Impact of Urbanization and Energy Consumption on CO2 Emissions in Bangladesh: An ARDL Bounds Test Approach

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Abstract— the aim of this study is to investigate the impact of urbanization and energy consumption on CO2 emissions under the theoretical framework of Environmental Kuznets Curve (EKC) hypothesis. The EKC hypothesis for CO_2 emissions reveal that at the initial path of economic development CO_2 emissions increase with the level of development but start to decline after reaching a maximum point with higher level of economic development. Augmented Dickey-Fuller unit root tests are performed to check the order of intrigation of the variables. ARDL bounds test approach has been employed for empirical works. Empirical results confirm that our variables are cointegrated, and the short-run deviations from the long-run equilibrium are corrected by 77.19% towards long-run equilibrium path each year. Empirical results confirm that EKC hypothesis is valid for both short-run and long-run in Bangladesh. Moreover urbanization and energy consumption have statistical significant positive impact on CO_2 emissions, while impact of Economic openness and FDI is found statistically insignificant. To conclude, we can say that economic growth need not to be controlled to reduce CO2 emissions, instead, we can think about controlling urbanization and energy use to reduce CO2 emissions.

Index Terms— ARDL Bounds test, Bangladesh, Carbon dioxide emissions, Cointegration, Energy consumption, Environmental Kuznets Curve (EKC), Urbanization.

1 Introduction

The story of development over the last hundred years can be categorized into two broader divisions. At the one hand we get the story of extraordinary progress in technology and remarkable achievements of the standard of livings in many countries around the world. On the other hand another story has been written which makes our world anxious about its existence. The later one is nothing but the story of environmental degradation. Some sort of human and economic activity gradually cause to degrade our environment. For example, use of land for industries and housing, construction of road and making brick are greatly responsible for the loss of agricultural land, soil erosion, change in soil structure and destruction of hills. Solid waste disposal by households and industries causes land pollution. Water is continuously polluted by effluents which are discharged by industries. Sewage disposal also causes water pollution. Therefore safe drinking water from natural sources becomes very scarce. The scenario of air pollution makes us more anxious, as air is polluted greatly by the smoke from transportation and industries and also emissions from toxic gas which are the byproduct of our urbanization and economic growth. Some of the most significant negative externality of urbanization and urban expansion are degradation of forest, destruction of wetlands, deforestation and loss in biodiversity.

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Moreover urbanization, economic growth and energy consumption are very much responsible for Greenhouse gas-induced warming, which is the single most important issue in the recent years around the world and Bangladesh is in risky position. Carbon dioxide (CO2) is considered to be the major contributor to global warming. Most of the empirical works like Soytas and Sari, 2003 [40], Ang, 2007 [6], Soytas et al., 2007 [42], Apergis and Payne, 2009 [7], Halicioglu, 2009 [14], Soytas and Sari, 2009 [41], Acaravi and Ozturk, 2010 [1], Apergis and Payne, 2010 [8], He and Richard, 2010 [15], Lean and Smyth, 2010 [20], Pao and Tsai, 2010 [25], Narayan and Narayan, 2010 [22], Sharma, 2011 [39], Pao et al., 2011 [27], Pao and Tsai, 2011 [26], Wang et al., 2011 [44], Al-mulali, 2012 [2], Al-mulali and Sheau-Ting, 2014 [5], Jafari et al., 2012 [17], Shahbaz et al., 2012 [37], Ozcan, 2013 [23], Saboori and Sulaiman, 2013 [32, 33], Saboori et al., 2013 [31], Kohler, 2013 [19], Chandran and Tang, 2013 [9], Shahbaz et al., 2013 [36] and Farhani et al., 2014 [12] use CO2 emissions per capita as an indicator of environmental degradation. Although per capita CO2 emissions in Bangladesh is no high enough but it is increasing rapidly. Per capita CO2 emission in Bangladesh was only 0.0519149 metric ton at 1972. But it is increased to 0.4375835 metric ton per capita at 2013. Over the last 50 years CO2 emissions have grown dramatically. Basically the use of fossil fuels consumption like coal, oil and gas are greatly responsible for that. But that fossil fuels are the main power of source of electricity generation, manufacturing activities, transport and consumption of goods and services that are directly related to economic growth. As the process of urbanization increases the

demand for energy consumption increases greatly to satisfy and maintain the higher needs of urban life, which in turn increases environmental degradation by increasing per capita CO2 emissions. Although urbanization causes to increase CO2 emissions by deforestation too, because of deforestation the absorption power of nature to absorb CO2 decrease gradually, but the urbanization induced energy demand is more responsible for air pollution. Therefore besides economic growth, urbanization and energy consumption are the main determinants of CO2 emissions.

