Is There an Environmental Kuznets Curve for Bangladesh?

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16 April 2012

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Abstract

The Environmental Kuznets Curve (EKC) posits that environmental degradation increases at the initial stages, but declines as the economy achieves a certain level of economic growth, measured in per capita income terms. This postulated relation produces an inverted U-shaped curve. The topic has drawn much research attention for both developed and emerging economies. Over the past few decades Bangladesh has been achieving remarkable rates of economic growth. A dense population along with a growing industrial base has raised the specter of a looming environmental crisis. The present study empirically investigates the EKC hypothesis for Bangladesh using data from 1971 to 2010. The Autoregressive distributed lag (ARDL) approach to cointegration has been implemented for a long run relation; and the Granger causality within the vector error correction model (VECM) for the short run dynamics. The series are found to be cointegrated. We find that energy consumption is a major contributor to CO2 emissions. Trade openness improves environment, but urbanization worsens it. Economic growth, energy consumption, trade and urbanization Granger cause CO2 emissions. Knowledge of the existence of an EKC relation can help craft appropriate policies to promote economic growth and identify the turning point, and help preserve the environment.

Key Words: EKC, ARDL, VECM, Bangladesh

JEL classification: O13; Q25; Q53

Introduction

The Environmental Kuznets Curve (EKC hereafter) posits that as the economy grows, environmental degradation increases at the initial stages, and then starts to decline after the economy has achieved a certain higher level of economic growth measured by of per capita income. The relation produces an inverted U-shaped curve and has been empirically verified for a number of nations. However, the results have come under intense criticism. (For a review see Hill and Magnani, 2002; and Lee and Lee, 2009) Bangladesh, a small emerging nation of 160 million in the Indian Subcontinent has been making remarkable rates of economic growth over the past two decades. A densely urban population coupled with a growing industrial base has raised the specter of a looming environmental crisis. Despite the fear of such possibility, environmental economics remains an understudied area in Bangladesh.

The objective of the study is to empirically investigate the EKC hypothesis for Bangladesh, using time series data from 1971 to 2010. We implement the Autoregressive distributed lag (ARDL) approach to cointegration for a long run relation and the Granger causality within the vector error correction model (VECM) to understand the short run dynamics. Knowledge about the existence of the EKC relation can help policymakers craft appropriate policies for sustained economic growth and help preserve the environment endogenously. Despite the need for a research, the topic has failed to draw serious academic interest in the context of Bangladesh. The lone exception however, is a conference paper by Alam and Huylenbroeck (2012) which is limited to causality analysis alone. For a long run relation they implemented both the ARDL and the Johansen Juselius (1990) approaches and found cointegration. The VECM analysis shows bidirectional Granger causality between economic growth and CO_2 emissions. The paper did not however, explore the non-linearity aspect of the EKC hypothesis for Bangladesh. It is plausible that the results might suffer from misspecification because over the past few decades, Bangladesh has undergone some major economic changes in two areas; (a) substantial economic liberalization; and significant urbanization. Thus, from theoretical considerations, inclusion of urbanization and trade openness appears justified as both of them have important bearing on energy consumption, and thus on CO_2 emission. The reason provides rationale for further research by incorporating the two series in the model. This paper contributes in three distinct ways. First, the paper offers fresh insight to a relevant and yet understudied area. Second, it uses a theoretically justified model. Finally, provides rigorous test for the non-linearity in the postulated relation and thus complements Alam et al. (2012). The findings are expected to help better understand the underlying dynamics; thereby provide ammunition for crafting appropriate policy for Bangladesh.

Environmental degradation and natural resources depletion in Bangladesh are major concerns. Poverty, over-population, rapid urbanization and urban sprawl complicate matters. Lack of environmental awareness is manifested in deforestation and cutting down hills; destruction of wetlands; depletion of soil nutrients; harmful emission in the air; and water pollution both surface and ground, inter alia. Natural calamities like floods, cyclones and tidal-bores produce severe socio-economic and environmental damage. Until the 1970s, Bangladesh had had severe bouts with health related problems caused by waterborne diseases e.g. cholera, typhoid etc., due to shortage of clean drinking water. Aid agencies such as UNICEF built shallow wells throughout the country to provide safe of drinking water. In the 1990s, arsenic contamination made headlines. As a result both people and the land they use turned victims of the poison. The

World Bank estimates that 25 percent of the country's 4 million wells may be arsenic contaminated. The government adopted National Environment Policy, National Conservation Strategy, and National Environment Management Action Plan to protect environment and natural resources; and control pollution through an integrated development strategy. Legal structure has been strengthened to prosecute those in violation of the laws. The Department of Environment is conducting surveys to identify polluters, control industries, rivers and vehicles – a remarkable achievement! However, further studies in this area is needed.

The rest of paper is organized as follows. Section-2 reviews the literature. Section-3 outlines the econometric strategy; and the data sources. The results are reported in section-4. Conclusion and discussion of policy implication are provided in section 5.

2. Literature review: Theory and the evidence

Kuznets (1955) was the first to posit that as economy grows, income inequality initially rises, reaches peak, and then falls. The idea has been extended to 'environmental poverty' and economic growth nexus and given the name Environmental Kuznets Curve (EKC). Over the past three decades, a bourgeoning literature has proliferated examining the theory and empirics behind the EKC[2], and yet, controversy over the concept and its existence continues to grow.

Several studies based on country specific data lend support to EKC. Stern (2004) argues that expansion of production scale and improvements of technology can affect EKC relation. A common theme across the approaches assumes that the structure of the economy shifts towards less polluting industries as economic growth continues. An alternative explanation assumes that quality environment is a luxury good. So, the desire for environmental protection increases with per capita income. These explanations are explored further in Copeland and Taylor (2001, 2005) and the explanations based on threshold effects and increasing returns to abatement.

