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# The relationship between institutional quality, industry, energy sources and environmental quality in Bangladesh: Insights from ARDL analysis

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## ABSTRACT

This study examines how institutional quality, industrial activities, energy sources, and environmental quality are connected in Bangladesh, with a particular focus on $CO_2$ emissions from 1990 to 2015. The research aims to evaluate how these factors contribute to environmental sustainability. Using five autoregressive distributed lag (ARDL) models, the study investigates both short- and long-term connections between $CO_2$ emissions, gross domestic product (GDP), industrial growth, and electricity generation from different sources. It also employs the Toda-Yamamoto Granger causality test to uncover the causal links between the variables. The findings reveal that higher institutional quality helps reduce $CO_2$ emissions, while economic growth and a reliance on nonrenewable energy increase emissions. This study provides a fresh viewpoint, showing the key role of institutional quality in promoting environmental sustainability, which contrasts with some earlier research. For policymakers, the research highlights the importance of strengthening institutional frameworks, enforcing environmental regulations, and advancing the use of cleaner energy and sustainable industrial practices. These steps are essential for supporting sustainable development in Bangladesh.

**Contribution/Originality:** This paper contributes by providing fresh evidence of institutional quality's imact on environment using a new indicator for institutional quality. It is the first to explore both short- and long-term relationships between institutional quality, GDP, industry, and energy sources, providing new findings and uncovering causal links through five distinct models.

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## 1. INTRODUCTION

There have been concerns that to achieve growth Bangladesh has compromised with environmental quality (Tisdell, 2002). Islam and Shahbaz (2012) identified environmental degradation and natural resource depletion as the main obstacles for the country's sustainable development. Gunter and Rahman (2012) argue that the country's $CO_2$ emissions would be fifteen fold in 2050 compared to 2005 in the absence of improvements in energy efficiency and some increments in $CO_2$ emissions are unavoidable due to poverty reduction efforts. The findings of Ghosh, Alam, and Osmani (2014) suggest that economic growth is positively affected by energy and negatively and insignificantly affected by $CO_2$ emissions. They suggest that in Bangladesh, economic growth drives energy consumption rather than energy consumption driving growth. They also point out that much of the country's energy comes from natural gas, which has relatively low $CO_2$ emissions. Therefore, while environmental degradation is a concern for the long term, it is not an issue in the short run. Using Johansen cointegration test to Bangladeshi data during 1972 to 2006, Alam, Begum, Buysse, and Van Huylenbroeck (2012) identified one-way causality from energy consumption to economic growth and two-way causality between electricity consumption and economic growth. In the absence of appropriate policy measures, environmental quality might degrade further and mere economic growth and higher income level are not sufficient to warrant an environmental up gradation.

In Bangladesh, understanding the factors that influence $CO_2$ emissions is vital for addressing environmental challenges, particularly as the country experiences rapid economic growth and rising energy demands. The industrial sector in Bangladesh is a major contributor to $CO_2$ emissions. As industries grow, their demand for energy increases, often met by fossil fuels like coal, oil, and natural gas, which are significant sources of greenhouse gases (Halkos & Tzeremes, 2013; Rodrik, Subramanian, & Trebbi, 2004). While natural gas is cleaner than coal, it still contributes to $CO_2$ emissions (Cole, 2007). The reliance on nonrenewable energy sources exacerbates environmental challenges, making it essential to examine how these energy choices, in conjunction with industrial growth and institutional effectiveness, influence $CO_2$ emissions (Farzin & Bond, 2006). Strong institutions not only directly control pollution but also foster economic conditions that lead to better environmental practices, thereby balancing economic growth with environmental sustainability. As such, the nation's economic performance, influenced by its institutional framework, significantly affects its environmental trajectory (Acemoglu, Johnson, & Robinson, 2001; Fredriksson, Neumayer, Damania, & Gates, 2005; Kaufman, Kraay, & Mastruzzi, 2006; North, 1990).

Research on institutional quality and its impacts on environmental quality have not received much attention in Bangladesh until very recently. Some recent works attempted to identify the factors affecting institutional quality in Bangladesh while some tried to ascertain the impact of institutional quality on $CO_2$ emissions (Islam, Khan, Tareque, Jehan, & Dagar, 2021; Mehmood, Tariq, Ul-Haq, & Meo, 2021; Toufique, 2024a, 2024b). However, the sign of the impact is undesirably negative, and the roles of industry and electricity generation sources have not been examined. The current research contributes to the existing field in the following aspects:

a. It provides fresh evidence about the impact of institutional quality on environmental quality using a new indicator for institutional quality.
b. The study, for the first time, looks into the short and long run relationship between $CO_2$ emissions, institutional quality, GDP, industry and electricity generated from different sources.
c. Discovers the causalities between $CO_2$ emissions, GDP, industry and electricity generated from different sources.
d. We estimate five distinct models, which allow for a more comprehensive analysis of the issue.

Section 2 provides a review of the literature, followed by Section 3, which outlines the data and methodology. Section 4 presents the results, and Section 5 offers the conclusions.

## 2. LITERATURE REVIEW

Grossman and Krueger (1995) demonstrated the Environmental Kuznets Curve (EKC) hypothesis, where pollution initially rises with development and later declines. Most studies use $CO_2$ emissions as an indicator of environmental quality, while fewer focus on other pollutants like sulfur dioxide or nitrous oxide (Cole, 2007; Cole, Rayner, & Bates, 1997; Liao, Dogan, & Baek, 2017). The literature lacks consensus on the relationship between environmental quality and its determinants. A brief review of the literature presented below.