2 Theoretical Framework

The theoretical framework of this study is the Environmental Kuznets Curve (EKC) hypothesis for CO2 emissions. EKC for CO2 emissions suggest that initially CO2 emissions will increase as per capita real income goes up but after reaching a maximum point it will start to decline with higher level of real per capita income. Grossman and Kruger (1995) first test this inverted U-shaped relationship between economic growth and CO2 emissions.

Initially only the non-linear relationship between economic growth and CO2 emissions were tested to check the validity of EKC, but later revised EKC hypothesis has been used widely to check the inverted U-shaped relationship between economic growth and CO2 emissions per capita including some other variables in the model like economic openness, energy consumption, foreign direct investment etc.

3 Literature Review

Most of the empirical works examined the impact of economic growth and energy consumption on CO2 emissions to identify the determinants of CO2 emissions. Ang, 2007 [6] studied France over the period of 1960-2000, Apergis and Payne, 2009 [7] studied the region of Central America over the period of 1971-2004, Acaravi and Ozturk, 2010 [1] examined the Europe countries over the period of 1965-2005, Apergis and Payne, 2010 [8] tested the data of Common wealth independent states over the period of 1992-2004, Lean and Smyth, 2010 [20] studied ASEAN countries over the period of 1980-2006, Pao and Tsai, 2010 [25] tested the data of BRIC countries over the period of 1971-2005, Pao and Tsai, 2011 [26] tested the data of Brazil over the period of 1980-2007, Pao et al., 2011 [27] studied Russia over the period of 1990-2007, Wang et al., 2011 [44] examined the data of China over the period of 1995-2007, Arouri et al., 2012 studied MENA countries over the period of 1981-2005, Ozcan, 2013 [23] examined the data of Middle East countries over the period of 1990-2008, Saboori and Sulaiman, 2013 [32] studied the ASEAN countries over the period of 1971-2009 and Shahbaz et al., 2013 [38] studied Romania over the period of 1980-2010. Almost all of these studies find statistical significant positive impact of energy consumption on CO2 emissions and most of the studies find economic growth positively affect CO2 emissions.

Some other empirical studies like Halicioglu, 2009 [14], Jalil and Mahmud, 2009 [17], Jayanthakumaran et al., 2012 [18], Shahbaz et al., 2012 [37], Kohler, 2013 [19] and Farhani et al., 2014 [12] include economic openness, that means trade percentage of GDP, besides economic growth and energy consumption as a determinant of CO2 emissions. Mainly they tried to test the EKC hypothesis for an open economy.

To identify the impact of urbanization on CO2 emissions many empirical works have been conducted. Parikh and Shukla, 1995 [28], Cole and Neumayer, 2004 [10], Liddle and Lung, 2010 [21], Sharma, 2011 [39], Al-mulali and Foon Tang, 2013 [4], Shahbaz et al., 2013 [36] and Sardorsky, 2014 [34] tried to investigate the impact of urbanization on CO2 emissions. Most of the works find statistical significant of urbanization on CO2 emissions, but the study of Sharma, 2011 [39] found statistical significant negative impact of urbanization on CO2 emissions. Al-mulali and Foon Tang (2013) found that there exist positive correlation urbanization and CO2 emissions among 86 percent of the countries.

Moreover foreign direct investment (FDI) had been used as a determinant of CO2 emissions and expected that FDI has negative impact on CO2 emissions. Some empirical works like Pao and Tsai, 2011 [26], Al-mulali, 2012 [2], He et al., 2012 [15], Chandran and Tang, 2013 [9] and Shahbaz et al., 2013 [38] include FDI and tried to investigate its impact on CO2 emissions.

There are also few studies related to Bangladesh. Among them the most significant study is conducted by Islam et al., 2013 [16] where he tested the EKC for Bangladesh including trade, energy use and urbanization over the period of 1971-2010.

4 Research Gap and Objective of this Study

The studies of Pao and Tsai, 2011 [26], Al-mulali, 2012 [2], He et al., 2012 [15], Chandran and Tang, 2013 [9] and Shahbaz et al., 2013 [36] suggest that FDI is also an important determinant of CO2 emissions. This study can be considered as an extension of the work of Islam et al., 2013 [16] by including FDI. In this study we attempt to investigate the impact of urbanization and energy consumption within the theoretical framework of EKC where besides real per capita GDP, urbanization and energy consumption, we also include economic openness and FDI into the model to test the revised EKC hypothesis for Bangladesh.

