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Macroeconomic factors affecting carbon dioxide emissions in Bangladesh: an ARDL approach

ABSTRACT: This study investigates how macroeconomic variables in Bangladesh from 1991 to 2021 affected emissions, using data from the World Development Indicators. This study used the autoregressive distributed lag (ARDL) model. The study finds that Bangladesh's GDP per person, energy use, and trade openness positively and significantly affect both short-term and long-term carbon dioxide emissions. However, statistics show that foreign direct investment does not affect from Bangladesh's. This study says that policymakers should focus on making energy policies and other economic policies that help the economy grow and have little to no effect on emissions. Additionally, economic growth will not hurt the environment as much if policies are implemented to encourage the growth of both the public and private sectors and make it easier to make money by allocating and distributing resources well. Finally, this study suggests looking for additional variables to improve the model's fit and using other estimating techniques to obtain more trustworthy findings.

KEYWORDS: macroeconomic factors, economic growth, emissions, energy consumption, ARDL approach

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Introduction

Environmental deterioration is one of the world's biggest problems. Both locally and worldwide, the severe pollution that has been present for many years has terrible long- and short-term effects. Pollutants in the air, lakes, and streams end up in drinking water and directly affect ecosystems in the area. When an ecosystem's functioning is changed, the balance of species that give us food and fresh air to breathe is disrupted. Everything from hunger, poverty and employment to living conditions and public health could suffer due to this (Woodcock 2002). In actuality, emissions from industrial facilities and other polluted locations directly affect individuals by making them ill with conditions including cancer, inflammation, and heart disease (Pope III and Dockery 2006). The destruction of the environment affects the entire planet, not just specific regions. The so-called greenhouse effect warms the entire world as pollution levels rise. The Arctic ice is melting more quickly as the earth's temperature rises, which causes the sea level to rise (McMichael et al. 2006). The world's most populous cities are located along the coast and are at risk of flooding. Another adverse effect of global warming is that it exacerbates droughts in areas where there are already many. As a result, living close to the equator is nearly impossible (Dai 2013). They are being moral, and protecting the environment on a local and global scale is not enough to combat pollution and combat climate change. The lives of people and the existence of the globe are also at risk.

The health of the ecosystem is currently greatly threatened by global warming, particularly by the alarming climatic changes that are receiving much attention from international issues. The water level has increased, and temperatures around the world have increased by 1.1 to 6.4 degrees (Bernstein et al. 2008). People who reside in coastal areas might suffer as a result (Lau et al. 2009). As a substantial contributor to climate change and global warming, emissions account for 58.5 percent of all atmospheric pollution brought on by human activities.

The average Bangladeshi citizen will have released 0.64 tons of into the atmosphere by 2024. Bangladesh's emissions increased at a mean annual rate of 5.4801 percent between 1971 and 2021, going from 0.05 tons of per person to 0.64 tons of CO_2 per person (Knoema 2021).

To attain maximum economic growth, nations use energy and other natural resources, which increases greenhouse gas emissions. Carbon dioxide emissions are one of the leading causes of greenhouse gas emissions that harm the environment (Hamilton and Turton 2002; Sarkodie and Strezov 2018; Asumadu-Sarkodie and Owusu 2016).

According to Hossain (2011), the primary sources of carbon dioxide emissions that harm the environment are oil, coal, and gas.

Lee and Jung (2018) used the "autoregressive distributed lag" (ARDL) model to examine the association between the study variables and the relationship between energy usage and economic development in South Korea from 1990 to 2012. The findings of the analysis indicate that using energy negatively affects economic growth. Therefore, they advised that strategists concentrate on expanding the economy rather than raising renewable energy.

A study by Tiwari et al. (2013) examined the relationship between emissions and economic growth. The results demonstrated that trade openness and energy use positively impact environmental degradation. However, the results also point to a one-way relationship between trade openness and economic development, energy use, and environmental harm, as well as a unidirectional relationship between trade openness and coal consumption.

Shahbaz et al. (2013) used the ARDL model to study the association between economic and financial progress and carbon dioxide emissions. The findings of the analysis show that while trade openness and the financial sector's expansion help lower emissions, economic growth and energy use raise them.

Two of the most talked-about problems in the past few decades have been emissions and speeding up the process of making trade more open. As a result, many experts in the field began investigating the relationship between trade openness and carbon dioxide emissions in the 1990s. First, they examined the direct and indirect effects of trade openness on emissions (Tachie et al. 2020).

According to Banerjee and Rahman (2012), the estimates of the vector error correction model (VECM) imply a substantially positive long-run causal flow from population increase and industrialization to carbon dioxide discharges in Bangladesh. By contrast, the causal flow from growth in foreign direct investment (FDI) is negative and slightly subdued.

