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Linking Per Capita GDP to Energy Consumption, Ecological Footprint, and Carbon Dioxide Emission in a Developing Economy in the World: The Case of Bangladesh

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Abstract

In developing economies, environmental pressure increases faster than the income does at early stages of economic development and slows down relative to income growth at higher income levels. Bangladesh is a rapidly growing South Asian country with large and increasing population and deteriorating environment. However, the link between its historical per capita GDP and major environmental attributes has not been sufficiently investigated in any literature. This study evaluates the type of relationship between per capita GDP with each of ecological footprint, CO2 emission and energy consumption in Bangladesh- an emerging developing economy in the world. The study used traditional linear, quadratic, and *log*-models with standard specifications to investigate the aforementioned relationships. The models confirmed that a direct and monotonically increasing relationship exists between per capita GDP and each of the major environmental attributes under study. Thus, the country country's environment is likely to face increasing pollution threats from potential economic growth in coming days. Stringent environmental policy is likely to help bring a balance between economic development and environmental stability. The study suggests for creation of massive environmental awareness, optimal tapping of natural resources, and adoption of green technologies to ensure sustainable economic growth while maintaining a healthy environment.

Keywords: Development, Ecological footprint, Environment, Energy, Emission, Policy.
JEL Classification: O13, O44, Q01, Q43, Q56.

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Contents

1. Introduction

The 21st century has experienced heightened economic activities due to industrial development that has characterized countries worldwide (Ayomoh *et al.*, 2008). The increasing rate of economic growth has greatly improved the lifestyle across the world (Bagliani *et al.*, 2008; Ahlstrom, 2010). At the same time, it has contributed largely to global environmental change both negatively (Gain and Moral, 2002) and positively (Huang *et al.*, 2008). GDP growth is always linked to environmental ups and downs (Selden and Song, 1995; Miah *et al.*, 2010; Bozkurt and Akan, 2014). Deterioration of environmental quality has created mounting public concerns worldwide. As a result, understanding environmental degradation along with its determinants is becoming increasingly important (Dinda, 2004; Farhani *et al.*, 2014; Xu and Lin, 2016) specially in the macroeconomic policy arena (Bennett *et al.*, 2008).

However, there has been arguments in environmental economics literature on the relationship between economic growth and environmental impacts for quite a large period of time (Galeotti and Lanza, 1999; Dinda, 2002; Van den Bergh, 2011). Some argued that the development and economic growth is necessarily harmful for environment as it is responsible for resource depletion, energy consumption, and carbon dioxide emission (Economy, 2011). These arguments are further concreted with the existence of unidirectional relationship between economic growth and environmental degradation as environmental degradation is accelerated with the increase of GDP (Boopen and Vinesh, 2011; Jaunky, 2011; Al-Mulali and Ozturk, 2015; Alam and Mahmudul, 2016). The development proponents, on the other hand, substantiated that economic growth is an obvious need for environmental protection and improvement (Bimonte, 2002; Carson, 2009; Kaika and Zervas, 2013) and a bi-directional causal relationship between income, such as per capita GDP, and environmental pollution (Dinda and Coondoo, 2006; Bozkurt and Akan, 2014; Dogan and Turkekul, 2016) is quite obvious. Interestingly, a third block claimed that there exists no direct link between environmental degradation and economic growth except, however, energy consumption and emissions in developed countries are causally linked (Soytas *et al.*, 2007).

Many studies are claiming that larger population, their huge demand for environmental services (Shi, 2003; Liddle, 2013) unplanned urbanization, political instability, Al-Mulali and Ozturk (2015) and lack of effective environmental policy and regulations (Al-Mulali *et al.*, 2015) in the developing countries are the major causes behind environmental deterioration rather than so-called per capita GDP, which is utterly higher in the developed nations. This claim is backed by the logic that, developed economies characterized with higher GDP have more stringent environmental regulations, greener technology, and better environmental quality. Thus, it leads to a reverse-link between economic growth and environmental degradation (Bagliani *et al.*, 2008). That means, environmental pressure increases faster than income in the early stage of development, which is common in developing economies, and it slows down relative to GDP growth in higher income levels, which is common in developed economies (Kuznets, 1955; Caviglia-Harris *et al.*, 2009; Balaguer and Cantavella, 2016; Dogan and Turkekul, 2016). This systematic relationship between income and environmental quality has been known as the Environmental Kuznets Curve (EKC) hypothesis (Kuznets, 1955; Adewuyi, 2016).

