JOURNAL FOR SOCIAL SCIENCE STUDIES
An International Peer-Reviewed Open Access Journal

ISSN (Online): 3006-2071 | ISSN (Print): 3006-2063
Volume 4 • Issue 6 • October 2026

ANALYZING THE RELATIONSHIP BETWEEN POLLUTION AGGRAVATION AND INCOME INEQUALITY: A COMPARATIVE STUDY OF CHINA AND PAKISTAN

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DOI: https://doi.org/10.5281/zenodo.23662096

Keywords
Income inequality, Environmental aggravation, ADF, ARDL, VECM, Pakistan, China.

Article History
Received: *25 June 2026*
Accepted: *16 September 2026*
Published: *26 October 2026*

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Abstract

Income inequality is considered as an undesired situation among the fast-growing economies worldwide. Various countries have been focusing on the reduction of this particular economic issue around the globe. Pakistan and China are currently developing economies and they are unable to afford such type of economic restrictions for their fast development. In this regard, the study highlights the possible historical role of environmental aggravation in addressing this particular issue. The research focuses on the effects of environmental aggravation on income inequality in Pakistan as well as China. The research used yearly time series data during 1990 to 2022 to capture the desired outcomes. Multiple analysis strategies have been utilized i.e. ADF analysis, ARDL analysis, VECM analysis and multiple diagnostic analyses for getting the main objective. Findings of ADF analysis revealed stationary level of all the factors at 1st difference except population. ARDL as well as VECM analyses highlight positive impacts of environmental aggravation, inflation and population on income inequality in both research areas. Therefore, trade openness and capital formation may be used to decline the income inequality. The multiple diagnostic analyses found stability and reliability in the coefficients utilized in the current research report. The analyst suggests significance reduction in CO_2 emissions, inflation rate and population to control the increasing income inequality in the research areas. Trade openness and capital formation may be elevated for the reduction of unequal income distribution in the regions.

INTRODUCTION

Background of the Study

Income inequality remains a major development challenge because the benefits of economic growth are not always shared evenly across households. At the same time, economic expansion, industrial activity, transport and fossil-fuel use can increase environmental pressure. These challenges may reinforce each other: lower-income households often have fewer resources to avoid polluted locations, pay for healthcare, or recover from illness and lost working time.

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Pollution can therefore affect not only health and environmental quality but also economic opportunity.

China and Pakistan provide useful comparative cases because both have experienced economic and structural change, but their development paths, industrial profiles and policy settings differ. Examining the two countries together can help identify whether the relationship between pollution and income inequality is similar across different economic contexts.

Income Inequality Trends, 1990–2022

The thesis figures indicate that Pakistan's Gini coefficient fluctuated over the period rather than following a consistent upward or downward path. China's Gini series increased substantially from the early 1990s, reached a higher level in the 2000s, and then declined in later years. The comparison figure shows higher inequality values for China than Pakistan at the selected years presented in the thesis. These descriptive patterns provide context for the econometric analysis; they do not by themselves establish that pollution caused changes in inequality.



Figure 1: Income inequality in Pakistan (1990-2022)

Air Pollution and Unequal Economic Outcomes

Air pollution is associated with respiratory and cardiovascular illness and may reduce work capacity, school attendance and productivity. Medical spending and missed work can place a greater burden on low-income households, which typically have fewer savings and less access to high-quality healthcare or cleaner residential areas. Over time, these differences may contribute to unequal earnings and opportunities across social groups.

The effects are not limited to health. Pollution can damage crops and ecosystems, raise healthcare costs and reduce labour productivity. Rapid urbanization and industrialization can intensify these pressures where monitoring and enforcement do not keep pace with emissions. However, the scale and direction of the pollution–inequality relationship must be assessed empirically rather than assumed.

Research Problem and Objectives

Although environmental degradation and income distribution have each received considerable attention, comparable evidence for China and Pakistan remains limited. This study addresses the issue using annual time-series data from 1990 to 2022. Income inequality is measured by the Gini coefficient, while carbon dioxide emissions represent pollution aggravation. The analysis also considers inflation, trade openness, gross capital

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formation and population, as specified in the thesis.

The study has three objectives: (1) to identify the main determinants of income inequality in China and Pakistan; (2) to examine the relationship and causal direction between carbon emissions and income inequality; and (3) to compare the results across the two countries.

Method and Contribution

The thesis uses the Augmented Dickey–Fuller (ADF) unit-root test, the Autoregressive Distributed Lag (ARDL) approach, the Vector Error Correction Model (VECM), and diagnostic tests. These methods are used to examine the time-series properties of the data, short-run dynamics and longer-run relationships. The comparative design aims to provide evidence that can inform policies linking cleaner production, public health protection and more inclusive development.

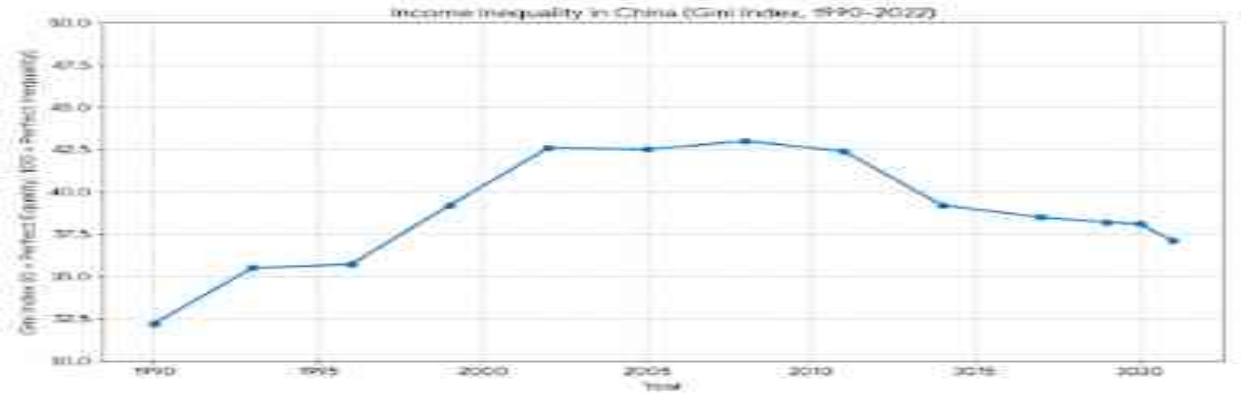


Figure 2: Income inequality in China (1990-2022)

Significance

The study brings environmental and distributional concerns into one empirical framework. Its findings may help policymakers consider emission controls, cleaner energy, and effective air-quality monitoring and targeted support for communities that face higher pollution exposure. Such measures should be designed alongside economic policies that support employment, investment and fairer access to opportunities.

LITERATURE REVIEW

2.1 Review of Literature

The environmental consequences of carbon emissions are conventionally understood in terms of ecological degradation, but their socioeconomic dimensions particularly their contribution to widening inequality warrant equal attention. To examine the intersection of these two phenomena, this study considers multiple environmental indicators, including carbon emissions, ambient air pollution, and water quality.

Other people have found things when they studied this topic. For example some people found that when income inequality is high environmental problems also get worse in countries that are still developing (Yang et al, 2011). They also found that when there are factories and cities in China it makes air pollution worse for some people, which can make health problems worse (Hao et al, 2015). Some people looked at how income affects carbon emissions in China. Found that when we reduce

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income inequality, carbon emissions also go down (Golley and Meng 2012).

