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Is There an Environmental Kuznets Curve for Bangladesh? Evidence from ARDL Bounds Testing Approach

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The environmental Kuznets curve (EKC) hypothesis posits that in the early stages of economic growth environmental degradation and pollution increase. However, as a country reaches a certain level of income, the trend reverses postulating a relationship that produces an inverted U-shaped curve. Bangladesh has been recording remarkable rates of economic growth which, along with other factors, has raised the specter of a looming environmental crisis. This paper empirically investigates the EKC hypothesis for Bangladesh using data from 1971 to 2010 applying the Autoregressive distributed lag (ARDL) approach to cointegration for a long run relation and the Granger causality within the vector error correction model for the short run dynamics. The results show that energy consumption is a major contributor to CO_2 emissions; trade openness lowers CO_2 emissions, but urbanisation worsens it. Economic growth, energy consumption, trade, and urbanisation Granger cause CO_2 emissions.

Keywords: EKC, ARDL, VECM, Bangladesh
JEL Classification: O13, Q25, Q53

I. INTRODUCTION

The environmental Kuznets curve (EKC, hereafter) hypothesis posits that in the early stages of economic growth environmental degradation and pollutions increase; but after a certain level of income is reached, measured in per capita terms, the trend reverses producing an inverted U-shaped curve. The postulated relationship has been empirically verified for a number of countries; and yet the

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results have come under intense criticism (for a review, see Hill and Magnani 2002, and Lee and Lee 2009). Bangladesh, a small emerging country of 160 million in the Indian Sub-continent, has been recording remarkable rates of economic growth over the past two decades. However, a dense population, expanding urbanisation and a fast growing industrial base have raised the specter of a looming environmental crisis. Despite the fear of such a possibility in Bangladesh, academic research in the area of environmental economics appears to have remained less than adequate.

The objective of the study is to empirically investigate the EKC hypothesis for Bangladesh, using 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) for short run dynamics. Knowledge about the existence of the EKC relation reinforced by a good understanding of the direction of causality can help policy makers craft meaningful policy for sustained economic growth and preserve environment endogenously. As noted, academic inquiry on EKC has been virtually absent; an exception, however, is Alam, Begum, Buysse and Huylenbroeck (2012). They examine the nexus of energy consumption, carbon emissions and economic growth in Bangladesh. The authors applied the ARDL and the Johansen Juselius (1990) approaches and found cointegration, and bidirectional Granger causality between economic growth and CO_2 emissions.[1] The authors did not, however, explore the non-linearity aspect of the EKC relationship. Also, the paper appears mis-specified in the context of Bangladesh as they did not consider some major changes over the past few decades. In particular, factors that might affect the results include: (a) substantial economic liberalisation and (b) significant urbanisation, both of which directly impinge on energy consumption and thus carbon emissions, particularly CO_2. Environmental degradation and natural resources depletion in Bangladesh are major threats to sustainable economic growth. Against the backdrops, the motivation behind the present research is to better understand the nexus of CO_2, urbanisation, energy consumption, economic

[1]They found uni-directional causality from CO_2 emissions to energy consumption in the long run, but the reverse is true in the short run. CO_2 emissions Granger cause 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.

growth and trade openness in Bangladesh. The paper contributes to the literature in three distinct ways: (a) the paper offers fresh insight to a relevant but understudied area, (b) the model better captures the underlying Bangladesh context, and (c) The model includes a non-linear term explicitly to formally examine the EKC hypothesis, and thus complements Alam *et al.* (2012).

A brief discussion of the context of Bangladesh environment is in order. By and large, environmental awareness appears to be lacking in the country as manifested in deforestation and reckless cutting down of hills; destruction of wetlands; depletion of soil nutrients; emissions of harmful particulates in the air; and water pollution–surface and ground–inter alia. Natural calamities like floods, cyclones and tidal-bores leave marks of severe environmental and socio-economic dent. Until the 1970s, shortage of clean drinking water caused serious health related problems e.g. cholera, typhoid, etc. Aid agencies such as UNICEF built shallow wells throughout the country to provide safe drinking water. Then in the 1990s, arsenic contamination made headlines. As a result, both the people and the land they use for survival had fallen victims of the poison. The World Bank estimates that 25 per cent of the country's 4 million wells are contaminated. Some of the notable public policies include National Environment Policy, National Conservation Strategy and National Environment Management Action Plan. All these aim at protecting the environment and natural resources, controlling pollution and strengthening the legal framework to prosecute and punish those in violation within an integrated development strategy. The Department of Environment (DoE) regularly conducts surveys to identify stationary and nom-stationary offenders (industries and vehicles)–remarkable so far, but more is needed.

