the developed countries getting the low-income turning point. The type of economic policy that Bangladesh should follow in regards to the discussed pollutants and sources is also revealed. From these discussions, contributions to policy stimulation in Bangladesh are likely to be made.

Keywords: Economic growth; Environmental degradation; Global warming

1. Introduction

A close relationship between economics and environment may be seen these days. Growth in Gross Domestic Product (GDP) or income per capita in a nation seems to be interlinked with environmental ups and downs. Where an economy develops by taking resources from the environment, at a certain level the economy must help the environment in order to maintain its sustainability as well as that of the environment. The abatement activity starts after a substantial amount of capital stock is achieved (Selden and Song, 1995). An Environmental Kuznets Curve (EKC) is a hypothesized relationship between economic growth (income per capita) and environmental quality. This curve indicates that economic growth initially degrades environmental quality, but with further growth the relationship appears to reverse and environmental degradation starts to reduce. This relationship produces an inverted U-shape curve, where environmental degradation first rises and then falls with increasing income per capita. The idea of Environmental Kuznets Curve came into the limelight in 1991 with the study of NAFTA[1] (Grossman and Krueger, 1991), though the idea of Kuznets curve (relationship of economic growth and income inequality) existed from 1955 (Kuznets, 1955). However, the Environmental Kuznets curve (EKC) hypothesis became very important after 1991 for its potentiality and promise of finding a final solution to environmental degradation. If this hypothesis is taken to be true, then the future environment may be assumed to be pollution free along with possessing higher living standards.

Global warming now presents the greatest potential threat to the environment in regards to climate change. Global average temperature has already increased by 0.6ºC and could increase to 6.4ºC by 2100 (IPCC, 2007). This trend of increasing temperatures throughout the world has raised an alarm of the extinction of the human race. Increased amount of greenhouse gases (GHG) is considered the main cause of global warming. The most important GHGs are CO_2, SOx, NOx, CH_4 and F-gases (gases that contain Fluorine). The contribution of suspended particulate matter, waste emission (for emission of CH_4) and deforestation cannot be ignored. Accordingly, this paper reviews the EKC for some specific GHGs, i.e., CO_2, SOx and NOx.

It is hypothesized that Bangladesh is following a full inverted U-shape curve for environmental quality. Like other developing countries of the world, Bangladesh is currently

[1] North American Free Trade Agreement

hypothesized to be at the initial up-facing stage of EKC. However, there is no validly published empirical work on EKC for Bangladesh. How EKC behaves for a developing economy is also still a matter of argument. This study was aimed at relating the results of EKC for other developing countries with Bangladesh. What will be the status of CO_2, SOx and NOx emission in Bangladesh with ongoing economic development? Will Bangladesh follow the inverted U-shape EKC curve in GHG emission? If so, what should be the economic and environmental policy? In answering these research questions, this paper is expected to contribute significantly to this environmental issue. The review synthesis and the judgments will help policy makers to choose the correct economic and environmental policy for Bangladesh.

2. Method of study

To explore the policy implications for the emissions of CO_2, SOx and NOx with relevance to Bangladesh, the study was conducted from August 2008 to August 2009. The data on global warming, causes, consequences; EKC, behavior of CO_2, SOx and NOx in the EKC trajectory; and the socio-economic status of Bangladesh, were collected mostly from the authoritative sources available on the Internet. Some facts were cross-checked directly in the offices of Bangladesh, mostly located at Dhaka and Chittagong. For searching the most recent facts, Scirus[2], Scopus[3] and ISI web of knowledge[4] were used for reviewing the most relevant scientific articles. For that, some common keywords like economic growth, environmental degradation, global warming, greenhouse gases, EKC, and Kuznets curve were used to search out the specific articles. In addition, the facts on global warming/climate change were collected from the recent web pages of UNFCCC[5] and IGES (Institute for

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[2] http://www.scirus.com/
[3] http://www.scopus.com/
[4] http://apps.isiknowledge.com
[5] http://unfccc.int

Global Environmental Strategies)[6]. To form a concrete understanding of the EKC regarding global warming, many cross-references were also used.

As CO_2, SOx and NOx are the important factors in global warming leading to climate change, they were considered for understanding the EKC behavior. The most important findings on those parameters were synthesized, their specific research paradigms were compared and deviations among the results were discussed. The calculation of GDP and/or income per capita were considered in US$ for the specific period. The synthesis of the original scientific articles on EKC and different environmental degradations was used to implicate those for Bangladesh considering the national income and other factors of EKC.

3. General Background

3.1.The EKC hypothesis

In 1955, Simon Smith Kuznets, a Russian American economist, proposed a hypothesis relating economic growth and income inequality known as the Gini Coefficient (Stern, 2004;Torras and Boyce, 1998). He states that income inequality may rise at first with increasing economic growth, but in the long run it will tend to diminish after a certain point in economic growth. This relation can be shown in an inverted U-shaped Kuznets curve, which is named after Simon Kuznets.

However, the idea of considering a relationship between the environment and Kuznets curve first emerged in 1991 with Grossman and Krueger's study of NAFTA (Bhattarai and Hammig, 2001; Grossman et al., 1991; Stern, 2004). A curve is produced with an inverted U-shape relationship between income per capita and environmental degradation. It was named the Environmental Kuznets Curve (EKC) in 1994 (Selden and Song, 1994).

[6] http://www.iges.or.jp/en/

This curve implies that environmental degradation first increases with increasing income per capita, but that after a certain point in increasing income per capita, environmental degradation tends to diminish (Fig. 1). Though environmental degradation rises quickly with a steep slope in the curve, its reduction forms a moderate slope. A hill-shaped curve is produced when income per capita occupies the X-axis and environmental degradation occupies the Y-axis. When there is no turning point in income per capita for any pollutant, a straight line is found (Fig. 1).