The connection between problems, health and income inequality has not been studied much. Most people think that when you have money you are less likely to be affected by environmental problems (Graff Zivin & Neidell 2013). This is because rich people can work in places and have good healthcare (Picatoste et al, 2018).. Poor people often live near factories, which can make them sick (Ebenstein et al, 2016). This can make health problems worse for people (Forastiere et al 2007).

In developing countries people are getting sick because of pollution and it is making it hard for them to work and be healthy (Khan et al, 2019a; Khan et al, 2020). Some people found that when countries grow economically they can make environmental problems worse if they use a lot of energy (Khan et al, 2019b). This is because they often use energy sources they're bad for the environment. Other people found that when income inequality is high environmental problems also get worse (Carrington, 2024; Khan et al, 2009).

Some people in China have found that air pollution can make people sick. It is getting worse over time (Chen et al, 2013). They also found that environmental problems are worse in some parts of China especially where there are a lot of factories and cities (Hao et al, 2015). This can exacerbate health burdens for populations residing in affected areas (Azimi et al., 2019). However, the relationship between income and environmental outcomes is not always straightforward, as some scholars have noted (Jiao et al., 2018).

The theoretical literature presents competing perspectives on how income inequality shapes environmental quality. One strand of scholarship posits that widening income disparities intensify environmental degradation (Gilfoyle, 2023). This argument rests on the premise that concentrated economic power enables affluent groups to influence policy decisions in ways that externalize environmental costs onto marginalized communities.

Other people think that when income inequality is high it can make it hard for people to work together to protect the environment (Carrington, 2024).

Some people have found that when we reduce income inequality it can help people work together to protect the environment (Magnani et al, 2000). They think that when people have equal incomes they are more likely to care about the environment and want to protect it. Other people think that the connection between income and the environment is more complicated and it depends on how people behave and what they buy (Heerink et al, 2001; Berthe & Elie 2015). They think that when people have money they may buy more things that are bad for the environment but they may also be able to afford things that are good for the environment.

People with incomes try to keep up with the spending habits of people with higher incomes and end up spending more than they can afford. This leads to a demand for luxury goods, which in turn causes more environmental pollution, like the increase in demand for cars.

Additionally when people work hours in societies where there is a big income gap it leads to more energy being used and more CO_2 is released. This is because people are consuming more and the economy is growing.

When we look at how financial instability affects the environment the research can be divided into two groups. One group says that the financial sector can help reduce damage. It can do this by encouraging growth while also reducing CO_2 emissions by investing more in sustainable initiatives.

However another group of researchers argues that a stable financial sector can actually accelerate decline. An advanced financial system can make it easier for people to get credit and buy luxury items, which leads to pollution. Progress in the stock market also allows companies to get

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financing at a cost and increase production, which ultimately leads to more energy consumption and CO_2 emissions.

Research in this area has used environmental indicators, such as biodiversity, water and soil contamination CO_2 emissions and nitrogen oxides. The lack of data on income distribution has led to the use of the GINI coefficient in academic studies. The scope of research varies with some studies focusing on countries and others comparing multiple countries.

The second group of studies looks at the relationship between instability and environmental quality. This area of research is relatively new. There is limited empirical evidence. Some studies have found that financial instability can lead to increased CO_2 emissions while others have found that financial crises can actually reduce CO_2 emissions.

Despite the growing body of literature on inequality and environmental outcomes, further research is required to fully elucidate the relationship between economic instability and environmental quality. The determinants of rising income inequality are themselves complex and multifaceted, encompassing structural, institutional, and policy-related factors that vary considerably across national contexts. Some researchers have argued that economic restructuring, technological changes and globalization are the drivers of income inequality.

Researchers like Ching and others found that the impact of income inequality on emissions really depends on income. For example Baek and Gweisah used data from households and found that as inequality goes down so does pollution. Golo and others also noted that when income is not evenly distributed it can lead to CO_2 emissions. Alam and others discovered that urbanization is directly linked to emissions.

The COVID-19 pandemic has also shown that income inequality can have consequences. Takin and others found that countries with economic inequality had more deaths from COVID-19. This is because poor people are more likely to have health problems and less access to healthcare. Belaïd and others well as Clercq and Dutt and Baloch and others have also found that rich countries may have better data and faster reporting of deaths, which can affect the numbers.

Pattison and others found that rich communities can avoid the consequences of their carbon-activities by moving them to poor areas. Gawande and others showed that hazardous waste sites are often located in neighborhoods. Mutangadura and others have found that as income rises environmental quality first gets worse and then gets better. This is known as the Environmental Kuznets Curve. Nugraha and Lewis found this pattern in 12 out of 14 air and water quality factors they studied.

In countries like Pakistan and China the relationship between income inequality, economic development and environmental degradation is complex. There is not research on this topic and the existing studies have inconclusive results. This study aims to fill this gap by looking at the relationship between carbon emissions and income inequality in both countries.

The study found that income and marginalized groups tend to produce more carbon emissions mainly due to rapid population growth and urbanization. In Pakistan this research is particularly important because it looks at the links between income inequality, population density, economic growth, urbanization and carbon emissions.

2.2 Research Hypotheses

Hypothesis 1:

- **H_0 (Null):** Carbon emissions have no significant influence on income inequality.
- **H_1 (Alternative):** Carbon emissions have a significant influence on income inequality.

Hypothesis 2:

- **H_0 (Null):** There is no significant difference between China and Pakistan in the effect of carbon emissions on income inequality.

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- **H_1 (Alternative):** Carbon emissions significantly worsen income inequality, with the effect differing between China and Pakistan.

2.3 Research Questions

This study seeks to answer the following research questions:

RQ1. What are the main factors that drive income inequality in Pakistan and China?

RQ2. What is the direction of the relationship between carbon emissions and income inequality?

RQ3. How do China and Pakistan compare in terms of the relationship between carbon emissions and income inequality?

2.4 Research Gap

There is a research gap in this area because no study has directly compared China and Pakistan to see if carbon emissions increase income inequality or to determine the direction of the causal link between them. This study aims to address this gap by comparing the two countries and focusing on the relationship, between carbon emissions and income inequality.

THEORETICAL FRAME AND ECONOMETRIC METHODOLOGY

1. Conceptual Framework

This study examines the relationship between income inequality and its economic and environmental determinants in Pakistan and China. The Gini coefficient is used as the dependent variable, while carbon dioxide emissions, inflation, trade openness, population, and gross capital formation are the independent variables. These factors represent environmental pressure and important macroeconomic and demographic conditions that may influence income distribution. Their effects may differ across countries depending on economic structures, investment patterns, and government policies.

2. Data and Variables

The study uses annual time-series data covering 1990–2022. Data are primarily obtained from the World Development Indicators database of the World Bank. The Gini coefficient measures income inequality, while CO_2 emissions represent environmental aggravation. Inflation measures changes in the general price level, trade openness reflects international trade integration, population represents demographic size, and gross capital formation captures investment in productive assets.

Table 1.1: Description of Variables

Variables	Symbol	Description	Source
Income inequality	GINI	GINI Coefficient	World Bank
Environmental Aggravation	CO_2	Carbon Emissions	
Inflation	INF	CPI Inflation	
Trade Openness	OPEN	Imports + Exports (million USD constant 2015)	
Population	POP	Number of persons (million)	

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Capital Formation	KF	Gross capital formation (million USD constant 2015)	

Source: World Bank (2026)

3. Econometric models

The following linear empirical model has been specified to underpin the econometric analysis and examine the relationships between income inequality and its selected determinants. The model is expressed as:

$$\log GINI_t = \beta_0 + \beta_1 \log CO_{2t} + \beta_2 \log INF_t + \beta_3 \log OPEN_t + \beta_4 \log POP_t + \beta_5 \log KF_t + \mu_t \quad \text{(Eq .1)}$$

Here, t represents the year, β_0 is the intercept, β_1 to β_5 are the estimated parameters, and μ_t is the error term. The model examines how changes in the explanatory variables are associated with income inequality. Logarithmic transformations are applied where appropriate and where the variables have positive values.