The rest of the paper is organised as follows. Section II reviews the extant literature. Section III outlines the econometric strategy and the data sources. The results are reported in section IV. Conclusion and policy implications are offered in section V.

II. LITERATURE REVIEW

The EKC relation has drawn considerable attention from academicians and policy makers. A natural outcome of this inquisitiveness has been the proliferation of a sizeable literature; a fuller treatment of which would easily entail a treatise. In an effort to avoid this, we present a brief review of the extant literature under three sub headings: (a) the theory, (b) the econometric challenges, and (c) the empirical results.

2.1 Theory of EKC

Kuznets (1955) was the first to posit that as economy grows, income inequality initially rises, reaches a peak, and then begins to fall after a certain level of income has been reached. Later, the idea was extended to the "environmental poverty" and economic growth nexus under the rubric of environmental Kuznets curve (EKC). Over the past three decades, a bourgeoning literature has proliferated examining the theory and empirics behind EKC[2], and yet there seem to be more questions than answers! The early theoretical contribution by Grossman and Krueger (1991), supplemented by the empirical work by Shafik and Bandyopadhyay (1992) and Shafik (1994), heralded the birth of the EKC. They added more countries and used additional environmental indicators to validate the EKC.[3] They found that environmental degradation is a monotonically increasing function in income with income elasticity less than unity.[4] Most believe that economic growth is critical to environmental awareness while poverty tops the list among the adversaries!

"… (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 2010:5). In general, the effect dominates in the fast growing and the middle-income economies. 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 countries are now addressing and even trying to remedy the pollution problems (Dasgupta, Laplante, Wang and Wheeler 2002).

While a relationship is observed stays valid with regard to lack of water and of urban sanitation; however, the relationship reverses with respect to river water. Increased municipal waste and carbon emission per capita are directly related to higher income. Municipal waste and carbon emissions confirm the existence of EKC hypothesis. It may be noted that the economic growth-energy consumption nexus in the context of CO_2 emissions is central to sustainability.

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[2]The relation is described by including linear and non-linear terms of GDPC in model.
[3]They used three different functional forms: log-linear, log-quadratic and log-cubic polynomial form.
[4]He found support for EKC relationships using a larger set of cross-section data.

Several research based on country specific data lend support to EKC. Stern (2004) argues that production scale and technology improvements can affect EKC relation. A common theme across the approaches is clearly palpable. They all assume that the structure of an economy shifts towards less polluting industries as an economy grows. An alternative view is based on the assumption that quality of environment is a luxury good. So, more environmental protection is demanded as per capita income rises. These are explored further in Copeland and Taylor (2001, 2005) along the ideas of threshold effects and increasing returns to abatement.

2.2 Econometric Issues

The EKC hypothesis, basically an empirical phenomenon, rose to prominence perhaps due to the inability to pay adequate attention to econometric diagnostics–a failure to distinguish stylised facts from spurious ones. "It is very easy to do bad econometrics and the history of the EKC exemplifies what can go wrong" (Stern 2004:1). When correct statistical tools are used, the EKC ceases to exist (Perman and Stern 2003). Also, environmental degradation is also not simply a function of income alone.

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[5] in terms of the pollution control effort,[6] while Lopez and Mitra (2000) (see, for example, Brock and Taylor 2005) point to the role of corruption on the turning point in the EKC relation.

2.3 Empirical Evidence

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

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[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]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) offer a theoretical explanation for the observed correlation.

favour of environmental awareness and enforcement of regulations; something corroborated by Dasgupta *et al.* (2002). 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. The econometric technique used by the later was superior. Economic liberalisation in the developing economies over the last three decades has lowered subsidy to activities deemed harmful to environment, which has helped more 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 years.[8] China's per capita income has gone up manifold in recent time, but sulfur and CO_2 emissions have also fallen.