In a developing economy, pollution grows rapidly since material output, employment, and income are prioritized over clean environment (Dasgupta *et al.*, 2000; Pao and Tsai, 2011; Adewuyi, 2016). The rapid growth inevitably results in greater use of natural resources along with inefficient use of energy, which ultimately leads to a pollution level greater than derived benefits (Dasgupta *et al.*, 2000; Kaika and Zervas, 2013; Chen *et al.*, 2016). In the later stage of industrialization, as income rises, people start valuing environment through the adoption of environmental regulations and improved technologies. As a result, pollution level declines (Stern, 2004a; Kaika and Zervas, 2013; Jammazi and Aloui, 2015; Bilgili *et al.*, 2016). This relationship provides an inverted U-shaped EKC (Agras and Chapman, 1999; Jimenez and Balandra, 2007; Kaika and Zervas, 2013; Saboori and Sulaiman, 2013; Jammazi and Aloui, 2015). The EKC expresses a functional relationship of energy use or economic growth with the underlying environmental quality (Stern, 2004b; Kaika and Zervas, 2013; Jammazi and Aloui, 2015).

With the world becoming a global economy, the concern for environmental quality has increased. There are an increasing number of empirical studies devoted to the EKC theory to determine the relationship between a country's income and corresponding levels of pollutants such as SOx, NOx, and CO2, ecological foot print, waste water, and solid wastes (Winslow, 2005; Al-Mulali *et al.*, 2015; Li *et al.*, 2016; Wang *et al.*, 2016). Since there exist debates on the causality between per capita GDP and environmental degradation based on whether the economy under consideration is developed or developing, it is worth validating the debate at least for emerging developing economies if not for all developing or under developed economies. Among the booming economies in the world, the Bangladesh economy is a forerunner with its constant growth rate of around 6.5+ percent over the last decade (Figure 1). Thus, we have chosen the Bangladesh economy to validate the causality between its per capita GDP and some other socio-environmental indicators such as per capita carbon dioxide emission, per capita energy consumption, and per capita ecological footprint.

Bangladesh is a developing country, located in the north-eastern part of South Asia and on the northern coastline on the Bay of Bengal. Due to its favorable geographical condition, Bangladesh has high opportunity to industrial development as well as economic growth. Industry has emerged as the largest sector of the economy contributing about 30 percent to its gross domestic product (Bangladesh Bureau of Statistics, 2008; BBS, 2008a). The GDP exhibited a robust growth rate of 6.51 percent in fiscal year 2015-2016 (Figure 1). The overall growth was led by the manufacturing and construction sub-sectors, which recorded 10 percent and 6 percent expansions, respectively, in FY 2010-2011 (BBS, 2012). Agriculture is the second largest sector of the economy, contributing 20 percent to the total GDP in FY 2010-2011 (BBS, 2012). The average per capita income in Bangladesh has increased from US$599 in 2007 (MoF, 2012) to US$1212 in 2015 (MoF, 2017).