4. Econometric Methodology

The Augmented Dickey–Fuller (ADF) test is used to examine the stationarity of the time-series variables. It determines whether variables are stationary at level or become stationary after first differencing. This step is important because non-stationary data may produce misleading regression results.

The Autoregressive Distributed Lag (ARDL) model is employed to examine short-run dynamics and long-run relationships. The ARDL bounds test determines whether a long-run relationship exists among the variables. If the calculated F-statistic exceeds the upper critical bound, the null hypothesis of no long-run relationship is rejected. If it falls below the lower bound, the null hypothesis is not rejected; a value between the bounds produces an inconclusive result. The ARDL approach is suitable for mixtures of I (0) and I (1) variables, provided that none is I(2).

Where the Cointegration results support its use, an error-correction representation can help explain short-run adjustments towards a long-run relationship. Any additional VECM analysis should be consistent with the variables' integration properties and the Cointegration method used.

5. Diagnostic Tests and Methodological Flow

The research follows a systematic procedure: data collection, variable preparation, ADF testing, model estimation, bounds testing, and diagnostic analysis. Diagnostic tests may examine serial correlation, Heteroscedasticity, residual normality, and model stability. These tests help assess the reliability of the estimated results. Each test's null hypothesis and decision rule should be reported clearly.

6. Research Contribution

This methodology provides a comparative framework for examining income inequality in Pakistan and China over 1990–2022. By considering environmental pressure alongside inflation, trade openness, population, and capital formation, the study aims to generate evidence that can support policies promoting environmental sustainability and more inclusive economic development.

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7. Flowchart of Methodology

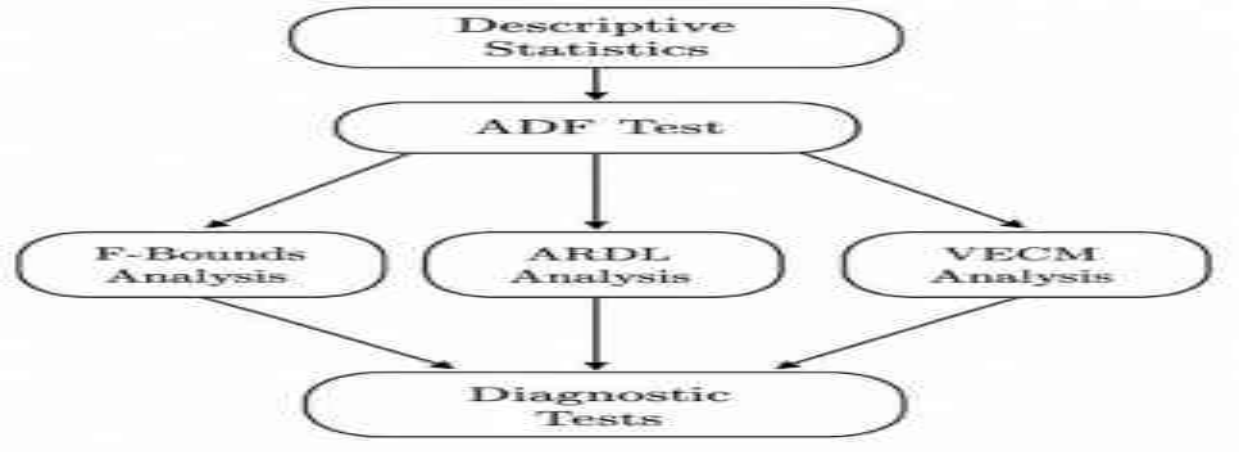


Figure 1.2: Flowchart of Methodology

The flowchart outlines the sequential stages of the study's methodology, beginning with the collection and preparation of data from the World Development Indicators database, followed by unit root (ADF) testing to establish the stationarity properties of the variables, then estimation of the relationships among the variables using the ARDL framework, and concluding with diagnostic testing to confirm the reliability of the model's results.

RESULTS AND DISCUSSION

4.1 Descriptive Statistics (Pakistan)

At 1st stage, fundamental information about analyzed data is necessary which can identify issues like outlier. Following table highlights the descriptive states of the selected factors for Pakistan. These states convey fundamental characteristics of the data and facilitate an understanding of the primary features of the variables. Table supplies essential information on the data. The mean represents average of the data. Median is the value that partitions lower and upper halves of data; it typically occupies the midpoint, necessitating that the data be arranged in ascending or descending sequence. Insights of this research report in case of the research area of Pakistan suggest the absence of outliers in the data, as no substantial discrepancy exists between the mean and median values of the variables. An outlier refers to a data point that exhibits a notably large and disproportionate distance from the mean of the dataset, often standing apart from the general pattern exhibited by the majority of observations. Such extreme values can arise due to various reasons, including measurement errors, data entry mistakes, or genuine but unusual occurrences within the population under study. The presence of outliers can exert a substantial influence on statistical analyses, potentially skewing results, distorting parameter estimates, and undermining the reliability of inferences drawn from the data. To assess the degree of dispersion or spread of data points around the mean, the standard deviation is employed as a widely used measure of variability. A high standard deviation indicates that the data points are widely scattered from the mean, suggesting greater heterogeneity within the dataset, whereas a low standard deviation signifies that observations tend to cluster closely around the mean, reflecting greater consistency. Together, the identification of outliers and the computation of standard deviation serve as

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essential diagnostic tools for evaluating data quality and ensuring the robustness of empirical findings.

Table 4.1: Descriptive Statistics (Pakistan)

Variables	GINI	CO_2	INF	OPEN	POP	KF
Mean	232371.50	731787.70	8.83	75902.95	180.07	38133.22
Median	227999.60	731427	9.10	80054.84	179.68	38301.54
Max.	402856.70	733539	20.30	150835.40	243.70	61025.46
Min.	116803.30	730232	2.50	35640.67	116.16	22356.83
S.D.	83856.82	1071.70	4.35	30103.83	39.25	11482.51
Total	33	33	33	33	33	33

4.2 Descriptive Statistics (China)

Following table highlights the descriptive states of the selected factors for China. These states convey fundamental characteristics of the data and facilitate an understanding of the primary features of the variables. Table supplies essential information on the data. The mean represents average of the data. Median is the value that partitions lower and upper halves of data; it typically occupies the midpoint, necessitating that the data be arranged in ascending or descending sequence. Insights of this research report in case of the research area of China suggest the absence of outliers in the data, as no substantial discrepancy exists between the mean and median values of the variables. An outlier is a data point that exhibits a large and disproportionate distance from the mean. The standard deviation estimates degree of dispersion of data around its mean.

Table 4.2: Descriptive Statistics (China)

Variables	GINI	CO_2	INF	OPEN	POP	KF
Mean	5779941	7066.19	3.87	2380882	1300000000	2490243
Median	2786356	6922.87	2.42	1774544	1310000000	1107937
Max.	18163546	12551.86	24.26	6857929	1410000000	7768897
Min.	362523.90	2414.28	-1.40	87591.52	1140000000	123261.30
S.D.	5778738	3635.09	5.32	2170041	83631420	2523578

Source: Author's calculations.

