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Climate change, governance, and economic growth in Asia: a panel cointegration analysis

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ABSTRACT

Asian economies are extremely vulnerable to climate due to rapid economic progress, poor governance structure and governmental performance. Keeping in view the fragility of Asia economies in context of environmental deterioration, we examine the role of climate change in shaping economic progress based on an extensive dataset of 47 Asia economies over the period of 2010–2020 through advance panel estimation models such as FMOLS and DOLS for long-run relationships, and panel-VECM for granger causality. The finding suggests a long run positive impact of climate change on economic progress. Further, the results also support the bi-directional relationship between climate change and economic development in Asia region. Hence, the current research suggest that proper policies should be warranted to balance government effectiveness for the increased implementation of environmental regulations and economic prosperity to meet the needs of society and maintain environmental sustainability in the long run.

PUBLIC INTEREST STATEMENT

We examine the relationship among climate change, governance and economic development in Asia, as this region is extremely vulnerable to disastrous impact of global warming. We ascertained the long relationship among climate change, governance and economic progress and hence suggested that policy makers may design a comprehensive governance policy related to environment in order to achieve sustainable economic development in Asia.

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1. Introduction

In the wake of economic development, several economies and manufacturing giants across the globe have emerged as industrial hubs, leading to a significant rise in greenhouse gas (GHG) emissions (Onifade & Alola, 2022). Countries across the globe are trying to promote their economic growth. However, governments should not ignore environmental problems arising from economic growth. Historically, economic growth has been considered a primary driver of GHG emissions and environmental damages. A significant contributing factor to economic development is energy consumption, provided through the combustion of natural gases and fossil fuels. Yet, it has also been considered a significant contributor to GHG emissions (Phong, 2019).

It is a global phenomenon that GHG emissions create climate change issues. According to IPCC, global warming of our age is the most crucial problem of climate change. It is evident that if current trends persist, human actions will cause a 1.5 °C rise in global temperatures between 2030 and 2050, above the pre-industrial levels. According to the Paris Agreement, governments control temperature increases

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below 2°C over pre-industrial levels. Nevertheless, It is widely acknowledged that global warming requires atleast 45% reduction in GHG emission by 2030, net-zero by 2050, and negative emissions afterwards. GHG emissions, especially CO₂, are responsible for the rise in global temperature because 73 per cent of GHG emissions come from CO₂ (Lenaerts et al.). Talukdar and Meisner (2001) found that the regulation of CO₂ emissions become an essential global phenomenon and is primarily responsible for global warming. Most studies on climate change alarm GHG emissions that depend on economic growth rate need intense mitigation action. For mitigation, the world should either decrease global GHG emissions from economic growth or face a reduction in economic growth (Lenaerts et al.).

Most countries have seen that continued economic growth is the need of today and worry that if engaged in mitigation, economic growth will be harmed (Shalizi & Lecocq, 2007). Akram (2013) documented that climate change shocks are unequally distributed among nations. The weak countries are adversely affected the most by climate change because of their vulnerability to the adverse effects of climate change (Nordhaus, 1991). Moreover, developing countries have limited adaptive capacities and are vulnerable to climate change hazards (Smit & Wandel, 2006). Developing countries need to increase industrial production for economic growth, which raises GHG emissions that lead to climate change (Rehman et al., 2021). Additionally, to compete with developing countries' economic growth, OECD countries use energy resources to enhance CO₂ emissions (Cao et al., 2022). This pessimistic view supports the notion that continued economic growth is incompatible with environmental sustainability because environmental sustainability halts economic growth.

On the contrary, the optimistic view supports that continued economic growth is compatible with environmental sustainability over continued technological changes. This view emphasizes using green technologies and other alternatives in production and consumption that do not halt long-term and short-term economic growth (Alagidede et al., 2016). To this extent, the academic literature on both views is mainly theoretical because economic growth is most important for welfare and issues like pensions, social security, and debt sustainability (Lenaerts et al.).

Prior studies identified different other variables that deteriorate the environment. However, these studies on climate change neither decompose environmental policies for various socio-demographic factors nor address the environmental distortions due to governance indicators (Danish et al., 2019). Recently, Fraj et al. (2018) documented that the concept of governance is multidimensional and composed of several political actions like democracy, control of violence and corruption, management of public affairs, and implementation of laws and regulations. Governance can significantly influence environmental protection and sustainable natural resource use (Samimi et al., 2012). Moreover, government systems and institutional quality directly or indirectly affect ecological quality. Through equality of power and income, intuitional quality reduces pollution and improves the environment (Hassan et al., 2020). Hosseini and Kaneko (2013) reported that a solid institutional framework enables the government to reduce pollution by regulating CO₂ emissions. The influence of governance on environmental welfare has recently attracted researchers' attention; however, the literature provides insufficient evidence on the relationship between governance and ecological interest (Liu et al., 2020).