5 Methods of the Study

In order to investigate the impact of economic growth, economic openness, energy consumption, urbanization and FDI in Bangladesh time series data of World Development Indicators 2017 [45] over the period of 1973-2013 have been employed. Real GDP per capita is used as economic growth, economic openness is captured by trade percentage of GDP, energy use is captured by energy use (kg of oil equivalent per capita), urbanization is captured by percentage of population living in urban areas to the total population, FDI is captured by net inflow of FDI at current US dollar and carbon dioxide emissions (metric ton per capita) has been used to capture environmental degradation. For statistical simplicity and

obtaining some desirable statistical properties logarithmic transformation of the variables have been performed. Autoregressive Distributed Lag (ARDL) bounds testing approach to cointegration is developed by Pesaran et al., 2001 [30] for empirical works. It has some econometric advantages in comparison to other traditional cointegration techniques. It can be applied if both series are I(0) or I(1) or admixture of both I(0) and I(1) and for small sample size it is superior to that of multivariate cointegration. The series which is stationary at level form is called I(0) and which becomes stationary after first difference is called I(1). There exists several test to check for unit root but among them Augmented Dickey Fuller (ADF) test, which is developed by Dickey and Fuller, 1979 [11], has been employed to test each series in this study.

6 Results and Discussion

6.1 Results of Unit root test

Find out the order of integration is important for ARDL bounds test approach because for bounds test neither of the variables would be I (2). Table-2 reports the results of ADF test. From Table-1 we observe that the series LNC and LNUR are stationary at their level form that means they are I(0) in nature, and the series LNPRGDP, LNPRGDP^2, LNEO, LNEC and LNFDI are nonstationary at their level form, that means they contain unit root, but become stationary at their first difference form, so they are I (1) in nature. Therefore in this study we have admixture of I (0) and I (1) variables.

TABLE 1: Results of Unit Root Test

variables	H_0 = Time series is non-stationary Exogenous: Constant and Linear trend			
	level form		first difference form	
	Test statistic	Prob	Test Statistic	Prob
LNCO2	-4.044587	0.0149	No need	No need
LNPRGDP	0.495027	0.9989	-13.31354	0.0000
LNPRGDP^2	2.078338	1.000	-12.47613	0.0000
LNEO	-0.988478	0.7483	-8.460242	0.0000
LNEC	-0.424319	0.9831	-8.875779	0.0000
LNUR	-8.008233	0.0000	No need	No need
LNFDI	-2.491391	0.3305	-7.138870	0.000

6.2 Results of Bounds Tests for Cointegration

There are two steps in ARDL bounds test. In the first step we run unrestricted VAR model and get the maximum lag length which is selected by Schwarz Criterion (SC) in this study. From VAR lag order selection criteria we get the maximum lag which is 1. Then using Schwarz Bayesian Criterion (SBC) we get our desired ARDL model which we found ARDL (1, 0, 0, 0, 0, 0, 1). Then we go for check the long-run association among the variables by bounds test. The results of bounds test are represented by Table-2. Here the calculated F-statistic is 14.79433 which is greater than the upper bound 3.99 of 1% level of significance. Therefore the null hypothesis of no cointegration is rejected at 1% level and alternative hypothesis of cointegration is accepted, that means our variables under consideration are cointegrated.

TABLE 2: Results of Bounds Test

Critical Value	F-Statistic 14.79433	
	Lower Bound	Upper Bound
90%	1.99	2.94
95%	2.27	3.28
99%	2.88	3.99

6.3 Long-run and Short-run Results

As economic growth, economic openness, energy consumption, urbanization, FDI and CO2 emissions are cointegrated, now the long-run relationship among them can be estimated. Here LNCO2 is the dependent variable and others are the explanatory variables. The long-run results of the model is presented in Table-3.

TABLE 3: Long-run Results

ARDL(1, 0, 0, 0, 0, 0,1) based on Schwarz Bayesian Criterion Dependent Variable LNCO2 40 observations used for estimation from 1974 to 2013			
Regressor	Coefficient	Standard Error	T-Ratio (prob)
LNPRGDP	8.9720	2.3660	3.7920 (0.001)
LNPRGDP^2	-0.72506	0.17584	-4.1234 (0.000)
LNEO	-0.023522	0.066892	-0.3516 (0.727)
LNEC	2.1035	0.33579	6.2642 (0.000)
LNUR	0.29641	0.093364	3.1748 (0.003)
LNFDI	-0.010884	-0.010034	-1.0847 (0.286)
CONSTANT	-40.3537	7.2417	-5.5728 (0.000)