Cruz et al. (2022) examined macroeconomic variables and emissions in the Philippines by using multivariate ordinary least square (OLS) regression. According to the investigated data, trade openness, energy consumption, and economic growth (GDP) are significant and positively correlated to emission factors. However, foreign direct investment has a somewhat favorable relationship with emissions in the Philippines.

To the best of our information, the literature has yet to examine the impact of macroeconomic factors on emissions in the context of Bangladesh, even when using the ARDL approach. However, many studies have examined how economic growth, energy use, and carbon dioxide discharges are connected. This research investigates how macroeconomic factors such as GDP per capita growth, energy consumption, trade openness and foreign direct investment affect carbon dioxide emissions in Bangladesh. Finally, this study would add to the body of knowledge that examines how macroeconomic issues in Bangladesh affect emissions. This study will benefit Bangladesh's environmental sector because it will help government agencies learn more about the economic factors that affect emissions in Bangladesh. The government can develop macroeconomic policies based on the findings to determine if expansion only makes environmental conditions worse over time or whether it eventually improves them in terms of levels of economic activity. The results may also have a significant impact on the literature on Bangladesh's economic development and contribute to the development of practical solutions to the nation's economic, environmental and healthcare challenges.

1. Literature review

The existing research on the significant macroeconomic factors influencing the rising emissions of Bangladesh is summarized in this portion of the study. Additionally, the consequences of energy use, trade openness, FDI, and GDP per person in Bangladesh and other nations have been examined. One of the most crucial challenges in recent years is global warming brought on by climate change. It is claimed that emissions are mostly the cause of global warming. Human activities, particularly the use of fossil fuels like coal, oil and gas, which serve as the main source of energy for producing electricity, manufacturing, transportation and the consumption of goods and services that are directly related to economic growth as measured by GDP per capita, have resulted in a significant increase in CO_2 emissions over the past century (Alam 2014).

Amin et al. (2012) used a multivariate framework to examine the causal connections between energy use, economic growth, and emissions in Bangladesh from 1976 to 2007. According to empirical data using the Johansen technique, yhe variables have long-term cointegration,. This study's findings demonstrate no direct causal link between rising emissions and economic growth, demonstrating that Bangladesh's economy may grow without deteriorating the environment.

In a particular economy, the entire quantity of energy is used by buildings (plants, machinery, office equipment) and homes (appliances). The amount of energy consumed by businesses (plants and machinery, office equipment) and households (appliances) within a given economy. An industry's energy consumption is influenced by its machinery, the environment, and other elements. In comparison, the type of household depends on the lifestyle, environment, age and type of dwelling, among other factors (Masuduzzaman 2012). Essential factors, including industrialization, urbanization, population expansion, a higher standard of life, and even the modernization of agriculture, is to blame for this increase in energy use. The biggest global economic, environmental, and development challenges revolve around energy. Climate change has also been significantly impacted by carbon emissions, a chemical in the atmosphere that emits radiation into the environment. Because the economy is growing, more energy is being used, which means that more is being released into the atmosphere. This concept gained worldwide attention in the nineteen-nineties due to its potential to damage the biosphere. Most respondents agreed that economic expansion should not harm the environment, raising the issue of making economic growth more sustainable. International organizations from every continent are constantly attempting to lessen the harmful effects of global warming. To lessen the negative impacts of global warming, the Kyoto Protocol accord, also known as the "United Nations Framework Convention on Climate Change" (UFCC), was created in 1997. A significant pollutant that accounts for 58.8% of greenhouse gas emissions is (Protocol 1997).

The association between trade openness and greenhouse gas discharges is an observed issue that depends on country-specific characteristics because each country's income level and the sorts of goods it exports, which have various emission intensities, are different (Baek et al.

2009). Therefore, country-specific case studies can aid in understanding the connection between trade openness and greenhouse gas discharges. Resources are transferred from one nation to another via comparative advantage, which promotes economic expansion. Depending on how it gets there, it affects the ecosystem in a variety of ways. If the impact of the opening of trading outweighs the technique/composition effects, trade openness is expected to have net negative environmental consequences.

Despite the above point, trade openness is anticipated to benefit the environment over the long run if the opposite is true. Additionally, trade openness can alter pollution emissions in a variety of ways. Making trade more open, for instance, sometimes has a different magnitude and sign of impact than making trade less open (Tachie et al. 2020). Because countries have to make more goods to trade, they have to use more natural resources, and trade can cause to be released into the atmosphere. It can be found in coal, natural gas and various other resources. Its production releases greenhouse gases into the atmosphere, which are detrimental to the nation's environment (Kim et al. 2019).