Using US-EPA state level dataset (1929-94) 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 over $1,000 to $20,000, but varied across states by a factor of 2-3. The results cast doubt on the estimates from cross-country panel dataset, and their relation to individual country. Aldy (2005) finds evidence in favour of an EKC for the US, which is consistent with Carson, Jeon and McCubbin (1997).

Romero-Ávila (2008) examines the link between economic growth and per capita pollution for 86 countries using data from 1960 to 2000, but failed to confirm an EKC relationship. Lean and Smyth (2010) found support for an EKC relation for the ASEAN countries. Following the framework of Ang (2007), Apergis and Payne (2009) found a relationship between energy consumption, CO_2 emissions and economic growth for Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama, and support for EKC from 1971 to 2004. The evidence linking energy consumption to CO_2 emissions offers a mixed bag. Such outcome tends to challenge the general validity of EKC (Dinda and Coondoo 2006, Nohman and Antrobus 2005, Dinda 2004, Stern 2004, Friedl and Getzner 2003, Coondoo and Dinda 2008, Heil and Selden 1999, Suri and Chapman 1998, Wyckoff and Roop 1994, and Lucas, Wheeler and Hettige 1992, among others). For a set of 43 low-income countries, Narayan and Narayan (2010) validated the EKC in the long and the short run; with the long run income elasticity smaller

[8]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 the model.

than the short run for Iraq, Jordan, Kuwait, Yemen, Qatar, the UAE, Argentina, Mexico, Venezuela, Algeria, Kenya, Nigeria, Congo, Ghana and South Africa. Panel results are 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) found that improvement in energy intensity lowers CO_2 emissions, while in China increased economic activity does the reverse. Using data from 38 Chinese sub-industries, Shiyi (2009) find that growth in industrial sector adds to pollution because they use of more energy; but development in agriculture lowers it. Using CO_2, SO_2 and PM_{10} emissions vs. GDP growth of per capita, Akbostanci, Türüt-Asik and Ipek (2009) did not find support for EKC. Fodha and Zaghdoud (2010) found EKC for SO_2, but not CO_2 for Tunisia. Ozturk and Acaravci (2010) found EKC for Turkey. Nasir and Rehman (2011) and Shahbaz, Lean and Shabbir (2012) found support for EKC relation in Pakistan.

Halkos and Efthymios (2001) found that that higher economic growth is linked with low deforestation, but not EKC. Omojolaibi (2010) did not find an EKC for Ghana, Nigeria and Sierra Leone. Asici (2011) found stronger positive effect of income on environment in middle- relative low and high income countries, but not in high income countries.

III. EMPIRICAL FRAMEWORK

The paper closely follows Ang (2007, 2008), Soytas *et al.* (2007), Jalil and Mahmud (2009), Halicioglu (2009), and Shahbaz, Lean and Shabbir (2012) but makes suitable modification to capture the particular features of Bangladesh. To estimate EKC for Bangladesh, we add urbanisation and trade as they appear relevant to environmental degradation. The relation is specified as follows:

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

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

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

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)]; U is urban population as share of total population; and μ is a white 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 coefficient of TR can go either way. $\beta_{TR} < 0$ implies adherence to and enforcement of environmental laws, and possibly import of environment-friendly technology. Grossman and Krueger (1991, 1993) argue that if $\beta_{TR} > 0$, then emissions might be generated from relocation of polluting industries from developed economies, a practice called the "safe-haven hypotheses." U represents urbanisation, a proxy for urban population and is measured as a share of total population. The higher the urban population, the more 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 tests precede cointegration test. However, with the ARDL the critical bounds apply irrespective of whether or not the regressors are *I(0) or I(1).* And yet, a test is useful to insure that we are not dealing with series that are *I(2)* or higher; in which case, the test results are not reliable (Ouattara 2004). So we implement the ADF test. The ARDL approach is preferable due to its better small sample properties compared to other methods (Haug 2002). 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.

