Towards sustainable development goal 13: The impact of key factors on environmental degradation in China

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Abstract

In the current situation, it is crucial to look into the effects of increased international or global trade, financial development, foreign direct investment (FDI), energy consumption, and institutional advancement on the environment. This study focuses on how the aforementioned variables have caused environmental degradation in China. To achieve Goal 13 of the Sustainable Development Goals (SDGs), to promote climate action and safeguard life as part of sustainable development, this involves the analysis of time-series type of data sets from 1975 to 2021 and the use of the dynamic version of ARDL (Autoregressive Distributed Lag) cointegration or simulation model. The results show that foreign direct investments play a critical role in reducing carbon dioxide (CO2) emissions over the long term, but financial development, the volume of international trade, and the level of energy use or consumption contribute to an increase in environmental deterioration. Moreover, China's environmental degradation is decreased by high institutional quality. To accomplish the SDGs and reduce environmental degradation, it is essential to take into account how these elements interact and to adopt a holistic strategy that includes regulations, policies, and education. On the basis of our trustworthy findings, suggestions are made to keep the sustainable development.

Keywords: Foreign direct investment; energy use; institutional strength; financial development; global trade.

1. Introduction

China's rapid economic growth and vast population provide substantial environmental challenges. Among the most significant problems are that China's air quality is among the worst in the world, with high levels of particulate matter and pollutants including sulphur dioxide and nitrogen oxides (Chen et al. 2022). Transportation, industrial pollutants, and rising coal energy consumption are the causes of this. The pollution caused by industrial and agricultural operations, as well as urbanisation and groundwater contamination, is putting a great deal of pressure on China's water resources (Zhang, Sharp, and Xu 2019). China's soil is heavily contaminated with heavy metals and other contaminants as a result of industrialization and intensive cultivation, hurting human health and lowering crop production (Sarkodie et al. 2020; Zhou, Li, and Liu 2020). Because of logging, urbanisation, and land conversion for industrial and agricultural use, China's forest cover has drastically decreased. China is one of the major producers of greenhouse gas emissions worldwide, hence it is affected by the effects of climate change, such as increased frequency of extreme weather events, rising sea levels, and desertification (Sharif, Mishra, et al. 2020; Teng, Cox, and Chatziantoniou 2021). In addition, China lacks the infrastructure and regulations necessary to effectively handle the vast amount of trash it produces as a result of its large population and rapid economic growth (Ahmed et al. 2020).

The Chinese government has been addressing these problems by enforcing stronger pollution rules, funding renewable energy sources, and encouraging sustainable agriculture methods. Still, additional work is required to successfully address these issues. Air, water, noise, soil pollution, deforestation, and the loss of biodiversity are examples of different environmental deterioration that can have an impact on ecosystems and human health (Wang et al. 2019). According to estimates from the World Bank, China's environmental deterioration costs 3 to 4% of its annual gross domestic product (GDP), taking into account increased health care expenditures, decreased productivity, and a loss of biodiversity. Recent research (e.g., Muhammad et al. 2021) suggests that air pollution alone accounts for a sizeable fraction of the nation's 1.1 million annual deaths.

Interconnected factors such as the volume of global trade, financial development, degree of FDI abroad, and environmental deterioration can all have an impact on the environment (Ahmad et al. 2020). International commerce can boost economic development and prosperity, but it can also harm the environment by accelerating industrialization and resource extraction (Khan and Ozturk 2021). International commerce can, however, also promote the use of sustainable management practices and environmentally beneficial technologies (Fang, Gao, and Sun 2020). Financial development can raise investments in green projects like clean energy, but it can also hasten environmental damage due to rising industrialization and resource extraction (Destek and Sarkodie 2019). FDI can introduce new technologies and managerial techniques to boost resource extraction and industrialization while also improving environmental performance (Muhammad et al. 2021). In order to implement policies that promote sustainable development, such as green trade agreements, laws, and guidelines for FDI and investment in sustainable development projects, policymakers must take into account these potential trade-offs (Aluko, Ibrahim, and Vo 2022). Excessive energy use can result in higher emissions of greenhouse gases and other pollutants, which can have a negative impact on the environment (Pata and Caglar 2021). The effectiveness of a nation's political, economic, and legal institutions, known as institutional quality, can also have an impact on how energy is used and how to manage environmental degradation (Qiang and Jian 2020). Effective environmental rules and enforcement mechanisms are more likely to exist in nations with strong institutions, which can help offset the negative consequences of energy use or consumption on the quality of the environment (Le and Ozturk 2020). On the other hand, nations with weak institutions might struggle to control energy use and lessen its negative effects on the environment. While creating strategies to alleviate environmental deterioration, policymakers must take institutional quality and energy use into consideration (Uzar 2020). Implementing energy-efficient measures, encouraging the use of sustainable and clean energy sources, and funding organizations that can effectively control and monitor the level of energy use or consumption with its detrimental effects on the state of environmental degradation are a few examples of how to do this (Sun et al. 2022). To investigate the impact of both positive and negative types of shocks on the level of foreign direct investment, financial development, level of energy consumption, volume of international trade, and institutional quality on environmental degradation in China, we use time-series type of data sets and the dynamic version of ARDL cointegration or simulation model (Jordan and Philips 2018). According to our knowledge, this study is the first to investigate this topic in this specific situation. The most recent econometrics model was employed in this study instead of the standard time series models that were used in earlier research since it can visually express positive and negative shocks. Our research makes recommendations for meeting Sustainable Development Goal (SDG) number 13, which is to increase all nations' resilience and capacity to respond to natural disasters and hazards related to climate change. The report urges increasing financial and technological accessibility as well as fostering awareness and education in order to achieve this.

2. Literature Review

There could be a link between FDI and environmental degradation in a roundabout way, since FDI could encourage economic activities that are bad for the environment, like extracting resources or building factories (Jafri et al. 2022; Udemba, Magazzino, and Bekun 2020; S. Wang, Wang, and Sun 2020). Also, foreign companies that invest abroad might not have to follow the same environmental rules as domestic companies (Ayamba et al., 2020). This could lead to more pollution and other environmental damage. Yet, FDI can also promote environmental advancement by introducing new technologies and management strategies. Also, it is crucial to keep in mind that FDI may contribute more resources to the fight against environmental degradation (Ayamba et al. 2020). Azam, Khan, and Ozturk (2019) underline the role that FDI can play in enhancing environmental circumstances by bringing cutting-edge management techniques. Foreign firms may be more likely to develop stronger environmental policies as a result of international pressure and legislation. Furthermore, FDI can increase resources, such as financial and technological resources, to fight environmental deterioration, which can help decrease negative effects (Tang et al. 2020; Zameer et al. 2020).