4.3 Data Trends (Pakistan)

Variation in considered factors in this research report with time fluctuations in case of the research area of Pakistan is graphically presented as below.

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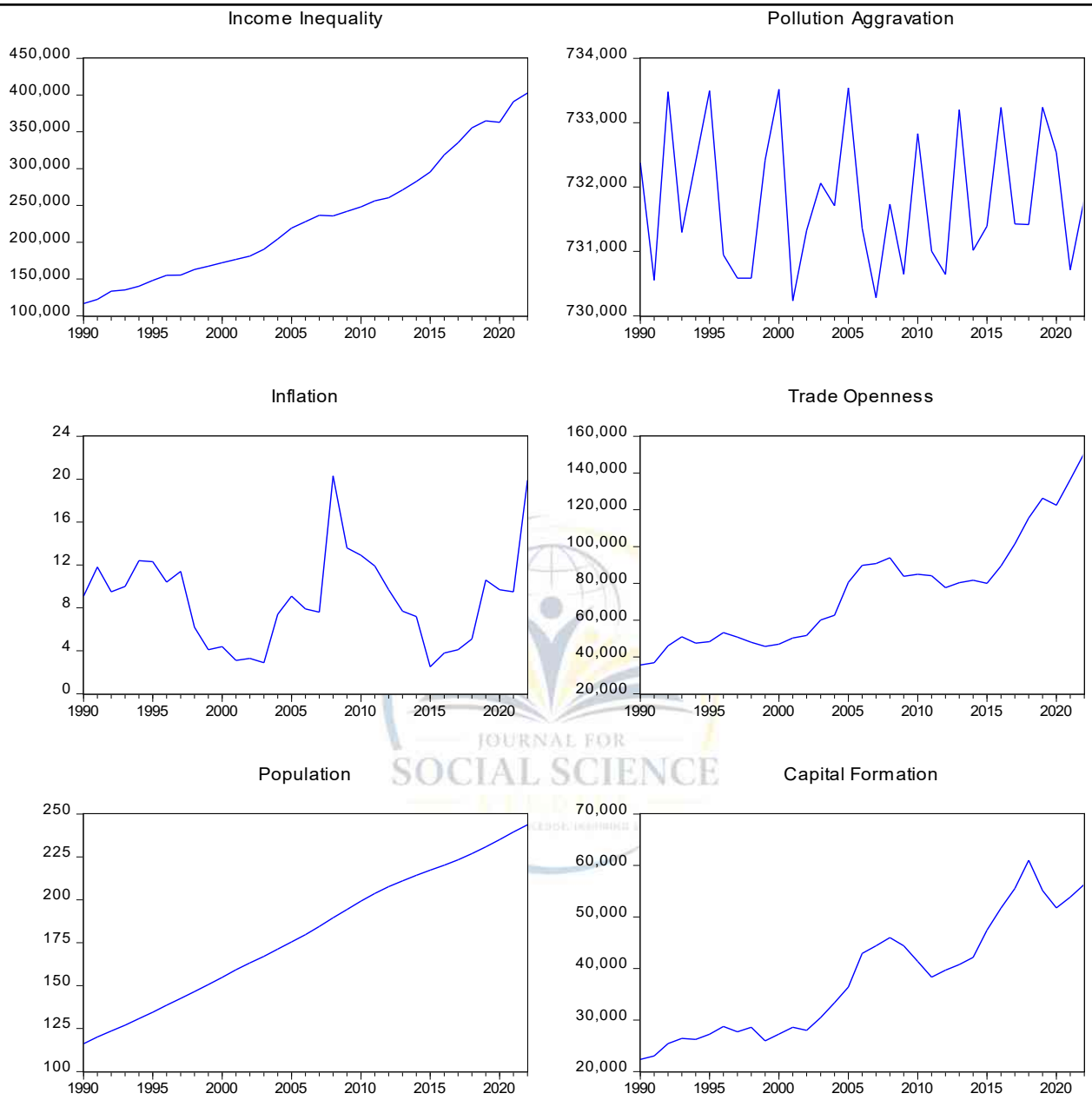


Figure 4.3: Data Trends (Pakistan)

The figure presents the time-series trends of the study's key variables for Pakistan — GINI, carbon emissions, inflation, trade openness, population, and capital formation — over the 1990–2022 period, illustrating how each factor evolved individually and providing the visual basis for the subsequent unit root and ARDL analysis.

4.4 Data Trends (China)

As for China the trends are also drawn for better understand and policymaking. The trends in case of Chinese research area are as follows:

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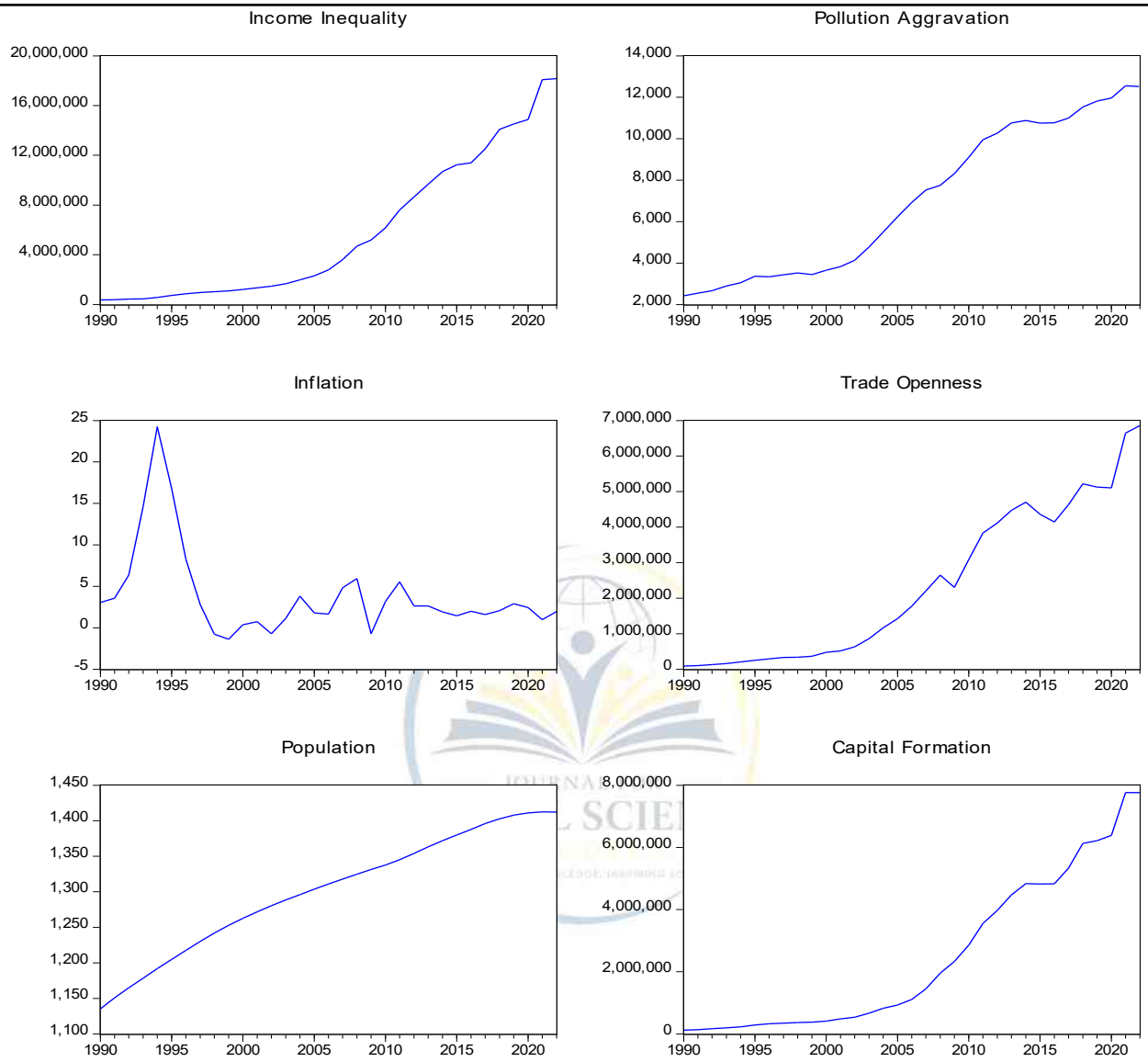


Figure 4.4: Data Trends (China)

The figure presents the corresponding time-series trends for China across the same set of variables over 1990–2022, allowing a visual comparison of how each factor's trajectory differs from that observed in Pakistan.