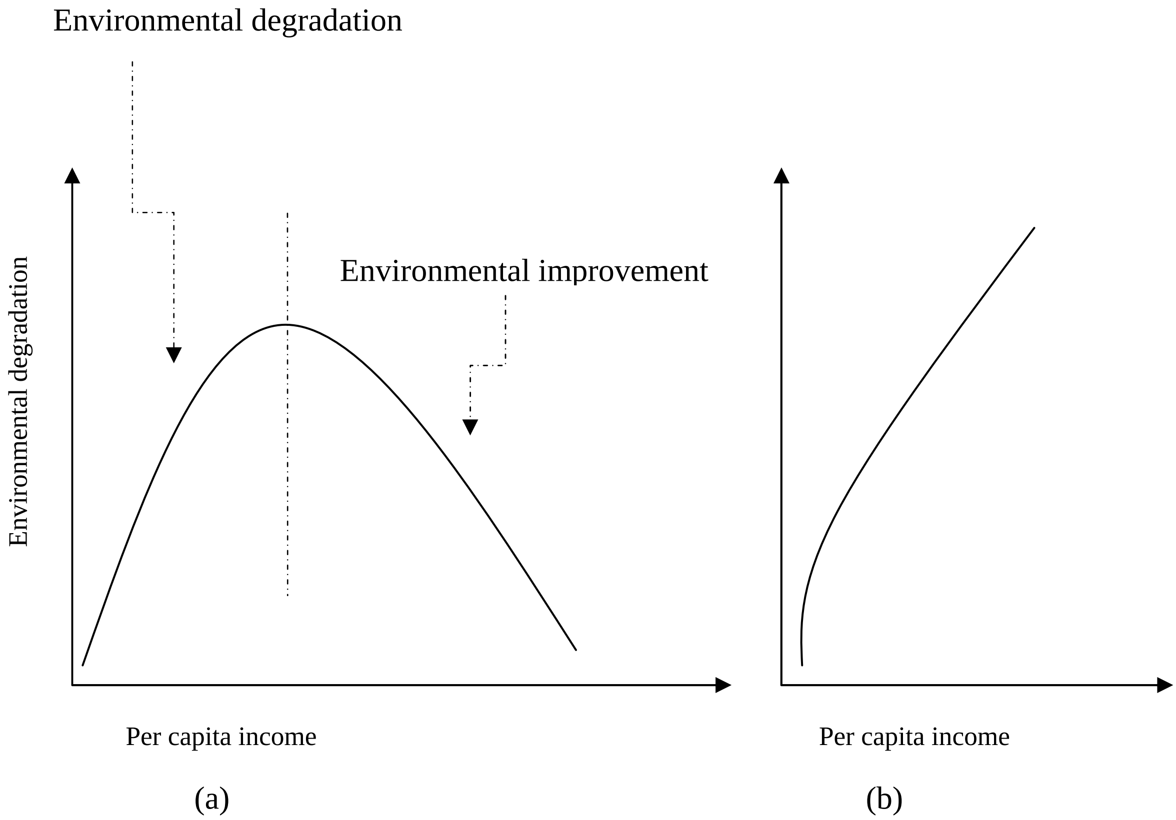

Fig. 1. General environmental Kuznets Curve, (a) A full trajectory of inverted U-shape EKC; (b) Straight line of EKC, where no turning point is found.

In some cases, an N-shaped EKC has been found as well, i.e. Bhattarai and Hammig (2001) for Deforestation, Torras and Boyce (1998) for SOx, etc. It occurs when environmental degradation shows a positive, negative and positive relationship, respectively, with income per capita in an economy. It means environmental degradation first increases with income per capita, and then decreases after a certain level, thus forming a peak. Along with further increase in income per capita, however, degradation tends to rise again, which creates a trough in EKC (Fig. 2).

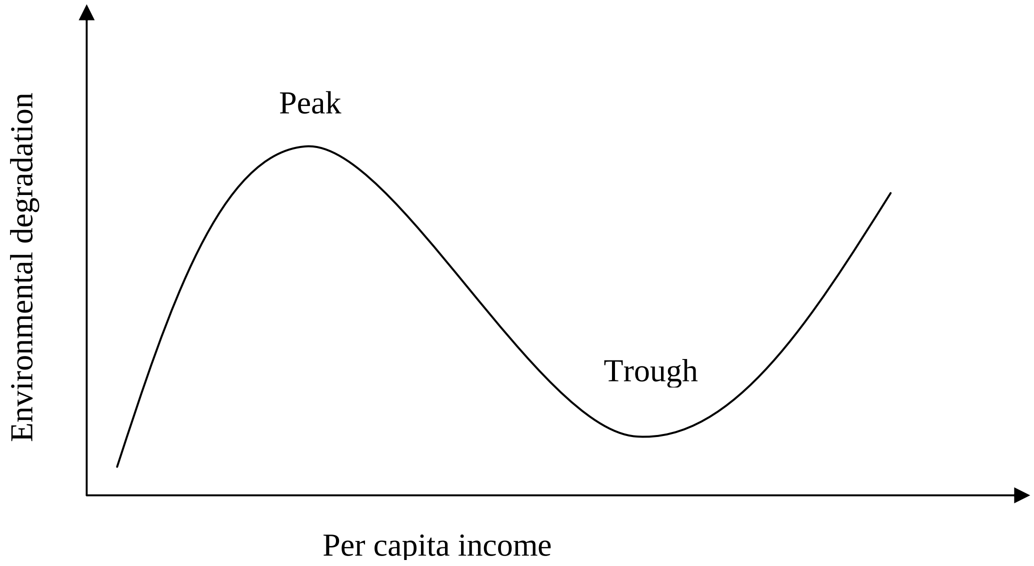

Fig. 2. Peaks and troughs of EKC for determining environmental degradation by per capita income.

Gangadharan and Valenzuela (2001) stated that, in an EKC relationship, the environment is like a luxury good. At the early stage of development, the environment is not really taken care of, but when income reaches a certain level, people want to act smart for the environment. However, this relationship is not as automated as it seems. Grossman and Krueger (1995) stated that it is 'an induced policy response' and that it has some variables working within it.

