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Article

Income inequality, governance quality, and environmental degradation in Asian countries: Does interaction of governance quality matter? Evidence from panel data

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Abstract: The objective of this research is to examine the effects of income inequality, governance quality, and their interaction on environmental quality in Asian countries. Time series data are obtained from 45 Asian countries for the period 1996–2020 for this empirical analysis. The research has performed various econometric tests to ensure the robustness and reliability of the results. We have addressed different econometric issues, such as autocorrelation, heteroskedasticity, and cross-sectional dependence, using the Driscoll-Kraay (DK) standard error estimation and endogeneity issues by the system generalized method of moments (S-GMM). The results of the study revealed that income inequality and governance quality have a positive impact on environmental degradation, while the interaction of governance quality with income inequality has a negative effect on it. In addition, economic growth, population growth, urbanization, and natural resource dependency are found to deteriorate the quality of the environment. The findings of the study offer insightful policies to reduce environmental degradation in Asian countries.

Keywords: income inequality; governance quality; environmental degradation; Asian countries; panel data

1. Introduction

Environmental degradation[1] has proven be the most fascinating and contentious issue in recent years among environmentalists, economists, and policymakers. With numerous and growing threats to the environment and society as a whole, the world has consented that climate change is a consequence of prolonged past and present greenhouse gas emissions (United Nations, 2019). At the backdrop of this, mitigating environmental damage and alleviating income inequality are essential objectives of the Sustainable Development Agenda, 2030. Environmental degradation is the consequence of the degradation of the natural environment by human activities such as deforestation, industrialization, pollution, and so on, which have a significant effect on climate, human health, biodiversity, and economic development (Hassan et al., 2015; Karimi Alavijeh et al., 2022). At present, human activities are more to blame than natural occurrences for the current environmental issues (Shrinkhal, 2019). Carbon dioxide (CO_2) is identified as a major cause of environmental degradation by many research scientists and scholars (Baloch et al., 2017; Pao et al., 2011; Uzar, 2020; Dehdar et al., 2022). So, in the contemporary industrialized era, environmental protection reducing environmental degradation is a major policy concern for environmental sustainability, particularly in rising economies (Farooq, 2021; Karimi Alavijeh et al., 2023). Asia is indeed the largest emitter of greenhouse gases, accounting for 53% of global emissions, and within Asia, China stands out as the world's largest emitter, emitting more than one-fourth of global emissions (Ritchie, 2019). According to the International Energy Agency (IEA) report (2023), with the exception of China, emerging markets and developing economies in Asia saw the largest increase in emissions in 2022, rising by 4.2%, or 206 Mt CO_2. **Figure 1** shows that average CO_2 emissions data from the World Bank in the Asian region is increasing over the period 1996–2020. During 1990, total CO_2 emissions were 169,831.74 kilotons and increased to 434,042.57 kilotons in 2020, i.e., about 2.5 times higher.

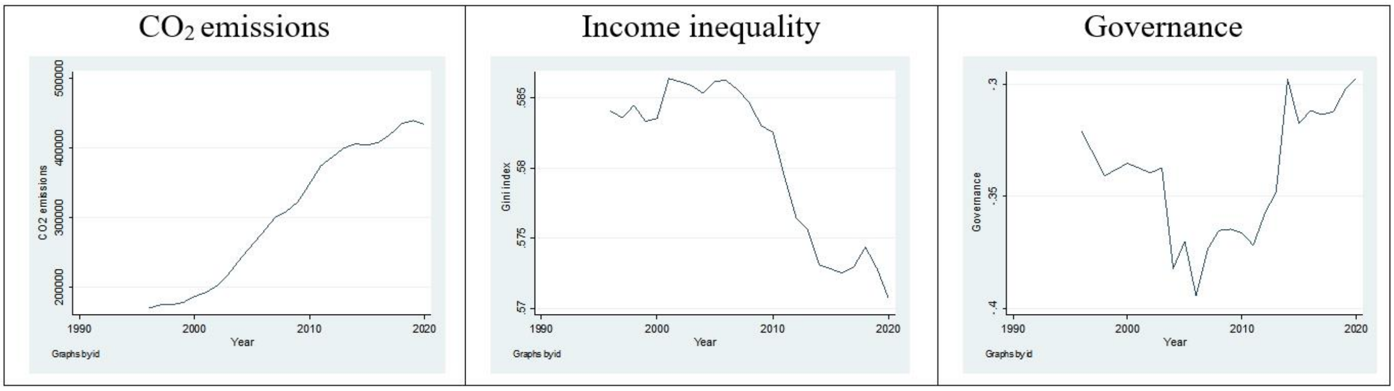

Figure 1. Trends of average CO_2 emissions, income inequality and governance.
Source: Authors' construction based on secondary data.

Asia is one of the fastest-growing emerging economies in the world. Such a rapid increase in economic growth sometimes brought social problems, exacerbating inequality in income among the rich and the poor (Hao et al., 2016). According to the World Inequality Database (2023), income inequality in many Asian countries is high, reflecting that the richest 10% in India, Thailand, and the Maldives earn more than half of the country's income; in Bangladesh, Singapore, and Nepal, the richest 10% earn 35% of the national income; and other Asian countries, such as Vietnam, Indonesia, and Pakistan, the richest 10% hold 40–50% of the country's income. It is argued that income inequality raises CO_2 emissions as it obstructs the implementation of environmental protection and can result in less environmental protection and ultimately be the cause of increased emissions (Baloch et al., 2020).