Besides this, governance also has developmental objectives. Empirically, prior studies tried to investigate the influence of governance on economic growth (see, for example, Thach et al., 2017). However, the results of these studies are inconclusive. According to the conventional view, governance quality enhances economic growth; however, countries with weak governance experience high economic growth (Fraj et al., 2018). Moreover, Fawaz et al. (2021) argued that the existing theoretical and empirical literature is inconclusive to believe that the association between governance and economic growth is negative, positive, or nonexistent for both low and high-income developing countries.

Although the extant literature provides a solid theoretical and empirical support regarding the drivers of climate change and its consequences. Nevertheless, little attention has been paid to examine the role of climate change in Asia region. Hence, the current the visited the climate change and economic progress relationship is Asia due to several reasons. (i) Climate change poses great threats to Asia, as approximately 60% of the world's population resides there (Akram, 2013; Tonby & Woetzel, 2020). (ii) Dolšák and Prakash (2018) stated that Asian countries are most vulnerable to climate change and contribute significantly to the world's GHG emissions. (iii) Economic growth for developing Asian countries is vital to decreasing unemployment, poverty, and hunger (Westman et al., 2004). However, these

countries have poor governance, and along with poor governmental performance, most of these countries experience outstanding economic growth that leads to environmental problems (Gil et al., 2019).

The study is motivated by several gaps in the existing literature. First, in recent decades, inconclusive evidence exists about the improved microeconomic performance in the Asian region. Compared to the pre-1980s period, contemporary studies revealed that the overall macroeconomic performance of Asian countries has considerably increased. World Bank Group (2017) predicts that Asian countries have experienced an average annual GDP growth of 5.4% over the past five decades. However, Vadlamannati (2009) found that poor governance quality prevents Asian countries from further improvement. Mendelsohn et al. (2006) documented that developing countries face the challenge of climate change because of geographical location, sensitivity, and lack of adaptive capacity. These discrepancies in the literature allow us to examine the simultaneous relationship between climate change and governance in influencing economic growth in Asia. Second, prior studies used individual governance indicators for the nexus with climate change and economic growth, ignoring a comprehensive composite governance index of all the governance indicators. For example, Liu et al. (2020); Fawaz et al. (2021); Zhuo et al. (2021) have predominantly used individual governance indicators in relationship with climate change and economic growth. To capture the overall governance quality, a synthetic governance measure is quantified by constructing a composite indicators index that combines all the governance features, helping to understand the simultaneous long-run association between governance, climate change, and economic growth in the Asian region. Third, the plethora of studies either link governance with economic growth (Fraj et al., 2018; Zhuo et al., 2021), governance with climate change (Gani, 2012; Halkos & Tzeremes, 2013) or climate changes with economic growth (Rahim & Puay, 2017). There is small number of studies that test the role of climate change, governance and economic progress in a unified framework in Asia region. Finally, regarding the methodological point, various econometric methods were used by prior researchers to explore the relationship among the study variables. However, there is a lack of studies that employ a panel cointegration approach in the Asian context. A panel cointegration allows us for the simultaneous long-run relationships among governance, climate change, and economic growth, accounting for heterogeneity across countries.

The remainder of the paper follows this sequence. The subsequent section delves into empirical literature and the foundation of the hypothesis. The third section provides details on the data and model specifications. The fourth section comprises results and discussions, and finally, the paper concludes by addressing policy implications and suggesting future directions.

2. Literature review

2.1. Theoretical evidence

Theoretically, The Triple Bottom Line (TBL) theory support the relationship among climate change, governance and economic progress. It emphasizes the interconnectedness of social, environmental, and economic sustainability (Elkington, 1998). This framework can help to conceptualize the interrelationship among climate change, governance, and economic growth as good governance practices enhance transparency, accountability, the rule of law and efficiency and allow efficient management of natural, economic, human, and financial resources for equitable, sustainable development that ensures society participation in decision making (Kardos, 2012). Fraj et al. (2018) define governance as ‘the exercise of authority on behalf of the people’, ensuring an equitable inclusion of a country’s citizens in the governance process. The TBL theory suggests that good governance can balance economic growth with environmental and social considerations (Omri & Mabrouk, 2020). Thus, good governance encourages investment and innovation in sustainable practices by balancing environmental, social and economic growth (Gupta, 2008).