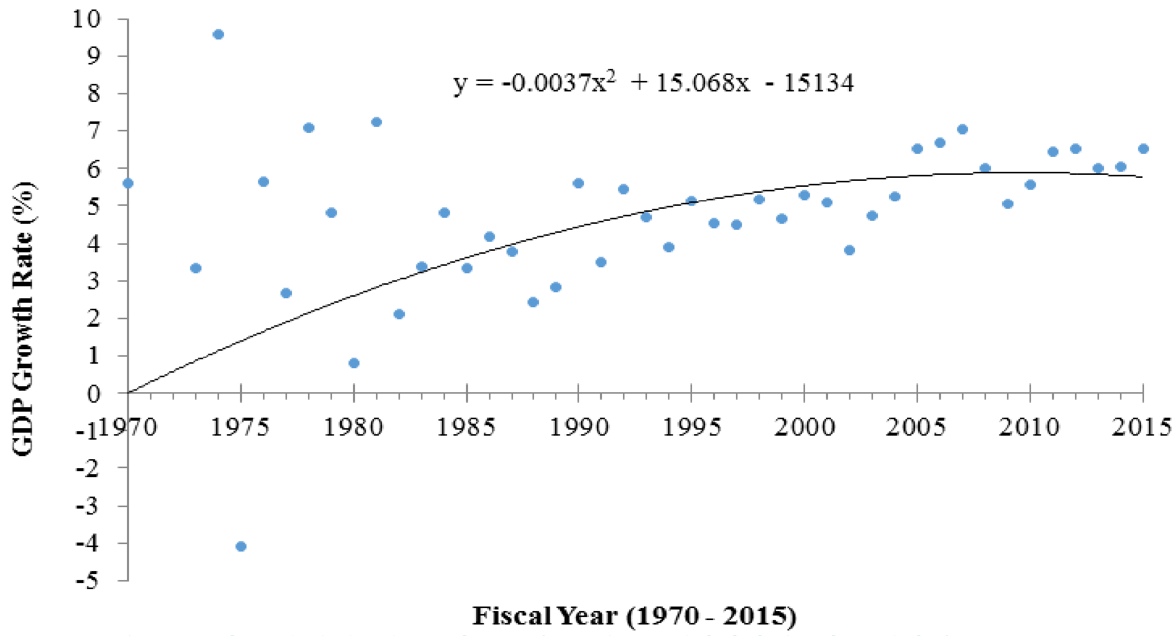

Figure-1. Chronological real growth rate of GDP in Bangladesh during the period of 1970 -2015
Source: World Bank (2015)

The environmental consequences of this continued income growth have not been sufficiently addressed in the existing studies. A recent study Islam *et al.* (2013) have investigate if there exists any EKC for Bangladesh. However, a quantitative analysis with strong econometric framework has not yet been conducted on how economic growth of this country is impacting its environment in terms of historical ecological footprint, carbon-dioxide emission, and energy consumption. This study is designed to examine how per capita GDP has impacted these environmental attributes over time in Bangladesh. The study is expected to recommend important conclusions that the country's environmental and economic policies should consider to ensure a more thriving economy in a healthy environment.

2. Materials and Methods

To accomplish the objectives of this study, we specified and estimated three quantitative models: linear, quadratic, and log models. Ordinary least square (OLS) framework was used to estimate the models. Each of the models expresses specific relationship between per capita GDP (X) and the aligned environmental pollution (Yi). The study considered per capita GDP as a proxy for income or development. The socio-environmental indicators were ecological footprint, carbon-dioxide emission, and energy consumption. The annual data on ecological footprint (EF) in global hectare per capita was collected from the Global Footprint Network (Global Footprint Network, 2012). GDP per capita, carbon dioxide emission, and energy consumption data came from the World Development Indicators 2014 (WB, 2014). The data available for this study was over a period of 43 years from 1971 through 2013.

However, the linear form of model is given by Equation (1):

$$Y_i = b_0 + b_1 X + \varepsilon_i \quad (1)$$

Where, $i \in \{EF, CO_2\ Emission,\ Energy\ Consumption\}$, b_0 denotes a constant term and ε_i is the normally distributed error term with mean zero and constant variance. If $b_1>0$, the per capita GDP is directly linked with environmental indicators. It indicates that any increase in income (per capita GDP) leads to a corresponding increase in environmental pollution. This reflects the scale effect in EKC hypothesis. The relationship would be monotonically decreasing if $b_1<0$. However, $b_1<0$ is an unlikely scenario in EKC hypothesis for a developing country like Bangladesh. However, in both the cases, the link between income and environmental pollution exists only if b_1 is statistically significant.