It is one of the most frequent concerns regarding FDI, and it can be said that it is harmful to the environment. Foreign direct investment (FDI) expansion may benefit the economy but also harm the environment. The environment may be impacted by FDI in a positive or negative way. Much empirical research has looked at the theoretical uncertainties about the relationship between FDI and the environment; however, because they come to different conclusions, their results only fuel the argument. Most studies so far show that FDI causes emissions to rise in the country that gets the money. By contrast, multiple studies have shown that FDI causes a decrease in emissions. Numerous studies demonstrate that foreign direct investments (FDI) worsen emissions, supporting the pollution-haven effect (Cole 2004; Cole et al. 2011; Ben Kheder and Zugravu 2012; Ur Rahman et al. 2019; Jebli et al. 2016). Furthermore, Shahbaz et al. (2015) showed a nonlinear link between FDI inflows and CO_2 emissions.

The association between Japan's emissions from 1970 to 2010 was examined using the ARDL's limits test for economic development, foreign trade, energy use and industrial growth (Ahmad et al. 2019). Their findings are intriguing because they unambiguously demonstrate that macroeconomic variables and discharges have a long-term connection. The predicted long-term model additionally demonstrated that increases in energy use, international trade, and industrial development had a beneficial effect on carbon dioxide releases. However, they further note that no statistically proven connection exists between economic expansion and emissions.

Bangladesh's emission drivers have been evaluated and looked at by Banerjee and Rahman (2012) – emissions, increases in industrial production, population growth, and FDI inflows in Bangladesh from 1972 to 2008. There is evidence that emissions are linked to population growth, FDI and development in industrial production. Additionally, interactions between the variables have net positive short-term feedback effects.

Alam (2014) investigated the association between economic expansion and emissions: the Bangladesh experience investigates the association between carbon dioxide discharges and economic development in Bangladesh using "World Bank" data from 1972 to 2010. From analyzing Bangladesh's sector-by-sector GDP growth over the past decade and year, it is clear that the na-

tion cannot reduce emissions because the GDP contribution of the industry and services sectors has grown dramatically.

The cointegration of emissions in Australia from 1960 to 2016 has been studied by Sherafatian-Jahromi and Othman (2020) using the autoregressive distributed lag-bound testing methodology. Energy consumption, financial progress, and trade openness only coexist once emissions are taken into account as the dependent variable. Environmental degradation happens when energy consumption and economic expansion go hand in hand, yet as the economy expands, so does the quality of Australia's environment over time. Trade openness benefits carbon dioxide discharge reduction in addition. However, energy consumption and economic growth results are considerably more critical. A direct causal link has also been established between emissions and economic expansion (Ben Jebli 2016).

The "Johansen cointegration test" and "vector error correction model" has been applied to examine the association between FDI and pollution in Turkey from 1974 to 2013. According to Kılıçarslan and Dumrul (2017), sustained foreign direct investment lowers discharges of carbon dioxide. The experts supported encouraging investments in clean technologies, research and development and environmentally favorable investments. Foreign investments should be taxed to decrease their effect on emissions.

Additionally, Rambeli et al. (2018) have investigated how Malaysia's GDP, electricity production, net trade, electricity use, and oil price are impacted by the nation's carbon dioxide discharges. The analysis reveals that the effects of carbon dioxide discharges are favorable for the country's GDP, electricity production, net trade, and energy consumption. However, the price of oil negatively impacts levels. Statistical analysis also reveals that the biggest influences on Malaysia's long-term emission combustion are the country's gross domestic product, the amount of power generated, and the amount of energy used.

Moutinho et al. (2018) examined evolution's effects using data from 1985 to 2011 to find which had the most influence on emissions. Complete additive decomposition was used to assess emissions and components. Additionally, comparative and decoupling analyses have been performed. From 1985 to 2011, the results showed that Europe's emissions were affected in good and bad ways compared to the rest of the globe. The recent decade has seen overall and negative changes in emissions, although fossil fuel energy consumption has increased. This is because of how well renewable resources work and how the economy's growth affects renewable electricity production based on GDP.

Sarkar et al. (2018) used the "World Development Indicators" database of the "World Bank" as a secondary source of data to examine the trends in Bangladesh's energy use, and carbon dioxide discharges between 1991 and 2011. They found a trend of increased emissions that outpaced Bangladesh's growth in GDP and energy.

Muhammad (2019) investigated how the Middle East and North Africa (MENA) region's economic growth, energy use and carbon dioxide discharges changed between 2001 and 2017. According to the "generalized method of moments" and the seemingly unrelated regression (SUR) technique, as energy use goes up in industrialized and rising countries, economic growth goes up. However, economic growth has gone down in MENA countries. Therefore, officials in

these nations should concentrate on using green technologies to reduce carbon dioxide discharges in light of the results.