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

In equation (3), $\beta, \delta, \varepsilon, \sigma$ and ω refer to the short, while $(\lambda_C, \lambda_Y, \lambda_{Y^2}, \lambda_E, \lambda_{TR}, \lambda_U)$ 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 which is compared against the tabulated critical bounds. 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 they are I(0). If the UCB is less than the computed F-statistic, the decision is in favour of cointegration. If the F-statistic is less than LCB, then there is no cointegration; and inconclusive if the F-statistic lies between UCB and LCB.[9] In such situation, we 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 confirmed, an error correction representation must exist, as shown in Equation 4. We check sensitivity, parameter stability and goodness of fit for the ARDL model using cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares of recursive residuals (CUSUMsq).

VECM Causality test

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

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 zero mean and finite covariance matrix. A significant F-statistic for the parameters of first differences of the series provides evidence in favour of short run causality, while long run causality is captured by a significant *t*-statistic pertaining to the ECM_{t-1}.

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[9]We use Turner's (2006) critical values instead of Pesaran, Shin and Smith (2001) or Narayan (2005) because the lower and upper bounds by Turner (2006) are better suited to small samples.

IV. DISCUSSION AND INTERPRETATION OF RESULTS

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

TABLE I
UNIT ROOT ESTIMATION

Variable	T-Statistics	Prob-Value*
ADF Test at Level with Intercept and Trend		
$\ln C_t$	-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 II
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*

Note: * 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) or higher series sets the stage for implementing the ARDL bounds testing approach to cointegration. Under the PSS (2001), lag length is determined by estimating first difference of the conditional error correction version of the ARDL model. The computed ARDL F-statistics is sensitive to the chosen lag. The latter, chosen on the basis of the minimum value of Akaike Information Criteria, is 2 (Table II). 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 from Narayan (2005), which is better for small sample, we find the F-statistics exceed UCB, when CO_2 emissions and energy consumption are forcing variables. This confirms cointegration at the 5% level (Table III).

TABLE III
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	7.527		8.803		
5 per cent level	5.387		6.437		
10 per cent level	4.447		5.420		

Note: The asterisks ** denote 5% significance level. The optimal lag is determined by AIC. The p-values are in parenthesis. Critical bounds are computed using the surface response procedure.

The short run results are reported in Table IV. We find that linear and non-linear terms of real GDP per capita have positive and negative signs and it is statistically significant at 5% levels respectively. This confirms the presence of environmental Kuznets curve in the short run. Energy consumption adds in CO_2 emissions but impact of trade openness is insignificant. The estimated coefficient of the lagged ECM term is -0.8744 and significant at the 1% level. This reconfirms a long run relation among the series and suggests that deviations of CO_2 emissions from short run to long run equilibrium are corrected by 87.44 % each year.

TABLE IV
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 long run elasticity of CO_2 with respect to economic growth, energy consumption, trade and urbanisation is reported in Table V (each elasticity is on average, ceteris paribus). The results suggest that a 1% increase in energy consumption raises pollutants by 1.9044% in the long run. 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 Mahmud (2009), Chang (2010) and Liu (2005) for China; Lean and Smyth (2010) for the ASEAN countries; and Nasir and Rehman (2011) and Shahbaz, Lean and Shabbir (2012) for Pakistan.

TABLE V
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 in the long run. The threshold pointis calculated at Tk. 21,900 (1$ =Tk84,3/2012). The results are consistent with those found by He (2008), Song, Zheng and Tong (2008), and Jalil and Mehmud, (2009) for China; Halicioglu (2009) for Turkey; Fodha and Zaghdoud (2010) for Tunisia; Lean and Smyth (2010) for ASEAN countries; Shahbaz, Lean and Shabbir (2012) for Pakistan; and Shahbaz and Leitão (2013) for Portugal. It is plausible that the threshold point is low due to wide spread poverty across the countries. This is an area that needs further academic research.