The estimated long-run results reveal that the EKC hypothesis is valid in the long-run in Bangladesh, as we see the sign of real per capita GDP is positive and the sign of real per capita GDP is negative. In the long-run one percent increase in real per capita GDP, on average, will cause to increase CO2 emissions by 8.972 percent. But if the square of GDP increases by one percent then, on average, CO2 emissions will reduce by 0.72 percent. Energy consumption and urbanization have

statistical significant positive impact on CO2 emissions in the long-run. One percent increase in urbanization will cause to increase emissions by 0.2941 percent on average, while one percent increase in energy consumption will cause to increase 2.1064 percent in the long-run. The long-run growth-emissions and energy-emissions elasticity are very high, which indicates that in the long-run economic growth and use of energy will cause to degrade our environment more. Moreover, the impact of economic openness and FDI on CO2 emissions are negative, which is relevant to most of the empirical works, but are found statistically insignificant in Bangladesh.

Now the results of short-run dynamics are reported in Table-4. Here we see EKC hypothesis is also valid in the short-run in Bangladesh. The estimated results for the short-run reveal that one percent increase in real per capita GDP, on average will cause to increase CO2 emissions by 6.9266 percent, but if square of real per capita GDP is increase by one percent then CO2 emissions will reduce by 0.5597 percent. The impact of energy consumption and urbanization are also found statistically significant and positive in the short-run. In the short-run one percent increase in urbanization will increase CO2 emissions by 0.22 percent and one percent increase in energy consumption will increase CO2 emissions by 1.6237 percent. Economic openness and FDI are found statistically insignificant in the short-run too.

TABLE 4: Short-run Results

ARDL(1, 0, 0, 0, 0, 0, 1) based on Schwarz Bayesian Criterion Dependent Variable dLNCO2 40 observations used for estimation from 1974 to 2013			
Regressor	Coefficient	Standard Error	T-Ratio (prob)
dLNPRGDP	6.9266	2.0810	3.3279 (0.002)
$dLNPRGDP^2$	-.55967	0.1660	-3.5856 (0.001)
dLNEO	-0.018167	0.5250	-0.3458 (0.732)
dLNEC	1.6237	0.3105	5.2281 (0.000)
dUR	0.22880	0.0860	2.6585 (0.012)
dLNFDI	0.0062263	0.0067	0.9279 (0.360)
dCONS	-31.1492	7.1163	-4.3279 (0.000)
ECM(-1)	-0.77190	0.1179	-6.5428 (0.000)
R-Squared 0.637 R-Bar-Squared 0.54396 S.E. of Regression 0.035417 F-stat. F(7, 32) 7.7882 (0.000) Mean of Dependent Variable 0.047176 S.D. of Dependent Variable 0.052445 Residual Sum of Square 0.038884 Equation Log-likelihood 81.9634 Akaika Info. Criterion 72.9634 Schwarz Bayesian Criterion 65.3634 DW-statistic 1.8553			

The negative and statistically significant value of ECM_{t-1}, -0.7719, leads to support a long-run relationship among the series in case of Bangladesh. The coefficient is statistically significant at 1% level and the significant value of ECM shows the speed of adjustment from short-run to long-run equlibrium. In this model the short-run deviations from the long-run equilibrium are corrected by 77.19% toward long-run equilibrium path each year.

6.4 Results of Diagnostic Tests

The diagnostic test are performed to check the serial correlation, functional form, normality and Heteroscedasticity among the variables in the model. The results of diagnostic tests are summarized in Table-5. Lagrange multiplier test of residual is performed to test the serial correlation. The null hypothesis for serial correlation test is that there is no serial correlation and the alternative hypothesis is there is serial correlation. As shown in Table-5, the null hypothesis cannot be rejected at 5% level of significance because the probability value is so high, that means there is no serial correlation in this model.

Test Statistic	LM-Version	F-Version
A. Serial Correlation CHSQ(1)	0.2889 [0.591]	F(1, 30)= 0.21822 [0.644]
B. Functional Form CHSQ(1)	1.0754 [0.300]	F(1, 30)= 0.82882 [0.370]
C. Normality CHSQ(1)	1.2162 [0.544]	Not applicable
D. Heteroscedasticity CHSQ(1)	0.0493 [0.824]	F(1, 35)= 0.04689 [0.948]
A: Lagrange multiplier test of residual serial correlation B: Ramsey's RESET test using the square of the fitted value C: Based on a test of Skewness and Kurtosis of residuals D: Based on the regression of squared residuals on squared fitted values		

Ramsey's RESET test are used to check the functional form where the null hypothesis is that the variables in the model have correct functional form and this null hypothesis cannot be rejected at 5% level of significance, which confirms that the variables in the model have correct functional form. The normality test is conducted based on a test of Skewness and Kurtosis of residuals where the null hypothesis is that the data is normally distributed. The null hypothesis of normality test cannot be rejected at 5% level that means the time series data is normally distributed. Finally we the null hypothesis of homoscedasticity cannot be rejected at 5% level, that means there is no heteroscedasticity problem in this model.