In 2020, Shaari et al. investigated the variables affecting Malaysia's carbon dioxide discharges in the short term and long term. The ARDL approach was used to analyze data that was gathered between 1985 and 2014. These findings indicate that both short- and long-term environmental degradation may occur from economic progress. The findings also suggest that population growth may negatively affect ecosystem health.

Researchers have also studied the significance of GDP on the carbon footprints of twenty-eight African nations from 1990 to 2019. They discovered that income affects emissions. Between 0.87 and 0.84 percent is the average growth rate. As a result of this, African economies can only grow by making compromises. According to researchers, African nations should invest more in renewable energy to lower carbon emissions and advance their economies (Adeleye et al. 2021). This is consistent, as stated by Aslam et al. (2021). The researchers also looked at how China's economy is related to industrialization, economic growth, carbon dioxide discharges, trade openness and the number of people living in a particular area. This study was performed using time series data from the "World Development Indicators" for 1962 to 2018 on the industry, trade openness, GDP per square population density, and carbon dioxide discharges. The researchers found a bidirectional causal association between population density and trade openness for carbon emissions and industrialization. The use of variance decomposition impulse analysis to scrutinize the association between the timing of carbon dioxide discharges, industrializatio, and GDP is highlighted (Aslam et al. 2021).

Aslam et al. (2021) used a nonlinear ARDL model to look at how the macroeconomic drivers of China's emissions were different from 1971 to 2019. In the long term, the amount and direction of carbon dioxide discharges are related to the expansion of the human population. In any event, the effect of agriculture on carbon discharges is more balanced. In the short term, agriculturalization has an asymmetric response to emissions in magnitude and direction, whereas GDP and industrialization have an asymmetric response only with regard to quantity.

Using the dynamic ARDL simulations model developed by Jordan and Philips (2018), Islam et al. (2021) investigated the impacts of globalization, foreign direct investment, economic development, trade, innovation, urbanization and energy consumption in Bangladesh from 1972 to 2016. Globalization, foreign direct investment and innovation help to enhance the environment's quality while economic growth, trade, energy use and urbanization increase emissions and exacerbate environmental degradation. The institutional quality of the political terror scale (PTS) influences carbon dioxide discharges in a way that both long-term and short-term degrades the environment.

Lastly, a multiple regression analysis has been utilized to look at the association between the emissions(dependent) and independent (GDP per person, energy consumption, trade openness, and foreign direct investment) variables in the Philippines from 1981 to 2014. These results demonstrate a positive link between carbon dioxide discharges and GDP per capita, energy consumption and trade openness. In addition, FDI and the Philippines' emissions are positively associated. However, the correlation is relatively slight (Cruz et al. 2022).

2. Methodology of the study

The time series data from the "World Development Indicator" from 1991 to 2021 were used in this study to look at how macroeconomic factors affect emissions in Bangladesh (World Development Indicators | Data Bank 2022). The model's dependent variable, emissions, is expressed in kilotons. By contrast, macroeconomic variables that are used as predictors are utilized to figure out what causes changes in emissions. They are (i) gross domestic product (GDP) per person, expressed in current US dollars, (ii) energy consumption (EC), (iii) trade openness (measured as the proportion of trade in GDP), and (iv) inflows of a foreign direct investment expressed in current US dollars (FDI). The ARDL model was used in this research to assess the effect of macroeconomic variables on the carbon dioxide discharges of Bangladesh. For time series analysis, it is required to check the stationarity of the data. Different tests can be used to run unit root testing, but one of the most well-known ones is the "Augmented Dickey-Fuller (ADF)" test (Dickey and Fuller 1979). It is required to determine whether or not the variables in this investigation are stationary. If time series is at I (0) and I (1) stationary, the autoregressive distributed lag (ARDL) model (Pesaran et al. 2001) must be utilized to calculate the effect of macroeconomic factors on CO_2 emissions. A sample of the research variables passed the unit root test, indicating that they are all stationary at the first difference (I (1)), but none are stationary at the second difference (I (2)). The ordinary least square (OLS) method-based autoregressive distributed lag (ARDL) model is suitable for the non-stationary and mixed-order integration order of time series. The ARDL Model is an unrestricted error correction model, so keep that in mind (ECM).

2.1. Model specification

To examine the connection between the variables under investigation, the general equation shown below is suggested:

$$(CO_2)_t = \beta_0 + \beta_1 GDP_t + \beta_2 EC_t + \beta_3 TO_t + \beta_4 FDI_t + \varepsilon_t \quad (1)$$

where:

- CO_2 – represents the emissions of carbon dioxide;
- GDP – macroeconomic factors – per capita in US dollars measures economic growth,
- EC – energy consumption,
- TO – trade openness,
- FDI – used as macroeconomic factors,
- β_0 – the constant,
- β_1 to β_4 – independent variable coefficients,
- ε_t – the error term, with the subscript (t) denotes time.