A global ethical dilemma concerning social justice affects the most vulnerable populations; addressing this dilemma requires a sustainability-oriented approach (Masud et al., 2018). These challenges hinder the achievement of the sustainable development goals (SDGs) in many nations across the world. Therefore, it is crucial for the leaders of these countries to improve governance quality, especially regarding policy design and implementation that foster socioeconomic development and sustainable resource management by ensuring universal access to clean, reliable, and affordable energy (Jarrett, 2017; Samimi et al., 2012). Effective governance, particularly environmental agencies that enforce environmental norms and regulations, contributes to environmental conservation (Liu et al., 2020). The United Nations recognizes the importance of good environmental governance at every level-global, national, regional, provincial, corporate, and civil society (United Nations, 2019). **Figure 1** shows the trends in the average governance quality of sample countries since

1996. Average governance quality is based on the six indicators of governance from the Worldwide Governance Indicators: government effectiveness, rule of law, control of corruption, no violence and political stability, regulatory quality, and voice and accountability. **Figure 1** shows that the average governance score during the study period lies between −0.39 to −0.30, indicating a low quality of governance[2]. But it is also true that some of the advanced Asian nations, such as Singapore, Japan, the Republic of Korea, Israel, etc., have high governance quality.

Therefore, this study has the motivation to investigate the effects of income inequality, governance quality, and their interaction on environmental quality in Asian countries.

The structure of this paper is as follows: section 2 provides a theoretical framework and empirical literature; section 3 describes the data and methodology employed; section 4 reports the empirical results; and chapter 5 is the conclusion with some policy recommendations.

2. Theoretical framework and empirical literature

Theoretical framework

This section summarizes the main theoretical contributions on how income inequality and governance quality influence the quality of the environment.

Various researchers and environmentalists have explored the determinants of environmental degradation across different countries or groups of countries or regions. A significant strand of literature has examined the effects of income inequality on environmental degradation (Baloch et al., 2017; Boyce, 1994; Ching et al., 2022; Hao et al., 2016; Ravallion et al., 2000; Wang et al., 2021) and the effects of governance on environmental degradation (Danish et al., 2019; Haseeb et al., 2018; Jamil et al., 2021; Korkut Pata et al., 2022; Samimi et al., 2012; Yang et al., 2022). However, the empirical evidence on this relationship is still inconclusive and requires further investigation. A review of the existing literature reveals conflicting evidence on the relationship between income inequality and CO_2 emissions. Some studies have reported a negative effect of income inequality (Ching et al., 2022; Hailemariam et al., 2019; Ravallion et al., 2000; Wang et al., 2021), while others found a positive impact of income inequality (Baloch et al., 2017; Baloch et al., 2020; Hao et al., 2016) on CO_2. Previous studies provided various mechanisms through which these relationships hold. Demir et al. (2018) explored the short-run and long-run dynamics of income inequality and environmental degradation. They argued that in the short-run, income inequality exacerbates environmental degradation by increasing the profits and outdated investments of the capitalists, which harm the environment. However, in the long-run, income inequality reduces environmental degradation by decreasing the aggregate consumption level in the economy, as richer households have a lower emission propensity (Demir et al., 2018). Another potential mechanism is that income inequality increases the rate of illiteracy and impedes the ability of people to acquire energy-efficient and low-emitting products due to low purchasing power and higher energy consumption, leading to an increase in CO_2 emissions (Baloch et al., 2020; Khan et al., 2022). Therefore, a more equitable distribution of income can reduce CO_2 emissions by enhancing renewable energy consumption, because a decrease in income inequality alleviates individuals' economic worries and raises demand for a better quality of environment (Uzar, 2020). In an unequal society, environmental degradation may be influenced by the disparity of power and income between the agents who benefit from environmental pollution and the agents who bear the environmental costs (Boyce, 1994). It can be asserted from Boyce's (1994) statement that beneficiaries with high bargaining power would influence the government to weaken environmental regulations, leading to ecological deterioration (Yang et al., 2022). Likewise, when inequality increases, the impoverished may exploit the environment to fulfill their needs, such as generating income by degrading the ecosystem, to sustain their livelihoods (Boyce, 1994). Hence, affluent losers may leverage their economic power to influence poor winners and lobby policymakers to impose stringent environmental regulations (Yang et al., 2022). Furthermore, the inconclusive relationship observed in studies between income inequality and CO_2 emissions also hinges on the methods employed to measure income inequality (Safar, 2022). Safar (2022) demonstrated that market income inequality does not affect CO_2 emissions but net income inequality has a negative impact on CO_2 emissions.

Several studies have examined the relationship between governance and environmental degradation, finding both positive effects (Kinda, 2011; Haseeb et al., 2018; Yang et al., 2022) and negative impacts (Farooq, 2021; Jamil et al., 2021; Korkut Pata et al., 2022; Samimi et al., 2012). Governance is a crucial factor for achieving sustainable development, as it influences both institutional performance and specific outcomes (Jamil et al., 2021). Regions with low institutional quality and weak environmental protection regulations are more likely to experience environmental damage (Yang et al., 2022). Conversely, when national institutions or governance systems are sufficiently robust to enforce environmental standards and norms, environmental sustainability is enhanced and becomes effective in mitigating environmental degradation (Danish et al., 2019; Yang et al., 2022). The quality of institutions or governance contributes to lower CO_2 emissions and fosters environmental sustainability by enhancing income and power equality (Liu et al., 2020). A common counterargument is that a good governance system attracts more foreign direct investment (FDI) in the region (Qamruzzaman, 2023), which leads to industrialization, economic growth, and increased consumption of conventional energy sources that are the main drivers of environmental problems (Kousar et al., 2020). A different perspective on the relationship between the governance system and CO_2 is the low efficiency of institutions and the lack of stringent environmental regulations, which result in environmental damage and increased emissions (Yang et al., 2022). Corruption, as a manifestation of a weak governance system, undermines the performance of institutions and hinders the effective enforcement of environmental laws and regulations (Haseeb et al., 2018; Wang et al., 2018). To address this issue, more rigorous environmental laws and regulations are needed to curb environmental degradation (Farooq, 2021). Hence, many researchers advocate for the adoption of different strategies to control environmental degradation.