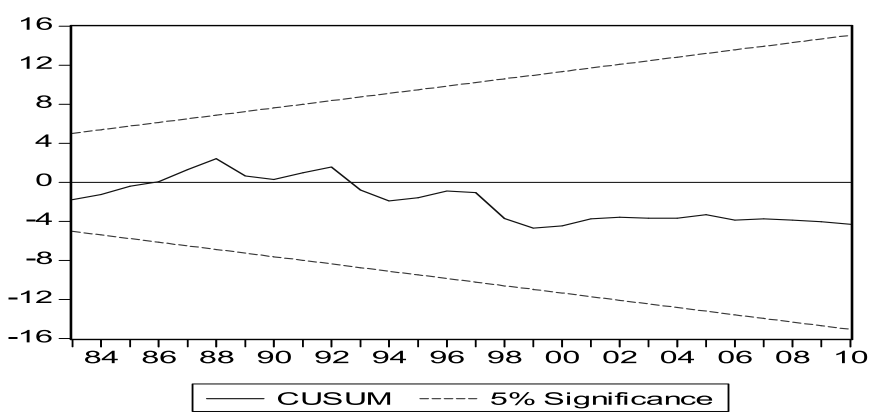
We also reported other long run elasticities (each on average, all else the same). The negative coefficient of trade openness implies that a 1% increase in trade reduces emissions by 0.0877%. Although small, the coefficient is significant at the 10% level and is in line with Jalil and Mahmud (2009) for China. The impact of urbanisation on pollution is positive and significant. A 1 % rise in urbanisation leads to an increase in pollutants by 0.2771%, all else is the same. The inclusion of the two series appears to capture the particular context of Bangladesh.

The short run coefficients of linear and non-linear terms of real GDP per capita in the context of an EKC relation are smaller than the corresponding long run coefficients. The finding that the long run income elasticity for CO_2 emissions is less than the short run elasticity reinforces support for EKC in the long run (See, Narayan and Narayan 2010 for more). The impact of trade and urbanisation is insignificant in the short run; both smaller than the long run coefficient. A 1% increase in energy consumption raises energy emissions by 1.50%, significant at the 1% level in the short run; smaller than the long run coefficients. Perhaps the polluters obey the rules in the short run only to find way to circumvent them in the long run later. The effect of trade on emissions is negative in the long and short runs. This may be due to import of better production technology and improved know-how.

4.1 Sensitivity Analysis and Stability Test

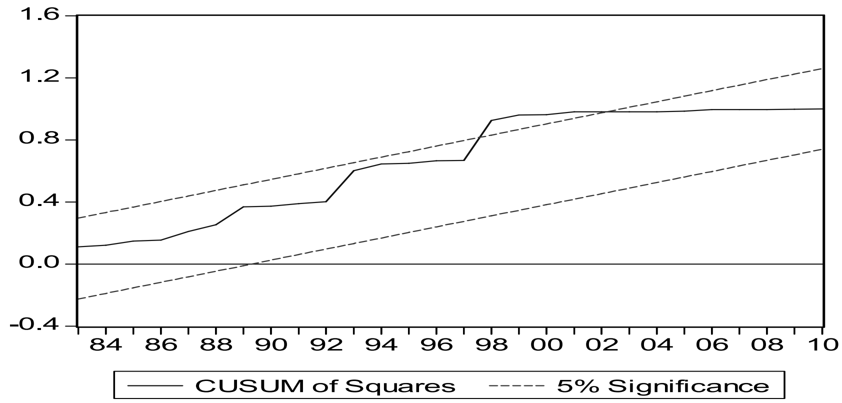
The short run model passes clearly diagnostics based on the LM test for serial correlation, normality of residual term and White heteroscedisticity (Table VI).

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



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

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



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

We employ cumulative sum (CUSUM) and cumulative sum of squares (CUSUMsq) tests to check for parameter stability. The straight lines in Figures 1 and 2 represent the 5% critical bounds. The parameters are considered stable if the graph lies within the bounds (Pesaran, Shin and Smith 2000, 2001). This is not the case here. The CUSUMsq graph indicates two structural break points one each in 1989 and 1999, which may be a reason for instability. The results for Chow forecast test over the period 1998-2010, reported in Table VII, suggests no such break in data. The formal Chow test is more reliable as graphs can be misleading (Leow 2004).