2.2. Autoregressive distributed lag bounds test

The long-term link between the research variables was investigated using a bound test when all of the study variables were at the same level. All research variables in this study are thus stationary at the first difference. Therefore, the optimum method for determining whether two or more series are cointegrated is the autoregressive distributed lag bounds test. The ARDL bound test model described below was utilized to look into the long-term relationship between the research variables:

$$\Delta(CO_2)_t = \Psi_0 + \Psi_1(CO_2)_{t-1} + \Psi_2 GDP_{t-1} + \Psi_3 EC_{t-1} + \Psi_4 TO_{t-1} + \Psi_5 FDI_{t-1} +$$
$$+\sum_{i=1}^{q}\beta_1\Delta(CO_2)_{t-1} + \sum_{i=1}^{q}\beta_2\Delta GDP_{t-1} + \sum_{i=1}^{q}\beta_3\Delta EC_{t-1} + \sum_{i=1}^{q}\beta_4\Delta TO_{t-1} + \sum_{i=1}^{q}\beta_5\Delta FDI_{t-1} + \varepsilon_t \quad (2)$$

where:

Δ – represents the difference operators,
CO_2 – the carbon dioxide emissions;
GDP – the gross domestic product per capita,
EC – the energy consumption,
TO – the trade openness,
FDI – the foreign direct investment,
t–i – represents the Akaike information criterion's best choice of lags (Sakamoto et al. 1986),
Ψ and β – examined for the long-run relationship among selected variables.

The short-run and long-run ARDL models are utilized due to the study variables having long-run connections. The following are the null and alternative hypotheses for the bound test:

$$H_0 : \Psi_i = 0 \quad \text{for all,} \quad i = 1,2,3,4,5$$
$$H_1 : \Psi_i \neq 0 \quad \text{for all,} \quad i = 1,2,3,4,5$$

The null hypothesis can either be accepted or rejected based on the value of the F statistic. According to Pesaran et al. (2001), a long-term relationship exists between the research variables if the estimated F-statistics values exceed the upper bound. The decision is inconclusive if the computed F-statistics value falls between the lower and upper limits values. There is no long-term association if the computed F-statistics value is less than the lower bounds value.

2.3. ARDL model

The ARDL model was proposed by Pesaran et al. (1999) and Pesaran et al. (2001). The ARDL model has various benefits over other time-series models. Short temporal data may be utilized with the ARDL model, claims Haug (2002). The ARDL model can be used if the series is stationary at I (0), I (I), or both. Different delays can be used by dependent and independent variables. The anticipated ARDL bound test findings indicate that the research variables are co-integrated. The long-term ARDL model appears to be as follows:

$$(CO_2)_t = \alpha_0 + \sum_{i=1}^{q} \sigma_1 (CO_2)_{t-1} + \sum_{i=1}^{q} \sigma_2 GDP_{t-1} + \sum_{i=1}^{q} \sigma_3 EC_{t-1} + \sum_{i=1}^{q} \sigma_4 TO_{t-1} + \sum_{i=1}^{q} \sigma_5 FDI_{t-1} + \varepsilon_t \quad (3)$$

The symbol σ in the equation above represents the research variables' long-run variation. For each variable, the Akaike information criteria were used to choose appropriate lags. The next error correction model was then used for the short-run ARDL model:

$$\Delta(CO_2)_t = \alpha_0 + \sum_{i=1}^{q} \beta_1 \Delta(CO_2)_{t-1} + \sum_{i=1}^{q} \beta_2 \Delta GDP_{t-1} + \sum_{i=1}^{q} \beta_3 \Delta EC_{t-1} + \sum_{i=1}^{q} \beta_4 \Delta TO_{t-1} + \\ + \sum_{i=1}^{q} \beta_5 \Delta FDI_{t-1} + ECT_{t-1} + \varepsilon_t \quad (4)$$

In the equation (4), β indicates the short-run variance and ECT is the error correction term that determines the rate of correction from disequilibrium, ranging from 0 to 1. If the term for error correction is statistically significant and negative, any shock is adjusted to approach equilibrium on the following occasion. Cumulative sum (CUSUM) and cumulative sum of squares (CUSMSQ) were used to test the model's stability (Brown et al. 1975). Breusch-Godfrey Lagrange multiplier was used to examine serial correlation. To determine whether there was heteroscedasticity, the Breusch-Pagan-Godfrey (BG), autoregressive conditional heteroscedasticity (ARCH) and Jarque-Bera tests were applied. The Jarque-Bera test was also used to see if there was residual normality. Finally, the model requirements were validated by the Ramsey reset test.

3. Results and discussion

The first descriptive analysis is given below according to the selected macroeconomic factors.