Figure 2 presents the theoretical link of environmental degradation with income inequality and governance quality.

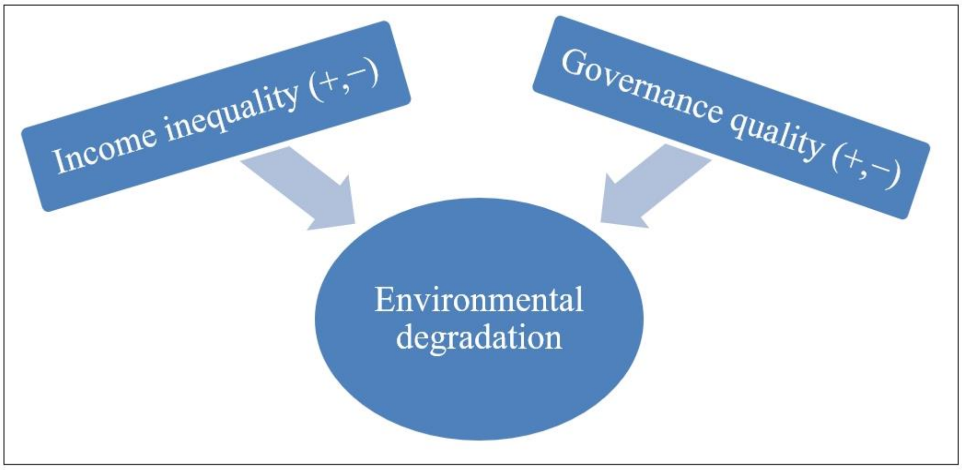

Figure 2. Theoretical link of environmental degradation with income inequality and governance quality.

Source: Authors' construction.

Figure 1 shows the trends of average CO_2 emissions, income inequality, and governance in Asian countries during 1999–2020. Over a period of time, the emissions of CO_2 have increased. Although income inequality exhibits a decreasing trend, it remains at a high magnitude. Governance quality showed deterioration until the mid-2000s, followed by an improvement.

3. Empirical literature

This section provides a concise overview of the existing literature on the empirical relationships between income inequality-environmental degradation and governance-environmental degradation.

3.1. Income inequality and environmental degradation

Boyce (1994) argued that the effect of income inequality on environmental degradation activity is mediated by political decision-making power. Environmental degradation activity is determined by the balance or dynamics of power between the beneficiaries (who gain from the activity) and the victims (who incur net costs) (Boyce, 1994). When the beneficiaries have more power than the victims, more environmental damage occurs than in the reverse situation (Boyce, 1994). Using the Autoregressive Distributed Lag Model (ARDL) model, Baloch et al. (2017) examined the relationship between income inequality and CO_2 emissions in Pakistan from 1966 to 2011. They revealed that higher income inequality leads to more CO_2 emissions. Hao et al. (2016) applied the first-difference GMM method to investigate the effect of income inequality on per capita emissions in 23 provinces of China from 1995 to 2012. They found a positive impact of income inequality on per capita emissions. The study by Korkut Pata et al. (2022) in South Asia from 2002 to 2016 showed that income inequality increased the ecological footprint. Hassan et al. (2015) study in Pakistan for the period 1980–2011 suggested that income inequality negatively affects the quality of the environment, i.e., with the rise in income inequality, the emission of CO_2 also rises. Using data from 90 countries across different levels of development for the period 1970–2000, Drabo (2011) applied the 2SLS method and found that income inequality worsens the quality of the environment. The study by Masud et al. (2018) of five Association of Southeast Asian Nations (ASEAN) during 1985–2015 found that income inequality brings about an increase in CO_2 emissions, which in turn reduces environmental sustainability. Baloch et al. (2020), using data from 40 SSA countries during the period from 2010–2016 and applying the Driscoll-Kraay (DK) regression method, revealed that CO_2 emissions increase with the increase in income inequality. Using the DK regression method, the study by Khan et al. (2022) in 18 developing Asian nations during 2006–2017 showed that a higher degree of income inequality deteriorates the quality of the environment. Research by Yang et al. (2022) used DK regression, fully modified ordinary least squares (FMOLS), and pooled mean group (PMG) in 42 developing countries during 1984–2016 and showed that an increase in income inequality increases CO_2 emissions. Using panel data from 158 countries over a period of 28 years (1980–2008) and a group-fixed effect estimator, Grunewald et al. (2017) showed a negative association between income inequality and CO_2 emissions in low-and middle-income countries and a positive association between the two in upper-middle and high-income countries. An investigation by Wang et al. (2021) in Pakistan during 1990–2018 reported that an increase in income inequality decreases CO_2 emissions. Ching et al. (2022) examined the impact of income inequality on environmental degradation in 64 countries during 1990–2016. Using dynamic common correlated effects (DCCE), the study revealed the negative impact of income inequality on environmental degradation. An analysis by Ravallion et al. (2000) in 42 countries from 1975–1992 revealed that higher inequality is associated with lower levels of CO_2 emissions. Khan et al. (2023) investigation using OLS, fixed effect, system GMM, difference GMM, and seemingly unrelated regression (SUR) models in the Belt and Road Initiative countries during the period from 2002 to 2019 revealed that income inequality has aCO_2 emission reducing effect. Hailemariam et al. (2019), employing Dynamic Ordinary Least Squares (DOLS), FMOLS, and common correlated effects mean group estimator (CCEMG) from panel data of the Organization for Economic Cooperation and Development (OECD) countries during the period 1945–2010, revealed a negative effect of income inequality on CO_2.