The EKC hypothesis, basically an empirical phenomenon rose to prominence in part, due to the inability to pay sufficient attention to econometric diagnostics – failure to distinguish stylized facts from spurious ones. "It is very easy to do bad econometrics and the history of the EKC exemplifies what can go wrong" (Stern, 2004, p.1). When correct statistical tools are used, the EKC ceases to exist (Perman and Stern, 2003). A realistic view of the effect of economic growth and technological changes on the quality of environment supports such relation. Environmental degradation under this approach is a monotonically rising function in income; with income elasticity less than unity. Also, the relation is not one of a simple function of income alone.

Not surprisingly, the concept of an EKC came initially from the trade and development economists not the environmental or resource economists. Long before the EKC became the standard in environmental economics literature (see for example, Frank and Bernanke 2005), a very different view was set out by Ehrlich and Holden (1971) – the IPAT equation (I = PAT), acronym for Impact of Population, Affluence, and Technology[3]. The IPAT model is a restricted version of the EKC, but the latter is a distinct improvement. "… (T)he problem with the EKC lies with the assumption of a causal role of income growth and the inadequacy of reduced-form specifications that presume that a common income-related process, conditional on fixed effects for political jurisdictions and a few observable covariates, adequately describes the generation of the pollutant of interest" (Carson, 2010; p. 5).

Jones and Manuelli (1995) argue that pollution correction can happen endogenously in response to increases in wealth. Andreoni and Levinson (2001) show that an inverted U-shaped EKC relationship occurs if there are increasing returns to scale[4] in terms of the pollution control effort[5]; while Lopez and Mitra (2000) (see Brock and Taylor, 2005) point out that corruption moves the turning point further for an EKC relation. The early advance in the theoretical work on the EKC relationship was made by Grossman and Krueger (1991). The empirical work by Shafik and Bandyopadhyay (1992) and Shafik (1994) came largely in response to the work of the former authors whose intent was to assess whether increased income leads to improved environmental indicators. Using additional environmental indicators and also adding countries they found support either for EKC or a monotonically increasing function in income[6]. Most believe that economic growth is a key to environmental protection and poverty is the single most important adversary!

The argument that economic growth is necessary for maintenance or improvement of environmental quality for sustained growth was already part of "*Our Common Future"* by the World Commission on Environment and Development (1987). The *World Development Report 1992* argued, "The view that greater economic activity inevitably hurts the environment is based on static assumptions about technology, tastes and environmental investments" (p. 38). The report adds, "As incomes rise, the demand for improvements in environmental quality will increase, as will the resources available for investment" (p. 39). The EKC theme got further boost in the writings of Beckerman (1992) who claimed, “there is clear evidence that, although economic growth usually leads to environmental degradation in the early stages of the process, in the end the best – and probably the only – way to attain a decent environment in most countries is to become rich” (p 482). Dasgupta et al., (2002), Perman and Stern, (2003) challenge the notion because the EKC has never been shown to apply to all pollutants.

Time related effects can slow down or reduce the environmental impacts in countries regardless of income levels. Generally, it is the fast growing and the middle income economies where the scale effect dominates. So, increases in pollution and other degradation tend to overwhelm the time effect. In developed economies growth rate is slower; and pollution reduction efforts can overcome the scale effect. This argument provides a foundation for the origin of the so called EKC effect. Many developing nations are now addressing and even remedying the pollution problems (see Dasgupta *et al*., 2002).

In the absence of changes in the structure or technology, pure growth in an economy results in a proportional growth in pollution and other environmental impacts – the scale effect. The notion that economic growth and environmental quality are in conflict is a reflection of the scale effect alone. Using larger set of cross-section data, Panayotou (1993)[7] found support for EKC. He notes that at higher levels of development, structural changes happen in favor of environmental awareness and enforcement of regulations. Technology lowers environmental degradation. Using the same dataset as Grossman and Krueger [global environmental monitoring system (GEMS)], Selden and Song (1995) also found support for an EKC, although the econometric technique used by the later was superior.

A number of theoretical models support an inverted-U relation for pollution intensity, although it is by no means inevitable. The results depend on the assumptions and the value of a particular parameter. Although none has been empirically tested, Lopez (1994) and, Selden and Song (1995) models assume that pollution is generated by production; but John and Pecchenino (1994), John et al. (1995), and McConnell (1997) blame it on consumption.

Dasgupta et al. (2002) show that the greatest pollution increase happens from low to middle income levels but diminishes with increased regulation and better enforcement, rather than at high income levels. Economic liberalization in the developing economies over the last three decades has lowered subsidy to activities deemed harmful to environment which has helped efficient use of inputs. Gallagher (2004) points out that China is following European Union standards with regard to car emissions, but the current lag is about eight to ten year. China's per capita income has gone up manifold in recent time, but sulfur and CO_2 emissions have fallen; and the nation has made progress in other areas for sustained growth (Diesendorf, 2003). Lopez (1994) considers stock externalities (e.g., soil erosion) and shows that a key issue is whether producers internalize the externality. If they do, growth in income or trade will be reflected in improved environment. Internalization may be voluntary, but government actions can help[8].

Holtz-Eakin and Selden (1995) found that CO_2 emissions were increasing over any plausible income range for the sample they used. This result drew clear distinction between local and global externalities; put a limit on the range of the EKC prediction; and recognized the need for global action (e.g., the Kyoto Protocol). Grossman and Krueger's (1991) looked at the average annual PM_{10} concentration in the Tijuana area from 1997 to 2007, which covers much of the

NAFTA agreement. They found virtually no change in the ambient PM_{10} concentrations. They suggest that particulates should be falling substantially as income increased about 20%. The inclusion of a few developing countries in the sample may have been a problem[9].