Table 1 displays the descriptive statistics for all macroeconomic factors. The average carbon dioxide discharges in Bangladesh are 35,798.31 kilotons, and the standard deviation

is 22,195.73. The maximum emissions are 82,760 kilotons, and the minimum is 10,830 kilotons. CO_2 emissions, GDP, EC, and TO are all positively skewed, whereas FDI is negatively skewed. Kurtosis statistics show that all variables are platykurtic except GDP, which is leptokurtic. The Jarque-Bera test shows that the result of the residuals of GDP is not normally distributed, whereas , FDI, EC, and TO are normally distributed.

Table 1. Descriptive statistics of the selected macroeconomic factors

Tabela 1. Statystyki opisowe wybranych czynników makroekonomicznych

Variable	CO_2	GDP	FDI	EC	TO
Mean	35,798.31	784.44	–8.34E+08	155.32	33.08
Median	28,630	499.46	–4.53E+08	141.977	32.09
Maximum	82,760	2,270.34	–1390444	229.25	48.11
Minimum	10,830	293.16	–2.77E+09	118.89	18.88
Std. deviation	22,195.73	596.11	8.88E+08	34.49	8.51
Skewness	0.72	1.36	–0.81	0.84	0.07
Kurtosis	2.23	3.53	2.29	2.42	1.97
Jarque-Bera	3.43	9.87	4.00	4.11	1.36
Probability	0.18	0.01	0.14	0.13	0.51
Observation	31	31	31	31	31

Table 2 illustrates that emissions are positively correlated with EC at a 5% level of significance, and TO and GDP are positively correlated at a 1% significance level but negatively correlated with FDI at a 5% level of significance.

Table 2. Correlation matrix for selected variables

Tabela 2. Macierz korelacji dla wybranych zmiennych

Variable		EC	TO	FDI	GDP
	1				
EC	0.38*	1			
TO	0.78**	0.71**	1		
FDI	–0.83**	–0.22	–0.72**	1	
GDP	0.57**	–0.10	0.46**	–0.82**	1

** Correlation is significant at 1%. *Correlation is significant at 5%.

It is crucial to ensure that no series are I (2) before using the ARDL model, otherwise the findings will be unreliable. The unit root of each series was examined using the unit root test ADF. None of the variables are stationary at I (2), according to the findings of the analysis. The

anticipated results of the above unit roots test indicate that the ARDL model could be utilized with the provided time series (Table 3).

Table 3. Unit roots test

Tabela 3. Test pierwiastków jednostkowych

Variable	Level		1st difference		Order of integration	Decision
	constant	constant with trend	constant	constant with trend		
	–2.835558 (0.1315)	–2.691319 (0.2482)	–1.928343 (0.0521)	–1.066517 (0.0620)	I (1)	1st difference stationary
GDP	4.471226 (1.00)	3.411267 (1.00)	–2.742618 (0.0812)	–4.159847 (0.0123)	I (1)	1st difference stationary
EC	–1.648541 (0.4462)	–1.334295 (0.8594)	–5.338767 (0.0001)	–5.491302 (0.0006)	I (1)	1st difference stationary
TO	–1.747050 (0.3938)	–0.622577 (0.97)	–4.440274 (0.0015)	–4.838159 (0.0029)	I (1)	1st difference stationary
FDI	–1.134171 (0.6888)	–2.359665 (0.3916)	–5.824632 (0)	–5.704505 (0.0003)	I (1)	1st difference stationary

The ARDL bound test was used to examine the long-term relationship between the study series. The F-statistics results are shown in Table 4. F statistics are used to determine the cointegration. Because the estimated F-statistics value exceeds the upper bound at 1, 2.5, 5 and 10% significance, cointegration between the research variables is present.

Table 4. ARDL bounds test

Tabela 4. Test granic ARDL

F-Statistic = 8.79		
Level of significance	Lower bound	Upper bound
10%	1.9	3.01
5%	2.26	3.48
2.5%	2.62	3.90
1%	3.07	4.44
R-Squared = 0.81, Durbin Watson Stat = 3.16		

The results of numerous diagnostic statistics are shown in Table 5. Diagnostic statistics were utilized to assess the model's consistency. Breusch-Godfrey LM test results show that the utilized model has no issues with serial correlation. The Breusch-Pagan-Godfrey analysis, which was used to see if there was a problem with heteroscedasticity, shows none. The "Ramsey RESET test" was used to determine whether the model was accurately defined and the results show that it was. According to Jarque-Bera's findings, the proposed model's residual is normal.