3.2. Governance and environmental degradation

Korkut Pata et al. (2022) study in South Asian nations during the period 2002–2016 showed that political stability helps to reduce environmental degradation. Samimi et al. (2012) analyzed the impact of good governance quality on environmental degradation in 21 Middle East/North Africa (MENA) regions from the period 2002–2007. They used government effectiveness as a proxy for governance and applied the fixed effect (FE) model. The study suggested that good governance has a negative impact on environmental degradation. Jamil et al. (2021) using the GMM method in Belt and Road Initiative (BRI) countries from 1996 to 2014 found that both in the long and short run, governance helps to reduce CO_2 emissions. An investigation by Liu et al. (2020) using FMOLS and DOLS in five high CO_2 emitting countries during 1996–2017 indicated that governance helps to enhance environmental quality. A study by Farooq (2021) in Asian economics during 2001–2019 applied estimated generalized least squares (EGLS), two-stage least squares (2SLS), system generalized method of moments (S-GMM), and FMOLS models and showed that governance negatively affects CO_2 emissions. A study by Danish et al. (2019) applying DK regression, DOLS, and a pooled mean group (PMG) estimator in BRICS countries for 1996–2017 found a negative effect of governance on CO_2. Yang et al. (2022) study using DK regression, FMOLS, and PMG in 42 developing countries during 1984–2016 showed that an improvement in institutional quality increased CO_2 emissions. Kinda's (2011) investigation using a panel of 122 developing countries during 1960–2008 and employing the system GMM method demonstrated that democratic institutions have a positive impact on income inequality. Haseeb et al. (2018), using democracy and corruption as indicators of governance and applying the fully modified ordinary least squares (FMOLS) model, revealed that the impact of corruption on CO_2 in low-income countries is higher than in high-income countries. Besides, democracy helps to reduce CO_2 emissions in all income group countries except low-income countries.

Based on the previous studies the following hypothesis has been framed:

(1) Income inequality exacerbates the environmental degradation, i.e., income inequality has positive impact on environmental degradation.

(2) Governance quality improves the quality of environment, i.e. governance quality has negative impact on environmental degradation.

(3) Interaction of governance quality with income inequality reduces $CO_{2,}$ i.e., interaction term has a negative effect on environmental degradation.

Although researchers have investigated the nexus between income inequality, governance, and CO_2 emissions in different countries or groups of countries, there is no relevant research that has investigated such a nexus in the context of Asian countries. Moreover, the moderating effect of governance quality on the income inequality-environmental degradation nexus has not been systematically examined in Asian countries. This study aims to fill this gap by exploring how income inequality, governance quality, and their interactions influence environmental degradation in Asian countries within a unified framework.

4. Data and methodology

4.1. Data used

The entire data for the present study is accessed from secondary sources for 45 Asian countries during the period 1996–2020 as shown in **Table 1**. The selection of the countries (see Table A1 in the appendix) and period is based on the availability of data. To reduce the omitted variable issues, control independent variables are included along with the main independent variables, as shown in **Table 1**.

The present study selected the Asian economy because Asian countries are developing countries whose economies continue to strive to improve the living conditions of their most vulnerable citizens by promoting economic growth, combating poverty, and erasing all forms of inequality (Khan et al., 2022; Yang et al., 2022). However, many developing countries in Asia are experiencing rising inequality despite their recent economic growth (Gnangoin et al., 2019). In terms of the quality of the environment, more than half of the world's greenhouse gas emissions during the period 2020 came from the 49 nations that make up Asia and the Pacific (Economic and Social Commission for Asia and the Pacific, 2022). In the meantime, Asian economies have had robust economic expansion in recent decades whereby, authorities have been gradually more concerned about the sustainability of output growth due to the region's rising pollution emissions (Khan and Rana, 2021). Furthermore, most of the studies identified that the quality of governance in Asian countries is weak, which can hamper the overall economic development of the region (Huang and Ho, 2017; Huynh et al., 2019).

Table 1. Variables, sources and role of variables.

Variables (proxy)	Symbol used	Description	Data source	Role of the variables
Environmental degradation {CO_2 emissions in kiloton (kt)}	CO_2	CO_2 emissions in kt	The World Bank	Main and dependent variable
Income inequality (Gini index)	INE	Inequality in income among individuals or households (index lies between 0 to 1, 0 means perfect equality and 1 means perfect inequality)	World Inequality Database (WID)	Main and independent variable
Governance quality (governance index)	GOV	Averages of six indicators of good governance[3] (index lies between −2.5 to +2.5, −2.5 means very weak governance and +2.5 means very strong governance)	The World Bank, Worldwide Governance Indicators (WGI)	Main and independent variable
Economic growth (Gross domestic product per capita (GDPPC)	EG	GDPPC measured in purchasing power parity (PPP), 2022 USD	World Inequality Database (WID)	Control and independent variable
Population (population growth)	POP	Population growth (annual %)	The World Bank	Control and independent variable
Urbanization (urban population growth)	URB	Urban population growth (annual %)	The World Bank	Control and independent variable
Natural resources (rent from natural resources)	NRR	Total rents from natural resources (% of GDP)	The World Bank	Control and independent variable

Source: Authors' compilation from secondary data.