On the other side, FDI inflows can reduce carbon dioxide emissions (An, Xu, and Liao 2021). When foreign companies invest in sophisticated emissions-reduction technologies or clean technology, this could happen (S. Wang et al. 2020). Moreover, international pressure and laws may increase the likelihood that foreign companies will adopt better environmental practices. To tackle climate change, FDI can also bring in new resources, such as financial and technical resources, which can help mitigate its harmful impacts (Yu, Yang, and Li 2019). Notably, the association between foreign direct investment (FDI) inflows and carbon dioxide emissions can vary based on a number of factors, including the industry or sector involved, local laws and regulations, and the environmental practices of the foreign corporations engaged (Ayamba et al. 2020).

Umar et al. (2020) say that financial development can help reduce carbon dioxide emissions by making rules and investments that support renewable energy and energy efficiency. Also, financial development can make more money available for things like investing in clean technologies and renewable energy sources that help fight climate change (Nasir, Huynh, and Tram, 2019).But, China's phenomenal economic growth and financial development over the past three decades have significantly increased carbon dioxide emissions (Shen et al., 2021). Yet, China has taken steps to solve the issue by implementing laws and regulations that promote clean energy and energy efficiency, making investments in renewable energy sources, and increasing funding for the creation of low-carbon technologies (Shahbaz et al. 2020). It should be highlighted that the relationship between financial development and carbon dioxide emissions in China depends on a variety of factors, including industry or sector specifics, the regulatory environment, and the environmental practices used by firms. This link can vary greatly depending on the contextual variables at play, as shown by earlier studies (Destek and Sarkodie 2019; R. Wang et al. 2020).

International trade and carbon dioxide emissions have a complex relationship. Foreign trade may encourage economic activities that raise carbon dioxide emissions, such as industrialization and resource extraction (Chen, Wang, and Zhong 2019; Li, Fang, and He 2019; Sharif, Godil, et al. 2020). Li, Fang, and He 2019, Chen, Wang, and Zhong 2019, Sharif, Godil, et al. 2020, and others This is due to the fact that many sectors that support global trade, such as manufacturing and energy production, are major producers of carbon emissions. Moreover, the transnational movement of commodities using fossil fuels adds to emissions (Nathaniel, Murshed, and Bassim 2021). (Bassim, Murshed, and Nathaniel 2021). Emissions of carbon dioxide can be reduced as a result of international trade. When nations buy greener, more energy-efficient technologies or focus on creating commodities with lower carbon emissions, this may occur (Chen et al. 2019, Pata and Caglar 2021). (Pata and Caglar, 2021; Chen et al., 2019). International commerce can also bring in more funds and technological resources to combat climate change, which can help lessen its harmful effects.

There is a strong link between carbon dioxide emissions and the use of both traditional and alternative sources of energy. Conventional energy sources like coal, oil, and natural gas contribute significantly to the emissions of carbon dioxide, but renewable energy sources like solar, wind, and hydropower have very little carbon emissions (Sharif, Mishra, et al. 2020). In 2020, Sharif, Mishra, et al. Notably, the relationship between global commerce and carbon dioxide emissions is complex and subject to change depending on a number of variables, such as the specific businesses or sectors involved, trade laws and regulations, and corporate environmental policies (Li et al. 2019). 2019 (Li et al.). International agreements that encourage collaboration among nations in addressing emissions and climate change, such as the Paris Agreement and the United Nations Framework Convention on Climate Change (UNFCCC), can also have an impact on international trade. Carbon dioxide emissions and the use of conventional and renewable energy sources have been found to be directly related.

The main sources of carbon dioxide emissions are conventional energy sources like coal, oil, and natural gas, while renewable energy sources like solar, wind, and hydropower produce no carbon dioxide emissions while they are in use (Sharif, Mishra, et al. 2020). In 2020, Sharif, Mishra, et al. The use of conventional energy sources causes more carbon dioxide to be released into the atmosphere. On the other hand, a rise in the use of renewable energy sources reduces carbon dioxide emissions. This is due to the fact that conventional energy sources are dependent on fossil fuels, which release a lot of carbon dioxide into the environment. On the other hand, when used, renewable energy sources don't produce any carbon emissions (Fan and Hao 2020).

2020's Fan and Hao Notably, a number of parties—including governments, organizations, and people—have been attempting to reduce carbon emissions by switching to renewable energy sources (Sarkodie et al. 2020). 2020 (Sarkodie et al.). These initiatives could take the form of regulations on conventional energy source emissions, carbon pricing, and subsidies for renewable energy. Moreover, developments in renewable energy technology, such as energy storage systems, solar, and wind power, have reduced the cost and increased the dependability of renewable energy, making it a more compelling alternative to conventional energy sources. (Li, Hong, and Wang 2020) 2020 (Li, Hong, and Wang). By establishing emission standards and sanctions for non-compliance, strong legal and institutional quality frameworks and efficient enforcement of environmental rules can help minimize emissions (Qiang and Jian 2020). In 2020, Qiang and Jian A strong political system and effective governance can also result in the creation and application of regulations that support clean energy and energy efficiency while discouraging carbon-intensive activities (Le and Ozturk 2020). 2020 (Le and Ozturk). On the other hand, low institutional quality can result in inefficient rules and enforcement as well as high emissions. Additionally, implementing policies supporting clean energy, energy efficiency, and discouraging carbon-intensive industries may be challenging for nations with low-quality institutional frameworks (Sun et al. 2019). 2019 (Sun et al.). Significantly, a variety of factors, including the specific businesses or sectors involved, the laws and regulations put in place, and the environmental practices of the organizations in question, can have an impact on the relationship between institutional quality and carbon dioxide emissions (Ahmad et al. 2022).

In order to solve these issues, the Chinese government has strengthened its pollution regulations, provided financing for renewable energy sources, and promoted sustainable agricultural practises. Even yet, more effort is needed to adequately solve these problems. Environmental deterioration in various forms, such as deforestation, noise pollution, soil pollution, air pollution, and biodiversity loss, can have an effect on ecosystems and human health (Wang et al. 2019). The World Bank has estimated that, after accounting for higher health care expenses, lower productivity, and a decline in biodiversity, China's environmental degradation costs 3 to 4% of its yearly gross domestic product (GDP). Recent studies (such as Muhammad et al. 2021) indicate that a sizable portion of the nation's 1.1 million annual deaths may be attributed to air pollution alone.

The amount of global trade, financial development, level of investment overseas, and environmental deterioration are all interconnected elements that may have an effect on the environment (Ahmad et al. 2020). Foreign trade can promote economic growth and prosperity, but by speeding industrialization and resource exploitation, it can also have a negative impact on the environment (Khan and Ozturk 2021). Foreign trade can, however, also encourage the deployment of ecologically friendly practices and technologies (Fang, Gao, and Sun 2020). Financial growth can increase investments in environmentally friendly initiatives like clean energy, but it can also speed up environmental harm because of growing industrialization and resource extraction (Destek and Sarkodie 2019).