Ahmed, Rehman, and Ozturk (2017) found that trade, energy, and population increase $CO_2$ emissions, while income reduces them. Similarly, Nasreen, Anwar, and Ozturk (2017) showed that energy consumption and economic development worsen environmental degradation in South Asia. Munir and Riaz (2019) observed that increased energy consumption in South Asia leads to higher CO2 emissions and that the relationship between electricity, coal use, and $CO_2$ emissions is non-linear. Zakaria and Bibi (2019) confirmed the EKC hypothesis for South Asia, noting that energy use and financial development harm environmental quality, while institutions play a key role in reducing emissions. Hunjra, Tayachi, Chani, Verhoeven, and Mehmood (2020) reported that financial development increases emissions but can be mitigated by strong institutions. Ahmed, Kousar, Pervaiz, and Shabbir (2022) found that both institutional quality and financial development promote green growth. Azam, Uddin, Khan, and Tariq (2022) highlighted that urbanization, GDP per capita, and energy use raise emissions in SAARC countries, while innovation and arable land help lower them.

For China, Dong, Sun, and Dong (2018) confirmed the EKC hypothesis and found that natural gas and renewable energy reduce emissions. Makhdum et al. (2022) concluded that strong institutions and renewable energy improve environmental quality in China, while financial development and resource use have the opposite effect. Tiwari, Shahbaz, and Hye (2013) confirm the EKC for India from 1966 to 2011, identifying coal consumption and trade as key factors in $CO_2$ emissions. Sajeev and Kaur (2020) find an inverted U-shaped EKC in India for 1980-2012 in the short run but not in the long run. Karedla, Mishra, and Patel (2021) show that trade reduces emissions, while manufacturing and GDP increase them. Sreenu (2022) supports the EKC using both linear and non linear autoregressive distributed lag (NARDL) models for India from 1990 to 2020. For Pakistan, Zhang, Wang, and Wang (2017) find that nonrenewable energy raises emissions, while renewable energy lowers them. Khan, Teng, Khan, and Khan (2019) observe that energy use, trade, financial development, and globalization increase emissions, while innovation and urbanization reduce them. Hassan, Khan, Xia, and Fatima (2020) show that institutions and higher incomes help lower emissions. Ahmed, Kousar, Pervaiz, and Ramos-Requena (2020) conclude that financial development and institutional quality significantly impact environmental sustainability, though institutional quality plays a smaller role.

In Turkey, Yurttagüler and Kutlu (2017) found an N-shaped relationship between income and $CO_2$. Kılavuz and Doğan (2021) reveal that industry drives emissions, with trade having a minimal effect. For Qatar, Abulibdeh (2022) links electricity, energy use, and crop production to increased greenhouse gases, while economic growth lowers emissions. Salahuddin, Alam, Ozturk, and Sohag (2018) find that foreign direct investment (FDI) and economic growth increase emissions in Kuwait, while Shahbaz, Sbia, Hamdi, and Ozturk (2014) confirm the EKC for the UAE, noting that urbanization raises emissions. Finally, Abdel-Gadir (2020) finds that economic growth and energy consumption increase emissions in Oman.

Shahbaz, Solarin, Mahmood, and Arouri (2013) found that energy consumption and economic growth drive $CO_2$ emissions in Malaysia. Lau, Choong, and Eng (2014) identified a long-run link between emissions, institutional quality, exports, and growth. Saudi, Sinaga, and Jabarullah (2019) showed that renewable energy lowers emissions, while nonrenewable energy and growth increase them. Aslam, Hu, Ali, AlGarni, and Abdullah (2022) found significant impacts of fuel consumption, trade, and GDP on emissions. In South Korea, Baek and Kim (2013) observed that nuclear energy improves environmental quality, while fossil fuel consumption worsens it. Adebayo, Awosusi, Kirikkaleli, Akinsola, and Mwamba (2021) argued South Korea's growth is energy-driven, calling for increased renewable energy use.

Ketenci (2018) supported the EKC for Russia, identifying energy consumption and urbanization as key factors in emissions. Agboola, Bekun, Agozie, and Gyamfi (2022) found that fossil fuels harm sustainability, but strong institutions improve it.

In South Africa, Udeagha and Ngepah (2022) confirmed institutions, green technology, and fiscal decentralization positively impact environmental quality, supporting the EKC. Sarkodie and Adams (2018) emphasized the role of political institutions in addressing climate change. Cherni and Jouini (2017) found bidirectional causality between GDP and $CO_2$ emissions in Tunisia. Negatively (Ayobamiji & Kalmaz, 2020) showed that energy consumption raises emissions in Nigeria, while FDI reduces them. In Kenya, Al-Mulali, Solarin, and Ozturk (2016) linked fossil fuel consumption, GDP, and urbanization to pollution, while renewable energy and financial development reduced it.

Banerjee and Rahman (2012) found population and industry increased emissions in Bangladesh, while FDI reduced them. Zaman (2012) and Alam (2014) found no link between trade openness and emissions in Bangladesh. Rahman and Kashem (2017) confirmed that energy use and industry increase $CO_2$. Islam et al. (2021) linked globalization and innovation to lower emissions, but institutional quality, energy consumption, and urbanization increased them. Mehmood et al. (2021) found institutional quality raises emissions but reduces them when interacting with GDP. However, renewable energy and financial development significantly lower emissions.

The literature review reveals that most research on Bangladesh has primarily addressed factors influencing environmental quality, particularly $CO_2$ emissions. Notably, Islam et al. (2021) and Mehmood et al. (2021) have examined the role of institutional quality in shaping environmental outcomes. Their findings indicate that institutional quality has a negative effect on the environment in Bangladesh, leading to unfavorable policy implications.

This highlights the need for further investigation to better understand the relationship between institutions and environmental quality in Bangladesh.