4.2. Basic regression model

Based on the literature review, we assume income inequality, governance, economic growth, population, urbanization, and natural resources have an impact on environmental degradation. All the variables we used are in natural log form. We form the following basic regression model to investigate the impact of selected variables on environmental degradation with and without the interaction effect (lnGOV × lnINE). Hence, Equation (1) is the regression to be estimated without the interaction term, and Equation (2) is the regression to be estimated with the interaction term.

$$lnCO_{2\,it} = B_{0it} + B_{01}\,lnINE_{it} + B_{02}lnGOV_{it} + B_{04}lnEG_{it} + B_{05}lnPOP_{it} + B_{06}lnURB_{it} + B_{07}lnNRR_{it} + \epsilon_{it} \quad (1)$$

$$lnCO_{2\,it} = B_{0it} + B_{01}\,lnINE_{it} + B_{02}lnGOV_{it} + B_{03}lnGOV_{it} \times lnINE_{it} + B_{04}lnEG_{it} + B_{05}lnPOP_{it} + B_{06}lnURB_{it} + B_{07}lnNRR_{it} + \epsilon_{it} \quad (2)$$

where, ln denotes a natural log; it denotes combination of time series and cross sectional data (panel data); B_0 is the intercept; B_{01}, B_{02}, B_{03}, B_{04} B_{05}, B_{06}, and B_{07} are the coefficients of $lnINE,\ lnGOV,\ lnGOV \times lnINE,\ lnEG,\ lnPOP,\ lnURB, and\ lnNRR$ respectively; and ϵ is the error term.

4.3. Methodology procedure

This study applied different econometric techniques to ensure the reliability of the results. First, the Levin-Lin-Chu (LLC) unit root test has been applied to check the stationarity of the data (Levin et al., 2002). Then, to check the appropriate model between the random effect (RE) and FE model, the Hausman test (null hypothesis (H_0): RE model is suitable, and alternative hypothesis (H_a): FE model is suitable) has been performed (Hausman, 1978). But before interpreting the results from the FE or RE model, we need to make sure that series are free from serial correlation and heteroskedasticity because these are the common problems in these models (Greene, 2000). So, we checked the issues of serial correlation proposed by Wooldridge (2010) (H0: no issue of serial correlation, and Ha: the presence of serial correlation) and heteroskedasticity proposed by Greene (2000) (H_0: homogeneity in data and H_a: series are heteroskedastic). We also checked the cross-sectional dependence (CD), which is a serious issue in panel data, using the CD test (H_0: no issue of CD and H_a: issue of CD) proposed by Pesaran (2020). One of the advantages of using the DK regression estimator is that this method addresses the potential concerns of dependencies across countries, heteroskedasticity, and autocorrelation (Baloch et al., 2019; Sarkodie and Strezov, 2019). So, this method can produce effective results in both temporal dependence and cross-sectional forms (Sarkodie and Adams, 2020). We also verified the outcome obtained in the DK regression model using the S-GMM method developed by Arellano and Bover (1995) and Blundell and Bond (1998) by taking the lag of dependent variable. The key benefit of the S-GMM estimator is that it avoids potential endogeneity by using internal instruments rather than depending on external instruments (Ramzan et al., 2019). We also checked multicollinearity of the series using variance inflation factor (VIF).

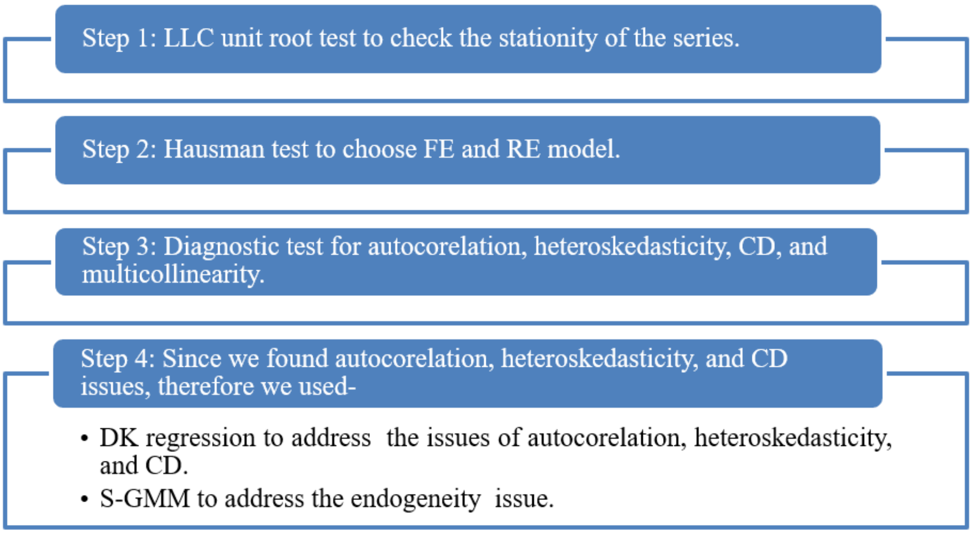

Figure 3. Steps used for main analysis.