2.2. Hypothesis development

2.2.1. Climate change and economic growth

Prior studies on climate change and economic growth nexus are inconclusive. Researchers either have a pessimistic or optimistic view about the association between climate change and economic growth.

Based on a pessimistic view, the growth process uses the environment as a source of raw material and energy and as a sink for waste that damages the environment. Therefore, continued economic growth is incompatible with the environment and needs to be halted. On the other hand, the optimistic view favours continued economic growth for environmental sustainability with continued technological changes. This view stresses that using green technology in both consumption and production does not compromise continued economic growth in the long and short run (Alagidede et al., 2016).

Empirically, the extant literature support the climate change and economic related developed inverse relationship. For instance, Nordhaus (1991) established the negative role of climate change in hindering the economic progress. Using data from 34 African countries, Abidoye and Odusola (2015) found that climate change negatively affects economic growth. Jones and Olken (2010) found that climate change negatively affects developing countries' export performance (Economic growth). Using Pakistani data, Rehman et al. (2021) documented the adverse influence of climate change on economic progress in the long run. While studying Sub-Saharan African countries, Alagidede et al. (2016) found that climate change reduces economic performance in Sub-Saharan Africa. Likewise, Adzawla et al. (2019) reported a monotonic decreasing relationship between GHG emissions.

2.2.2. Governance and economic growth

There exist a divergent views in the extant literature regarding the nexus between governance (institutional quality) and economic development. On school of thought of advocates, the notion that strong governance is key driver of economic development and therefore, strong governance mechanism guarantees sustainable economic. Empirically, Using data from 2002 to 2017 covering the eight (08) WAEMU countries, the Degbedji et al. (2024) examined the role of institutional quality and green economic growth using advance statistical techniques such FMOLS and supported the positive role of strong governance in shaping green economic development. Corradini (2021) tested the impact of institutional quality on economic growth in Italian NUTS-3 regions and supported the positive role of governance quality in shaping economic related development. However, this study reported the uni-directional relationship running from quality of governance to economic development and not the vice versa. Based on Asia economies from 2000 to 2008, Ahmed et al. (2022) investigated the role of institutional governance and economic progress via FMOLS and DOLS and supported the positive nexus between institutional quality and economic development. Using data of 05 Western Balkan countries from 2006 to 2016, Nedić et al. (2020) examined the institutional quality and economic growth nexus in panel setting framework and supported the constructive role of governance in shaping economic progress in Balkan region. On contrary, some researchers acknowledged the role of economic progress in shaping governance structure and they argued that strong economic development is crucial for strong governance mechanism (Maruta et al., 2020). Using the data of 67 economies from 2005 to 2018, Nair et al. (2021) examined the role of economic development in shaping institutional quality and established the positive effect of higher economic development on governance quality. Arvin et al. (2021) tested the relationship between economic development and institutional quality in lower and lower middle income economies over the period of 2005–2019 and supported the notion that there is exist an endogenous relationship between institutional quality and economic development. Similarly, Saha and Sen (2023) also complement the nexus between economic growth and institutional quality based on a sample of 130 countries.

2.2.3. Governance and climate changes

Several cross-country studies empirically examined the association between governance and climate change. For instance, Panayotou takes an interest in governance, specifically for the quality of governance and property rights, and suggests that better governance policies can offset the adverse effects of economic growth on climate change and make it more environmentally friendly. Bhattarai and Hamming also found that good governance positively relates to climate change. Bernauer and Koubi (2009) found that political stability positively affects climate change. Further, Tamazian and Rao (2010) examined the link between governance and climate change. They confirm a country's climate change and good governance are significantly related. Gani (2012) examines the relationship between five different governance indicators, i.e. (government effectiveness, political instability, quality of regulations, corruption, and the rule of law) and CO₂ emissions of 99 developing countries. His findings reveal that

corruption, political instability, and the rule of law are negatively related to per capita CO₂ emissions. Likewise, Bekun et al. (2021) argued that weak institutions dampen the environment's quality. Halkos and Tzeremes (2013) found that the link between governance and CO₂ emissions is non-monotonic and non-linear. Lau et al. (2014) found that governance quality is essential to control CO₂ emissions.