## 3. DATA AND METHODOLOGY

To measure institutional quality we use the Quality of Government Index (QoG) from the International Country Risk Guide (ICRG), which has been available since 1984. However, for Bangladesh, the World Development Indicators (WDI) has information on $CO_2$ emissions for the 1990-2015 periods. Thus, we have a time span of 26 years, from 1990 to 2015. QoG integrates assessments of corruption, law and order, and bureaucratic quality into a single metric ranging from 0 to 1, with higher scores representing better governance. Corruption assessments cover financial misconduct and favoritism, which can affect investment and political stability. Law and order evaluations measure the effectiveness of legal systems and societal adherence, while bureaucratic quality reflects institutional strength and competence.

To address the research gap we estimate a couple of models. In the first model, the impact of institutional quality on environmental quality is analyzed while controlling for per capita GDP and the percentage of electricity produced from oil, gas, and coal sources. For the time period considered, per capita GDP and industry's GDP share are highly correlated in Bangladesh.

Thus, we estimate model 2, which is identical to model 1, except that industry replaces GDP. In model 3, we retain all the variables from model 2 but replace the percentage of electricity produced from oil, gas, and coal sources with the percentage of electricity produced from natural gas only. Model 4 builds on model 3 by including the percentage of electricity produced from oil.

Model 5 also extends model 3 by incorporating the percentage of electricity produced from renewable sources. Because of the shorter time span, it is not possible to incorporate all the variables in a single model. Table 1 gives a description of the variables considered.

**Table 1.** Variable descriptions.

| **Variable** | **Proxy/Indicator** | **Representation (In natural log)** | **Description** |
|---|---|---|---|
| Environmental quality | Carbon di oxide emissions | lnCO2PC | CO2 emissions (metric tons per capita) |
| Institutional quality | Quality of Government | lnQoG | ICRG Indicator of Quality of Government for Bangladesh |
| Level of development | Per capita GDP | lnGDP | GDP per capita (Constant 2015 US$) |
| Industrialization | Industry's GDP share | lnIND | Industry (Including construction), value added (% of GDP) |
| Electricity from nonrenewable source | | lnET | Electricity production from oil, gas and coal sources (% of total) |
| Electricity from natural gas | | lnENG | Electricity production from natural gas sources (% of total) |
| Electricity from oil | | lnEO | Electricity production from oil sources (% of total) |
| Electricity from renewable sources | | lnERenh | Electricity production from renewable sources, excluding hydroelectric (% of total) |

To determine the stationarity of the variables three distinct unit root testing procedures are used. They are: the Augmented Dickey-Fuller (ADF) test, the Phillips-Perron (P-P) test, and the modified Dickey-Fuller (DF-GLS) test. We use the ARDL approach to estimate the model. The following outlines the ARDL equations with p lags for the dependent variable and k lags for the independent variables.

Model 1:

$$lnCO2PC_t = \beta_0 + \sum_{i=1}^{p} \beta_i \, lnCO2PC_{t-i} + \sum_{i=0}^{k} \gamma_i \, lnQoG_{t-i} + \sum_{i=0}^{k} \delta_i \, lnGDP_{t-i} + \sum_{i=0}^{k} \rho_i \, lnET_{t-i} + \varepsilon_t \tag{1}$$

Model 2:

$$lnCO2PC_t = \beta_0 + \sum_{i=1}^{p} \beta_i \, lnCO2PC_{t-i} + \sum_{i=0}^{k} \gamma_i \, lnQoG_{t-i} + \sum_{i=0}^{k} \delta_i \, lnIND_{t-i} + \sum_{i=0}^{k} \rho_i \, lnET_{t-i} + \varepsilon_t \tag{2}$$

Model 3:

$$lnCO2PC_t = \beta_0 + \sum_{i=1}^{p} \beta_i \, lnCO2PC_{t-i} + \sum_{i=0}^{k} \gamma_i \, lnQoG_{t-i} + \sum_{i=0}^{k} \delta_i \, lnIND_{t-i} + \sum_{i=0}^{k} \rho_i \, lnENG_{t-i} + \varepsilon_t \tag{3}$$

Model 4:

$$lnCO2PC_t = \beta_0 + \sum_{i=1}^{p} \beta_i \, lnCO2PC_{t-i} + \sum_{i=0}^{k} \gamma_i \, lnQoG_{t-i} + \sum_{i=0}^{k} \delta_i \, lnIND_{t-i} + \sum_{i=0}^{k} \rho_i \, lnENG_{t-i} + \sum_{i=0}^{k} \rho_i \, lnEO_{t-i} + \varepsilon_t \tag{4}$$

Model 5:

$$lnCO2PC_t = \beta_0 + \sum_{i=1}^{p} \beta_i \, lnCO2PC_{t-i} + \sum_{i=0}^{k} \gamma_i \, lnQoG_{t-i} + \sum_{i=0}^{k} \delta_i \, lnIND_{t-i} + \sum_{i=0}^{k} \rho_i \, lnENG_{t-i} + \sum_{i=0}^{k} \rho_i \, lnERenh_{t-i} + \varepsilon_t \tag{5}$$

The ARDL bounds tests are formulated as follows:

Model 1:

$$\Delta lnCO2PC_t = \beta_0 + \sum_{i=1}^{p} \beta_i \, \Delta lnCO2PC_{t-i} + \sum_{i=0}^{k} \gamma_i \, \Delta lnQoG_{t-i} + \sum_{i=0}^{k} \delta_i \, \Delta lnGDP_{t-i} + \sum_{i=0}^{k} \rho_i \, \Delta lnET_{t-i} + \lambda_1 lnCO2PC_{t-1} + \lambda_2 lnQoG_{t-1} + \lambda_3 lnGDP_{t-1} + \lambda_4 lnET_{t-1} + \varepsilon_t \tag{6}$$