Source: Authors' construction using Microsoft Word 2007.

5. Results and discussion

5.1. Descriptive statistics

Table 2 presents the descriptive statistics of the variables used in the study with their mean value, standard deviation (SD), maximum, and minimum values. The mean value of CO_2 is 306,732.24, which implies a higher level of environmental degradation. The SD of CO_2 is 1,146,331.6, which indicates that there is a lot of variation in CO_2 emissions across countries. The mean of income inequality is 0.58, which means that on average, there is a high degree of income inequality in the sample. The SD is 0.06, which shows less variation in income inequality within the countries. The mean of governance quality is 0.933, which means that on average, the sample country has moderate-level governance quality. The SD of governance quality of 0.685 shows some variance in governance quality across countries. The mean of EG is 35,350.459, which represents an average high rate of economic growth in the sample countries. The SD shows lots of variation in economic growth across the countries, with a value of 1631.622. The POP has a mean value of 4.128, representing a high rate of population growth with a variation of 3.703. The mean of urbanization is 5.722, which means on average low levels of urbanization across countries with an SD of 0.061. The mean value of the NRR is 11.061, which indicates a higher level of dependence on natural resources across the sample countries. The SD of the NRR is 14.483, representing a lot of variation across sample countries.

Table 2. Descriptive statistics.

Variable	Mean	Standard deviation (SD)	Minimum	Maximum
CO_2	306,732.24	1,146,331.6	281.6	10,944,686
INE	0.58	0.06	0.428	0.694
GOV	0.933	0.685	0.234	3.553
EG	35,350.459	37,855.575	1631.622	178,475.57
POP	4.128	3.703	0.073	38.747
URB	5.722	4.061	0.056	39.25
NRR	11.061	14.483	0	75.366

Source: Authors' calculation based on secondary data. Here the governance score is after transforming negative values into positive value using the method [$y = \ln(x + \sqrt{(x^2 + 1)})$] used by Busse and Hefeker (2007) to generate natural log.

5.2. Bivariate correlation matrix

A bivariate correlation matrix is performed to check for a linear association between dependent and independent variables. **Table 3** shows the bivariate correlation between CO_2 and independent variables. The results show the negative correlation of CO_2 with INE, EG, POP, and NRR.

Table 3. Bivariate correlation matrix between dependent (CO_2) and independent variables.

Independent variables	Correlation (*r*-value)
INE	−0.080***
GOV	−0.005
EG	−0.055*

Table 3. (*Continued*).

Independent variables	Correlation (*r*-value)
POP	−0.123***
URB	−0.009
NRR	−0.092***

Source: Authors' calculation based on secondary data.
*** and * indicate significance level at 1% and 10% respectively.
Here the governance score is after transforming negative values into positive value using the method $[y = \ln(x + \sqrt{(x^2 + 1)})]$ used by Busse and Hefeker (2007) to generate natural log.

5.3. Unit root test

The results of the unit root displayed in **Table 4** show that all the variables are stationary at level, except population and governance. But population and governance become stationary after the first difference.

Table 4. LLC unit root test.

Variables	At level	1st Difference
$\ln CO_2$	−4.424***	-
lnINE	−4.3561***	-
lnGOV	−1.2722	−12.2073***
lnGOV × lnINE	−1.6003*	-
lnEG	−4.0011***	-
lnPOP	−1.0924	−11.503***
lnURB	−1.7602**	-
lnNRR	−1.3299*	-

Source: Authors' calculation based on secondary data.
***, **, and * indicate significance level at 1%, 5%, and 10% respectively.

5.4. Checking for appropriate model and diagnostic test

The Hausman test shown in **Table 5** suggests us to use the RE model as the p-value is not significant. But after detecting autocorrelation, heteroskedasticity, and CD issues as detected in **Table 5**, we move towards the DK standard error estimation regression model (RE results are not shown for these issues) (Driscoll and Kraay, 1998). To corroborate the results from the DK regression model, we applied the S-GMM method proposed by Arellano and Bover (1995) and Blundell and Bond (1998), which uses the lagged values of CO_2 emissions (the dependent variable). Moreover, the variance inflation factor (VIF), as shown in **Table 5** shows the absence of multicollinearity in our study as the VIF value is lower than 10 (Gujarati and Porter, 2009).

Table 5. Autocorrelation, heteroskedasticity and multicollinearity test.

Diagnostic Test	Hausman test	Autocorrelation	Heteroskedasticity	CD test	Mean VIF
Without interaction	$\chi^2 = 4.36$	F = 234.085***	$\chi^2 = 40048.62$***	17.754***	1.12
Including interaction	$\chi^2 = 3.15$	F = 234.808***	$\chi^2 = 42378.35$***	16.657***	1.67

Source: Authors' calculation based on secondary data.
*** indicates significance level at 1%.

5.5. Regression results

Table 6 shows the results of DK standard error estimation and S-GMM results with and without the interaction effect. The diagnostics test of S-GMM is tested by the Sargan test (H_0: instruments are valid, Ha: instruments are not valid) of overidentifying restrictions to check the overall validity of instruments (Chong and Gradstein, 2007). The Sargan test results indicate the overall validity of the instruments, as the p-values are not significant (models 3 and 4). The Arellano and Bond (1991) (H_0: no serial autocorrelation and H_a: the presence of serial autocorrelation) first order (AR 1) reveals the presence of serial autocorrelation as the p-values are significant at a 1% level (models 3 and 4). But the Arellano and Bond (1991) second-order (AR 2) shows the absence of serial autocorrelation as the p-values are statistically not significant in models 3 and 4. Hence, the S-GMM approach confirms the validity and consistency of the model.