3. Data Set and Application of Methodology

3.1 Data Source and Variables Description

In this research, we utilized extensive time-series type of data set from 1975 to 2021 for China to analyze the impact of level of foreign direct investment inflows, financial development, volume of international trade, level of energy consumption, and institutional quality on carbon dioxide emissions. In selecting variables, we followed previous literature. FDI inflow and environmental degradation in selected OECD countries were applied by (Apergis, Pinar, and Unlu 2022);

Financial development was used as an element for environmental degradation by (Zafar, Saud, and Hou 2019); Bhowmik et al. (2022) investigated the relation of trade with the carbon dioxide (CO_2) emissions. Besides, energy consumption is causing environmental degradation (Ozcan, Tzeremes, and Tzeremes 2020; Paramati, Alam, and Apergis 2018; Xia et al. 2022); institutional quality and environmental degradation are used by (Apergis and Ozturk 2015; Mehmood 2021). We employ the fundamental equation below to explore the correlation among the study variables.

$$CO_{2t} = \sigma_0 + \sigma_1 FDI_t + \sigma_2 FD_t + \sigma_3 TRD_t + \sigma_4 ENGC_t + \sigma_5 INSTQ_t + \varepsilon_t \quad (1)$$

Equation 1 incorporates various factors to analyze the relationship between the level of environmental degradation, represented by carbon dioxide emissions CO_{2t}, and other variables such as foreign direct investment inflow (FDI), financial development (FD), volume of international trade (TRD), level of energy consumption (ENGC), institutional quality (INSTQ), and the error term (ε_t). Table 1 presents a comprehensive description of each variable used in the research.

Table 1: Variables Description

Variables	Description	Source
Carbon Dioxide Emissions	Carbon dioxide emissions in metric tons	World Bank (2022)
FDI Inflow	Percent of GDP	World Bank (2022)
Financial Development	Domestic level credit to the private own businessesesor sector (Total % of GDP)	World Bank (2022)
Institutional Quality	PCA of Bureaucracy Quality; Corruption; Democratic Accountability; Government Stability; Law and Order	International Country Risk Guide (ICRG)
Energy Consumption	Fossil Fuel energy consumption (% of total)	World Bank (2022)

3.2 Econometric model and Methodology

3.2.1 For Unit Root Tests (URT)

Time-series analysis often incorporates the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. These two tests are frequently employed to ascertain the stationarity of a time series, which refers to the statistical properties of the series remaining constant over time. A stationary time series is a key assumption for many time series models, including ARIMA models and cointegration analysis. The ADF and PP tests utilize a regression equation as their foundation, which is as follows:

$$\Delta y \;=\; \beta 0 \;+\; \beta 1 t \;+\; \beta 2 \Delta y(t-1) + \ldots + \beta p \Delta y(t-p) \;+\; \varepsilon t;$$

where Δy denotes the first difference of the time series y, t represents a time trend, and ε_t is the error term. The null hypothesis of the ADF test posits that $\beta 1 \;=\; 0$, which implies that the time series contains a unit root and is non-stationary. Conversely, the alternative hypothesis suggests that $\beta 1 < 0$ means the time series is stationary. Conversely, the PP test is similar to the ADF test but adjusts the test statistic for serial correlation in the error term, which can often be found in time series data.

The ADF and PP tests can provide valuable information regarding the stationarity of a time series. The tests produce test statistics compared to the values of critical bounds from a significant and standard distribution, such as the standard normal distribution, to decide whether to accept or reject the selected or null hypothesis. If in the case of test statistic is found to be less than the values of critical bounds, then the null hypothesis is considered to be rejected, indicating that the time series type of data is stationary. Conversely, if the values of test statistic exceed the values in critical bounds, the null hypothesis cannot be rejected, suggesting that the time series is non-stationary.

3.2.2 Auto Regressive Distributed Lags (ARDL) approach

Autoregressive Distributed Lag (ARDL) version of cointegration models, as first developed by Pesaran et al. in 2001, are a type of econometric model that enables the analysis of the relationship between a dependent variable and one or more independent variables in a time series context. The primary advantage of ARDL models is their ability to capture both short- and long-run relationships between variables. This makes them suitable for analyzing dynamic systems that exhibit both short- and long-term impacts. These models combine autoregressive and distributed lag structures to capture the relationships between variables, with the autoregressive component accounting for the short-term dynamics and the distributed lag component representing the system's long-term behavior. Regression techniques are used to estimate the model. The findings are utilized to examine the influence of exogenous variables on the system and to predict future values of the variables based on past observations. ARDL models are commonly employed in various fields, such as economics and finance, to analyze time series data and forecast future trends and behaviors.

The ARDL model is superior to other time-series models in a number of ways. ARDL models, for instance, are useful for analyzing non-stationary and cointegrated data, which are prevalent in many time series. Data with a time-varying mean and variance are referred to as non-stationary data. On the other hand, data that are cointegrated have a long-term relationship even though they initially appear to be unrelated. ARDL models have the ability to handle cointegrated and non-stationary data utilizing first differences or error correction terms. Another advantage of ARDL models over others, such as autoregressive models, which only capture short-run relationships, or vector error correction models, which only capture long-run relationships, is that they can capture both short-run and long-run relationships between variables, making them useful for analyzing dynamic systems with both short-term and long-term impacts. In contrast to other models, including autoregressive integrated moving average (ARIMA) models, which demand the specification of the order of differencing and the number of lags, ARDL models do not impose a limit on the number of lags that can be included in the model. The ideal number of lags can also be determined by ARDL models using the data. Moreover, ARDL models are versatile and helpful for a variety of applications since they can manage a high number of variables and add exogenous factors with ease. As a result of its ability to support variables with a variety of integration orders, including either or both, the ARDL model is flexible.

3.2.3 Bounds test

Bounds F-statistics is a technique for assessing cointegration within the confines of time series analysis. Cointegration is a crucial concept in this field as it refers to the long-term relationship between two or more time series, which cannot be explained through a short-term relationship. The bounds F-statistics technique scrutinizes the hypothesis that the error correction term in a cointegrating regression is equivalent to zero. A cointegrating regression model represents the long-term relationship between time series by incorporating a term that portrays the deviation from the long-run relationship. Meanwhile, the error correction term captures the short-run dynamics of the system and reflects the swiftness with which the system reverts to the long-run relationship. The bounds F-statistics technique generates upper and lower bounds for the F-statistic of the hypothesis test. It evaluates the calculated F-statistic by comparing it to the bounds to determine if it falls within an acceptable or unacceptable range.