The EKC is generally measured with two models, i.e. Fixed Effect (FE) and Random Effect (RE). The first model is deployed where all other variables remain constant and only the changes in emission are measured with the changing income per capita. The second model is deployed where other additional variables are calculated as a changing factor. If the model is different, then the result will surely also be different. For example, RE model has a higher given value for turning point than FE model in NOx study (Selden et al., 1994). Again, Grossman and Krueger (1991) have found that FE model has shown higher value for turning point. Not only has the turning point differed according to the model, but also the presence of a hill-shaped EKC depends on them too. This is corroborated by Koop and Tole (1999), who found a turning point for deforestation using FE model, but no statistically significant turning point using RE model.

3.2. Climate change: a general overview

Climate change, caused by anthropogenic global warming, is the most discussed and feared environmental concern in the world today. There are indications of an increase in the average temperature of the earth's near-surface air and oceans. According to Intergovernmental Panel on Climate Change (IPCC)'s third assessment report, the temperature of the atmosphere has increased by 0.6ºC during the twentieth century (IPCC, 2007). Measurements and estimates of sea level show increases of 6–8 inches (15–20 cm) in the last century. Climate model projections summarized in the latest IPCC report indicate that the global surface temperature will probably rise a further 1.1 to 6.4 °C (2.0 to 11.5 °F) during the 21st century (IPCC, 2007). Along with that, projections on rises in sea level were done. This is of course a severe threat to the survival of the human race and is what prompted the experts to initiate necessary programs to abate it. In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) provided a general framework for reducing the emission of GHGs, which is the main cause of global warming. At the third conference of the parties (COP-3), the Kyoto protocol was adopted, in which the responsible countries were given specific targets for reducing GHGs. However, the Kyoto protocol came into force in February, 2005.

IPCC concludes that increasing GHG and aerosol concentrations is the main cause of global warming in the last century. Rather than being natural, this increase has resulted from various anthropogenic activities. It was observed that fossil fuel burning and deforestation are responsible for most of the measured temperature increases since the middle of the 20th century. It shows that GHG emission has increased by 70% from 1970 to 2004.

These gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and F-gases. Among these gases, CO_2 is the most important anthropogenic gas. Its annual emission has increased by about 80% from 1970 to 2004 (IPCC, 2007). Global increases in CO_2 concentrations are primarily due to fossil fuel burning, which accounts for 56.6% of the total emission. Land-use changes have surely made some contribution, but are smaller in comparison. Deforestation, decay of biomass, etc. produces CO_2 and contributes 17.3% in total emission (IPCC, 2007). Some other sources also exert CO_2, accounting for 2.8%. This means that CO_2 alone contributes 76.7% of the total GHG emission (IPCC, 2007). Increase in CH_4 is mainly due to untreated waste emission. Methane contributes 14.3% in total GHG emission. N_2O contributes 7.9% in total GHG emission (IPCC, 2007). Thus, the contribution of NOx to global warming cannot be ignored at any level. Though in small amounts, the contribution of F-gases in global warming is undeniable. Among these gases, one of the most important ones is sulfur hexafluoride. This is why a study of sulfur emission is also necessary. IPCC also includes some natural phenomena, such as solar variation and volcanoes, which produced most of the warming from pre-industrial times to 1950 (IPCC, 2007).

4. Synthesis on the general efficacy of EKC

Since Grossman and Krueger's study on NAFTA shook the economic view of the world in 1991, many papers have been published on the EKC. Since then, the basic argument of each paper has been whether or not there is any turning point for environmental degradation. In this section, some basic reviews have been done on the effectiveness of EKC.

It is obvious that when income per capita crosses a certain point, the nation attempts to invest in mitigation measures for the betterment of the environment (if society is fully aware of the environment and the new technology). In general, the idea of EKC assumes that environmental degradation has no effect on economic growth (Stern, 2004). However, most of the primary pollutants like SO_2, SPM, NOx and CO show an inverted-U shape EKC, while secondary pollutants form a monotonous straight line (Cole et al., 1997).

Selden and Song (1994) have shown in their FE model that turning point in income per capita for emission is higher than the concentration. EKC estimated with FE using only data on developed countries is not true for the whole world, especially in developing countries, because the assumed parameters are conditional on the country and time effects in the selected sample of the data (Stern, 2004).

The fate of developing and poor countries through the viewpoint of EKC is often argued by several experts. As EKC tells us, economic growth is the only possible way to reduce pollution; thus, when will they achieve enough income per capita for turning point of global pollutants to occur? At that point, what will be the scenario of global pollution? This is also hotly debated. However, Munasinghe (1995) has hypothesized a tunnel through the EKC which will help the developing countries to attain lower turning point by adopting measures from the developed ones (Fig. 3).