Carson et al., (1997) finessed the dilemma by looking at only one side of the inverted-U curve. They used data from all fifty U.S. states which allowed a larger sample and a wider range of income. For the US it was the downside of a turning point, but the pollutants were non CO_2. Using air toxics, e.g., CO_2, NO_2, SO_2, volatile organic compounds (VOC), and PM_{10} for state-level point-source data for 1990, they found that per capita emissions of all pollutants monotonically decreased as income increased[10]. Despite support for the EKC hypothesis, their analysis of a panel dataset on air toxics emissions failed to show any relationship between the two series between 1989 and 1994. Interestingly, the wealthy and not so wealthy states were reducing emissions due to strong regulatory structure in high-income states. In addition, the use of technology is cost effective when significant amount of pollutants are present.

Using US-EPA state level dataset from 1929 to 1994 on per capita SO_2 and NO_2 emissions, List and Gallet (1999) found that the turning points for real income levels for states ranged from more than $1000 to $20,000, but varied by states by a factor of two to three. The results cast doubt on the estimates from cross-country panel dataset; and their relation to individual country. Aldy (2005) finds evidence in favor of an EKC for the US which is consistent with Carson et al., (1997)[11]. Using a wider income range, the estimated turning points also showed difference by states; and even followed substantially different income–pollution paths. The turning point, based on consumption and per capita emissions, is 40% higher than production-based estimate because higher income states import energy from lower-income states.

The evidence linking energy consumption to CO_2 emissions offers a mixed bag. Such outcome tended to challenge the general validity of EKC [see e.g. Lee and Lee (2009); Managi et al., (2008); Dinda and Coondoo (2006); Nohman and Antrobus (2005); Dinda (2004); Stern (2004); Friedl and Getzner (2003); Coondoo and Dinda (2002); Heil and Selden (1999)**;** Suri and Chapman, (1998); Wyckoff and Roop (1994); and Lucas et al., (1992); among others.] Romero-Ávila (2008) examines the link between economic growth and per capita pollution for 86 countries using data from 1960-2000, but failed to confirm an EKC. Lean and Smyth (2010) used panel vector error correction model (PVECM) to examine the relation between electricity consumption, CO_2 emissions and output for the ASEAN countries. They found support for an EKC relation. Following the framework of Ang (2007), Apergis and Payne (2009) investigated the relationship between energy consumption, CO_2 emissions and economic growth for Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama. They found evidence in favor or EKC from 1971 to 2004. Narayan and Narayan (2010) explored the EKC hypothesis for 43 low income countries and validated the EKC both in the long and the short run with long run income elasticity less than the short run one. They argue that countries reduce CO_2 emissions as income rises. Narayan and Narayan (2010) examined data from Iraq, Jordan, Kuwait, Yemen, Qatar, the UAE, Argentina, Mexico, Venezuela, Algeria, Kenya, Nigeria, Congo, Ghana, and South Africa. Results based on the panel data were consistent with those found for individual country.

Dhakal (2009) found that increase in income per capita adds to CO_2 emissions. Jalil and Mahmud (2009) found a non-linear relationship between the two series and support for EKC in China. Zhang and Cheng (2009) decomposed energy-related CO_2 emissions for China using time series data from 1991 to 2006. They found that improvement in energy intensity lowers CO_2 emissions; while increased economic activity does the reverse. Development of agriculture sector has positive impact on CO_2 emissions in China. Using data from 38 Chinese sub-industries, Shiyi (2009) found that use of more energy in China's industrial sector adds to pollution[12]. Akbostanci et al. (2009) examined EKC for Turkey using CO_2, SO_2 and PM_{10} emissions vs. the growth of GDP per capita; but did not find support for EKC. They argue that energy emissions are automatically reduced due to rapid economic growth. Fodha and Zaghdoud (2010) examined the relationship between energy pollutants and economic growth for the Tunisia from 1961 to 2004 using CO_2 and SO_2 emissions for environmental pollutants. They found EKC for SO_2; but not CO_2. Ozturk et al (2010) found EKC for Turkey. Nasir and Rehman (2011) and Shahbaz et al. (2012) found support for EKC relation in Pakistan.

III. Empirical Framework

The paper closely follows Ang, (2007, 2008), Soytas et al. (2007), Jalil and Mahmud, (2009), Halicioglu, (2009), and Shahbaz et al. (2012) by making suitable changes to capture country characteristics. To estimate EKC for Bangladesh, we add urbanization and trade. Both appear relevant as determinants of environmental degradation. The relation is specified as follows:

$$C_t = f(Y_t, Y_t^2, E_t, TR_t, U_t) \qquad (1)$$

In the log-linear form the specification is written as:

$$\ln C_t = \beta_1 + \beta_Y \ln Y_t + \beta_{Y^2} \ln Y_t^2 + \beta_E \ln E_t + \beta_{TR} \ln TR_t + \beta_U \ln U_t + \mu_t \qquad (2)$$

where, C refers to carbon emissions per capita (in kt); E is energy use (kg of oil equivalent per capita); Y and (Y^2) refer to real GDP per capita and its square respectively; TR is trade openness [(exports + imports)/ GDP)] per capita; and U is urban population as share of total population; μ is a while noise process. A priori, we expect energy use to increase pollutants: $\beta_E > 0$. The EKC hypothesis requires that $\beta_Y > 0$ and $\beta_{Y^2} < 0$. The sign of the coefficient of TR can go either way. $\beta_{TR} < 0$ implies adherence to and enforcement of environmental laws, and possibly import of environment friendly capital and technology. Grossman and Krueger (1991, 1993) argue that if $\beta_{TR} > 0$, then emissions might be generated due to relocation of polluting industries from developed economies, a practice known in the literature as the 'safe-haven hypotheses'. U stands for urbanization which is proxy for urban population and is measured in terms of share of total population. The more the urban population the higher is the demand for energy which in turn causes more environmental degradation. We expect $\beta_U > 0$.