The quadratic form of the model is the most traditional one in EKC studies, which can be specified as follows:

$$Y_i = b_0 + b_1 X + b_2 X^2 + \varepsilon_i \quad (2)$$

Quadratic functions are chosen to inspect if the EKC has reached a turning point. The turning point is obtained imposing first order condition on Equation (2):

$$\frac{\partial Y_i}{\partial X} = 0$$
$$b_1 + 2b_2 X = 0$$
$$X = -\frac{b_1}{2b_2} \quad (3)$$

Equation (3) is the necessary condition for the extreme value of quadratic function (2). Second order condition can be imposed on Equation (2) to confirm the global maximum of the function, i.e. the turning point of the inverse U-shaped EKC. If the Bangladesh economy has already turned this point, which is very unlikely, we end up with Equation (4).

$$\frac{\partial^2 Y_i}{\partial X^2} < 0$$
$$b_2 < 0 \quad (4)$$

Since the economy of Bangladesh is rapidly growing at a considerable rate, X is real and positive. So, combining (3) and (4) will yield a positive value for b_1. Thus, the Bangladesh economy will follow a growing path as depicted in the EKC hypothesis, if $b_1>0$, $b_2<0$; and both are statistically significant. If $b_1<0$ and $b_2>0$, a U-shaped pattern is obtained which is unexpected particularly for sustainably developing nation (Hervieux and Darne, 2012).

If an EKC is yet to reach the turning point, which is common for a developing economy, it is important to examine whether environmental pollution increases monotonically with corresponding growth of the economy. To evaluate such relationship between the two, the *log*-models are traditionally used in EKC studies (Granda *et al.*, 2008). This model is more relevant for a developing economy. Since Bangladesh is at its early stage of development, the *log*-model seems relevant to validate the EKC hypothesis for the Bangladesh economy. The model can be specified as follows:

$$Y_i = b_0 + b_1 log(X) + \varepsilon_i \qquad (5)$$

The EKC hypothesis holds if $b_1>0$ and is statistically significant. Note that, $b_1>0$ validates the EKC hypothesis if $X>1$. Since per capita GDP in Bangladesh is well over one US dollar ($X>1$), the study meets this requirement.

3. Results and Discussion

3.1. Link between Per Capita GDP and Per Capita Carbon Dioxide Emission

In linear model, the coefficient of GDP per capita was 5.74×10^{-04}, which was significant at 1% level (Table 1). The implication of this model is that - an increase in income (per capita GDP) by USD1 corresponds to a per capita emission of 5.74×10^{-04} metric tons of CO_2. The regression R^2 was 0.90, meaning that the model can capture 90% of the variation in the dependent variable. This result is in line with the EKC hypothesis that the level of CO_2 emission initially increases with income until it reaches its peak. In quadratic model, the coefficient of *GDP* was, $b_1 =8.97\times10^{-04}$ and of GDP^2 was, $b_2=4.09\times10^{-07}$with a R^2 of 0.92 (Table 1).

Table-1. Estimation of different models between per capita carbon dioxide emission (metric tons) and per capita GDP (US dollar) in Bangladesh

Betas	Linear Model	Quadratic Model	Log Model
b_0	7.97×10^{-03}	-5.92×10^{-02}**	-8.05***
b_1	5.74×10^{-04}**	8.97×10^{-04}***	1.09***
b_2	--	4.09×10^{-07}**	--
R^2	0.90	0.92	0.88
F	337.90***	206.90***	291.40***

Note: Independent variable in all the models is per capita GDP; *b*'s are the parameter estimates; *** = p<0.001, ** = p<0.01, * = p<0.05.

Since b_2 was positive, the model ended up with the evidence that the Bangladesh economy is developing and is way behind reaching a turning point on its EKC. Since the economy did not meet the requirements of a peaked EKC as prescribed by the quadratic model, it was important to examine if the emission level was monotonically increasing with its per capita GDP growth. In the Log model the coefficient of log (GDP) was b_1 = 1.09, which was significant at 1% level (Table 1). The positive value of the coefficient confirmed monotonically increasing trend of both per capita GDP and carbon dioxide emission for the Bangladesh economy.