Model 2:

$$\Delta lnCO2PC_t = \beta_0 + \sum_{i=1}^{p} \beta_i \, \Delta lnCO2PC_{t-i} + \sum_{i=0}^{k} \gamma_i \, \Delta lnQoG_{t-i} + \sum_{i=0}^{k} \delta_i \, \Delta lnIND_{t-i} + \sum_{i=0}^{k} \rho_i \, \Delta lnET_{t-i} + \lambda_1 lnCO2PC_{t-1} + \lambda_2 lnQoG_{t-1} + \lambda_3 lnIND_{t-1} + \lambda_4 lnET_{t-1} + \varepsilon_t \tag{7}$$

Model 3:

$$\Delta lnCO2PC_t = \beta_0 + \sum_{i=1}^{p} \beta_i \, \Delta lnCO2PC_{t-i} + \sum_{i=0}^{k} \gamma_i \, \Delta lnQoG_{t-i} + \sum_{i=0}^{k} \delta_i \, \Delta lnIND_{t-i} + \sum_{i=0}^{k} \rho_i \, \Delta lnENG_{t-i} + \lambda_1 lnCO2PC_{t-1} + \lambda_2 lnQoG_{t-1} + \lambda_3 lnIND_{t-1} + \lambda_4 lnENG_{t-1} + \varepsilon_t \tag{8}$$

Model 4:

$$\Delta lnCO2PC_t = \beta_0 + \sum_{i=1}^{p} \beta_i \, \Delta lnCO2PC_{t-i} + \sum_{i=0}^{k} \gamma_i \, \Delta lnQoG_{t-i} + \sum_{i=0}^{k} \delta_i \, \Delta lnIND_{t-i} + \sum_{i=0}^{k} \rho_i \, \Delta lnENG_{t-i} + \sum_{i=0}^{k} \theta_i \, \Delta lnEO_{t-i} + \lambda_1 lnCO2PC_{t-1} + \lambda_2 lnQoG_{t-1} + \lambda_3 lnIND_{t-1} + \lambda_4 lnENG_{t-1} + \lambda_5 lnEO_{t-1} + \varepsilon_t \tag{9}$$

Model 5:

$$\Delta lnCO2PC_t = \beta_0 + \sum_{i=1}^{p} \beta_i \, \Delta lnCO2PC_{t-i} + \sum_{i=0}^{k} \gamma_i \, \Delta lnQoG_{t-i} + \sum_{i=0}^{k} \delta_i \, \Delta lnIND_{t-i} + \sum_{i=0}^{k} \rho_i \, \Delta lnENG_{t-i} + \sum_{i=0}^{k} \theta_i \, \Delta lnERenh_{t-i} + \lambda_1 lnCO2PC_{t-1} + \lambda_2 lnQoG_{t-1} + \lambda_3 lnIND_{t-1} + \lambda_4 lnENG_{t-1} + \lambda_5 lnERenh_{t-1} + \varepsilon_t \tag{10}$$

$\Delta$ is the first difference operator, t indicates the time index, i represent the lag, and $\varepsilon$ is the i.i.d. error term. The null hypothesis assumes that there is no co-integration, while the alternative hypothesis indicates that co-integration is present.

$$H_0: \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = 0 \tag{11}$$

$$H_1: \lambda_1 \neq 0, \lambda_2 \neq 0, \lambda_3 \neq 0, \lambda_4 \neq 0, \lambda_5 \neq 0 \quad (12)$$

Endogeneity is less of a concern in ARDL and consistent results are generated (Rahman & Islam, 2020; Uzar, 2020). Moreover, the ARDL approach provides unbiased estimates for the long-term model (Harris & Sollis, 2003). The model performs well in small sample (Meo, Chowdhury, Shaikh, Ali, & Masood Sheikh, 2018).

For two variable $X_t$ and $Y_t$, to test if $X_t$ Granger causes $Y_t$, we write the augmented VAR model as:

$$Y_t = \alpha_0 + \sum_{i=1}^{k+d_{max}} \alpha_i Y_{t-i} + \sum_{i=1}^{k+d_{max}} \beta_i X_{t-i} + \epsilon_{Y,t} \quad (13)$$

$$X_t = \gamma_0 + \sum_{i=1}^{k+d_{max}} \gamma_i X_{t-i} + \sum_{i=1}^{k+d_{max}} \delta_i Y_{t-i} + \epsilon_{X,t} \quad (14)$$

k is optimal lag length based on standard information criteria, $d_{max}$ is the maximum order of integration among the variables, $\epsilon_{Y,t}$ and $\epsilon_{X,t}$ are white noise error terms. The null hypothesis for testing whether $X_t$ does not Granger-cause $Y_t$:

$$H_0: \beta_1 = \beta_2 = \cdots = \beta_k = 0 \quad (15)$$

The null hypothesis for testing whether Yt does not Granger-cause Xt:

$$H_0: \delta_1 = \delta_2 = \cdots = \delta_k = 0 \quad (16)$$

To test the null, we conduct the Wald test on the coefficients of the original k lags ($\beta_i$, $\delta_i$). The augmented lags, the lags beyond k, are not included in the hypothesis. When the null is rejected, the excluded variable Granger-causes the dependent variable. Non-rejection of the null indicates no Granger causality.

## 4. RESULTS AND DISCUSSION

Table 2 reports the results of the three unit root tests, namely, augmented Dicky-Fuller (ADF), Phillips-Perron (P-P), and modified Dicky-Fuller (DF-GLS). All variables are either I(0) or I(1), and the data is suitable for ARDL estimation.