The null hypothesis proposes that the error correction term equals zero, while the alternative hypothesis contends otherwise. Should the calculated F-statistic be in the reject range, the null hypothesis is refuted, and we can conclude that the time series are cointegrated. This method is powerful because it accounts for residual serial correlation, a common issue with time series data. Various fields, including economics, finance, and engineering, utilize the bounds F-statistics technique to scrutinize long-term relationships between time series and forecast future trends and behaviors. During the estimation, we tested the null hypothesis of no long-term relationship, denoted as Ho = δ1= δn = 0, and the alternative hypothesis of a long-term relationship, denoted as H1 ≠ δ1 ≠ δn ≠ 0, employing the ARDL bounds testing estimation model:

$$\Delta Y_t = \sigma_0 + \sigma_1 X1_{t-i} + \sigma_2 Xn_{t-i} + \sum_{l=1}^{q} \theta_1 X1_{t-i} + \sum_{l=1}^{q} \theta_2 Xn_{t-i} + \varepsilon_t;$$

where, Δ represents the change and $\mathrm{t} - \mathrm{i}$ signifies the optimal lag selection based on the Akaike information criterion. The variables of interest in this study are represented by the parameters σ and θ.

After obtaining the Bounds test results, which suggest a potential long-term relationship among the variables examined, the subsequent phase will conduct dynamic long- and short-term ARDL simulations. These simulations consider the Bounds test outcomes and seek to investigate the variables' behavior over extended and abbreviated periods, respectively. The ARDL model will serve as the framework for the simulations. We will scrutinize both the long-term and short-term findings obtained from these simulations to facilitate a comparison between them.

3.2.4 ARDL Long and Short Run

An ARDL model combines autoregressive and distributed lag structures to capture the long- and short-term relationship between variables. The long-run relationship represents the system's behavior over a prolonged period, while the short-run relationship represents the behavior over a short period. The long-run relationship is captured through the cointegrating regression equation, which is formulated as follows:

$$y(t) = \alpha + \beta 1x1(t) + \beta 2x2(t) + \ldots + \beta kxk(t) + \varepsilon(t)$$

where $y(t)$ denotes dependent variable; $x1(t), x2(t), \ldots, xk(t)$, independent variables; α, constant term; $\beta 1, \beta 2, \ldots, \beta k$, coefficients of the independent variables; and $\varepsilon(t)$, the error term. The coefficients $\beta 1, \beta 2, \ldots, \beta k$ capture the long-run relationship between the variable being studied and the variables that are used to explain it. The short-run relationship in an ARDL model is captured by the error correction equation, which is conveyed as follows:

$$\Delta y(t) = \gamma 0 + \gamma 1 \Delta y(t-1) + \gamma 2 \varepsilon(t-1) + \varepsilon(t)$$

where $\Delta y(t)$ represents the first difference of the dependent variable; γ0, constant term' γ1, the coefficient of the lagged first difference of the dependent variable; γ2, the coefficient of the lagged error correction term; and ε(t), the error term. The coefficients γ1 and γ2 capture the short-run relationship between the dependent variable and the error correction term.

The long- and short-run relationships in an ARDL method are estimated simultaneously using regression techniques, and the model can be used to generate dynamic simulations of the system over time. These simulations can be used to analyze the impact of exogenous variables, such as policy interventions, on the system or to forecast future values of the variables based on past observations.

3.2.5 Dynamic ARDL Simulations

Dynamic ARDL simulation models are a powerful tool used in econometrics to investigate the complex interplay of multiple variables within a time series context. ARDL models represent a hybrid of the autoregressive (AR) and vector autoregression (VAR) models, offering both approaches' benefits while simultaneously providing a flexible and reliable analytical framework for time series analysis. In a Dynamic ARDL simulation model, the relationships between variables are captured through a combination of autoregressive and distributed lag structures. The model's autoregressive component captures the system's short-term dynamics, while the distributed lag component captures the long-term relationships among the variables. Besides, the parameters of a Dynamic ARDL simulation model are estimated using regression techniques, and the model can be used to generate dynamic simulations of the system over time. These simulations can be used to analyze the impact of exogenous variables, such as policy interventions, on the system or to forecast future values of the variables based on past observations. Dynamic ARDL simulation method is frequently employed across various disciplines, such as economics, finance, and engineering, to investigate the dynamic associations between variables and anticipate future patterns and behavior.

Following previous literature, we use the dynamic ARDL simulation model (Khan et al., 2019 a, b; Khan et al., 2020). Notably, the dynamic ARDL model has improved upon the standard ARDL model by fixing errors. It can simulate and predict positive and negative shock graphs, whereas traditional ARDL models can only do one or the other (Sarkodie et al., 2019). We used a dynamic ARDL simulation model with 5000 simulations for the vector of variables and multivariate normal distributions (Jordan & Philips 2018).

$$\Delta Y_t = \sigma_0 Y_{t-1} + \beta_1 X1_t + \sigma_1 \Delta X1_{t-1} + +\beta_2 Xn_t + \sigma_2 \Delta Xn_{t-1} + \varphi ECT_{t-1} + \varepsilon_t$$

The equation provided demonstrates the long- and short-run coefficients with $\beta\ and\ \sigma$, respectively, while the $ECTt-1$ equation is utilized to determine the rate of adjustment toward equilibrium aftershocks. The short-run outcomes are represented by γ. The ECT value varies between 0 and -1.

4. Data Analysis and Results with Discussions

4.1. Details and Description of Statistics

The outcomes with the description of considered statistics used to evaluate the mean, standard deviation, minimum, and maximum values of the analyzed series are presented in Table 2. The subsequent observations were made.

Table 2: Details and description of statistics

Name of variables	Obs	Mean	Std. Dev.	Min.	Max.
1. CO_2 Emissions-CO2	47	8.266	0.73	7.076	9.348
2. Foreign Direct Investment-FDI	47	2.38	1.754	-0.01	6.187
3. Financial Development-FD	47	101.379	39.17	34.917	200.346
4. Trade-T	47	32.958	15.887	8.385	64.479
5. Energy Consumption-EC	47	78.991	7.505	64.436	88.898
6. Institutional Quality-IQ	47	7.912	2.39	4	12

Source: Authors estimates.

According to Table 2, which presents the results of the description of statistics with the analysis, the value of mean for the carbon dioxide level of emissions for the China is 8.226, with a value of standard deviation of 0.73. The bounds of minimum and maximum values were 7.076 and 9.348, respectively. The value of mean for the flow of foreign direct investment is 2.38, with a standard deviation of 1.754. Moreover, we examined the financial development trend and found that the average value was 101 with a standard deviation of 39, with the highest and lowest values being 200 and 34, respectively. In addition, trade has a value for mean of 32 points with a value of standard deviation of 15.887 points. The mean energy consumption value is 78, while institutional quality has a mean value of 7.9.