3.1. Estimation Strategy

In general, unit root test precedes cointegration test. However, with ARDL the critical bonds apply irrespective of whether or not the regressors are I(0) or I(1); but the test results are not reliable if any of the series turns out to be I(2) or higher (Ouattara, 2004).

As such, we implement the ADF test prior to implementing the ARDL bounds test *a la* Pesaran et al. (2001). Haug (2002) argues that ARDL approach is preferable due its better small sample properties compared to other methods. The unrestricted error correction model (UECM) with appropriate lags captures the data generating process within the general-to-specific framework (Laurenceson and Chai, 2003). Appropriate modification of the orders of the ARDL model simultaneously corrects for residual serial correlation and endogeneity problems (Pesaran and Shin, 1999). The following UECM is used for our purpose.

$$\begin{aligned}\ln C_t &= \alpha_0 + \alpha_T T + \sum_{i=1}^{p}\beta_i \Delta\ln C_{t-1} + \sum_{i=0}^{q}\delta_i \Delta\ln Y_t + \sum_{i=0}^{r}\sigma_i \Delta\ln Y_t^2 + \sum_{i=0}^{u}\varepsilon_i \Delta\ln E_t \\ &+ \sum_{i=0}^{v}\varpi_i \Delta\ln T_t + \sum_{i=0}^{s}\phi_i \Delta\ln U_t + \lambda_c \ln C_t + \lambda_Y \ln Y_t + \lambda_{Y^2} \ln Y_t^2 + \lambda_E \ln E_t \\ &+ \lambda_{TR} \ln TR_t + \lambda_U \ln U_t + \mu_t\end{aligned} \qquad (3)$$

In Equation (3), $\beta, \delta, \varepsilon, \sigma$ and ω represents the short, and ($\lambda_C, \lambda_Y, \lambda_{Y^2}, \lambda_E, \lambda_{TR}, \lambda_U$) represent the long run parameters. The no cointegration hypothesis $H_0 : \lambda_C = \lambda_Y = \lambda_{Y^2} = \lambda_E = \lambda_{TR} = \lambda_U = 0$ is tested against the alternate of cointegration $H_1 : \lambda_C \neq \lambda_Y \neq \lambda_{Y^2} \neq \lambda_E \neq \lambda_{TR} \neq \lambda_U = 0$. The decision about cointegration is based on the computed F-statistic against the tabulated critical bounds[13]. The upper critical bound (UCB) is based on the assumption that the regressors are I(1) or of mixed order, and the lower critical bounds (LCB) applies if the series are I(0). If UCB is less than the F-statistic, the decision is in favor of cointegration among the series. If the F-statistic is less than LCB, then there is no cointegration; and inconclusive if the F-statistic lies between UCB and LCB. In such situation, we may have to rely on the lagged error correction term (ECM_{t-1}) for a long run relationship.

Once the long run relationship among the series has been established, an error correction representation can be derived as in Equation 4:

$$(1-L)\begin{bmatrix}\ln C_t \\ \ln Y_t \\ \ln Y_t^2 \\ \ln E_t \\ \ln TR_t \\ \ln U_t\end{bmatrix} = \begin{bmatrix}\phi_1 \\ \phi_2 \\ \phi_3 \\ \phi_4 \\ \phi_5 \\ \phi_6\end{bmatrix} + \sum_{i=1}^{p}(1-L)\begin{bmatrix} a_{11i}a_{12i}a_{13i}a_{14i}a_{15i}a_{16i} \\ b_{21i}b_{22i}b_{23i}b_{24i}b_{25i}b_{26i} \\ \delta_{31i}\delta_{32i}\delta_{33i}\delta_{34i}\delta_{35i}\delta_{36i} \\ \pi_{41i}\pi_{42i}\pi_{43i}\pi_{44i}\pi_{45i}\pi_{46i} \\ \theta_{51i}\theta_{52}\theta_{53i}\theta_{54i}\theta_{55i}\theta_{56i} \\ \sigma_{61i}\sigma_{62i}\sigma_{63i}\sigma_{64i}\sigma_{65i}\sigma_{66i}\end{bmatrix} + \begin{bmatrix}\beta \\ \chi \\ \xi \\ \zeta \\ \rho \\ \psi\end{bmatrix} ECM_{t-1} + \begin{bmatrix}\eta_{1t} \\ \eta_{2t} \\ \eta_{3t} \\ \eta_{4t} \\ \eta_{5t} \\ \eta_{6t}\end{bmatrix} \dots \quad (4)$$

where, $(1-L)$ is the lag operator; ECM_{t-1} is the lagged error-correction term, derived from the long run cointegrating equation, and $\eta_{t1}, \eta_{t2}, \eta_{t3}, \eta_{t4}, \eta_{t5}$ and η_{t6} are serially independent random error terms with mean zero and finite covariance matrix. A significant F-statistic for the parameters of the first differences of the series provides evidence on the direction of the short run causality; while long run causation is captured by a significant *t*-statistic pertaining to the ECM_{t-1}. In addition to sensitivity analysis, stability of the parameter and goodness of fit for ARDL model is checked by cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares of recursive residuals (CUSUMSQ).

4. Discussion and Interpretation of results

The unit root results reported in Table-1 confirm that the series are non-stationary at levels, but first difference stationary, i.e. I(1).