Table 6. DK and S-GMM results (dependent variable: $\ln CO_2$).

Independent variables	**DK (*t*-value)**	**DK (*t*-value)**	**S-GMM (*z*-value)**	**S-GMM (*z*-value)**
	(1)	(2)	(3)	(4)
$\ln CO_{2\ t-1}$	-	-	0.890*** (30.04)	0.905*** (50.11)
lnINE	−0.382 (−0.36)	−0.349 (−0.34)	−0.121 (−0.97)	0.192* (1.78)
lnGOV	0.277 (0.32)	0.468 (0.52)	0.120*** (8.36)	0.193*** (6.72)
lnGOV × lnINE	-	−0.313** (−3.34)	-	−0.200*** (−4.09)
lnEG	0.559*** (108.18)	0.703*** (17.79)	0.163*** (3.18)	0.175*** (6.11)
lnPOP	−0.024 (−0.21)	−0.039 (−0.33)	0.014*** (3.34)	0.011*** (3.33)
lnURB	−0.082 (−1.64)	−0.069 (−1.27)	0.022*** (5.29)	0.025*** (6.98)
lnNRR	0.127*** (14.51)	0.105*** (7.22)	0.009*** (3.77)	0.003 (1.57)
Constant	4.879*** (6.89)	3.196*** (3.24)	−0.537** (−2.15)	−0.796*** (−5.16)
Sargan test (*p*-value)	-	-	χ^2 = 39.274 (1.000)	χ^2 = 41.097 (1.000)
AR(1) (*p*-value)	-	-	−3.877 (0.0001)	−3.885 (0.0001)
AR(2) (*p*-value)	-	-	−0.202 (0.840)	−0.230 (0.818)
R-squared	0.10	0.11	-	-

Source: Authors' calculation based on secondary data.
***, **, and * indicate significance level at 1%, 5%, and 10% respectively.

Impact of income inequality: the impact of income inequality on environmental degradation is positive. A 1% increase in income inequality deteriorates the quality of environment by 19.2% (model 4). The result is collaboration with that of Baloch et al. (2017), Hao et al. (2016), Korkut Pata et al. (2022), Drabo (2011), Masud et al. (2018), Baloch et al. (2020), Khan et al. (2022), and Yang et al. (2022). This result indicated that if the beneficiaries are strong enough, they will exert political pressure on the government to relax the regulations, which will cause environmental degradation (Yang et al., 2022). Similarly, when inequality rises, the poor may overuse the environment to meet their requirements, including generating income by destroying the ecosystem, to meet their daily necessities (Boyce, 1994). A potential reason is that income inequality could elevate the rate of illiteracy and constrain the ability of the population to acquire energy-efficient and low-emitting products due to limited purchasing power, leading to higher energy consumption and consequently higher CO_2 emissions (Baloch et al., 2020; Khan et al., 2022).

Impact of governance quality: the coefficient of governance quality is positive and significant at a 1% level. It means that an improvement in governance quality by 1% deteriorates the quality of the environment by 12% (model 3) and 19.3% (model 4). This result follows a similar finding from previous studies by Kinda (2011), Haseeb et al. (2018) and Yang et al. (2022). A well-functioning governance system can enhance the foreign direct investment inflow in the country, which stimulates industrial development, economic growth, and conventional energy use, leading to environmental problems (Kousar et al., 2020). Another possible explanation for this phenomenon is that poor institutional performance, weak environmental regulations, and corruption, as indicators of low governance quality, may affect the effectiveness of environmental policies and enforcement either directly or indirectly which is harmful to the environment (Wang et al., 2018; Yang et al., 2022).

Interaction impact: the coefficient of the interaction of governance quality with income inequality is negative and significant at a 1% level in models 2 and 4. The result shows that a 1% improvement in governance quality by reducing income inequality can minimize environmental degradation by 31.3% (model 2) and 20% (model 4). This interaction impact indicates that improvement of governance quality by reducing income inequality can reduce environmental degradation and thereby improve the quality of the environment. Numerous studies have confirmed that a high quality of governance is essential to reducing income inequality (Acemoglu et al., 2001; Roy-Mukherjee and Udeogu, 2020). So, when income inequality declines, people become educated, aware of environmental degradation, and aware of the importance of environmental sustainability. This result demonstrates the importance of enhancing governance quality to reduce income inequality in Asian countries.

Impact of economic growth: economic growth has significantly a positive impact on CO_2. A 1% increase in economic growth worsens environmental quality by 55.9% (model 1), 70.3% (model 2), 16.3% (model 3), and 17.5% (model 4). This result is the same as that of Kahuthu (2006), Rahman (2020) and Karimi Alavijeh et al. (2023). Their study found the existence of the traditional Kuznets inverted U hypothesis. Since most of the Asian countries are developing countries, these countries are perhaps at the initial stage of development, and with the rapid increase in economic growth, the quality of the environment tends to degrade.

Impact of population: population has a positive and significant impact on environmental degradation at a 1% significance level as per the S-GMM approach.

The result shows that a 1% percent increase in population degrades the environment by 0.14% (model 3) and 0.11% (model 4). The study follows the same results as Shi (2003), O'Neil et al. (2012), Mohsin et al. (2019) and Karimi Alavijeh et al. (2022). A shocking rate of population expansion is responsible for the misuse of natural resources and energy sources (both renewable and non-renewable), which leads to ecological and environmental damage (Mohsin et al., 2019).