TABLE VI
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. We apply the Granger causality test within the VECM to check for this. Test results are reported in Table VII. The joint significance of LR test on the lagged explanatory variables shows short-run causality. A significant t-test on a negative ECM_{t-1} implies long run causality. We find long run causality from economic growth to CO_2 emissions only. This result also supports the existence of an EKC relation in Bangladesh (see, for example, Coondoo and Dinda 2008, Dinda and Coondoo 2006, Akbostanci, Türüt-Asik and Ipek 2009 and Lee and Lee 2009). The findings are consistent with Maddison and Rehdanz (2008) for North American countries; Zhang and Cheng (2009) and Jalil and Mahmud (2009) for China; Ghosh (2010) for India; Nasir *et al.* (2011) and Shahbaz, Lean and Shabbir (2012) for Pakistan; and Alam *et al.* (2011) for Bangladesh. As noted, Alam did not offer any formal procedure to check for EKC in Bangladesh.

TABLE VII
VECM 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: Figures in parenthesis are t-statistics. *, ** and *** refer to significance at the 1, 5 and 10% levels.

The long run unidirectional causality from trade openness to CO_2 emissions supports Grossman and Krueger (1991, 1993) and Halicioglu (2009). They argue that lower pollution is the result of adherence to and enforcement of law. The finding that urbanisation causes environmental degradation is in line with Martínez-Zarzoso (2008). Energy consumption is Granger-caused by income, trade openness and urbanisation. This relation validates (a) growth-led-energy consumption, (b) trade-led-energy consumption, and (c) urbanisation-led-energy consumption in Bangladesh. Finally, we find feedback relation between energy consumption and CO_2 emissions. The causality from CO_2 emissions to energy consumption might be due to the lack of coordinated strategy of economic growth in Bangladesh.

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

A coefficient of ECM_{t-1} for CO_2 emissions and energy consumption in the VECM equations shows speed of adjustment towards the long-run equilibrium. These are (-0.789) and (-0.119) respectively, both significant at the 1% level. The coefficients of ECM_{t-1} for income, trade openness and urbanisation are negative, but not statistically significant.

V. CONCLUSION AND POLICY IMPLICATIONS

The paper implements the ARDL bounds testing approach to cointegration to examine a long run relationship among energy consumption; trade, urbanisation, economic growth and CO_2 emission; and the VECM for the direction of causality. The aim is to explore the EKC relation in Bangladesh using data from 1971 to 2010. The results confirm a long run relation among the series and also provide evidence in support of EKC.

The causality test shows that economic growth Granger causes CO_2 emissions. We find unidirectional causality from trade openness and urbanisation to CO_2 emissions. Income, urban population and trade openness Granger cause energy consumption and thus support growth-led-energy consumption, urbanisation-led-energy consumption and trade-led-energy consumption. Energy consumption and CO_2 emissions Granger cause each other. In the short run, bidirectional causality is found between trade openness and energy consumption, economic growth and trade openness, and urbanisation and economic growth. We also find unidirectional causality from economic growth to urbanisation.

The results on the directions of causality can shed additional light on the need for crafting appropriate energy policies and help to meet rising energy demand caused by rapid economic and demographic changes, as well as support sustainable economic growth. The finding that causality runs from energy consumption to CO_2 emissions is expected, but the reverse causation implies absence of appropriate policy parameters. For Bangladesh rapid economic growth is an absolute necessity to feed its people most of whom are poor. The factor alone has dictated the tenet of high priority on economic growth at the expense of the environment. The nation in the face of severe shortage of foreign exchange cannot afford to import energy efficient capital and technology. Priorities belong elsewhere! However, in recent times environmental aspects of development are being carefully considered. In particular, legal framework is being developed and enforced, although more needs to be done. 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 of environmental rises, such causality should disappear, although much will depend on how the laws are enforced.

In the short run, we find bidirectional causality between trade openness and energy consumption and economic growth and trade openness. Trade openness and urbanisation Granger cause CO_2 emissions. It is likely that trade openness did not help environment much. Perhaps, imported technology meant to save energy and reduce CO_2 emissions did not materialise for a lack of interest and understanding on the part of public officials. It is also plausible that the foreign investors did not import the energy efficient machinery and technology. They might have taken the advantage of the inadequate legal system. The unidirectional causality from economic growth to urbanisation and urbanisation to trade openness appear intuitively appealing.

The immediate future does not look bright because urbanisation 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, inter alia. To address a potential disaster, government must provide capital to support the development of small-scale entrepreneurial skill in the short and medium terms in an effort to create more jobs in the rural areas. In longer 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 more desirable outcome for sustainable economic development.

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