**Table 2.** Unit root tests.

| Variable | ADF |  | P-P |  | DF-GLS |  | I(?) |
|---|---|---|---|---|---|---|---|
|  | Level | First diff. | Level | First diff. | Level | First diff. |  |
| ln $CO_2$PC | -4.509*** |  | -4.276*** |  |  | -3.150*** | I(0), I(1) |
| lnQoG | -6.667*** |  | -6.993*** |  |  | -2.734*** | I(0), I(1) |
| lnGDP |  | -2.936** |  | -2.877** |  | -5.178*** | I(1) |
| lnIND |  | -5.180*** |  | -5.171*** |  | -3.579** | I(1) |
| lnET | -4.585*** |  | -4.619*** |  |  | -6.255*** | I(0), I(1) |
| lnEO |  | -6.890*** |  | -6.487*** |  | -4.221*** | I(1) |
| lnENG |  | -5.200*** |  | -5.186*** |  | -4.203*** | I(1) |
| lnERenh |  | -4.849*** |  | -4.849*** |  | -2.812*** | I(1) |

**Note:** ***and ** indicate significance at 1% and 5% levels, respectively.

We consult the Akaike Information Criterion (AIC) to find the lag order of the variables in the ARDL model. The orders of the five ARDL models are: ARDL (2, 2, 1, 2), ARDL (2, 2, 1, 2), ARDL (2, 2, 1, 1), ARDL (2, 2, 1, 1, 1) and ARDL (2, 2, 1, 1, 1).

For the five models, the ARDL results are reported in Table 3, results of the bounds tests are presented in Table 4, whereas Table 5 presents the results of the ARDL diagnostic tests.

As reported in Table 3, in the first model, per capita $CO_2$ emissions are explained by institutional quality, per capita GDP, and the percentage of electricity produced from oil, gas, and coal sources. The impact of institutional quality on $CO_2$ emissions is negative and significant, while both GDP and electricity produced from oil, gas, and coal sources have positive and significant effects on $CO_2$ emissions.

The elasticity measures for GDP and electricity production are both greater than 1, indicating elastic impacts. In contrast, the elasticity for institutional quality is less than 1 in absolute value, indicating an inelastic impact. In the short run, only electricity produced from oil, gas, and coal sources significantly affects $CO_2$ emissions, while the impacts of other variables are insignificant. The error correction term (ECT) is -1.096, indicating a dampening oscillation towards long-run equilibrium if deviated. The bounds test confirms a long-run relationship among the variables in Model 1.

The model explains 75.40% of the variation in per capita $CO_2$ emissions, which adjusts to 56.40% when considering degrees of freedom. The presence of homoscedasticity is confirmed by both the B-P and White's tests, and the model does not suffer from omitted variable bias (at 5%). Two of the three tests suggest that it is free from serial correlation. Additionally, the residuals are normally distributed, and the estimated parameters are stable.

**Table 3.** ARDL estimation with the quality of government index from the ICRG.

| **Y=InCO$_2$PC** | **Model 1 (2 2 1 2)** | **Model 2 (2 2 1 2)** | **Model 3(2 2 1 1)** | **Model 4(2 2 1 1 1)** | **Model 5(2 2 1 1 1)** |
|---|---|---|---|---|---|
| **Variable** | **Long run** | | | | |
| lnQoG | -0.085$^{**}$(0.034) | -0.284$^{***}$(0.085) | -0.0215(0.103) | -0.0906(0.120) | 0.017(0.119) |
| lnGDP | 1.301$^{***}$(0.067) | | | | |
| lnIND | | 4.470$^{***}$(0.580) | 5.92$^{***}$(0.448) | 5.938$^{***}$(0.428) | 5.493$^{***}$(0.760) |
| lnET | 4.167$^{***}$(1.005) | 6.515$^{***}$(1.725) | | | |
| lnENG | | | 2.261$^{***}$(0.674) | 2.550(1.707) | 2.853$^{**}$(1.136) |
| lnEO | | | | 0.044(0.162) | |
| lnERENH | | | | | 0.542(0.711) |
| Short run | | | | | |
| Δ ln CO$_2$PC | 0.087(0.172) | -0.322$^{**}$(0.145) | -0.403$^{**}$(0.137) | -0.431$^{**}$(0.149) | -0.385$^{**}$(0.145) |
| Δ lnQoG | -0.047(0.042) | -0.099$^{*}$(0.052) | -0.177$^{***}$(0.048) | -0.185$^{***}$(0.053) | -0.189$^{***}$(0.052) |
| Δ lnQoG(-1) | -0.077(0.045) | -0.227$^{***}$(0.068) | -0.229$^{***}$(0.053) | -0.247$^{***}$(0.067) | -0.229$^{***}$(0.055) |
| Δ lnGDP | -1.255(1.195) | | | | |
| Δ lnIND | | -0.048(0.430) | 0.193(0.334) | 0.247(0.366) | 0.307(0.376) |
| Δ lnET | -3.899$^{***}$(1.151) | -4.341$^{***}$(1.228) | | | |
| Δ lnET(-1) | -2.537$^{**}$(0.772) | -2.345$^{**}$(0.880) | | | |
| Δ lnENG | | | -1.338$^{***}$(0.396) | -1.759$^{**}$(0.624) | -1.530$^{***}$(0.503) |
| Δ lnEO | | | | -0.037(0.042) | |
| Δ lnERENH | | | | | -.134(0.189) |
| Constant | -31.991$^{***}$(6.966) | -21.999$^{***}$(5.568) | -9.622$^{***}$(1.847) | -11.102$^{***}$(3.397) | -10.475$^{***}$(2.341) |
| ECT(-1) | -1.096$^{***}$(0.211) | -0.483$^{***}$(0.097) | -0.319$^{***}$(0.059) | -0.351$^{***}$(0.071) | -0.333$^{***}$(0.066) |

**Note:** Standard errors are presented in parentheses. $^{***}$, $^{**}$, and $^{*}$ indicate significance at 1%, 5%, and 10% levels, respectively.