4.5 Results of ADF Analysis (Pakistan)

The study applied ADF analysis to identify and rectify unit root in data. The unit root problem indicates that mean & variance of data are not constant. If data are partitioned into distinct segments and mean & variance of each segment are estimated, outcomes will diverge across segments when a unit root exists. The issue typically emerges due to presence of a trend (the influence of time) in the data. A regression incorporating variables afflicted by unit root is termed a spurious regression, and the results of such a regression are unreliable and unpredictable (Granger & Newbold, 1974).

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Initially the research area of Pakistan was tested where the upcoming table presents the outcomes of ADF analysis. The researcher has adjudicated the identification and remediation of unit root in ADF test by considering the probability value of each variable. Variables lacking the **Δ** symbol denote results prior to the stationary transformation, while variables marked with the **Δ** symbol indicate their results after undergoing the differencing process. The ADF test employs the differencing approach to eliminate unit root issue from the data. The decision rule is if the p-value of a variable below 5%, H_1 is accepted, signifying the absence of the issue in variable; if the probability value exceeds 5%, H_0 is accepted, signifying the existence of problem. According to ADF outcomes in this research, all selected variables are non-stationary at level (zero difference) except population. After undergoing the ADF analysis, however, the variables attain stationary at first difference, i.e., I(1), because their probability values are greater than 5% (> 0.05) at level and less than 5% (< 0.05) at first difference. Hence, for the variables, the alternative hypothesis H_1 will be accepted, demonstrating that the variables are free from the issue.

Table 4.5: ADF Results (Pakistan)

Variables	Coefficients	*t* stat.	*P* value	Lags	Conclusion
$\boldsymbol{logGINI_t}$	-0.004	-0.34	0.91	(1)	
$\boldsymbol{\Delta logGINI_t}$	-0.97	-5.21	0.00	(1)	I(1)
$\boldsymbol{logCO2_t}$	-0.03	-1.48	0.53	(1)	
$\boldsymbol{\Delta logCO2_t}$	-0.94	-5.02	0.00	(1)	I(1)
$\boldsymbol{logINF_t}$	-0.28	-1.94	0.31	(1)	
$\boldsymbol{\Delta logINF_t}$	-1.10	-5.67	0.00	(1)	I(1)
$\boldsymbol{logOPEN_t}$	-0.01	-0.30	0.91	(1)	
$\boldsymbol{\Delta logOPEN_t}$	-0.76	-4.19	0.00	(1)	I(1)
$\boldsymbol{logPOP_t}$	-0.01	-3.86	0.01	(1)	
$\boldsymbol{\Delta logPOP_t}$	⎓	⎓	⎓	⎓	I(0)
$\boldsymbol{logKF_t}$	-0.04	-0.99	0.74	(1)	
$\boldsymbol{\Delta logKF_t}$	-1.17	-4.06	0.00	(1)	I(1)

Source: Author's calculations.

4.6 Results of ADF Analysis (China)

Same analysis has been considered for the other research area, China. The upcoming insights reveal Chinese data conclusions. Same decision standard is adapted where variables lacking the **Δ** symbol denote results prior to the stationary transformation, while variables marked with the **Δ** symbol indicate their results after undergoing the differencing process. The ADF test employs the differencing approach to eliminate unit root issue from the data. The decision rule is if the p-value of a variable below 5%, H_1 is accepted, signifying the absence of the issue in variable; if the probability value exceeds 5%, H_0 is accepted, signifying the existence of problem. According to ADF outcomes in this research, all selected variables are non-stationary at level (zero difference) except population. After undergoing the ADF analysis, however, the variables attain stationary at first difference, i.e., I(1), because their probability values are greater than 5% (> 0.05) at level and less than 5% (< 0.05) at first difference. Hence, for the variables, the alternative hypothesis H_1 will be accepted, demonstrating that the variables are free from the issue.

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The conclusions of ADF analysis have made the data in both of the research areas suitable and appropriate for further analysis.

Table 4.6: ADF Results (China)

Variables	Coefficients	*t* stat.	*P* value	Lags	Conclusion
$logGINI_t$	-0.02	-2.10	0.24	(1)	
$\Delta logGINI_t$	-1.83	-6.10	0.00	(1)	I(1)
$logCO2_t$	-0.02	-1.26	0.64	(1)	
$\Delta logCO2_t$	-1.36	-7.46	0.00	(1)	I(1)
$logINF_t$	-0.35	-2.52	0.12	(1)	
$\Delta logINF_t$	-1.37	-4.75	0.00	(1)	I(1)
$logOPEN_t$	-0.04	-2.55	0.11	(1)	
$\Delta logOPEN_t$	-0.76	-4.17	0.00	(1)	I(1)
$logPOP_t$	-0.03	-4.11	0.00	(1)	
$\Delta logPOP_t$	---	---	---	---	I(0)
$logKF_t$	-0.01	-0.93	0.76	(1)	
$\Delta logKF_t$	-0.51	-2.99	0.04	(1)	I(1)

Source: Author's calculations.

4.7 Results of F-Bound Analysis (Pakistan)

F-Bound analysis is a part of ARDL analysis which insights the effectiveness and significance of long time duration bonds between dependent and independent factors. F-stat value is considerable for conclusions where it is compared with lower as well as upper bound outcomes. Based on the upcoming solutions of F-Bound analysis in the research area of Pakistan, F-stat results exceed upper bound outcomes at 1% highly significant level. It concludes a remarkable and strengthened long time duration influences of environmental aggravation and other considered factors on income inequality in the research area of Pakistan.

Table 4.7: F-Bound Results (Pakistan)

F-Bound Test		
F-statistic	5.40	
K	5	
Significance level	L_0 (lower bound critical value)	L_1 (upper bound critical value)
10%	2.08	3
5%	2.39	3.38
2.5%	2.7	3.73
1%	3.06	4.15

Source: Author's calculations.

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4.8 Results of F-Bound Analysis (China)

The Chinese F-Bound insights are also identifying almost similar conclusions as the research area of Pakistan. Based on the upcoming solutions of F-Bound analysis in the research area of China, F-stat results exceed upper bound outcomes at 1% highly significant level. It concludes a remarkable and strengthened long time duration influences of environmental aggravation and other considered factors on income inequality in the research area of China. The conclusions may be made based on the insights of F-Bound analysis in both of the research areas that there is healthy long time duration effect of environmental aggravation and other considered factors on income inequality in both of the research areas i.e. Pakistan as well as China.