Table-1: Unit Root Estimation

ADF Test at Level with Intercept and Trend		
Variable	T-Statistics	Prob-Value*
$\ln C_t$	-0.2960	0.9870
$\ln E_t$	-2.3993	0.3740

$\ln Y_t$	0.4353	0.9987
$\ln Y_t^2$	-0.1559	0.8918
$\ln TR_t$	-0.9626	0.9365
$\ln U_t$	-2.2018	0.4715
ADF Test at 1st Difference with Intercept and Trend		
$\ln \Delta C_t$	-6.8985	0.0000
$\ln \Delta E_t$	-6.7119	0.0000
$\ln \Delta Y_t$	-6.8690	0.0009
$\ln \Delta Y_t^2$	-6.7551	0.0000
$\ln \Delta TR_t$	-5.7913	0.0002
$\ln \Delta U_t$	-3.3050	0.0825
Note: *MacKinnon (1996) one-sided p-values.		

Table-2: Lag Length Selection Criteria

VAR Lag Order Selection Criteria					
Lag	LogL	LR	FPE	AIC	HQ
0	257.4229	NA	5.05e-14	-13.5904	-13.4983
1	578.9902	521.4605	1.03e-20	-29.0265	-28.3818
2	642.9822	83.01670*	2.65e-21*	-30.5396*	-29.3423*
* indicates lag order selected by the criterion LR: sequential modified LR test statistic (each test at 5% level)					

FPE: Final prediction error AIC: Akaike information criterion HQ: Hannan-Quinn information criterion

The absence of any I(2) series sets the stage for implementing the ARDL bounds testing approach to cointegration. Under the (PSS, 2001), the lag length is determined by estimating first difference of the conditional error correction version of the ARDL model. The lag order is based on the minimum value of Akaike Information Criteria is 2 (Table-2). The computed ARDL F-statistics is sensitive to the chosen lag. The total number of regressions generated by ARDL is $[(p+1)^k] = (6+1)^2 = 49$ for each estimated equation; where p is the number of variables and k is the lag length. The F-statistic is calculated from the unrestricted version of equation-3 using OLS. Based on the critical values provided by Narayan (2005), we find the F-statistics exceed UCB, when CO_2 emissions and energy consumption are the forcing variables. This confirms cointegration at the 5% level (Table-3).

Table-3: The Results of Cointegration Tests

Bounds Testing to Cointegration			Diagnostic tests		
Estimated Models	F-statistics	χ^2_{NORMAL}	χ^2_{ARCH}	χ^2_{RESET}	χ^2_{SERIAL}
$F_C(C/E,Y,Y^2,TR,U)$	7.336**	6.9570	[1]: 0.3857	[1]: 0.0526	[1]: 0.9212; [2]: 3.0535
$F_Y(Y/C,E,Y^2,TR,U)$	5.132	0.3383	[1]: 0.3140	[1]: 0.1456	[1]: 0.0452; [2]: 0.2204
$F_{Y^2}(Y^2/C,E,Y,TR,U)$	5.027	0.3861	[1]: 0.2742	[1]: 2.0130	[1]: 0.0260; [2]: 0.1860
$F_E(E/C,Y,Y^2,TR,U)$	7.130**	1.4173	[1]: 0.6745	[2]: 0.8967	[1]: 2.1277; [2]: 3.6746

$F_{TR}(TR/C, E, Y, Y^2, U)$	1.435	1.2438	[1]: 0.0399	[1]: 0.9844	[1]: 4.3341; [3]: 1.9136	
$F_U(U/C, E, Y, Y^2, TR)$	1.160	0.4281	[1]: 0.0399	[1]: 1.2884	[1]: 0.3537; [2]: 0.2504	
Significant level	Critical values (T= 40)					
	Lower bounds $I(0)$	Upper bounds $I(1)$				
1 per cent level	6.053	7.458				
5 per cent level	4.450	5.560				
10 per cent level	3.740	4.780				
Note: The asterisks ** denote 5% significance level. The optimal lag is determined by AIC. The p-values are in parenthesis. # Critical values for the bounds are computed using the surface response procedure.						

The long run elasticity of CO_2 with respect to economic growth, energy consumption, trade and urbanization is reported in Table-4. The results suggest that on an average, 1 percent increase in energy consumption raises pollutants by 1.9044 percent in the long run, ceteris paribus. This is consistent with results found by Hamilton and Turton, (2002) for OECD countries; Friedl and Getzner, (2003) for Austria and China; Say and Yücel, (2006) and Ozturk and Acaravci, (2010) for Turkey; Ang, (2008) for Malaysia; Halicioglu, (2009) for Turkey; Jalil and Mehmud, (2009), Chang, (2010), and Liu (2005) for China; Lean and Smyth, (2010) for ASEAN countries; Nasir and Rehman (2011) and Shahbaz et al. (2012) for Pakistan.

Table-4: Long Run Relationship

Dependent Variable = $\ln C_t$				
Variable	Coefficient	Std. Error	T-Statistic	Probability
Constant	-126.7069	17.081	-7.4177	0.0000
$\ln Y_t$	24.2354	3.5707	6.7871	0.0000
$\ln Y_t^2$	-1.2694	0.1803	-7.0403	0.0000
$\ln E_t$	1.9044	0.2711	7.0238	0.0000
$\ln TR_t$	-0.0877	0.0465	-1.8864	0.0689
$\ln U_t$	0.2771	0.0802	3.4555	0.0017
R-Squared = 0.9832 Adjusted R-Squared = 0.9822 Akaike info Criterion = -3.6455 Schwarz Criterion = -3.3818 F-Statistic = 12.7164 Prob(F-Statistic) = 0.0006 Durbin-Watson = 1.7399				

The coefficients of linear and non-linear terms for GDP per capita are 24.2354 and -1.2694 respectively, both are highly significant. This lends support to an EKC hypothesis in Bangladesh. The threshold point is calculated at Tk 21,900 (1$ = Tk 84, 3/ 2012). The results are consistent with those found by He (2008), and Song et al. (2008), Jalil and Mehmud, (2009) for China; Halicioglu, (2009) for Turkey; Fodha and Zaghdoud, (2010) for Tunisia; Lean and Smyth, (2010) for ASEAN countries and Shahbaz et al. (2012) for Pakistan.