We find that the correlation between GDP per capita and the industry's (including construction) share of GDP is 0.9825. Therefore, we use the industry's GDP share as one of the explanatory variables and exclude GDP from the regression. In the second model, institutional quality, the industry's GDP share, and the percentage of electricity produced from oil, gas, and coal sources are used to explain CO$_2$ emissions per capita. The ARDL estimation results, reported in Table 6, show that all these variables are significant determinants of per capita CO$_2$ emissions. Improvements in institutional quality reduce CO$_2$ emissions, while higher industrial activities and electricity production increase CO$_2$ emissions. In the short run, an increase in per capita CO$_2$ emissions in the previous year significantly lowers the current year's emissions. Similarly, the institutional quality and electricity production from the previous year also have significant impacts. The ECT is -0.483, correctly signed and highly significant, indicating that 48.3% of deviations from the long-run equilibrium are corrected each year. For Model 2, the bounds test suggests a long-run relationship among the model's variables. The R-squared is 0.736, with an adjusted R-squared of 0.534. The model does not suffer from heteroscedasticity, serial correlation, non-normality, or structural breaks. However, the model does not pass the Ramsey RESET test for omitted variables.

**Table 4.** Pesaran, Shin, and Smith (2001) bounds test.

| **H0: no level relationship** | | | | | |
|---|---|---|---|---|---|
| | **Test statistic** | **Value** | **p-value I(0)** | **p-value I(1)** | **Decision** |
| Model 1 | F | 7.153 | 0.006 | 0.023 | Reject $H_0$ at 5% |
| | t | -5.177 | 0.001 | 0.008 | |
| Model 2 | F | 6.511 | 0.009 | 0.032 | Reject $H_0$ at 5% |
| | t | -4.978 | 0.001 | 0.011 | |
| Model 3 | F | 7.869 | 0.004 | 0.015 | Reject $H_0$ at 5% |
| | t | -5.350 | 0.001 | 0.006 | |
| Model 4 | F | 5.656 | 0.011 | 0.046 | Reject $H_0$ at 5% |
| | t | -4.877 | 0.002 | 0.018 | |
| Model 5 | F | 5.738 | 0.011 | 0.044 | Reject $H_0$ at 5% |
| | t | -5.052 | 0.001 | 0.014 | |

In Model 3, we replace electricity production from nonrenewable sources with electricity generated from natural gas sources only. From the ARDL output, we find that institutional quality has no significant impact on CO$_2$ emissions per capita. However, both the industry's GDP share and the percentage of electricity produced from natural gas have significant positive impacts on CO$_2$ emissions. In the short run, the impacts of CO$_2$ emissions, institutional quality, and electricity from natural gas are all negative and significant. The significant error correction term (ECT) of -0.319 implies that if the model deviates from the long-run equilibrium, 31.9% of the deviations are corrected each year. The ARDL bounds test confirms a long-run relationship among the variables in Model 3. The R-squared is 0.736, with an adjusted R-squared of 0.567. At the 5% level, the model exhibits constant variance, no omitted variables, normally distributed residuals, and no structural breaks. The only caveat is the presence of serially correlated residuals.

Model 4 explains $CO_2$ emissions per capita using institutional quality, industry's GDP share, electricity from natural gas, and electricity from oil. The ARDL long-run estimates suggest that only the industry's GDP share has a significant impact on per capita $CO_2$ emissions. In the short run, all coefficients except for industry and electricity produced from oil are significant. The error correction term (ECT) is -0.351, indicating that deviations from the long-run equilibrium are corrected at a rate of 35.1% per year, meaning it will take approximately 2.849 years to restore equilibrium. The bounds test confirms that the variables in the model are cointegrated. The model explains 75.3% of the variations in the dependent variable. The residuals are homoscedastic, not serially correlated, and non-normally distributed. Additionally, the model has no omitted variables and no structural break.

In Model 5, institutional quality, industry's GDP share, electricity produced from natural gas, and electricity from renewable sources are used as explanatory variables. Among these, industry and electricity from natural gas have significant long-run impacts on $CO_2$ emissions per capita. In the short run, all variables except industry and electricity from renewable sources have significant impacts. The error correction term suggests that if the model deviates from the long-run equilibrium, it takes approximately 3 years to restore equilibrium. The bounds test confirms that the variables in the model are cointegrated. Model 5 explains around 75% of the variation in $CO_2$ emissions per capita. The residuals are homoscedastic, normally distributed, and not serially correlated according to the Durbin-Watson test. Additionally, Model 5 does not suffer from omitted variable bias, and the estimated parameters are stable.

Models 1, 2, and 3 each have three independent variables, while Models 4 and 5 each have four independent variables. Models 1 and 2 are of the same order (2 2 1 2). In Model 2, the industry's GDP share is used instead of GDP per capita. When examining the long-run coefficients, the impact of the variables is similar in both models. The short-run coefficients also have the same sign in both models, although they differ in terms of significance. A major difference is observed in the magnitude of the error correction term (ECT) – Model 1 is characterized by dampening oscillatory convergence, whereas Model 2 exhibits regular convergence. The bounds test suggests that the variables in both models are cointegrated. Both models have residuals that are homoscedastic, normally distributed, and serially uncorrelated. Neither model has structural breaks. Model 1 is free from omitted variable bias, whereas Model 2 is not.