When per capita CO_2 emission was regressed against per capita GDP, none of the linear, quadratic, and log models confirmed any peak or turning point with the associated EKC. All the three models confirmed that the EKC for Bangladesh is sharply progressing upward to the right. Since the regression line between income and CO_2 emission still runs in the north-east direction in a two-dimensional space, the country is likely to face an increasing stage of CO_2 emission with its economic growth in coming days.

3.2. Link between Per Capita GDP and Per Capita Energy Consumption

In linear model, the coefficient of GDP per capita was 0.21 (Table 2), which was significant at 1% level. The implication of this model is that an increased income (per capita GDP) by US$1 corresponds to an energy consumption of 0.21Kg of oil equivalent. The regression R^2 was 0.93 (Table 2) indicating that the model could capture 93% of the variation in the dependent variable. Thus, a direct relationship between per capita GDP and corresponding energy consumption was confirmed with the linear model. In the quadratic model, the coefficient of GDP was, b_1 = 0.29, and that of GDP^2 was, $b_2 = 1.01\times10^{-04}$ (Table 2).

Table-2. Estimation of different models between per capita energy consumption (Kg of oil equivalent) and per capita GDP (US dollar) in Bangladesh

Betas	Linear Model	Quadratic Model	Log Model
b_0	63.01***	50.34***	2.12***
b_1	0.21***	0.29***	0.48***
b_2	--	1.01×10^{-04}*	--
R^2	0.93	0.93	0.89
F	484.60***	272.60***	302.00***

Note: Independent variable in all the models is per capita GDP; *b*'s are the parameter estimates; *** = p<0.001, ** = p<0.01, * = p<0.05, NA = Not Applicable

Since is b_1 and b_2 were both positive, the conditions of a quadratic relationship between GDP and energy consumption did not hold. The *log*-model also came up with a positive beta (b_1=0.48) (Table 2) indicating a monotonically increasing relationship being maintained by per capita GDP and per capita energy consumption in the country. Thus, from the link between per capita GDP and per capita energy consumption, we can also conclude that the economy of Bangladesh has more to grow with greater level of energy consumption in the future.

3.3. Link between Per Capita GDP and Per Capita Ecological Footprint

In the linear model, the coefficient of GDP per capita was 1.72×10^{-04}, which was significant at 1% level (Table 3). That is, an increase in income by US$1 corresponds to an increase of ecological footprint of 1.72×10^{-04} global hectares per capita. That means the direct relationship between per capita GDP and ecological footprint is justified. The quadratic model showed that, the coefficient of GDP was, $b_1 = -5.86\times10^{-04}$ and the coefficient of GDP^2 was, $b_2 = 9.61\times10^{-07}$, both of which were significant at 1% level (Table 3). The signs of the betas were opposite to what is expected in a developing economy.

Table-3. Estimation of different models between per capita ecological footprint (global hectare) and per capita GDP (US dollar) in Bangladesh

Betas	Linear Model	Quadratic Model	Log Model
b_0	5.35×10^{-01}***	6.55×10^{-01}***	-0.81***
b_1	1.72×10^{-04}**	-5.86×10^{-04}***	0.05*
b_2	--	9.61×10^{-07}***	--
R^2	0.23	0.52	0.17
F	14.10***	20.17***	7.90***

Note: Independent variable in all the models is per capita GDP; *b*'s are the parameter estimates; *** = p<0.01, ** = p<0.05, NA= Not Applicable

To further investigate this anomaly, we tried to graphically examine the relationship between per capita GDP and ecological footprint, a proxy for the pressure on country's natural resource base. Figure 2 further confirmed an unexpected quadratic relation relationship (U-shaped) between the two. The main reason of this unusual relationship requires deeper investigation of the two. An explanation can be done from a historical investigation on how the country's agricultural and industrial sectors contributed to its GDP (MoF, 2017).