Table 3: Matrix of correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)
1. CO2 Emissions-CO2	1					
2. Foreign Direct Investment-FDI	-0.444	1				
3. Financial Development-FD	0.538	0.357	1			
4. Trade-T	0.808	0.705	0.666	1		
5. Energy Consumption-EC	0.573	0.568	0.876	0.903	1	
6. Institutional Quality-IQ	-0.391	0.684	0.276	0.718	0.542	1

Source: Authors estimates.

4.2. Correlations matrix

In Table 4.2, we presented the results of the correlation matrix, which is a commonly used tool to analyze the degree of association between variables in a study. The findings imply a connection between environmental degradation in China and foreign direct investment (FDI). This suggests that a rise in FDI will probably hasten China's environmental degradation. Nonetheless, the findings indicate a negative relationship between FDI influx and China's carbon dioxide emissions. This suggests that a rise in FDI inflow will probably result in a reduction in China's carbon dioxide emissions.

The findings also show that in China, money supply (financial development) and ecological degradation are strongly correlated. This suggests that China's environment will probably get worse as financial development grows. Similar to commerce, it is discovered that energy use and trade both have a positive link with environmental degradation in China. The results do, however, also point to a negative relationship between China's environmental degradation and institutional quality. This indicates that a rise in institutional quality will probably slow China's environmental degradation.

Table 4: Unit Root Tests

Variable	Dickey-Fuller test		Phillips-Perron test	
	At Level (Diff.)	At 1st level diff.	At Level (Diff.)	At 1st level Diff.
CO2 Emissions	2.552(0.9991)	-2.744(0.0667)	1.422(0.9972)	-2.761(0.0641)
Foreign Direct Investment	-1.661(0.4511)	-5.774(0.0000)	-1.712(0.4248)	-5.722(0.0000)
Financial Development-FD	1.026(0.9945)	-5.503(0.0000)	1.139(0.9955)	-5.425(0.0000)
Trade-T	-1.472(0.5474)	-5.436(0.0000)	-1.510(0.5285)	-5.485(0.0000)
Energy Consumption-EC	-2.777(0.0617)	-3.786(0.0031)	-2.285(0.1767)	-3.750(0.0035)
Institutional Quality -IQ	-1.251(0.6511)	-5.488(0.0000)	-1.505(0.5310)	-5.495 (0.0000)

Source: Authors estimates.

4.3. Unit root tests

It is required to confirm that the series being utilised are stationary in order to apply the dynamic ARDL simulation model. The results of the ADF and PP tests are displayed in Table 4. The findings show that while the variables i.e., flow of foreign direct investment, financial development, volume of international trade, and institutional quality are not stationary at level $I(0)$, they are stationary at the first difference $I\ (I)$. This suggests that these variables can be included in the dynamic ARDL simulation model.

Table 5: VAR Lag form and Order Selection Criteria

Lag level	LogL	LR	FPE	AIC	SC	HQ
0	-1000.073	NA	1.06e+12	44.71435	44.95524	44.80415
1	-674.0890	550.5504	2714711.	31.82618	33.51240*	32.45478*
2	-629.4930	63.42547*	2019676.*	31.44413*	34.57568	32.61154
* Indicates the version of lag order and selection of the criterion						

Source: Authors estimates.

4.4. VAR Lag order selection

While establishing the dynamic ARDL simulations with the time series dataset, the results of the VAR Lag order selection are shown in table 4.4. These findings hold true for both self-controlled and experiment-controlled variables. To find the best lag for the dependent and independent variables, we used the selection criteria produced by the Schwarz Criterion and Hannan-Quinn information criterion. The outcomes show that for both variables, one lag is the best option. The dynamic ARDL simulation model used in this study used a lag of one for both the independent and dependent variables since the evidence backs up these conclusions.

Table 6: Cointegration Bounds Test

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Significance	$I(0)$	$I(1)$
			Asymptotic: n=1000	
F-statistic	15.32437	10%	3.18	3
K	5	5%	2.09	3.81
		2.5%	2.72	2.13
		1%	2.66	2.85
Actual Sample Size	46		Finite Sample: n=50	
		10%	1.229	2.214
		5%	3.607	1.089
		1%	2.513	3.089
			Finite Sample: n=45	
		10%	1.226	1.335
		5%	1.014	2.021
		1%	2.102	4.910

Source: Authors estimates.

4.5. Bounds test

The F-Bounds test was conducted in Table 6 to investigate the long-term relationship between the variables. The Bounds test results show that the calculated F-Statistic value is larger than the upper bound at 105, 5%, 2.5%, and 1%, suggesting cointegration among the study variables. Therefore, the dynamic ARDL simulation model was implemented based on these results.

Table 7: Long Run Dynamic version of ARDL Simulations

Variable	Coefficient	Std. Error	*t*-Statistic	Prob.
Foreign Direct Investment-FDI	-1.8295	0.7732	-2.3668	0.0223
Financial Development-FD	3.3721	1.0081	3.34524	0.0022
Trade-T	0.7701	0.2670	2.88427	0.0072
Energy Consumption-EC	2.7295	0.8142	3.3532	0.0022
Institutional Quality-IQ	-3.5921	0.7712	-4.6578	0.0001
C	0.2881	0.0477	6.03983	0.0000

Source: Authors estimates.

4.6. Long-run dynamic ARDL

Table 7 displays the outcomes of the ARDL simulation with a long-term dynamic approach. The evidence reveals a noteworthy and negative influence of foreign direct investment on environmental deterioration in China. Specifically, the findings demonstrate that a one percent rise in FDI inflows leads to a decrease in carbon dioxide emission. One of the objectives stated in the United Nations' SDGs is SDG 13, which emphasizes the significance of taking prompt measures to confront climate change and its repercussions to preserve life. The adverse impact of FDI inflows on environmental degradation in China could jeopardize the attainment of this SDG. As foreign companies often bring in their own technology and processes, which may not be as environmentally friendly as local ones, this can lead to increased pollution and environmental degradation in the host country.

Additionally, FDI often leads to the developing of new infrastructure and industries, which can also contribute to environmental degradation. Studies have found that foreign-invested firms have higher emissions and energy consumption than domestic firms in China. Therefore, a negative impact of FDI inflow on environmental degradation can be seen as a challenge for achieving SDG 13. FDI can bring in new technologies and management practices that can improve environmental performance and increase resource extraction and industrialization (Muhammad et al. 2021). Policymakers must consider these potential trade-offs and implement policies encouraging sustainable development, such as green trade agreements, regulations, and guidelines for FDI and investment in sustainable development projects (Aluko et al. 2022).