Models 3, 4, and 5 have ARDL orders of (2 2 1 1), (2 2 1 1 1), and (2 2 1 1 1), respectively. Model 3 can be considered the basic model, where the explanatory variables are institutional quality, industry's GDP share, and electricity generated from natural gas. By adding electricity generated from oil sources to Model 3, we obtain Model 4. Similarly, adding electricity generated from renewable sources to Model 3 gives us Model 5. In all three models, institutional quality has no significant long-run impact on $CO_2$ emissions. However, the industry's GDP share has significant long-run impacts in all models. Electricity generated from natural gas has significant long-run impacts on $CO_2$ emissions in Models 3 and 5. Electricity produced from oil and renewable resources have no long-run impacts in Models 4 and 5, respectively. In these models, the short-run coefficients of the common variables have similar signs and almost identical levels of significance. All three ECTs are close to -0.3. In Model 3, the residuals are serially correlated, while in Model 4, they are not normally distributed.

Table 6 presents the significant results from the Todo-Yamamoto Granger causality test conducted for all five models. Small-sample degrees-of-freedom adjustments are made, and small-sample F statistics are reported. We find three unidirectional Granger causalities in Model 1 - GDP Granger causes $CO_2$ emissions, Institutional quality Granger causes GDP, and electricity generated from nonrenewable resources Granger causes GDP. In Model 2, industry Granger causes institutional quality and also, institutional quality Granger causes industry. Additionally, there exist unidirectional causalities from $CO_2$ emissions to industry and to electricity generated from nonrenewable sources.

**Table 5.** ARDL Diagnostics.

| **Test and/or null hypothesis** | **Model 1** | **Model 2** | **Model 3** | **Model 4** | **Model 5** |
|---|---|---|---|---|---|
| R-squared | 0.754 | 0.736 | 0.736 | 0.753 | 0.751 |
| Adj R-squared | 0.564 | 0.534 | 0.567 | 0.527 | 0.523 |
| Breusch-Pagan / Cook-Weisberg test for heteroskedasticity<br>$H_0$: Constant variance | 2.70(0.1004)<br>do not reject $H_0$ | 1.19(0.274)<br>do not reject $H_0$ | 1.20(0.272)<br>do not reject $H_0$ | 0.62(0.432)<br>do not reject $H_0$ | 0.81(0.368)<br>do not reject $H_0$ |
| White's test<br>$H_0$: homoskedasticity | 24.00(0.403)<br>do not reject $H_0$ | 24.00(0.403)<br>do not reject $H_0$ | 24.00(0.403)<br>do not reject $H_0$ | 24.00(0.403)<br>do not reject $H_0$ | 24.00(0.403)<br>do not reject $H_0$ |
| Ramsey RESET test<br>$H_0$: model has no omitted variables | 3.66(0.0515)<br>do not reject $H_0$ | 9.63(0.003)<br>reject $H_0$ | 1.20(0.356)<br>do not reject $H_0$ | 3.69(0.055)<br>do not reject $H_0$ | 1.13(0.386)<br>do not reject $H_0$ |
| Breusch-Godfrey LM test<br>$H_0$: no serial correlation | 6.147(0.013)<br>reject $H_0$ | 0.047(0.828)<br>do not reject $H_0$ | 4.577(0.032)<br>reject $H_0$ | 4.894(0.026)<br>reject $H_0$ | 8.435(0.004)<br>reject $H_0$ |
| Durbin-Watson<br>(at 5%) | 2.664 (11,24)<br>dl=0.431 du= 2.761<br>do not reject $H_0$ | 2.059 (11,24)<br>dl=0.431 du= 2.761<br>do not reject $H_0$ | 2.630(10,24)<br>0.506, 2.613<br>reject $H_0$ | 2.637(12,24)<br>0.362, 2.908<br>do not reject $H_0$ | 2.822(12,24)<br>0.362, 2.908<br>do not reject $H_0$ |
| Jarque-Bera test<br>$H_0$: normality | .791(.673)<br>do not reject $H_0$ | 4.547(.103)<br>do not reject $H_0$ | 5.798(.0551)<br>do not reject $H_0$ | 6.125(.046)<br>reject $H_0$ | 5.586(.061)<br>do not reject $H_0$ |
| Cumulative sum test for parameter stability (recursive, OLS)<br>$H_0$: No structural break | 0.604, 0.432<br>do not reject $H_0$ | 0.318, 0.322<br>do not reject $H_0$ | 0.564,0.282<br>do not reject $H_0$ | 0.425,0.223<br>do not reject $H_0$ | . , 0.212<br>do not reject $H_0$ |