Similarly, Liu et al. (2020) argued that government effectiveness reduces CO₂ emissions in high-carbon emitting countries. Danish et al. (2019) documented that governance lower CO₂ emissions and enhances environmental quality. Moreover, due to regulatory quality, control of corruption and the rule of law, CO₂ emissions can be reduced (Appiah et al., 2022). Keeping in view the above theoretical and empirical support in the existing literature. This study test the following hypotheses (Table 1).

H₁: Climate change adversely affects economic growth.

H₂: Economic growth positively affects climate change

Table 1. Summary of literature.

Author	Year	Period	Region/Country	Main variables	Method	Findings	Sign
Kaufmann and Kraay (2002)	2002	2000–2001	175 countries	GI and EG	OLS and IV	GI↑EG↑	Positive
Adams and Mengistu (2008)	2008	1991–2002	82 developing countries	GI and EG	Least squares dummy variable (LSDV)	GI↑EG↑	Positive
Zugrave et al.	2008	1995–2003	Central and Eastern European countries	EG and CO ₂	2SLS, 3SLS	EG↑CO ₂ ↑	Positive
Huynh and Jacho-Chavez (2009)	2009	1996–2006	125 countries	GI and EG	OLS, fixed effect, random effect	GI↑EG↑	Positive
Bernauer and Koubi (2009)	2009	1971–1996	107 cities in 42 countries	GI and SO ₂	Fixed effect, random effect	GI↑SO ₂ ↑	Positive
Tamazian and Rao (2010)	2010	1993–2004	24 transition economies	GI and CO ₂	Random effect, GMM	GI↑CO ₂ ↓	Negative
Gani (2012)	2012	1998–2007	99 Developing Countries	GI and CO ₂	Regression	GI↑CO ₂ ↓	Negative
Halkos and Tzeremes (2013)	2013	1996–2010	G-20 Countries	GI and CO ₂	Non-parametric regressions	GI↑CO ₂ ↑	Positive
Shahbaz et al. (2013)	2013	1965–2008	South Africa	EG and CO ₂	ARDL bounds test	EG↑CO ₂ ↑	Positive
Emara and Jhonsa (2014)	2014	2009	197 countries	GI and EG	OLS, 2SLS	GI↑EG↑	Positive
Lahouij (2017)	2017	2002–2014	78 countries	GI and EG	Fixed effect, random effect	GI↑EG↑	Positive
Danish et al. (2019)	2019	1996–2017	BRICS countries	GI and CO ₂	Pooled mean group (PMG) estimator	GI↑CO ₂ ↓	Negative
Adzawla et al. (2019)	2019	1970–2012	Sub-Saharan Africa (SSA)	EG and CO ₂	VAR, OLS	EG↑CO ₂ ↓	Negative
Liu et al. (2020)	2020	1996–2017	China, India, Japan, Russia, and the USA	EG, GI and CO ₂	FMOLS & DOLS	EG↑CO ₂ ↑, GI↑CO ₂ ↓	Positive/Negative
Destek et al. (2020)	2020	1800s–2010	G-7 countries	EG and CO ₂	Time-varying cointegration and bootstrap-rolling window estimation	EG↑CO ₂ ↓	Negative
Abbasi et al. (2021)	2021	1972–2018	Pakistan	CO ₂ and EG	ARDL, frequency domain causality test	CO ₂ ↑EG↑	Positive
Fawaz et al. (2021)	2021	1996–2018	111 high and low-income developing countries	GI and EG	Fixed effect	GI↑EG↑	Positive

3. Research design

3.1. Data

A panel dataset of 47 Asian countries from 2010 to 2020 has been collected from different sources. The countries in the sample were selected based on data availability during the study period. We took 11 years (2010–2020) to align with the prior studies. For instance, researchers took 11 years (Huynh & Jacho-Chavez, 2009), 12 years (Adams & Mengistu, 2008), 9 years (Zugrave et al.), 12 years (Tamazian & Rao, 2010), and 13 years (Lahouij). The study variables, their definition and data sources are reported in Table 2.

3.2. Operationalization of variables

3.2.1. Climate change

Researchers used different proxies for climate change, such as temperature (Abidoye & Odusola, 2015; Jones & Olken, 2010), temperature and precipitation (Akram, 2013; Alagidede et al., 2016), carbon monoxide, nitrogen dioxide, and sulfur dioxide (Friedl & Getzner, 2003), Carbon dioxide (Adzawla et al., 2019). Intergovernmental Panel on Climate Change stated that the share of CO₂ emissions is 76.7% of total GHG emissions, the primary reason for environmental degradation. Adzawla et al. (2019) argued that the primary source of climate change is CO₂ emissions. Based on this, the study used CO₂ emissions as a proxy for measuring Climate Change.