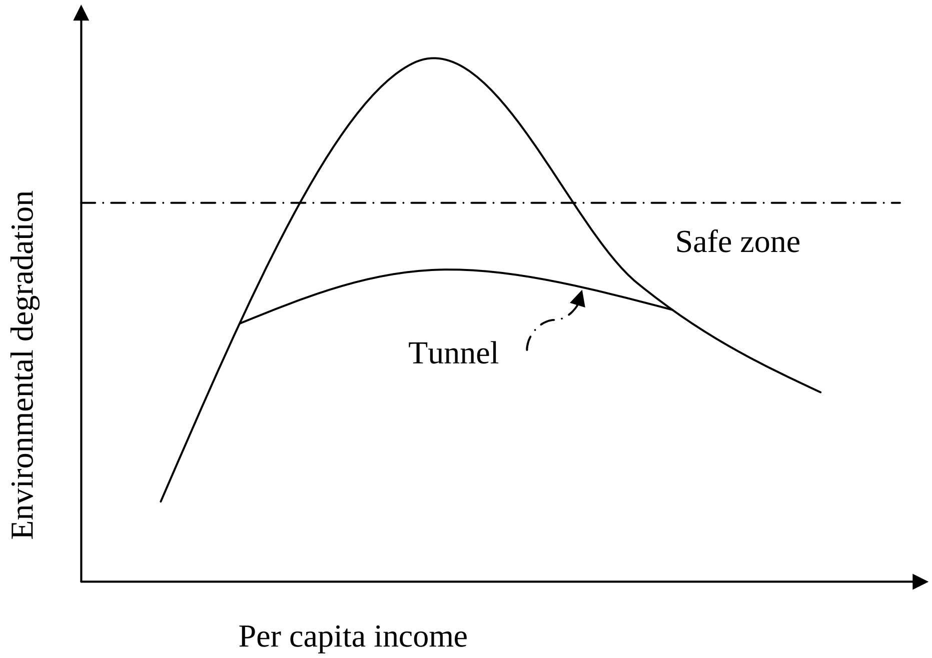

Fig. 3. Tunneling through the Environmental Kuznets Curve to lower the turning point.

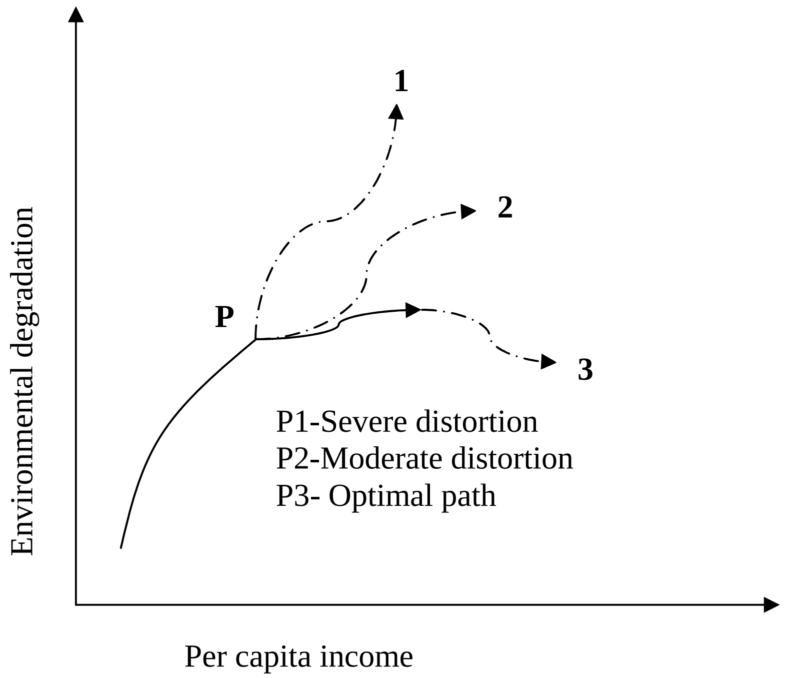

Fig. 4. Alternate path of development to reduce environmental degradation along with the increase of per capita income.

In this way, the developing countries can avoid a higher amount of income per capita for turning point and reduce environmental degradation in their developmental path. He proposed an alternate developmental path by proposing a tunnel, in one word (Fig. 4). He has shown three possible paths of economic development aligned with the environmental damage. The optimal path is the one path; an economy should look for in order to avoid the severe or moderate distortions of environment.

One noticeable factor which is lacking in, all the studies which have found a desired hill-shaped EKC, is that are done only for one specific pollutant. The aggregation of the pollutant's activities is not considered. It is for this reason that the question of how mitigation measures for a pollutant cause pollution in other faculties of the environment is still a question mark on the face of EKC.

5. **EKC for CO_2**

CO_2 is considered the major GHG that contributes the lion's share in global warming. According to an IPCC report, CO_2 alone contributes 76.7% of the total GHG (IPCC, 2007). Increases in the emission of this gas provide a direct correlation to global warming. This is why the study of EKC for CO_2 is very important.

Holtz-Eakin and Selden (1995) have done probably the first study on EKC for CO_2 and found a monotonous straight line. They used a quadratic model for data estimation. They estimated data for a panel of 130 countries (with complete data of 108 countries) from 1951-1986 and obtained some support for an EKC of CO_2. However, their estimated turning point occurs at a very high level of per capita income ($35,428 in per capita 1986 dollars) for the 1995 study.

Selden and Song (1994) have performed a study for EKC in both RE and FE models and found no turning point for CO. Shafik (1994) studied the effectiveness of EKC in relation to linear, quadratic and cubic models. His findings showed various relationships for CO_2 and no specific turning point was detected. His study was done in 47 cities in 31 countries.

However, Agras and Chapman (1999) found a surprisingly low amount of income per capita for turning point of CO_2 (only $13630). They studied data from 34 countries using FE model. Among these countries were developed ones such as the U.S.A. as well as developing ones such as Bangladesh. Maradan and Vassiliev (2005) found a turning point for CO_2 at an average GDP per capita of $5924. As he studied a number of countries with a wide variety of per capita GDP, his derived turning point was also widely varied. His minimum GDP per capita (expressed in PPP) for turning point was $325 and maximum was $17508 in 1985 value.

Gangadharan and Valenzuela (2001) adopted data from the World Development Indicators 1998, compiled by the World Bank. They used data from 51 countries, and those countries were the habitat of 70% of the world's population at that time. Among those countries, 43% (22 countries) were from the OECD countries. They found an upward straight line for carbon pollution. Hill and Magnani (2002) have done the largest study on CO_2, with a panel data of 156 countries around the world. They used Generalized Least Square (GLS) model for estimating EKC. However, they found no evidence of inverted U-shape EKC and emissions monotonically increase with income pre capita. Lindmark (2002) performed his experiment on EKC for CO_2 in Sweden, using dynamic structural model. Like most of his predecessors, he didn't find any turning point for CO_2 too. Friedl and Getzner (2003) have worked with data for Australian income per capita and CO_2 emission. In their experiment they found a turning point, but pollution tended to increase afterwards and didn't follow any specific trend. Shafik and Bandyopaddhyay (1992) studied data of 135 countries with Log linear model and found an upward straight line. Table 1 shows a summary of the different studies of EKC for CO_2, most of which were cited in Winslow (2005) and Lieb (2004).