Table 4.8: F-Bound Results (China)

F-Bound Test		
F-statistic	84.18	
K	5	
Significance level	**L_0 (lower bound critical value)**	**L_1 (upper bound critical value)**
10%	2.08	3
5%	2.39	3.38
2.5%	2.7	3.73
1%	3.06	4.15

Source: Author's calculations.

4.9 Results of ARDL Analysis (Pakistan)

ARDL outcomes in case of Pakistan may be found in the upcoming table. The table includes short time as well as long time duration conclusions in case of the research area of Pakistan. Symbol of **Δ** reveals short time duration where the factors without the symbol represent long time duration conclusions. P-value of below 5% factors are considered as significant and having strong influences on the dependent one. Coefficients of all the factors also reveal elasticity because of containing log.

The ARDL results for Pakistan show that environmental pollution, inflation, and population growth increase income inequality in both the short run and long run. However, trade openness and capital formation help reduce income inequality by supporting economic activities and investment. In the short run, previous levels of income inequality also have a significant positive effect on current inequality. In the long run, population becomes elastic, indicating a stronger response of income inequality to changes in population. Overall, the findings suggest that Pakistan should focus on controlling environmental pollution and inflation, managing population growth, and promoting trade and investment to reduce income inequality and achieve sustainable economic development.

Table 4.9: ARDL Results (Pakistan)

Variables	Short run elasticity	Std. error	t-statistic	prob.
$\Delta logGINI_{t-1}$	1.23	0.38	3.22	0.01
$\Delta logCO2_t$	0.88	0.27	3.29	0.01
$\Delta logINF_t$	0.27	0.10	2.61	0.04
$\Delta logOPEN_t$	-0.04	0.02	-2.34	0.04
$\Delta logPOP_t$	0.04	0.02	2.64	0.03

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$\Delta logKF_t$	-0.33	0.09	-3.56	0.01
	Long run elasticity			
$logCO2_t$	0.33	0.08	4.26	0.04
$logINF_t$	1.03	0.21	4.82	0.04
$logOPEN_t$	-0.42	0.08	-5.55	0.03
$logPOP_t$	1.02	0.20	5.16	0.04
$logKF_t$	-0.87	0.13	-6.88	0.02
Constant	3.64	0.64	5.64	0.00

Source: Author's calculations.

4.10 Results of ARDL Analysis (China)

The second research area is China. ARDL analysis has also been employed in case of this research area. The short as well as long time duration insights of ARDL declare matching findings of China with outputs of Pakistan. Most of the coefficients of the factors are inelastic. Just a single component of income inequality is elastic, inflation. Role of independent factors in this research area seems less effective for income inequality in contrast with the other research area of Pakistan. Based on analysis of short time duration conclusions one lag of income inequality has direct relationship with income inequality. Coefficient of one lag is significant therefore is inelastic due to holding value lower than 1.

The ARDL results for China show that most of the selected variables have an inelastic relationship with income inequality in both the short run and long run, while inflation becomes elastic in the long run. Environmental pollution and inflation increase income inequality, whereas trade openness and capital formation help reduce it. Population growth also contributes to rising income inequality in China. The results highlight the importance of controlling environmental pollution and inflation while promoting trade and investment to reduce income inequality and support sustainable economic development.

Table 4.10: ARDL Results (China)

Variables	Short run elasticity	Std. error	t-statistic	prob.
$\Delta logGINI_{t-1}$	0.26	0.07	3.67	0.04
$\Delta logCO2_t$	0.79	0.18	4.39	0.02
$\Delta logINF_t$	0.03	0.01	4.57	0.02
$\Delta logOPEN_t$	-0.27	0.06	-4.54	0.02
$\Delta logPOP_t$	0.31	0.09	3.32	0.04
$\Delta logKF_t$	-0.036	0.01	-8.45	0.01
	Long run elasticity			
$logCO2_t$	0.53	0.06	8.13	0.01
$logINF_t$	1.04	0.03	33.75	0.00
$logOPEN_t$	-0.63	0.12	-5.41	0.03
$logPOP_t$	0.91	0.14	6.70	0.02
$logKF_t$	-0.49	0.08	-5.81	0.03
Constant	0.03	0.01	6.14	0.02

Source: Author's calculations.

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4.11 Results of VECM Analysis (Pakistan)

In support of short time duration ARDL analysis the current research project considered famous as well as familiar analysis strategy of VECM. The upcoming upshots of VECM in the research area of Pakistan fully acknowledge conclusions of short time duration influences of factors resulted by ARDL analysis concerned with income inequality. Most factors are inelastic except investments in case of research area of Pakistan. P-values support standards of significance levels in analysis.

Table 4.11: VECM Results (Pakistan)

Variables	Short run elasticity	Std. error	t-statistic	prob.
Constant	1.39	0.34	4.05	0.00
$\Delta logCO2_t$	0.87	0.22	3.93	0.00
$\Delta logINF_t$	0.30	0.11	2.74	0.01
$\Delta logOPEN_t$	-0.25	0.10	-2.46	0.02
$\Delta logPOP_t$	0.92	0.20	4.54	0.00
$\Delta logKF_t$	-1.62	0.37	-4.40	0.00

Source: Author's calculations.

4.12 Results of VECM Analysis (China)

VECM analysis is also considered in the other research area of China. Similar conclusions have been drawn where two factors have become desired for control on income inequality in the research area of China. Remaining three independent factors does not insight friendly findings for income inequality. Chinese policymakers cannot bear elevations and enhancements in these factors while beneficial two factors trade as well investments may be arose in favour with equal income distribution.

Table 4.12: VECM Results (China)

Variables	Short run elasticity	Std. error	t-statistic	prob.
Constant	0.01	0.001	3.53	0.00
$\Delta logCO2_t$	0.73	0.10	7.17	0.00
$\Delta logINF_t$	0.03	0.01	2.85	0.01
$\Delta logOPEN_t$	-0.16	0.05	-3.10	0.00
$\Delta logPOP_t$	0.01	0.001	2.20	0.04
$\Delta logKF_t$	-0.93	0.08	-11.86	0.00

Source: Author's calculations.

4.13 Results of Diagnostic Analyses (Pakistan)

At final stages, multiple diagnostic analyses have been performed in the research area of Pakistan for testing factors' reliability. Conclusions of diagnostic analyses found the factors very reliable as well as durable. Predictable outcomes can be drawn using these factors regarding income inequality in Pakistan. P-values of these diagnostics should support acceptance of null hypothesis. It denotes absence of spurious issues in the analysed econometric model.

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Table 4.13: Diagnostics Results (Pakistan)

Test type	Statistic	Value	d.f	Prob.
White test	χ^2stat.	13.55	*df* (18)	0.76
ARCH test	χ^2-stat.	1.80	*df* (1)	0.15
Breusch–Pagan-Godfrey LM test	χ^2-stat.	6.70	*df* (5)	0.18
Jarque–Bera test	F-stat.	1.42		0.49
Ramsey RESET test	F-stat.	1.24	*df* (1,26)	0.16

Source: Author's calculations.

CUSUM analysis a form of diagnostics also declares spurious free coefficients in the research area of Pakistan.