Impact of urbanization: the impact of urbanization is positive and significant at a 1% level in S-GMM. This indicates that a 1% expansion in urbanization deteriorates the environment by 0.22% (model 3) and 0.25% (model 4) in the S-GMM model. This result is consistent with the studies of Mohsin et al. (2019) and Raheem and Ogebe (2017). Over the last four decades, most of the Asian economies (Japan, the East Asian economies, Southeast Asia, and the PRC) underwent enormous economic transformations as workers migrated from the rural areas (primary agriculture) to the city, and manufacturing output increased sharply in parallel (Felipe, 2018). Raheem and Ogebe (2017) suggested that the transition from an agrarian to a manufactured industrial process brought about by urbanization is accompanied by an increase in energy consumption and environmental pollution. Raheem and Ogebe (2017) also added that the increased mobility of people and goods brought on by urbanization raises vehicular traffic and its related environmental pollutants.

Impact of natural resources: the coefficient of natural resources is positive and significant at a 1% level in models 1, 2, and 3. This shows that an increase in the extraction of natural resources by 1% pollutes the environment by 12.7% (model 1), 10.5% (model 2), and 0.09% (model 3). The result is parallel to the studies of Muhammad et al. (2021), and Nathaniel et al. (2020). Since the Asian economies underwent a remarkable economic transformation in the past four decades (Felipe, 2018), this process involved a shift from relying on natural resources to developing industrial sectors and enhancing economic growth, which has a negative impact on environmental quality.

6. Conclusion

We investigated the impact of income inequality, governance quality, and their interaction on environmental degradation in a panel of 45 Asian countries over the period 1996–2020. We investigated this relationship using DK regression estimation (with and without interaction terms) to address the issues of cross-sectional dependency, autocorrelation, and heteroskedasticity, and in addition to DK regression estimation, we also applied the S-GMM method (with and without interaction terms) to deal with the issue of endogeneity in panel data. The results of our study revealed that income inequality and governance quality deteriorate environmental quality, while the interaction of governance quality with income inequality helps mitigate environmental degradation. The control variables-economic growth, population growth, urbanization, and natural resources seemed to increase environmental degradation.

The study provides important policy recommendations to improve the quality of the environment in Asian countries. Income inequality across the Asian region should be reduced, which can be achieved through inclusive growth policies such as progressive taxation, expenditure on health and education, etc. Implementation of strict environmental rules and regulations by improving the quality of governance can contribute to the achievement of a more sustainable development path. The improvement of governance quality should be accompanied by policies that reduce income inequality, lower environmental degradation, and achieve sustainable environmental outcomes. Effective initiatives that promote green economic growth with low-carbon technologies and energy efficiency must be put in place to reduce the inertia of CO_2 emissions. Population growth should be kept under control, which can be done by implementing family planning programs. To lessen the strain on the environment that promotes smart urban planning, investment in green infrastructure and public services is necessary to address the problems caused by population expansion and urbanization. Policies that promote the efficient and equitable management of natural resources and the diversification of the economy are needed to avoid the resource curse and its environmental consequences. The policies should also foster economic diversification and structural transformation to reduce dependence on natural resources and create more value-added sectors.

Although our study provides rigorous evidence on the determinants of CO_2 emissions while accounting for autocorrelation, heteroskedasticity, CD, and endogeneity, future researchers can reinvestigate this linkage in different groups of countries. Moreover, future research can test the Kuznets hypothesis and the short-term and long-term dynamics between the variables of interest.

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Notes

1. Environmental degradation and CO_2emissions are interchangeably used in this paper. The higher the CO_2 emissions, the greater the environmental degradation.
2. Cooray (2009) classified levels of governance into four categories: very high governance ($\theta \geq 1.5$), high governance ($1.5 > \theta > 0$), low governance ($0 > \theta > -1.5$), and very low governance ($\theta \leq -1.5$), where θ is the governance index.
3. This study makes use of the overall average score of governance indicators because all the indicators are highly correlated (Buchanan et al., 2013) and the use of a single indicator may provide misleading and biased results (Kousar et al., 2020). Abbas et al. (2021) claimed that all six indicators provided by the WDIs appear to be connected to one another and have an impact on one another. For this, Abbas et al. (2021) gave the example from the study of Méon and Sekkat (2005) of how different indicators correlate to each other.

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Appendix

Table A1. list of 45 Asian countries.

Afghanistan, Armenia, Azerbaijan, Bahrain, Bangladesh, Bhutan, Brunei, Cambodia, China, Cyprus, Georgia, India, Indonesia, Iran, Iraq, Israel, Japan, Jordan, Kazakhstan, Kuwait, Kyrgyzstan, Laos, Lebanon, Malaysia, Maldives, Mongolia, Myanmar, Nepal, Oman, Pakistan, Philippines, Qatar, Saudi Arabia, Singapore, South Korea, Sri Lanka, Syria, Tajikistan, Thailand, Turkey, Turkmenistan, UAE, Uzbekistan, Vietnam, Yemen.

Missing values for the rent from natural resources for Afghanistan (1996–2001), Turkmenistan (2020), and Yemen (2019–2020), and governance indicators data for all selected countries (1997, 1999, and 2001) are generated by the method of interpolation and extrapolation using STATA software.
Source: United Nations, Statistics Division.