Table 1
EKC studies for CO_2 emission contributing to climate change.

References	**Cities/Countries**	**Model type**	**EKC Result**	**Turning point(s)**
Gangadharan and Valenzuela, 2001	51 countries	Not found	Straight line, upward	N/A[i]
Selden and Song, 1994 (for CO)	22 OECD and 8 developing countries	Quadratic, RE[ii]	Straight line, upward	N/A
Selden and Song, 1994 (for CO)	22 OECD and 8 developing countries	Quadratic, FE[iii]	Straight line, upward	N/A
Holtz-Eakin and Selden, 1995	A panel of 130 countries	Quadratic, FE	Inverted U-shape	$35,428 in 1986 dollars
Agras and Chapman, 1999	34 countries	FE	Inverted U-shape	$13630 in 1990 dollars
Shafik, 1994	47 cities in 31 countries	Linear, quadratic and cubic GDP	Relationship varied	N/A
Lindmark, 2002	Sweden	Dynamic structural model	Relationship varied	N/A
Hill and Magnani, 2002	In a panel of 156 countries	Generalized Least Squares	Straight line, upward	N/A
Friedl and Getzner,	Austria	Linear, Quadratic	N-shape	Varied

References	Cities/Countries	Model type	EKC Result	Turning point(s)
2003		and Cubic model		
Maradan and Vassiliev, 2005	76 developed and developing countries	Log linear	Inverted U-shape	$5924 in 1985 dollars
Cole et al., 1997	11 OECD countries	Generalized Least Squares, FE	Inverted U-shape	$62700 in 1985 dollars
Shafik and Bandyopaddhyay, 1992	135 countries	Log linear	Straight line, upward	N/A

[i] indicates Not Applicable, [ii] indicates Random Effect model, [iii] indicates Fixed Effect model

Most empirical results for CO_2 have given an upward straight line with no turning point (Gangadharan and Valenzuela, 2001;Hill and Magnani, 2002;Holtz-Eakin and Selden, 1995;Lindmark, 2002;Shafik, 1994). According to some experts, a straight line of EKC fits the scenario of Environmental Economics, as CO_2 is a global pollutant. In the case of local pollutants, impacts are local and can be internalized within a single economy or region (Stern, 2004). The impacts of global pollutants cannot be internalized by a single economy, however, as there is no specific region which shows their impacts.

The most promising result of EKC for CO_2 is provided by Agras and Chapman (1999): $13630 income per capita for turning point. This amount is unpredictably low for a global pollutant. Holtz-Eakin and Selden (1995) estimate turning points of up to $8 million per capita in some cases. Though this is not the average result, it is of course a warning. According to them, the underlying economic growth will actually increase CO_2 emissions over time and outweigh the effects that reduce the emissions. This study proves once again that EKC is not an automated relationship between only pollution and economic growth. Lieb (2004) has observed 17 empirical observations of various authors and found an upward straight line for 13 observations. Thus, it may easily be observed that the general EKC for CO_2 is a monotonous straight line in almost all cases. This indicates that economic growth will not maintain the environment in regards to CO_2.

6. EKC for SOx

SOx are the oxides of Sulfur. Combustion of coal and petroleum generates SOx, as coal and petroleum often contain sulfur. These SOx are harmful to the environment, as their further oxidation produces H_2SO_4, leading to acid rain. The utilization of SOx has increased in recent decades due to its specific utility as a preservative, reducing agent, refrigerant, reagent and solvent in laboratories, etc. This has brought an unpleasant change in the environment which has shaken the experts. Besides, its contribution to global warming is huge. The oxides of sulfur are considered to be one of the major GHGs that contribute to global warming.

Many empirical studies on SOx, especially SO_2, have been done and almost all cases have produced the desired inverted U-shape curve (Table 2). Table 2 shows a summary of the different studies of EKC for SOx, most of which were also cited in Winslow (2005) and Stern (2004).

Grossman and Krueger (1991) started the study of EKC for SO_2 in 1991. They studied data from up to 52 cities in 32 countries. They used cubic FE and RE models and their turning point of income per capita was between \$4772 and \$5965. Shafik and Bandyopaddhyay (1992) used Quadratic FE model and found the peak of the inverted U-shape curve at \$3670. They studied data from 25 cities in 18 countries for 1976 and 31 cities in 21 countries for 1985. Shafik (1994) worked with concentration of Sulfur (1972-1988) for 47 cities in 31 countries. He used a Quadratic FE model and found an inverted U-shape EKC with a turning point of \$4379. Cole et al. (1997) compiled 12 years' worth of data (1970-1992) from 11 OECD countries and also found an inverted U-shape curve with a turning point of \$8232. Panayotou (1997) showed a turning point of \$5965 when he worked with 3 years' worth of data (1982-1984) from 30 developed and developing countries. Torras and Boyce (1998) employed data for SO_2 from 1977 to 1991. They worked on a maximum 52 (minimum 18) cities in a maximum of 42 (minimum 19) countries. They found an N-shape EKC by using Ordinary Least Square (OLS), FE model. Their results showed a peak and a trough at $3360-3890 and $15000, respectively.

Table 2
EKC studies for SOx emission contributing to climate change.