To test the stability of the short-run and long-run parameters

cumulative sum (CUSUM) of recursive residuals and cumulative sum of squares (CUSUMSQ) of the recursive residuals have been used. The cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) of the recursive residuals are presented in Figure-1 and Figure-2, respectively. The plot of CUSUM and CUSUMSQ are within the bounds and significant at 5% level. This ensures the stability of the long-run and short-run coefficients and there is no structural break.

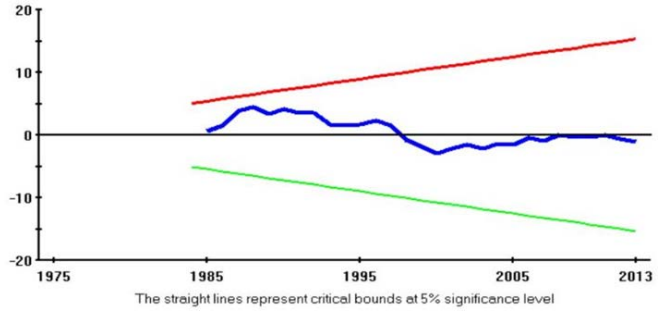

Fig. 1. Plot of CUSUM

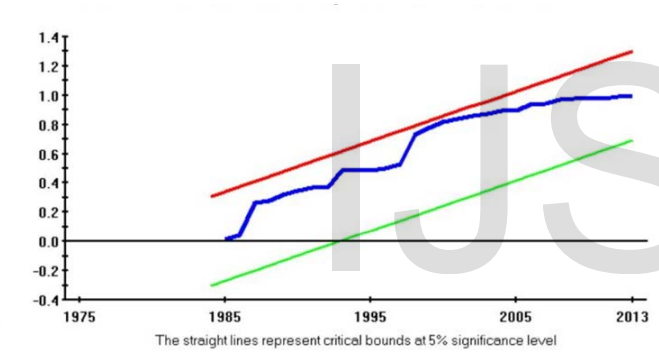

Fig. 2. Plot of CUSUM Square

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6.5 Results of Granger Causality Test

From pairwise Granger causality test results we find that real per capita GDP, economic openness and FDI does not Granger causes CO2 emissions, but there is a unidirectional causality running from urbanization and energy consumption to CO2 emissions. At the same time real per capita GDP and square of real per capita GDP Granger causes energy consumptions, which validate the nexus between economic growth and energy consumption in Bangladesh. Moreover energy consumption Granger causes FDI which is very much relevant in the context of Bangladesh, because in Bangladesh a large portion of FDI is coming in the energy sector. And urbanization also Granger causes FDI in Bangladesh.

7 Conclusion and Recommendations

The most significant findings of this study is that the long-run emissions elasticities are greater than the short-run elasticities. The short-run growth-emissions elasticity is 6.92, urbanization-emissions elasticity is 0.2288 and energy-emissions elasticity is 1.6237, where in the long-run they are 8.972, 0.2964 and 2.1035, respectively. This findings suggest that as economic growth, urbanization process and consumption of energy will increase, environmental damage will also increase in Bangladesh gradually. The rational of this findings are that Bangladesh is now experiencing rapid and unplanned urbanization process and although is growing at a good rate, but there is no monitoring of environmental damage.

At the same time the share of non-renewable energy to total energy use is showing an increasing trend over the last several years. That's why environmental damage will continue at a good rate. As higher per capita real GDP will cause to reduce CO2 emissions in the long-run, policy makers can take policy without controlling economic growth, but they have to consider seriously about urbanization process and energy use if they want to safe our environment from serious damage and they want to make development sustainable. Planned urbanization, increase monitoring of environmental damage, taking environmental friendly project and reducing the share of non-renewable energy to total energy use can play a good role to reduce environmental damage, without controlling economic growth in Bangladesh.

8 Conclusion

Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions. Authors are strongly encouraged not to call out multiple figures or tables in the conclusion—these should be referenced in the body of the paper.

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