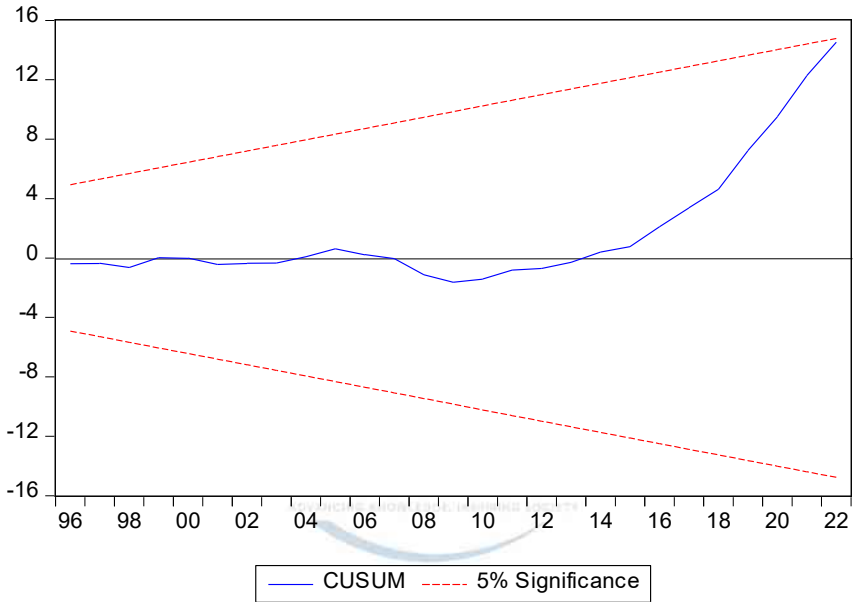


Figure 4.13a: CUSUM Analysis (Pakistan)

The CUSUM plot shows the cumulative sum of recursive residuals for the Pakistan model remaining within the two critical bound lines at the 5% significance level throughout the sample period, indicating that the estimated coefficients are stable over time.

CUSUM of Squares another diagnostic analysis in case of same research area of Pakistan also reveals fitness of coefficients.

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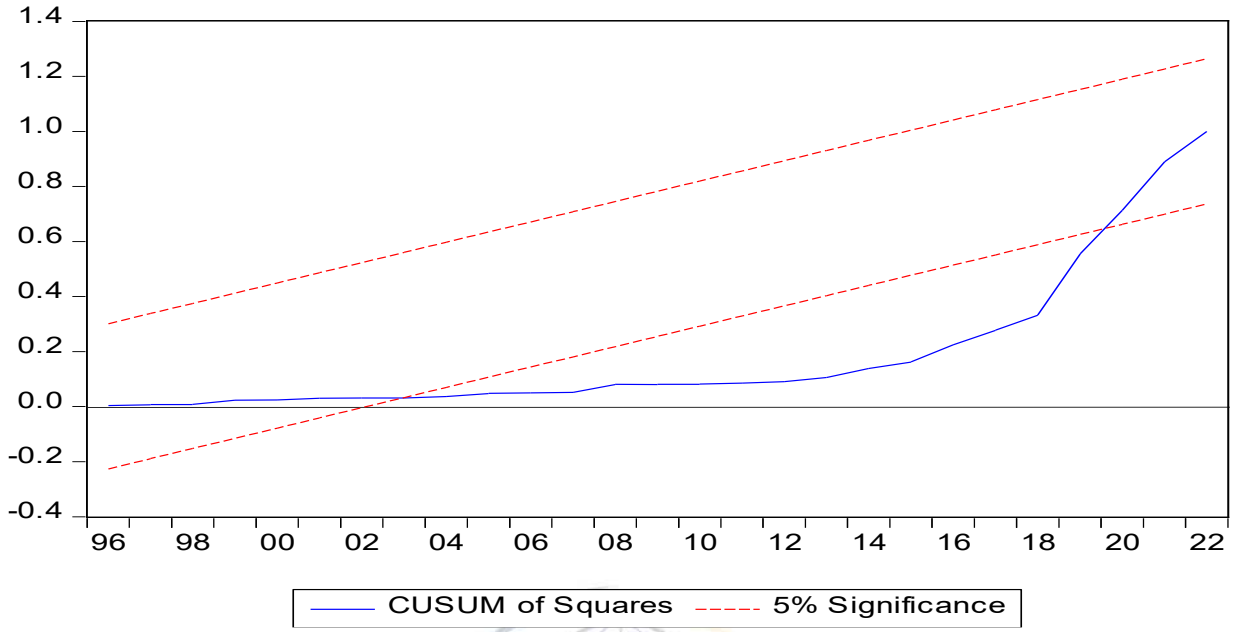


Figure 4.13b: CUSUM Analysis (China)

The CUSUM plot for the Chinese model likewise stays within the 5% critical bounds across the sample period, confirming the stability of the estimated coefficients for the research area of China.

4.14 Results of Diagnostic Analyses (China)

In case of China same diagnostic analyses have also been performed for testing factors' reliability. Outputs of diagnostics discovered the factors very reliable as well as durable. According to research standards the p-values of these diagnostics should support acceptance of null hypothesis as well. While considering the upcoming conclusions, p-values clearly highlight acceptance of null hypothesis in the research area of China. Decision may be drawn that the Chinese data is also free from spurious problems.

Table 4.14: Diagnostics Results (China)

Test type	Statistic	Value	d.f	Prob.
White test	χ^2stat.	14.68	*df* (16)	0.55
ARCH test	χ^2-stat.	0.74	*df* (1)	0.39
Breusch–Pagan-Godfrey LM test	χ^2-stat.	7.47	*df* (5)	0.19
Jarque–Bera test	F-stat.	1.84		0.40
Ramsey RESET test	F-stat.	1.60	*df* (1,26)	0.19

Source: Author's calculations.

Same CUSUM analysis gives same outputs in case of the research area of China as factors are free from spurious issue.

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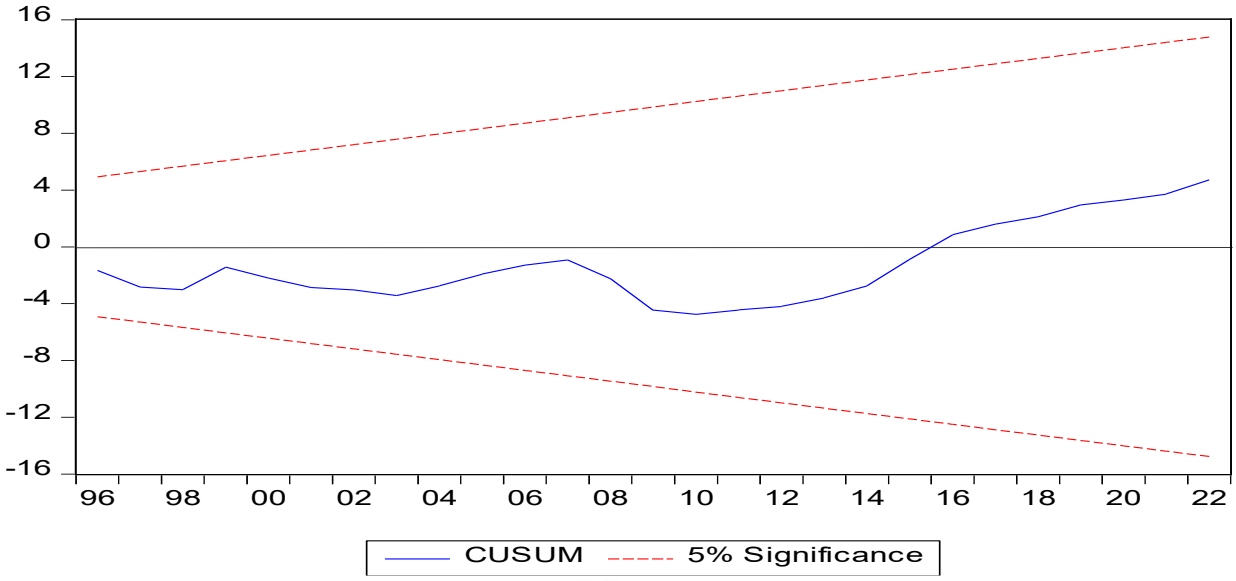


Figure 4.14a: CUSUM of Squares Analysis (Pakistan)

The CUSUM of squares plot for Pakistan also remains within the critical bound lines throughout the sample period, providing further confirmation that the model's parameters are stable and free from structural breaks.