References	Time period	Countries/cities	Model	EKC Result	Turning point (in 1990 dollars)
Grossman and Krueger, 1991	1977, 1982, 1988	52 cities of 32 countries	Cubic, FE[i] and RE[ii]	Inverted U-shaped	$ 4772-5965
Shafik and Bandyopaddhyay, 1992	1972-1988	47 cities in 31 countries	Quadratic, FE	Inverted U-shaped	$3670
Torras and Boyce, 1998	1977-1991	18-52 cities in 19-42 countries	Ordinary Least Square, FE	N-shaped	$ 3360-3890, but increases again from $15000
Dinda et al., 2000	1979-1982, 1983–86 and 1987–90)	39 cities in 26 countries	Ordinary Least Square, Quadratic	Inverted U-shaped	$3000-6000 in 1985 dollars
Hill and Magnani, 2002	1975-1995	A panel of 156 countries	Generalized Least Square	Inverted U-shaped	$9300 in 1985 dollars
Shafik, 1994	1972-1988	47 cities in 31 countries	Quadratic, FE	Inverted U-shaped	$4379
Panayotou, 1997	1982-1984	30 developed and developing countries	Generalized Least Square	Inverted U-shaped	$5965 in 1985 dollars
Cole et al., 1997	1970-1992	11 OECD countries	Generalized and Ordinary Least Square, FE	Inverted U-shaped	$8232
Selden and Song, 1994	1979-1987	22 OECD and 8 developing countries	Quadratic, RE	Inverted U-shaped	$10391-10620
List and Gallet, 1999	1929-1994	US States	Quadratic and Cubic, FE	Inverted U-shaped	$22675
Stern and Common, 2001	1960-1990	73 developed and developing countries	Quadratic, FE	Inverted U-shaped	$101,166

[i] indicates Fixed Effect model, [ii] indicates Random Effect model

Stern and Common (2001) worked with data from 73 countries. Their turning point in income per capita was $101,166. However, their study in OECD countries has shown the turning points of $9239 and $9181 for FE and RE models, respectively. Non-OECD countries have shown higher income per capita for turning point, $908178 and $344689, respectively, for FE and RE models.

Grossman and Krueger (1991), Shafik (1994), Panayotou (1997), and Torras and Boyce (1998) have collected data from GEMS[7]. Cole et al. (1997) and Selden and Song (1994) have obtained data from the OECD sources. List and Gallet (1999) have worked with the highest duration of data for 65 years of United States history. Income per capita in their sample ranges was from $1,162 to $22462 at 1987 rates and their turning point in income per capita was $22675 at 1990 rates. They used fixed coefficients estimate model to estimate EKC.

Some studies were done which measured PPP (Purchasing Power Parity) rather than per capita GDP. These are Shafik (1994), Torras and Boyce (1998), Selden and Song (1994), Cole et al. (1997), and Stern and Common (2001). Concentration of sulfur was taken into consideration in some studies, while others have measured emission. Concentrations were measured by Torras and Boyce (1998), Grossman and Krueger (1991), Panayotou (1997), Shafik (1994), etc. Emissions were measured by Cole et al. (1997), Selden and Song (1994), List and Gallet (1999), Stern and Common (2001), etc.

Most of the cases have shown positive results of EKC for sulfur. The amounts of turning points in sulfur emissions were quite low in almost all studies. The study of Dinda et al. (2000) showed comparatively lower turning point income ($3000-6000 in 1985 dollars). Grossman and Krueger (1991), Shafik and Bandyopaddhay (1992), and Shafik (1994) also showed that a vast amount of turning point is not needed to reduce sulfur emissions.

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[7] GEMS stands for Global Environment Monitoring System. It was formed by UNEP (United Nations Environment Programme) in 1975 to organize the global set of comparable measures of ambient air and water quality.

Hill and Magnani (2002), Selden and Song (1994), and Cole et al. (1997) showed that at around $8000-$10000, SOx starts to reduce. This amount is not easily achieved by any economy. Yet their studies have shown a medium amount of turning point which is greater than that of Panayotou (1997), Dinda et al. (2000), etc. Of note is the fact that developing countries have shown lower income per capita for turning point than developed ones. The reason may be that the worldwide use of sulfur has been reduced at once, whether the income per capita is reached at a fixed turning point or not. This may be due to the Sulfur Protocol of 1985.

7. EKC for NOx

NOx comprises the various oxides of Nitrogen, i.e. Nitric oxide (NO), Nitrogen dioxide (NO_2), Nitrous oxide (N_2O), Dinitrogen trioxide (N_2O_3), Dinitrogen tetroxide (N_2O_4), and Dinitrogen pentoxide (N_2O_5). N_2O accounts for about 7.9% of total GHG emissions (IPCC, 2007), which highlights the significance of the contribution of NOx to global warming. In addition, it damages our lung tissues and causes emphysema, bronchitis, etc.

Table 3 shows a summary of the different studies on EKC for NOx, most of which were cited in Winslow (2005). Selden and Song (1994) conducted a wide study on aggregate NOx emissions from 1979 to 1987. They worked on data from 22 OECD countries and 8 developing countries. They used Quadratic RE and FE models for aggregated NOx emissions, which produced an inverted U-shaped relationship with income per capita. For RE and FE models, turning point in income per capita were $21773 and $12041, respectively. They repeated the same study using Cubic RE and FE models. Again, they were successful in gaining evidence that supports a hill-shaped EKC for NOx. This time, the turning point in income per capita was $6200 and $19100 for FE and RE models, respectively.

Hill and Magnani (2002) have done the largest study for NOx, with a panel data of 156 countries around the world. They used GLS model, which provides the lowest standard error. However, they found that there was no significant turning point for NOx and emissions was monotonically increased with income per capita. Cole et al. (1997) conducted their study in 11 OECD countries from 1970 to 1992. Their turning point in income per capita for an inverted U-shape EKC was $14700.

Table 3

EKC studies for NOx emission contributing to climate change.