The negative coefficient of TR implies that 1 percent increase in international trade is expected reduce emissions by 0.0877 percent, on average. While small, the coefficient is significant at the 10 percent level; which is in line with Jalil and Mehmud, (2009) for China. The impact of urbanization on pollution is positive and significant. A 1 % rise in urbanization leads to an increase in pollutants by 0.2771%, on an average, all else same.

Table-5 presents the short run results. The coefficients of linear and non-linear terms of real GDP per capita also support EKC relation; but they are smaller than the long run coefficient. The finding that the long run income elasticity for CO_2 emissions is less than the short run elasticity reinforces the long run evidence in favor of EKC (See Narayan and Narayan, 2010 for more). Impact of trade is very small but insignificant in the short run. A 1 % increase in energy consumption is expected to raise energy emissions by 1.50%, and significant at the 1% level; lower than the long run result. Perhaps the polluters obey the rules in the short run but tend to circumvent them in the long run. The impact of urbanization on CO_2 emissions is insignificant. The effect of trade on emission is negative in the long and the short run. The long run impact is much larger in absolute terms than in the short run, but the latter is insignificant.

Table-5: Short Run Results

Dependent Variable = $\Delta \ln C_t$				
Variable	Coefficient	Std. Error	T-Statistic	Probability
Constant	0.0192	0.0200	0.9608	0.3448
$\Delta \ln Y_t$	12.944	6.3742	2.0307	0.0519
$\Delta \ln Y_t^2$	-0.7038	0.3284	-2.1431	0.0409
$\Delta \ln E_t$	1.5032	0.2984	5.0367	0.0000
$\Delta \ln TR_t$	-0.0058	0.0315	-0.1854	0.8542
$\Delta \ln U_t$	0.1717	0.2612	0.6576	0.5162
ECM_{t-1}	-0.8744	0.2006	-4.3569	0.0002
R-Squared = 0.6505 Adjusted R-Squared = 0.5757 Akaike info Criterion = -3.7002 Schwarz Criterion = -3.3891 F-Statistic = 8.6894 Prob(F-statistic) = 0.0002 Durbin-Watson = 1.9519				

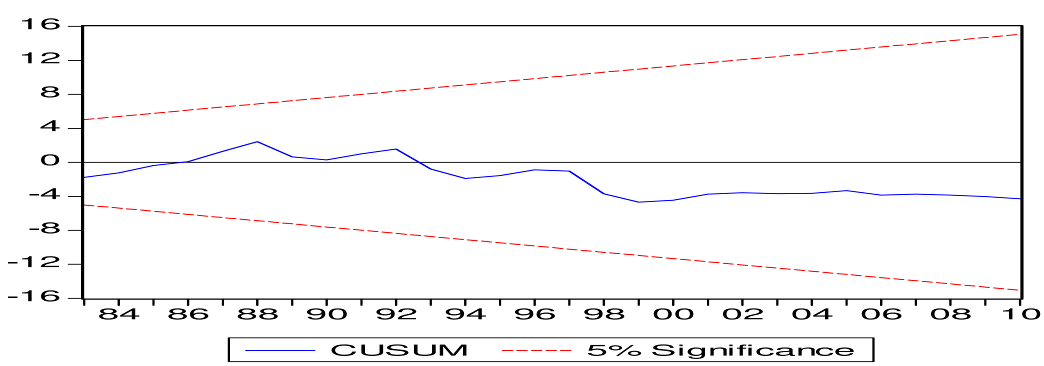
Sensitivity Analysis
Serial Correlation LM = 0.1442 (0.7070)
ARCH Test = 0.1114 (0.7406)
Normality Test = 1.4873(0.4753)
Heteroscedisticity Test = 1.5105 (0.1937)

The estimated coefficient of the lagged ECM term is -0.6333 and significant at the 1% level. This establishes long run relation among the running variables. This suggests that deviations of CO_2 emission in short run from the long run equilibrium are corrected by 63.33% each year.

4.1 Sensitivity Analysis and Stability Test

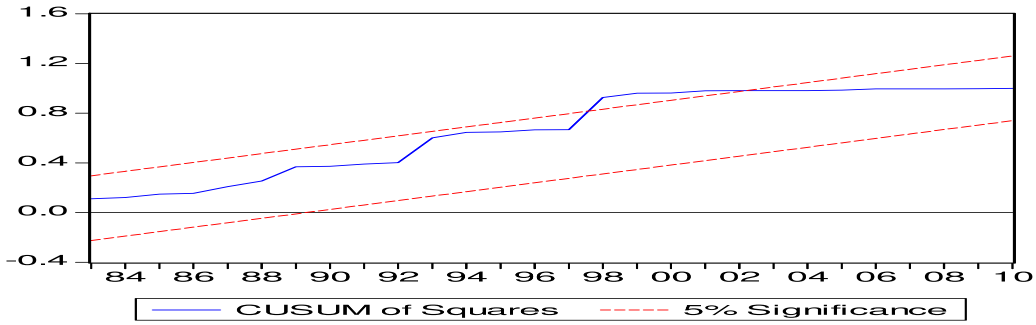
Diagnostics based on the LM test for serial correlation, normality of residual term and White heteroscedisticity; the short run model passes them clearly[14] (Table-6). There is no evidence of autoregressive conditional heteroscedisticity or White heteroscedisticity.