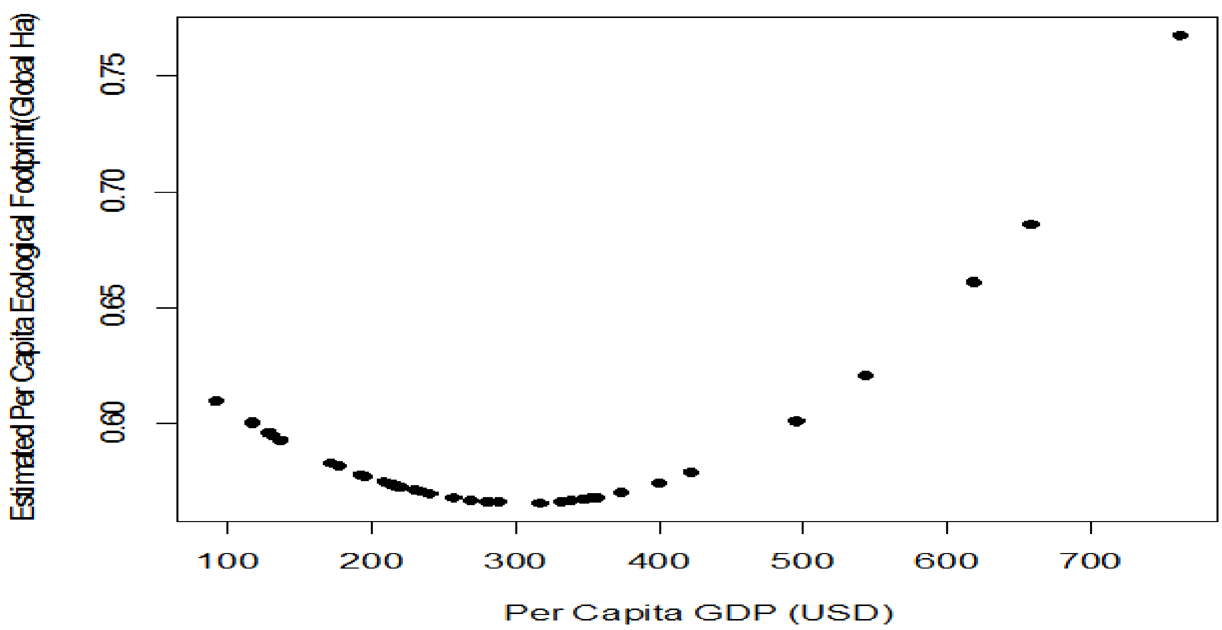

Figure-2. The quadratic relationship of per capita GDP (US Dollar) and estimated per capita ecological footprint (global hectare) in Bangladesh from 1971 to 2013
Source: GFN (2012)