Based on the results, it can be deduced that the development of the financial sector has a favorable impact on environmental degradation in China. Moreover, a single percent escalation in financial development significantly influences the environment in China. Exerting the indirect message of SDG 8 (decent work and economic growth) goal, financial development, which encompasses enhanced accessibility to financial services and credit, can contribute positively to environmental degradation. One potential approach to achieve this is encouraging sustainable investment and financing, which can aid the transition toward a more sustainable, low-carbon economy. A case in point is financial institutions providing funds for renewable energy projects, energy-efficient measures, and sustainable transportation infrastructure.

This undertaking could lead to the reduction of greenhouse gas emissions and alleviate the consequences of climate change, aligning with the objectives of SDG 13. Furthermore, financial development could assist in implementing policies and regulations to reduce environmental degradation. For instance, financial institutions could provide funds for implementing environmental policies and monitoring and for the research and development of innovative technologies that could curtail pollution and safeguard natural resources. Additionally, financial development can help to promote a culture of sustainability among consumers and businesses, which can also contribute to reducing environmental degradation. Notably, financial development alone cannot solve the problem of environmental degradation; it should be part of a comprehensive approach that includes regulations, policies, and education. FDI inflows can reduce carbon dioxide emissions (An et al. 2021). This can happen when foreign companies invest in clean technology or more advanced, energy-efficient technologies that lower emissions (S. Wang et al. 2020).

Based on the long-term dynamic ARDL simulation model, the outcomes indicate a noteworthy and affirmative connection between international trade and environmental deterioration in China. Specifically, the evidence suggests that increased international trade corresponds to higher carbon dioxide emissions in China. The transfer of cleaner technologies and best practices from developed nations to China through international trade can aid in decreasing pollution and enhancing environmental performance. Additionally, international trade can stimulate economic growth, increasing government revenue and investment in environmental protection. Nonetheless, international trade could contribute to environmental degradation through amplified resource extraction and industrialization. Nevertheless, international trade can also facilitate the transfer of eco-friendly technologies and management practices (Fang et al. 2020).

Our findings reveal that energy consumption has a positive and statistically significant impact on environmental degradation in China. The study concludes that the augmentation of traditional energy consumption results in environmental degradation issues in China. Moreover, a lack of access to energy could prompt the use of unsustainable and conventional energy generation methods, such as burning wood or charcoal, which could result in deforestation, habitat loss, and air pollution. It is vital to promote the adoption of renewable energy sources, enhance the energy efficiency, regulate fossil fuel usage, and promote cleaner technologies to attain SDG 7 (affordable and clean energy) while minimizing environmental degradation.

Furthermore, energy access should be provided sustainably, considering the environmental, social, and economic impacts. Increasing the usage of traditional energy sources will result in increased carbon dioxide emissions. Conversely, an increase in adopting renewable energy sources will lead to a decline in carbon dioxide emissions. This is due to traditional energy sources relying on fossil fuel combustion, which generates significant amounts of carbon dioxide into the atmosphere. Conversely, renewable energy sources do not release carbon emissions during operation (Fan and Hao 2020).

Moreover, improving institutional quality is crucial for reducing environmental deterioration in China. By implementing environmental protection laws, policies, and regulations as well as providing oversight and monitoring of activities that could lead to environmental damage, strong and effective institutions can aid in promoting sustainable development and safeguarding the environment. Adopting such measures can help achieve SDGs 14 and 15, as well as SDG 13, which calls for rapid action to prevent climate change and its repercussions. SDG 15 intends to protect, restore, and promote the sustainable use of terrestrial ecosystems, forests, biodiversity, and wetlands. SDG 14 promotes the sustainable use of oceans, seas, and marine resources for sustainable development. Significantly, a number of variables, such as the industries or sectors involved, current policies and regulations, and business environmental practices, might affect the relationship between institutional quality and carbon dioxide emissions (Ahmad et al. 2022).

Table 8: Short Run Dynamic version of ARDL Simulations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Foreign Direct Investment-FDI	0.3848	0.2187	1.7595	0.0853
Financial Development-FD	1.9601	0.7201	2.7220	0.0092
Trade-T	2.2979	0.2181	10.5360	0.0000
Energy Consumption-EC	2.0953	0.8241	2.5425	0.0145
Institutional Quality-IQ	2.9488	0.8209	3.5922	0.0008
CointEq (-1)	-1.3877	0.3487	-3.9796	0.0002
R-Squared	0.78			
Breusch-Pagan or Cook-Weisberg test	Prob > chi2 = 0.7609			
Durbin's alternative test for autocorrelation	0.2591			
Breusch Godfrey [LM] Value	0.6792			
Ramsey [RESET] Value	0.6394			
Jarque Berra Value	0.8396			

Source: Authors estimates.

4.7. Short-run dynamic ARDL

Several studies have reported that foreign firms have greater energy consumption and emissions than domestic firms in China. This negative impact of FDI on the environment can be seen as a hurdle to achieving SDG 13, which requires immediate action to fight climate change and its effects. However, the results of this study reveal a positive influence of financial development on environmental degradation. Financial development can help enforce regulations and policies aimed at reducing environmental damage. Additionally, financial development can help to promote a culture of sustainability among consumers and businesses, which can also contribute to reducing environmental degradation.

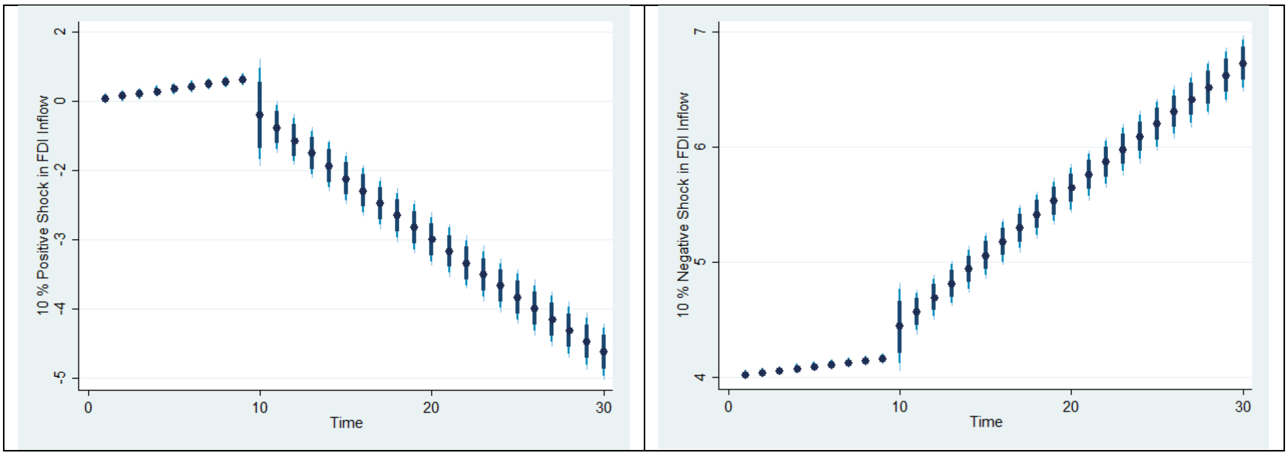
However, financial development alone cannot solve the problem of environmental degradation, and it should be part of a comprehensive approach that includes regulations, policies, and education. International trade can contribute to increased pollution and environmental degradation by encouraging the growth of industries that are heavy polluters, such as manufacturing and energy production. Additionally, environmental degradation can be caused by the shipping of goods and resource extraction. However, international trade can also positively impact environmental degradation by promoting the transfer of cleaner technologies and best practices from developed countries to China, as our study has shown. This can result in a pollution reduction and an improvement in environmental performance. Moreover, energy consumption can significantly affect environmental degradation in the short term in China. Increasing access to energy using fossil fuels (e.g., coal and oil) can lead to increased greenhouse gas emissions and air pollution, contributing to environmental degradation. Weak and ineffective institutions can lead to a lack of enforcement of environmental regulations, policies, and laws, resulting in increased pollution and environmental degradation.