References	**Countries/cities**	**Time period**	**Model**	**EKC Result**	**Turning point (In 1990 dollars)**
Selden and Song, 1994	22 OECD and 8 developing countries	1979-1987	Quadratic, RE[ii]	Inverted U-shape	$21773
Selden and Song, 1994	22 OECD and 8 developing countries	1979-1987	Quadratic, FE[iii]	Inverted U-shape	$12041
Selden and Song, 1994	22 OECD and 8 developing countries	1979-1987	Cubic, FE	Inverted U-shape	$6200
Selden and Song, 1994	22 OECD and 8 developing countries	1979-1987	Cubic, RE	Inverted U-shape	$19100
Hill and Magnani, 2002	A panel of 156 countries	1975-1995	Generalized Least Squares	Straight line	N/A[i]
Cole et al., 1997	11 OECD countries	1970-1992	Generalized and Ordinary Least Square, FE	Inverted U-shape	$14700 (in 1985 dollars)

[i] indicates Not Applicable, [ii] indicates Random Effect model, [iii] indicates Fixed Effect model

It is notable that only the observations in OECD countries yielded results which produced an inverted U-shaped EKC. Data for a panel of 156 countries produced an upward straight line, with a major number of them being developing countries. The cause may be relatively higher NOx emission abatement costs having not yet been achieved by most developing countries (Bruvoll and Medin, 2003). However, Selden and Song (1994)'s study has given some hope about turning point as it was only $6200. Also, their study contains data for 8 developing countries. They got the lowest results for turning point in income per capita with cubic FE models. In most cases, FE models have shown lower income per capita for turning point, but its effectiveness in comparison with the RE model is negligible. Though a reduction in emissions was promised by the countries which signed Kyoto protocol, the worldwide aggregate for emissions is increasing. The possibility of a lack of implementation of applicable laws may be responsible, along with the higher abatement cost of NOx.

8. EKC implications in Bangladesh

Bangladesh is a country with a developing economy. It is assumed that Bangladesh is now at the early stage (upward slope) of EKC for environmental degradation. The hypothesis of EKC also gives the assumption that Bangladesh has the right to pollute now, get developed and abate later on. However, the environmentalists are concerned about the results of further pollution in our country and when the turning point of EKC will occur. Bangladesh is under severe threat of climate change. According to the IPCC and Bangladesh Climate Change Strategy and Action Plan 2008, Bangladesh will be among the most severely affected countries of climate change (MoEF, 2008). The GDP trend and the drivers of EKC in Bangladesh can show the movement of environmental degradation through the EKC. The learnt EKC movement discussed in the previous sections can focus on how to shorten the first stage of the EKC by establishing appropriate economic and environmental policy in Bangladesh. The following sections examine that aim.

8.1.GDP trend in Bangladesh

Observing the trend of the last twenty years, it is assumed that Bangladesh will become a middle income country by 2020. In three out of the last five years, the economy has grown by 6% or more (Fig. 5) (CIA, 2008). The economic survey of Bangladesh (GOB, 2000) states that though a decrease in growth rate has been observed in some years, it is nonetheless steady (Table 4). For a developing country with this GDP growth rate, Bangladesh is defying the impact of the global economic fallout (ADB, 2009) and ranked 68th in the world according to the CIA World Factbook (CIA, 2008). According to the ADB quarterly (ADB, 2009), Bangladesh is one of the thirteen countries that has the potential to grow faster. They also reported that the global centre for economic activity is already being shifted to India, China and other large emerging economies, and Bangladesh must make all efforts to capitalize on its comparative advantages to benefit from this global paradigm shift.

Table 4

Growth trend of real Gross Domestic Product (GDP) in Bangladesh from 1975 to 2000 (at 1984/85 prices).

Year	Real GDP (millions of taka)	Growth Rate (%)
1975-76	293820	5.7
1976-77	301670	2.7
1977-78	323010	7.1
1978-79	338520	4.8
1979-80	341300	0.8
1980-81	352880	3.4
1981-82	357220	1.2
1982-83	374700	4.9
1983-84	395030	5.4
1984-85	406930	3.0
1985-86	424590	4.3
1986-87	442340	4.2
1987-88	455130	2.9
1988-89	466610	2.5
1989-90	497530	6.6
1990-91	514440	3.4
1991-92	536190	4.2
1992-93	560230	4.5
1993-94	583840	4.2
1994-95	609790	4.4
1995-96	642440	5.3

1996-97	680210	5.9
1997-98	718670	5.7
1998-99	756120	5.2
1999-2000 (provisional)	801710	6.0

(GOB, 2000)

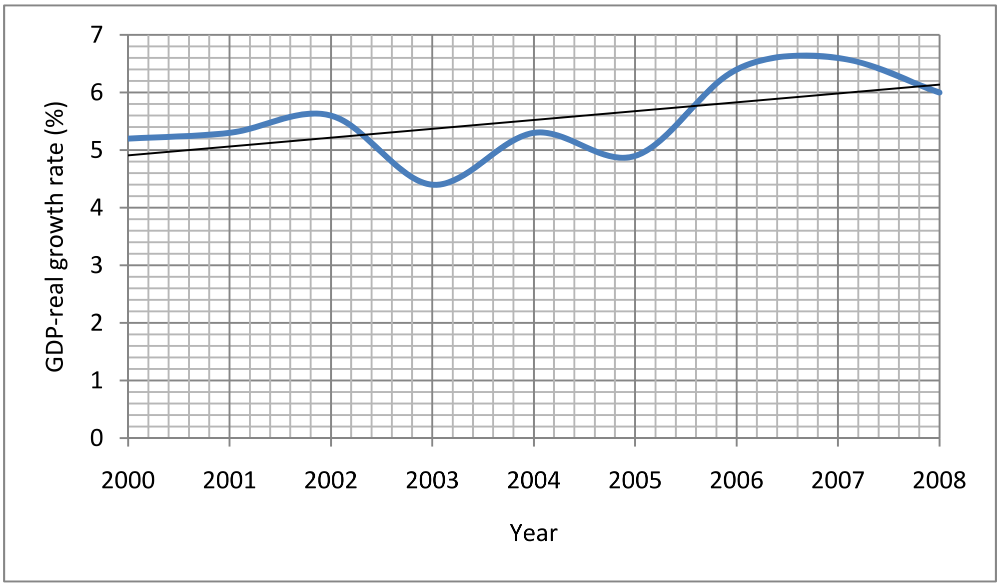

Fig. 5. GDP real growth rate of Bangladesh from 2000 to 2008.