Figure **1: Plot of Cumulative Sum of Recursive Residuals**



The straight lines represent critical bounds at 5% significance level.

Figure **2: Plot of Cumulative Sum of Squares of Recursive Residuals**



The straight lines represent critical bounds at 5% significance level.

The straight lines in Fig 1 and 2 represent the 5% critical bounds for the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMsq) tests which have been employed to check for parameter stability. The graph should be within the appropriate bounds, 5% in this case, if the parameters are stable (Pesaran et al., (2000, 2001)). This is not supported here. The CUSUMsq graph indicates two structural break points one in 1989 and the other in 1999 which may be a reason for instability. The results for Chow forecast test for the period 1998-2010, reported in Table-7, however suggest no structural break in data. The Chow test is more reliable and is preferred to the graphs. The graphs can be misleading (Leow, 2004).

Table-6: Structural Break Test

Chow Forecast Test: Forecast from 1998 to 2010			
F-statistic	0.5746	Probability	0.8389
Log likelihood ratio	14.1475	Probability	0.3637

4.2 VECM Granger Causality

The presence of cointegration among the series implies that causality must exist at least in one direction. To check for this, we applied the Granger causality test within the VECM. Test results are reported in Table-7. The long run causality is captured by t-test on a negative ECM_{t-1}. The joint significance of LR test on the lagged explanatory variables shows short-run causality.

The long run causality runs from economic growth to CO_2 emissions only. This result also supports the existence of an EKC relation in Bangladesh [on this, see e.g., Coondoo and Dinda (2002); Dinda and Coondoo (2006); Akbostanci et al., (2009) and Lee and Lee (2009)]. The findings are consistent with those of Maddison and Rehdanz (2008) for North American countries; Zhang and Cheng (2009) and, Jalil and Mahmud (2009) for China; Ghosh (2010) for India[15] and, Nasir et al. (2011), Shahbaz et al. (2012) for Pakistan, and Alam et al (2011) for Bangladesh. However, Alam did not provide any formal test on Bangladesh about EKC.

The long run unidirectional causality from trade openness to CO_2 emissions supports Grossman and Krueger (1991, 1993) and Halicioglu (2009). They argue that pollution is reduced due to enforcement of environmental protection laws. Urbanization causes environmental degradation. This is in line with Martínez-Zarzoso (2008). Energy consumption is Granger-caused by income, trade openness and urbanization. This relation validates (a) growth-led-energy consumption; (b) trade-led-energy consumption; and (c) urbanization-led-energy consumption in Bangladesh. Finally, feedback hypothesis is found between energy consumption and CO_2 emissions. The causality from CO2 emission to energy consumption appears counterintuitive.

In the short run, bidirectional causality is found between trade openness and energy consumption, economic growth and trade openness. Trade openness and urbanization Granger cause CO_2 emissions. We find unidirectional causality from economic growth to urbanization and urbanization to trade openness. Both the results are intuitively quite appealing.

A significant of ECM_{t-1} for CO_2 emissions and for energy consumption in VECM equations shows the speed of adjustment towards the long-run equilibrium are (-0.7888), and (-0.1193) respectively; both significant at the 1% level. The coefficients of ECM_{t-1} for income, trade openness and urbanization VECM equations have negative sign, but not statistically significant.

Table -7: Granger Causality Analysis

Dependent Variable	Types of Granger Causality						
	Short Run						Long Run
	$\sum \Delta \ln C_t$	$\sum \Delta \ln Y_t$	$\sum \Delta \ln Y_t^2$	$\sum \Delta \ln E_t$	$\sum \Delta \ln TR_t$	$\sum \Delta \ln U_t$	ECM_{t-1}
	F-statistics						t-statistics
$\sum \Delta \ln C_t$	…..	0.1309 [0.8779]	0.3518 [0.7070]	0.2099 [0.8121]	4.3147** [0.0251]	3.6725** [0.0406]	-0.7888* [-4.2899]
$\sum \Delta \ln Y_t$	0.5563 [0.5805]	…..	11.2524* [0.0004]	1.2139 [0.3146]	2.9046*** [0.0742]	0.9560 [0.3986]	
$\sum \Delta \ln Y_t^2$	3.3750*** [0.0511]	8.1548* [0.0020]	…..	2.1527 [0.1318]	8.0864* [0.0021]	1.4242 [0.2603]	

$\sum \Delta \ln E_t$	1.0674 [0.3596]	1.1931 [0.3206]	1.7597 [0.1936]	…..	5.0620** [0.0146]	7.1391* [0.0037]	-0.1193* [-3.4067]
$\sum \Delta \ln TR_t$	2.2834 [0.1236]	20.4225* [0.0000]	3.8961** [0.0343]	3.7547** [0.0381]	…..	10.6626* [0.0005]	
$\sum \Delta \ln U_t$	0.1580 [0.8547]	3.5548** [0.0444]	4.1777** [0.0277]	0.6362 [0.5380]	0.8415 [0.4434]	…..	
Note: significant at 1%, 5% and 10% level of significance is shown by *, ** and *** respectively.							

V. Conclusion and Policy Implications

The paper uses Bangladesh data from 1971 to 2010 to examine a long run relationship among energy consumption; international trade; economic growth; urbanization; and CO_2 emissions. ADF unit root tests check for stationarity; and the ARDL approach to cointegration for an EKC relation. The results confirm a long run relation among the series and provide evidence in support of EKC in Bangladesh. The direction of causality results can help policymakers to craft energy policies and meet rising energy demand from economic and demographic changes.