Table 5. Diagnostic test

Tabela 5. Test diagnostyczny

Diagnostic test statistics	Statistic value	(p-value)	Results
Breusch-Godfrey LM	21.39991	0.15	No problem with serial correlations
Breusch-Pagan-Godfrey	19.41191	0.1498	No problem of heteroscedasticity
Ramsey RESET test	2.035	0.2332	The model is specified correctly
Jarque-Bera	0.949743	0.621965	Residuals are normally distributed

Table 6 represents the ARDL estimation of macroeconomic variables' effects on Bangladesh's carbon dioxide emissions. The first column indicates a variable list with a short and long run and ECT and R-squared values. The second column is the coefficient, the third is the t-statistic, and the fourth is the p-value.

Table 6. ARDL estimation

Tabela 6. Oszacowanie ARDL

Variable	Coefficient	t-statistic	P-value
GDP	0.012750	1.651918	0.0080
ΔGDP	0.0041335	1.08105	0.3731
EC	59.43579	0.213097	0.0430
ΔEC	37.11698	0.546392	0.0592
TO	1083.440	0.641907	0.0027
ΔTO	811.5571	1.933413	0.0723
FDI	3.67E-05	1.280104	0.2000
ΔFDI	1.0E-05	2.171632	0.1463
ECT (–1)	–0.592714	–7.463023	0.0000
R-squared	0.8100		

According to the ARDL estimate findings, the environmental deterioration of Bangladesh is a result of its high GDP per capita. The results show that a 1% increase in GDP per capita has terrible effects on the environment and speeds up the deterioration of the environment by 0.012750% and 0.0041335% in the short-term and long-term, respectively. Bangladesh's economy remains in its infancy; thus, many conventional energy sources are used in an effort to achieve massive economic growth at the expense of resources that harm the environment and cause its deterioration environment. The observed outcomes were also found by previous studies. Mikhailov et al. (2018) looked at how economic growth affects the damage to the environment in Azerbaijan. According to them, environmental degradation is accelerated by Azerbaijan's econo-

mic expansion. Ang (2007) stated that economic growth in France positively impacts emissions. Saboori et al. (2012) said that economic growth is the primary reason for the worsening of the environmental conditions. They drew attention to the U-shaped relationship between economic expansion and emissions.

Wang et al. (2011), Arouri et al. (2012) and Khan et al. (2019a) found that economic growth has a positive effect on emissions. emissions are positively and significantly impacted by energy use. The energy consumption results that were looked at showed a 1% increase in carbon dioxide discharges controlled to 59.43579 kilotons and 37.11698 kilotons in the long term and the short term, respectively. Previous studies by Dogan and Seker (2016a) and Jebli et al. (2016) are in agreement with the results of the energy use study. Dogan and Seker (2016b) said that the use of energy in the European Union helps to stop the environmental conditions from worsening. Jebli et al. (2016) also found that energy consumption increases environmental degradation. Jebli and Youssef (2015) measured that energy use boosts environmental degradation. Khan et al. (2019b) examined and found that energy consumption significantly influences emissions.

Openness to trade significantly and positively carbon dioxide discharges. The studied trade openness results showed that in both the long term and the short term, a 1% increase lifts the carbon dioxide discharges up to 1,083.440 kilotons and 811.5571 kilotons, respectively. The observed trade openness results are similar to those of the earlier research Dogan and Seker (2016a). Dogan and Seker (2016b) said that the European Union's environment is improving because trade is more open than in other countries.

Even though a statistical link was found between emissions and FDI, the results showed that they are related in both the short and long term in a positive way but that CO_2 emissions are a small part of carbon dioxide discharges in Bangladesh. This means that the factories in Bangladesh that use FDI must use clean technologies or have low levels of FDI. The observed results of FDIs are similar to those of the earlier research (Cruz et al. 2022). Cruz et al. (2022) stated that FDI has a positive effect on emissions.

The acronym "ECT" stands for error correction terminology, which gauges adjustment speed. According to the examined data, ECT is statistically significant and negative. According to the ECT term, the long-term imbalance is corrected by 59.2714%. According to the R-squared value, the regressors used in this study account for 81% of regress and variability. The model is fit when a p-value for F-statistics is calculated.

The CUSUM test makes use of Figure 1. The CUSUM test is used to determine whether or not the coefficients are stable. The fact that the blue lines on both graphs are located below the red lines proves that the coefficients are stable. This finding follows the result reached by CUSUM, which states that the coefficients are stable at a level of significance of 5%. The investigated graphs show that the used models are reliable.