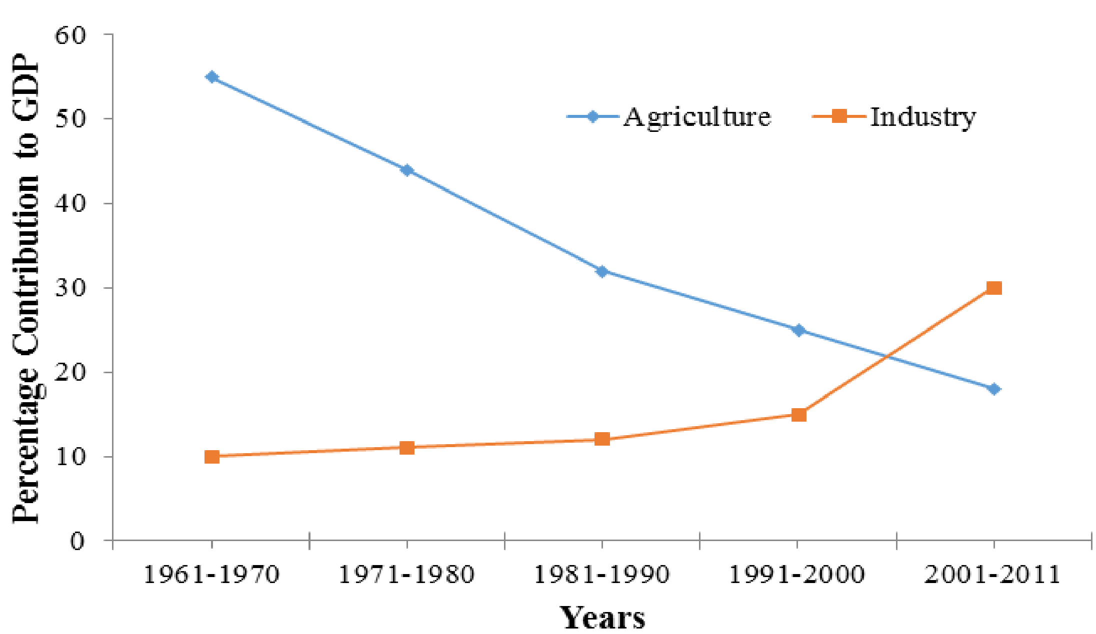

Figure-3. Percentage contributions of agricultural and industrial sectors to national GDP of Bangladesh from 1961 to 2011
(**Source:** WB (2014))

Figure 3 shows that, in the 60's through 80's, country's development was extremely dependent on agriculture, which was gradually being substituted by industrial development until 2000. In 2011, the industry's share to GDP was 30% and of agriculture was only 18% (Figure 3). Excessive dependence on agriculture possibly with simultaneous increase of its forest and other natural resource stock pushed down the ecological footprint of the country in that particular period of GDP growth. The industrial growth boomed in the country after 2000, which raised the ecological footprint with increased per capita GDP pulling the EKC up to the N-E direction. This is a unique finding of this study that a developing country faces a U-shaped EKC when it switches from agriculture to industrial development.

4. Conclusions

This study examined the EKC of Bangladesh economy using per capita GDP against each of per capita carbon dioxide emission, energy consumption, and ecological footprint - the major players in environmental degradation in the country. The study outcomes reveal that Bangladesh is on the upward slope behind the turning point of the EKC. This confirms that Bangladesh owns a rapidly developing economy with increasing rates of carbon dioxide emission, energy consumption, and ecological or carbon footprint. Thus, its environment is likely to face extended threats of pollution attributed to potential economic development and resource depletion.

According to the World Bank's World Development Indicators Database and IMF's World Economic Outlook, Bangladesh advanced 14 steps from the 58th position to 44th in the world economy during 2012-1014. This tremendous economic development certainly left an equivalent amount of CO_2 back into the atmosphere. To make this economic gain sustainable, and to help reduce the burden of global warming, the country needs to ensure sustainable use of natural resources with introduction of green technology in the industrial sector. The reality is that the environmental regulation in the country is becoming more stringent and country's industrial sector is in harmonious adjustment in adopting environment friendly and energy efficient production technologies. According to the World Bank reports, the average amount of energy used to produce a thousand dollar of GDP in Bangladesh was 96.4 kilograms of oil equivalent in 1995 and 79.09 kilograms of oil equivalent in 2011. Thus, the energy use efficiency is on the rise probably through the adoption of better technology.

Again, Bangladesh is an emerging democracy in the world with a developing economy being backed by an industrial boom. However, a humongous size of population of 165 million on a land area of only 148 thousand square km leaves the country with one of the lowest per capita bio-capacity in the world. Thus, industrial raw materials, natural resources are being recklessly consumed with little or no care for environment. This, in turn, is leading to massive depletion of those resources at a rate faster than any time in the past. As a result, the gap between ecological footprint and bio-capacity is increasing over time. Given this, the country needs massive environmental awareness and optimal tapping of raw material resources. Strong regulations will help monitor material tapping rate and adopt technologies for recycling and reuse of products. Like elsewhere in the world, environmental issues are getting higher priority even in political and economic fields in Bangladesh. Policy makers have to seek for optimality between the development activities in the country and the associated negative impacts on the ecosystems to sustain the development and to reduce the risks of current threats being posed by climate change and natural disasters. Thus, finding an equilibrium between the two is not just a matter of sustaining a balance between production and consumption, but also very important for our existence on the planet. Country's environmental and development policies should be more realistic to accommodate sustainable economic growth while caring for better environmental qualities.

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