The causality analysis shows that economic growth Granger causes CO_2 emissions and also supports the existence of EKC in Bangladesh. Trade openness Granger causes CO_2 emissions. The unidirectional causality runs from urbanization to CO_2 emission. A rise in income, urban pollution and trade openness Granger cause energy consumption thus supports growth-led-energy consumption, urbanization-led-energy consumption and trade-led-energy consumption. Energy consumption and CO_2 emissions Granger cause each other confirming feedback hypothesis. In the short run, bidirectional causality is found between trade openness and energy consumption, economic growth and trade openness, urbanization and economic growth. We also find unidirectional causality from economic growth to urbanization.

The results on the directions of causality should shed additional light on the future need for crafting appropriate energy policies. Such policy will help to meet rising energy demand caused by rapid economic and demographic changes and support sustainable economic growth. The finding that causality runs from energy consumption to CO_2 emission is normal, but the reverse causation implies absence of policy parameters. For Bangladesh economic growth is absolute necessity to feed over 165 million people most of whom are poor. The fact alone has been the determining factor for high priority on economic growth alone without much importance to environmental laws. The nation in the face of severe shortage of foreign exchange could not afford to pay much attention to importing energy efficient capital and technology; as priorities had to be placed on more important things. However, only in recent times environmental aspects of development are being carefully considered. In particular, legal framework is being developed and enforced; although still in formative stage. Against such backdrops, the above noted reverse causality is not unusual. Over time, as the laws take full effect, and public awareness about the need for quality environmental increases, the causality likely will disappear, although much will depend on how the laws are enforced.

In the short run, bidirectional causality is found between trade openness and energy consumption, economic growth and trade openness. Trade openness and urbanization Granger cause CO_2 emissions. Openness did not quite help environment. Perhaps, import of technology that could have saved energy and lower CO2 emission did not materialize. This can happen for lack of interest and understanding on the part of local government officials; or the foreign investors used the poor legal structure to their advantage. We also find unidirectional causality from economic growth to urbanization and urbanization to trade openness. Both the results are intuitively quite appealing.

The immediate future does not appear bright. The main is that urbanization will continue unabated in the absence of off farm job opportunities in the rural areas. The current rate of rural urban migration is unsustainable. City life will deteriorate significantly which will take its toll on environment. To address this government should create ground for jobs in the rural, provide capital to support small scale entrepreneurial skill in the short and medium term. In the long term, emphasis should be placed on need-based skill creation and support human capital formation. Ultimately technological improvement should be the main thrust where private public partnership can yield the best outcome for sustainable economic development.

Endnotes

1. They found uni-directional causality from CO_2 emissions to energy consumption in the long run, but the reverse in the short run. CO_2 granger causes economic growth both in the short and in the long run, they argue, is inconsistent with the EKC hypothesis. They point out that the dynamic link between energy consumption and economic growth rejects the 'neo-classical' assumption of neutrality; and the former can limit economic growth in Bangladesh – energy conservation may hurt economic growth – a challenge to balancing sustainable energy use and economic growth.
2. The relation is described by including linear and non-linear terms of GDPC in model.
3. Ehrlich's best-seller, *The Population Bomb* (1968) and the Club of Rome's *Limits to Growth* (Meadows et al. 1972) see population growth and affluence as hurtful to environment. Some saw technology mildly beneficial, but to Commoner (1972) it is destructive. However, technology conserves resource, reduces pollution, and offsets both affluence and population growth. The Club of Rome puts adverse environmental impact on exponential growth in resource use, not technology.
4. Factors like population growth, technological change, or shifts in consumption or trade patterns can be a source of increasing returns to scale for pollution control.
5. They show a linear relationship in case of constant returns to scale, but U-shaped, for decreasing returns to scale.
6. Exception was made for dissolved oxygen in rivers; and CO_2. They also included trade indicators and political freedom, as predictors of environmental quality.
7. He found support for EKC relationships using a larger set of cross-section data.

8. The argument goes as follows. As the substitution elasticity between output and pollution, and the relative risk-aversion coefficient falls, an inverse U-shaped curve for the income–pollution relationship emerges. The model included production and utility to explain EKC, for some plausible parameter values. Using an overlapping generation model, John and Pecchenino (1994) offers a theoretical explanation for the observed correlation.
9. There were 22 high, 6 middle and 2 low-income countries in the sample, not enough to identify a nonlinear relationship (Selden and Song, 1995).
10. The results were similar for CO_2 emissions for the point and the mobile sources at the state level; and for PM_{10} emissions from a sample of 1,748 counties. The finding was similar across all air pollutants. The high-income states had low per capita emissions; but the per capita emissions from lower-income states were highly variable. The results were robust to the use of alternative statistical techniques and functional forms.
11. He estimated CO_2 emissions (based on fossil fuel use 1960 to 1999) in the 48 continental US states.
12. Song et al. (2008) used Chinese provincial data to investigate EKC relation using three measures for pollutants (waste gas, waste water and solid wastes) per capita and found inverted U- relationship. Zhang and Cheng, (2009) examined the relationship between CO_2 emissions, energy consumption and economic growth using Toda and Yamamoto, (1995) and impulse response function for forecasting. They included fixed capital formation and urban population in rthe model.
13. We use Tuner's (2006) critical values instead of Pesaran et al. (2001) and Narayan (2005) because the lower and upper bounds by Turner (2006) are better suited to small samples.
14. The short-run model did not pass the Ramsey test for specification.

15. For Malaysia, Ang (2008) finds one-way causality from economic growth to energy use.

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