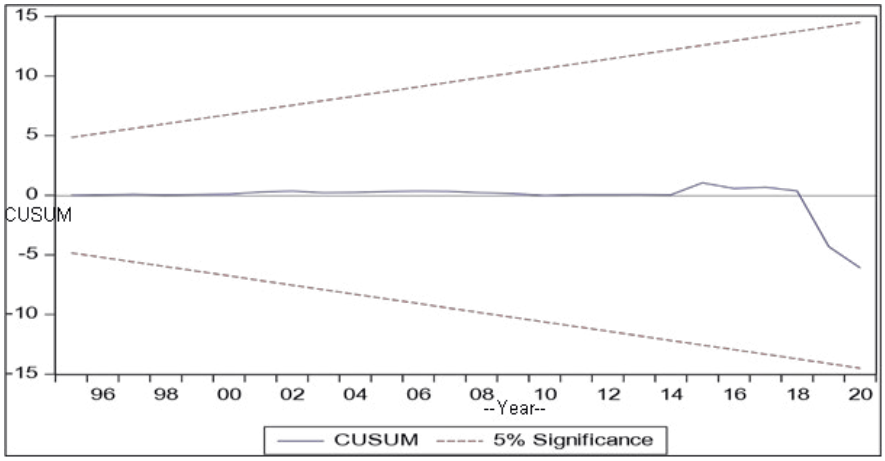

Fig. 1. CUSUM test results

Rys. 1. Wyniki testu CUSUM

Conclusion and recommendations

This study used the ARDL approach to explore the influence of selected macroeconomic factors on emissions in Bangladesh from 1991 to 2021. These factors included economic development, which was assessed by foreign direct investment (FDI), GDP per capita, energy consumption, and trade openness. This study observed that economic growth (GDP per capita), energy consumption, and trade openness boost the emissions in Bangladesh both in the short term and the long term. In addition, the statistical method was used to investigate the connection between emissions and FDI. The results showed that carbon dioxide emissions and FDI have a positive relationship in both the short and long run but that FDI is not a significant factor in carbon dioxide emissions in Bangladesh. The significant growth in GDP per capita from $293.16 in 1991 to $2,503.04 in 2021 in Bangladesh may be the reason behind this. Increased per capita GDP implies high production. When production levels are increased, there is a corresponding increase in the amount of waste and pollution produced. The rise in income implies that more natural resources were used resulting in increased emissions in Bangladesh.

Regarding energy use, it has been found that emissions in Bangladesh are strongly linked to it. Rising energy use will likely result in rising emissions. As a result of this, it is essential to reduce the use of fossil fuels and switch to renewable energy sources in a developing nation like Bangladesh, where industrialization is taking place. Additionally, the government has to make laws and strictly follow them if a factory releases too many emissions that hurt the environment. Trade contributes significantly to GDP, which is relevant to trade openness. However, such a lar-

ge trade means that goods and services must be moved around, which uses more energy and releases more .

If different countries have different levels of environmental regulation rigor, trade liberalization may cause some of them to specialize in activities that produce large amounts of pollution. Increased energy use and subsequent emissions are a byproduct of Bangladesh's economic progress. The ecosystem and human health are both significantly in danger from this. As a result of this, people in charge of making decisions must be careful to come up with energy and other economic policies that help the economy grow and have little to no effect on emissions. Economic growth will be boosted without causing environmental degradation by implementing policies that encourage the growth of the government and private sectors and create income possibilities with effective resource distribution and allocation.

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Musa Khan

Czynniki makroekonomiczne wpływające na emisje dwutlenku węgla w Bangladeszu: podejście ARDL

Streszczenie

W niniejszym artykule zbadano, wykorzystując dane z World Development Indicators, w jaki sposób w jaki sposób zmienne makroekonomiczne w Bangladeszu w latach 1991–2021 wpłynęły na emisje. W tym badaniu wykorzystano model autoregresyjnego rozproszonego opóźnienia (ARDL). Badanie wykazało, że PKB Bangladeszu na osobę, zużycie energii i otwartość handlu pozytywnie i znacząco wpływają zarówno na krótko-, jak i długoterminowe emisje dwutlenku węgla. Statystyki pokazują jednak, że bezpośrednie inwestycje zagraniczne nie wpływają na sytuację w Bangladeszu. To badanie mówi, że decydenci powinni skupić się na kształtowaniu polityki energetycznej i innych polityk gospodarczych, które pomagają gospodarce rozwijać się i mają znikomy wpływ na emisje. Ponadto wzrost gospodarczy nie będzie tak bardzo szkodził środowisku, jeśli wdrożona zostanie polityka zachęcająca do rozwoju zarówno sektora publicznego, jak i prywatnego, oraz ułatwiająca zarabianie pieniędzy poprzez dobrą alokację i dystrybucję zasobów. Wreszcie, to badanie sugeruje poszukiwanie dodatkowych zmiennych w celu poprawy dopasowania modelu i wykorzystanie innych technik szacowania w celu uzyskania bardziej wiarygodnych wyników.

Słowa kluczowe: czynniki makroekonomiczne, rozwój ekonomiczny, emisje, zużycie energii, podejście ARDL