Notably, the R-square value suggests that 78% of the variation observed in environmental degradation can be accounted for by the factors included in the analysis; Breusch Pagan's findings demonstrate that no heteroskedasticity exists. Durbin and Breusch, Godfrey LM tests, show no autocorrelation exists, and Ramsey RESET indicates no misspecification exits in the regression model. Jarque Berra's findings demonstrate that the data used is normal.

4.8. Dynamic ARDL Simulation Graphs

The following figures demonstrate the impact of positive and negative both types of changes for independent variables of the dynamic version of ARDL simulation model on the dependent variable.

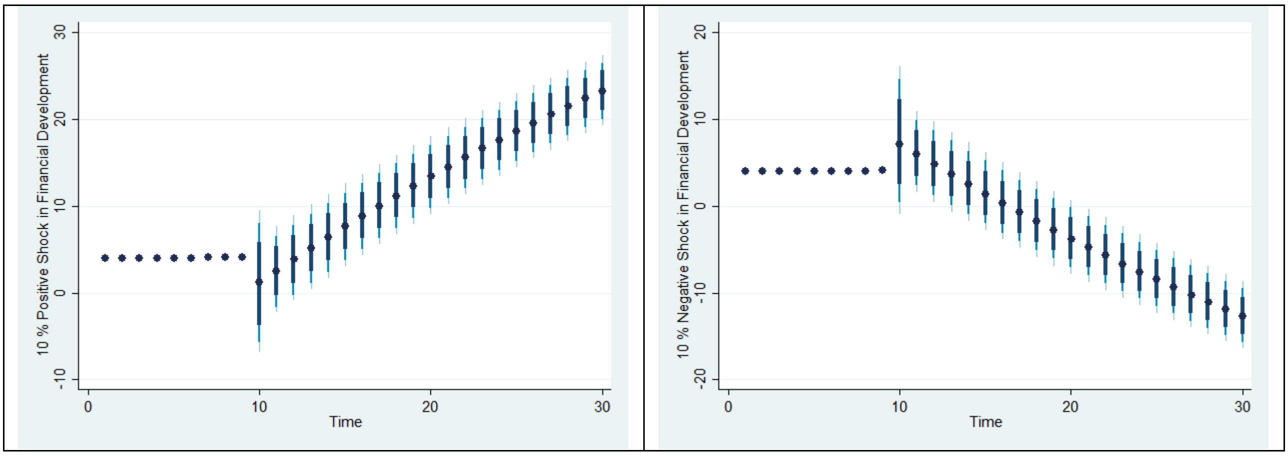
Figure 1: Positive and Negative Shocks in FDI



Source: Authors estimates.

Specifically, Figure 1 depicts the effects of a 10 percent positive and negative shock on environmental degradation in China resulting from foreign direct investment inflow. The outcomes indicate that the positive shock causes a decline in environmental degradation, while the negative shock positively impacts environmental degradation.

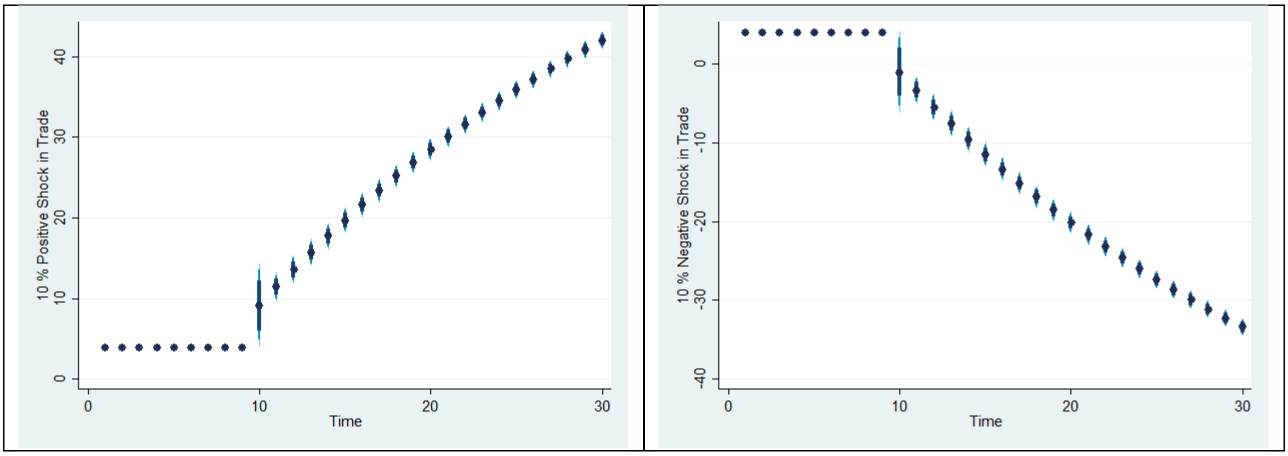
Figure 2: Positive and Negative Shocks in Financial Development



Source: Authors estimates.

Figure 2 presents the effects of positive and negative shocks on environmental degradation resulting from changes in financial development are displayed. The data on the graph indicate that an increase in financial development corresponds to a rise in environmental degradation levels in China. Conversely, a decrease in financial development leads to a reduction in environmental degradation.