**Table 6.** Granger causality wald tests.

| Model | Variables | F stat (p-value) | Direction of causality |
|---|---|---|---|
| Model 1 | lnGDP→ln $CO_2$PC | 16.008$^{***}$(0.001) | GDP Granger causes $CO_2$ emissions |
| | lnQoG→lnGDP | 7.383$^{**}$(0.014) | Institutions Granger cause GDP |
| | lnET→lnGDP | 3.568$^{*}$(0.076) | ET Granger causes GDP |
| Model 2 | lnIND→lnQoG | 7.031$^{**}$(0.017) | IND Granger causes institutions |
| | ln $CO_2$PC→lnIND | 48.413$^{***}$(0.000) | $CO_2$ emissions Granger cause IND |
| | lnQoG→lnIND | 18.168$^{***}$(0.001) | Institutions Granger cause GDP |
| | ln $CO_2$PC→lnET | 5.995$^{**}$(0.025) | $CO_2$ emissions Granger cause ET |
| Model 3 | lnIND→lnQoG | 6.986$^{**}$(0.017) | Industry Granger causes institutions |
| | ln $CO_2$PC→lnIND | 57.394$^{***}$(0.000) | $CO_2$ emissions Granger cause IND |
| | lnQoG→lnIND | 23.946$^{***}$(0.000) | Institutions Granger cause IND |
| | lnQoG→lnENG | 12.39$^{***}$(0.003) | Institutions Granger cause ENG |
| | lnIND→lnENG | 19.567$^{***}$(0.000) | IND Granger causes IND |
| Model 4 | lnIND→lnQoG | 8.241$^{**}$(0.011) | IND Granger causes institutions |
| | lnQoG→lnIND | 7.776$^{**}$(0.013) | Institutions Granger cause IND |
| | lnEO→lnIND | 3.962$^{*}$(0.063) | EO Granger causes IND |
| | lnIND→lnEO | 9.868$^{***}$(0.006) | IND Granger causes EO |
| | ln $CO_2$PC→lnIND | 71.189$^{***}$(0.000) | $CO_2$ emissions Granger cause IND |
| | lnQoG→lnENG | 4.217$^{*}$(0.056) | Institutions Granger cause ENG |
| | lnIND→lnENG | 15.62$^{***}$(0.001) | IND Granger causes ENG |
| | lnEO→ln $CO_2$PC | 3.189$^{*}$(0.093) | EO Granger causes $CO_2$ emissions |
| | lnENG→lnEO | 11.77$^{***}$(0.003) | ENG Granger causes EO |
| Model 5 | lnIND→ln $CO_2$PC | 3.756$^{*}$(0.068) | IND Granger causes $CO_2$ emissions |
| | lnENG→ln $CO_2$PC | 3.397$^{*}$(0.081) | ENG Granger causes $CO_2$ emissions |
| | ln $CO_2$PC→lnIND | 10.093$^{***}$(0.005) | $CO_2$ emissions Granger cause IND |
| | lnQoG→lnIND | 6.403$^{**}$(0.020) | Institutions Granger cause IND |
| | ln $CO_2$PC→lnERenh | 12.713$^{***}$(0.002) | $CO_2$ emissions Granger cause ERenh |
| | lnQoG→lnERenh | 5.394$^{**}$(0.032) | Institutions Granger cause ERenh |
| | lnENG→lnERenh | 29.685$^{***}$(0.000) | ENG Granger causes ERenh |

**Note:** p-values are presented in parentheses. $^{***}$, $^{**}$, and $^{*}$ indicate significance at 1%, 5%, and 10% levels, respectively.

In Model 3, again, bidirectional causality exists between industry and institutional quality. Also, there are three unidirectional causalities. $CO_2$ emissions Granger cause industry and both institutional quality and industry, individually, Granger cause electricity from natural gas. In Model 4, bidirectional causalities exist between industry and institutional quality, and between industry and electricity produced from oil. There are five unidirectional causalities – from $CO_2$ emissions to industry, from institutional quality to electricity from natural gas, from oil-produced electricity to $CO_2$ emissions, and from electricity from natural gas to electricity from oil. Seven unidirectional causalities are found in Model 5. Industry and ENG Granger cause $CO_2$ emissions, $CO_2$ emissions and institutional quality Granger cause industry, and $CO_2$ emissions, institutional quality and ENG granger cause electricity from renewable resources.

## 5. CONCLUSION

The aim of this chapter is to conduct an in-depth investigation into the influence of institutional quality on environmental quality in Bangladesh. By employing a previously unexplored measure of institutional quality and estimating five ARDL models, this research seeks to offer a detailed and nuanced understanding of the relationship between institutional frameworks and environmental outcomes. This comprehensive analysis is intended to fill the current research gap by providing a stronger evaluation of how institutional quality affects environmental quality in Bangladesh. The data come from the WDI and the ICRG. We estimate five ARDL models. The first model is the same as before. The next four models are different, though related.  The five models examine the determinants of per capita $CO_2$ emissions in Bangladesh, focusing on institutional quality, GDP, industry share, and electricity production from various sources. Model 1 finds that institutional quality negatively affects $CO_2$ emissions, while GDP and electricity from oil, gas, and coal sources have positive effects. In Model 2, replacing GDP with the industry's GDP share yields similar results. Model 3 replaces nonrenewable electricity with natural gas, showing significant positive impacts from the industry's GDP share and electricity from natural gas, but institutional quality becomes insignificant. Model 4 adds electricity from oil but finds only the industry's GDP share significantly affects $CO_2$ emissions. Model 5 includes electricity from renewable sources, finding that industry and natural gas have significant long-run impacts. Across all models, long-run relationships among variables are confirmed, and the models generally exhibit stable parameters, with some issues like serial correlation and omitted variables addressed in specific cases. According to the Toda-Yamamoto Granger causality test across five models, in Model 1, GDP Granger cause $CO_2$

and institutional quality and electricity from nonrenewable sources Granger cause GDP. Model 2 shows bidirectional causality between industry and institutional quality, along with unidirectional causalities from $CO_2$ emissions to industry and electricity from nonrenewable sources. Model 3 again finds bidirectional causality between industry and institutional quality, with three unidirectional causalities. Model 4 highlights bidirectional causalities between industry and institutional quality and between industry and electricity produced from oil, with five other unidirectional causalities. Lastly, Model 5 reveals seven unidirectional causalities.

Policymakers in Bangladesh should focus on enhancing institutional quality to reduce $CO_2$ emissions by strengthening regulatory frameworks and enforcing environmental laws. Sustainable economic growth should be promoted through cleaner production technologies and less carbon-intensive industries. The energy sector should prioritize diversifying into renewable sources, with incentives to encourage this transition. Additionally, improving energy efficiency across all sectors is essential to lower emissions. Regular monitoring and adjustments of policies will ensure that environmental sustainability is achieved alongside economic growth.

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