8.2.Drivers of EKC in Bangladesh

The global findings of the EKC studies for CO_2, SOx and NOx and the growth trend of the national income of Bangladesh show that Bangladesh, a low-income country, will need to achieve a particular income per capita in order to reach the EKC turning point. If we are to wait for the normal turning point, the environmental situation of Bangladesh will worsen day by day. From the studies of EKC in several developing countries, it is clear that environmental complications will steadily increase until the turning point is achieved. But, as a signatory to the Kyoto Protocol, Bangladesh has an ethical responsibility to contribute to the climate change mitigation, even though Bangladesh has no formal commitment. Economic growth and development are also important, but the priority will be to eliminate the upcoming environmental threats. It will be best to follow alternative routes (Fig. 3 and

Fig. 4). The energy sources of Bangladesh are biomass, oil, coal and natural gas. Biomass energy sources are traditionally used for domestic cooking and in small rural industries. The technology used for burning biomass in Bangladesh has been proven to be very primitive, which could potentially increase GHG emissions and create health hazards (Miah et al., 2009). Due to the overuse of forest biomass, deforestation is a proven phenomenon in Bangladesh. During the period 2000-2005, the annual rate of deforestation in Bangladesh was 0.3% (2000 ha) as stated by FAO (2007). This deforestation is also contributing significantly to the climate change (FAO, 2007). Furthermore, the consumption of fossil fuels is growing by more than 5% per year (Azad et al., 2006). As Bangladesh is a comparatively fast-developing country, it is now impossible to slow the use of fossil fuels. Thus, following the suggestion of Munasinghe (1995), Bangladesh can only seek to tunnel through the EKC with the help of policy changes and technology.

9. Policy suggestions for Bangladesh

To mitigate the climate change without hampering economic growth in Bangladesh, the study importantly suggests the market regulation, adoption of new technology, Clean Development Mechanism (CDM) and Reduced Emissions from Deforestation and Degradation (REDD). All of these can make tunnel through the EKC for Bangladesh.

The emission of CO_2, SOx and NOx mostly occurs in the industrial activities. The poor or unregulated market is the important factor to enhance this emission. The neoclassical theory (or Keynesian theory) of economics concludes that the price of commodity will be decided by the market itself, which will be governed by the free-trade economy (Fanti and Manfredi, 2009). This theory, however, is only based on making profit in monetary terms. As we know, thinking only about profit and reducing the production costs will lead to a disastrous impact on the environment. Therefore, we have to control the market (rather than through the market itself) to save our economy and, with higher technologies, we can save our environment. Promoting private sector production also threatens the environment. By nature, private capital will only think about profit and nothing else, so government regulation on market is critical to environmental protection. No industry should go into production without a detailed Environmental Impact Assessment (EIA). Higher technology from the developed countries must be introduced in both production and waste treatment. Tax introduction and law enforcement have proven to be effective in the cases of some specific pollutants in different countries (Vehmas, 2005; Kumbaroglu, 2003; Backhaus, 1999). Those policies should be introduced and implemented properly.

The present 'Renewable energy policy 2008' of Bangladesh is committed to promoting clean energy through Clean Development Mechanism (CDM) of the Kyoto Protocol (GOB, 2008). However, there are no strong guidelines for the CDM activities in the policy. The policy should be clearer and stronger to encourage small- and large-scale CDM projects in Bangladesh, which can provide sustainable development in the country as well as reduction of GHGs (Silveira, 2005). Receiving GHG benefits from the slowing deforestation, the COP 13 in Bali, 2007 vigorously discussed Reduced Emissions from Deforestation and Degradation (REDD), as did the COP 14 in Poznan, 2008. The mechanism has not yet come into force, as negotiations are still continuing. However, it is expected that REDD will be the central force behind forestry activities (i.e., slowing deforestation) in tropical developing countries after 2012 (Skutsch and Trines, 2008). Before adopting REDD as an effective deforestation reduction mechanism, decisions on the nature of carbon buyers and sellers, financing mode, the compensation scheme, and type of land use targeted should be made (Oestreicher et al., 2009). In this way, the forest policy of Bangladesh should be reoriented for REDD to receiving GHG benefits. Political power is another important factor that drives both the economy and the environment. According to Torras and Boyce (1998), if conflicts of interest are taken into account, inequalities in the distribution of political power must be considered. All of these changes in the policy of Bangladesh are expected to construct the tunnel through EKC. Just as importantly, the national environment policy, energy policy, forest policy, and industrial policy should be coordinated and monitored strongly to achieve all of these benefits.

10. Conclusion

Many empirical studies provide evidence in support of the theme of EKC hypothesis. The global observation of EKC hypothesis for CO_2, SOx and NOx shows that an economy needs higher income per capita as a turning point in the EKC for retarding the emission in most cases. But, evidences against a hill-shaped curve cannot be ignored. SOx have shown hill-shaped curves throughout the world and in almost every type of economy. NOx emissions have shown hope for EKC only in developed countries. CO_2, however, didn't follow the trend of reversing degradation. In this study, it was demonstrated that there can be degradation which cannot be reversed if we are to wait for such higher income per capita as an environmental turning point in Bangladesh. The literature shows that the economy of Bangladesh is growing. We cannot stop the wheel of economic growth as the EKC hypothesis gives us the right to pollute now, but in the interest of the greater good, strong policy regarding the climate change mitigation/environment should be established and properly applied. To mitigate the climate change in Bangladesh, the study suggests market regulation, adoption of innovative technology, CDM and REDD. Above all, strong political commitment on climate change mitigation has been recommended. This study is expected to contribute to economic growth as well as climate change mitigation in Bangladesh.

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