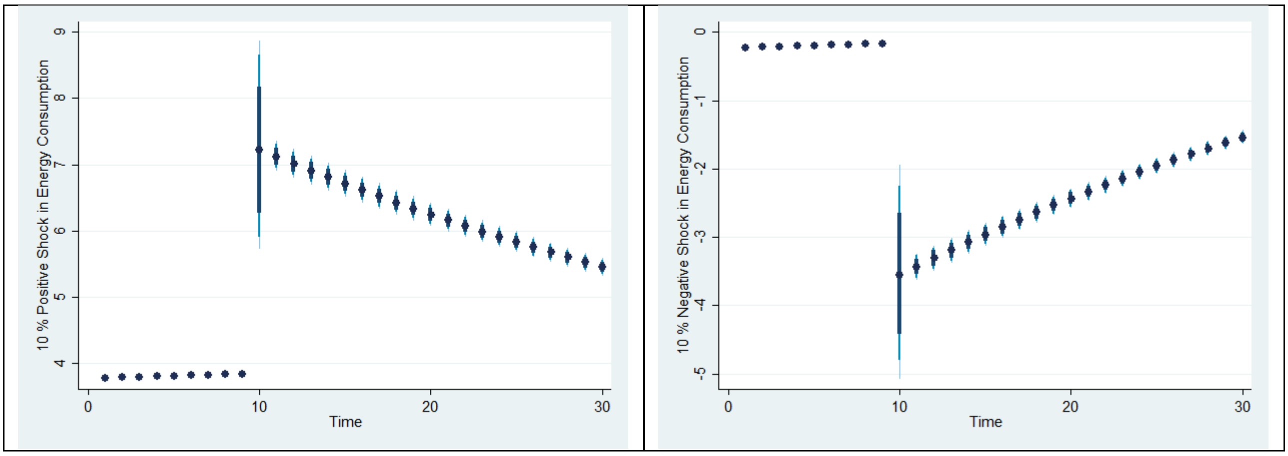
Figure 3: Positive and Negative Shocks in Trade



Source: Authors estimates.

Figure 3 displays the positive and negative shocks that can occur in international trade, as well as the impact that this can have on the degradation of the environment. Positive shocks provide evidence that trade is responsible for environmental degradation in China. Conversely, the presence of negative shocks in international trade promotes the mitigation of environmental degradation.

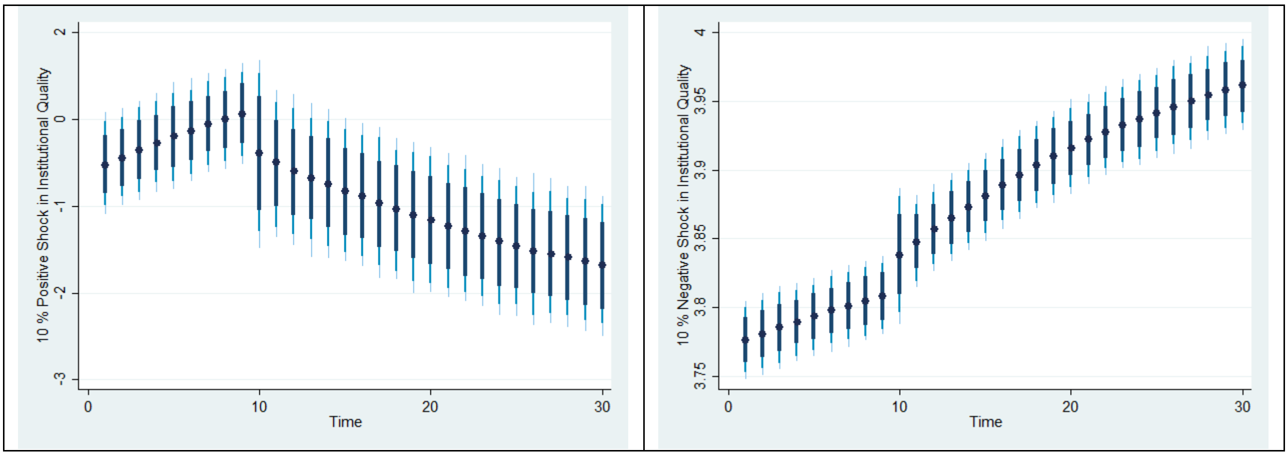
Figure 4: Positive and Negative Shocks in Energy Use or Consumption



Source: Authors estimates.

In Figure 4, we can observe the effects of positive and negative shocks on environmental degradation in China. Positive shocks cause an increase in environmental degradation, whereas negative shocks lead to a decrease in environmental degradation.

Figure 5: Positive and Negative Shocks in Institutional Quality



Source: Authors estimates.

In Figure 5, we can find the effects of positive and negative shocks in institutional quality on environmental degradation in China. As the graph indicates, a positive shock in institutional quality hurts environmental degradation, whereas a negative shock in institutional quality has a positive impact.

5. Conclusions and Recommendations

In order to address SDG 13 of the sustainable development agenda, the current study uses a time series type of data set from 1975 to 2021 to justify this study with the impact of various factors, including the volume of international trade, financial development, level of foreign direct investment, level of energy consumption, and institutional quality on environmental degradation in China. Beginning with unit root tests like the ADF and PP tests, we evaluate the necessary condition of stationarity with all the factors taken into consideration. We discover that the variables are stationary at both the level and the first difference, demonstrating the viability of the dynamic ARDL simulation model. Also, we run the Bounds test to see if there is cointegration between all of the study's variables. The results point to cointegration between all of the variables that were taken into consideration.

The main findings show that a rise in foreign direct investment has a long-term beneficial impact on lowering carbon dioxide emissions. Environmental degradation is accelerated by growth in finance, global trade, and energy consumption. Additionally, environmental degradation in China is negatively correlated with institutional quality. We make a few policy ideas to help China achieve the SDGs and deal with the problem of environmental deterioration. Set high goals for increasing the share of renewable energy in the entire energy mix and put rules in place to restrict carbon emissions from conventional energy sources in order to first adopt policies that encourage clean energy and energy efficiency. Provide a solid legal foundation for environmental protection by adopting and enforcing rules to safeguard biodiversity, clean air and water, and other aspects of the environment. Encourage recycling and trash reduction, as well as rules to lessen the environmental effect of goods and services, to promote sustainable consumption and production habits.

Fourth, invest in sustainable infrastructure. China may finance green buildings, bike-sharing programmed, and other sustainable infrastructure initiatives, as well as sustainable transportation infrastructure. Promote sustainable farming practices, such as agroforestry and conservation agriculture, to safeguard soil, water, and biodiversity resources. This is the fifth strategy. Sixth, cooperate with other nations and international organizations: China may do this to address international environmental issues like climate change and advance sustainable development. Importantly, these suggestions are not all-inclusive and could vary based on the situation and current events in China. Furthermore, it is crucial to remember that achieving the SDGs calls for a comprehensive strategy including numerous sectors and actors as well as a long-term outlook.

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