CUSUM of Squares in case of Chinese research area also reveals desired and beneficial outcomes.

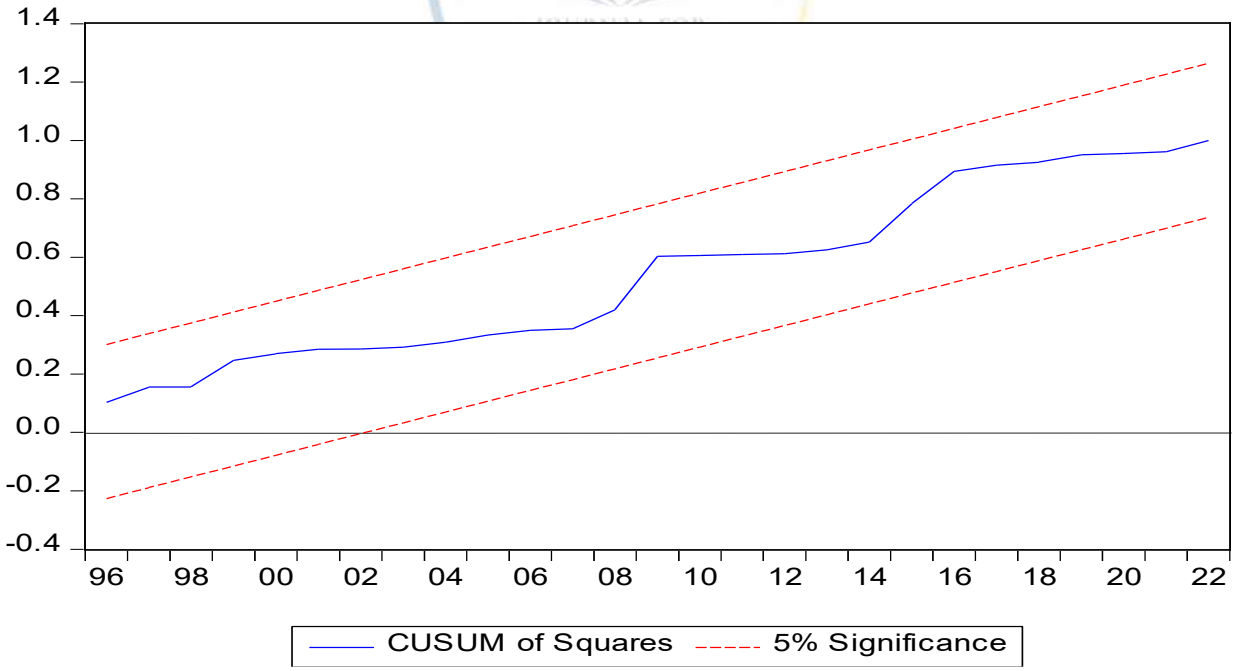


Figure 4.14b: CUSUM of Squares Analysis (China)

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The CUSUM of squares plot for China similarly stays within the critical bounds, reinforcing the conclusion that the Chinese model's coefficients are stable over the sample period.

4.16 Pakistan-China Comparison

The comparative analysis of Pakistan and China shows that the factors affecting income inequality differ between the two countries in the short run and long run. The short-run ARDL results indicate that environmental pollution and inflation have stronger effects on income inequality in Pakistan, while trade openness, population, and capital formation show stronger effects in China. However, the long-run ARDL results show that environmental pollution and inflation have stronger effects in China, whereas population and capital formation have greater effects in Pakistan. Trade openness continues to show a stronger effect in China. Furthermore, the VECM results suggest that the selected economic factors have comparatively stronger effects on income inequality in Pakistan than in China. Overall, the findings highlight that environmental and economic conditions influence income inequality differently in both countries, suggesting that Pakistan and China need country-specific policies to reduce income inequality and promote sustainable economic development.

Table 4.13: Pakistan-China Comparison

ARDL Comparison				
Variables	Pakistan		China	
	Short run elasticity	Prob.	Short run elasticity	Prob.
$\Delta logGINI_{t-1}$	1.23	0.01	0.26	0.04
$\Delta logCO2_t$	0.88	0.01	0.79	0.02
$\Delta logINF_t$	0.27	0.04	0.03	0.02
$\Delta logOPEN_t$	-0.04	0.04	-0.27	0.02
$\Delta logPOP_t$	0.04	0.03	0.31	0.04
$\Delta logKF_t$	-0.33	0.01	-0.036	0.01
Variables	Pakistan		China	
	Long run elasticity	Prob.	Long run elasticity	Prob.
$logCO2_t$	0.33	0.04	0.53	0.01
$logINF_t$	1.03	0.04	1.04	0.00
$logOPEN_t$	-0.42	0.03	-0.63	0.03
$logPOP_t$	1.02	0.04	0.91	0.02
$logKF_t$	-0.87	0.02	-0.49	0.03
VECM Comparison				
Variables	Pakistan		China	
	Short run elasticity	Prob.	Short run elasticity	Prob.
$\Delta logCO2_t$	0.87	0.00	0.73	0.00
$\Delta logINF_t$	0.30	0.01	0.03	0.01
$\Delta logOPEN_t$	-0.25	0.02	-0.16	0.00
$\Delta logPOP_t$	0.92	0.00	0.01	0.04
$\Delta logKF_t$	-1.62	0.00	-0.93	0.00

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4.17 Conclusion

The study concludes that the selected variables, data, and analytical methods were appropriate for examining the relationship between environmental pollution and income inequality in Pakistan and China. Comparing these two countries helped identify common patterns and differences, providing useful insights for future research and policymaking.

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study examines the relationship between environmental pollution and income inequality in Pakistan and China from 1990 to 2022. The study uses annual time-series data and applies descriptive statistics, the Augmented Dickey-Fuller (ADF) test, the Autoregressive Distributed Lag (ARDL) model, and the Vector Error Correction Model (VECM).

The findings indicate that environmental pollution, inflation, and population growth are positively associated with income inequality in both countries. This suggests that increasing pollution and inflation may create additional economic difficulties for low-income households. In contrast, trade openness and capital formation may help reduce income inequality by supporting economic opportunities, investment, and employment. The ADF test examines the stationarity of the variables, while ARDL and VECM are used to investigate their short-run and long-run relationships. Overall, the study highlights the importance of addressing environmental problems alongside income inequality in both Pakistan and China.

5.2 Recommendations

Based on the findings, both countries should strengthen environmental regulations, promote renewable energy, and encourage cleaner industrial production. Governments should also control inflation and protect low-income households through appropriate economic policies. Trade and investment policies should focus on creating employment opportunities and ensuring that the benefits of economic growth reach different income groups. Furthermore, investment in education, healthcare, and vocational training can improve living standards and reduce inequality. Environmental protection and income distribution should therefore be considered together when designing economic policies.

5.3 Limitations and Future Research

This study focuses only on Pakistan and China and covers the period from 1990 to 2022. Future research could include more countries, extend the study period, and examine additional factors such as environmental regulations, green technology, and institutional quality to develop a broader understanding of the relationship between environmental pollution and income inequality.

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