3.2.2. Economic growth

Economic growth is the third variable used in this study. Different proxies have used for economic growth, such as the logarithm of gross domestic product (ln(GDP)) (Zhuo et al., 2021), change in the gross domestic product (Pao & Tsai, 2011). Following Zhuo et al. (2021), we used the log transformation of GDP as a proxy of economic growth because log transformation provides consistent and efficient estimates and covers the problems of multicollinearity and heteroscedasticity (Zafar et al., 2019).

3.2.3. Governance index

We considered the institutional quality as measure for measurement of governance process in Asia. By following Kaufmann and Kraay (2002); Liu et al. (2020), we used the widely known 06 proxies of institutional quality such as voice and accountability, political stability, the rule of law, control of corruption, government effectiveness, absence of violence, and regulatory quality. We constructed governance index based on principal component analysis (Kaufmann et al., 2011). Prior to the PCA estimation, we have applied Meyer-Olkin (KMO) and Bartlett test of Sphericity to validate the use of the PCA technique. Both test support the use of PCA for the construction of composite governance indicator. The results of PCA based total variance, Bartlett's test of Sphericity, and the KMO are presented in Table 3.

3.3. Econometric model

To empirically examine the long-run causal nexus among climate change, governance, and economic growth in an Asian region, an advanced panel data framework was employed. Panel data have several advantages over other types of data. Baltagi documented that panel data have more informative, efficient, variability, and degree of freedom and less collinearity among variables. It allows to study the

Table 2. Variable description.

S. No.	Variables	Definition	Source
1	Climate Change	Proxy by CO ₂ emissions as metric tons per capita at the country level	https://www.bp.com (BP Statistical Review of World Energy)
2	Governance	A composite governance index of 06 widely known governance indicators of Liu et al. (2020)	WDI
3	Economic growth	log transformation of GDP as a proxy of economic growth	WDI

Table 3. Principal component analysis.

Component	Eigenvalue	%Variance	Cum. Variance	KMO test	Bartlett's test of sphericity
PC1	4.734	0.789	0.789	0.887	Chi-square =4541.277
PC2	0.681	0.113	0.902		p-Value =0.000
PC3	0.382	0.064	0.966		
PC4	0.122	0.02	0.986		
PC5	0.047	0.008	0.994		
PC6	0.035	0.006	1.000		

dynamics of change with short time series, controlling unobserved time-invariant heterogeneity (Arellano & Honoré, 2001) and capturing the variability between the cross-sections and the temporal dimension (Alvarado et al., 2022). Therefore, the study employed a panel cointegration procedure as a general autoregressive model of order p in Z_{it} where Z_{it} is a column vector as follows:

$$Z_{it} = \begin{bmatrix} EG_{it} \\ GI_{it} \\ CO2_{it} \end{bmatrix} \dots \quad (1)$$

The panel cointegration procedure enables us to address the well-known problems of cross-sectional dependency across panel units and unobserved heterogeneity. The following general analytical model was employed.

$$Z_{it} = \alpha_0 + \sum_{j=1}^p \beta_{1j} Z_{it-j} + \sum_{j=0}^q \beta_{2j} X_{it-j} + v_i + \varepsilon_{it} \quad (2)$$

where p and q are the lags of dependent and independent variables, X are the exogenous and control variables, and ε is the error term.

3.4. Analytical procedure

In analogous to the steps involved in time series analysis, Our panel cointegration procedure consists of (i) panel unit root, (ii) testing of cointegration, and (iii) the long and short-run relationship estimations.

3.5. Data analysis techniques

We tested the impact nexus between climate change and economic development in Asia via the following steps. In first step, we test the stationarity of data via widely known panel unit root test such as Levin et al. (2002) (LLC); ADF-Fisher and PP-Fisher tests introduced by Maddala and Wu (1999) to test whether the data is stationary at level or first order. In second step, we tested the long run relationship via best suitable panel cointegration test by Kao (1999) and Pedroni (2004) to examine the long run relationship among the variables. In third step, we employed we employed the fully modified ordinary least square (FMOLS) developed by Phillips and Moon (1999), and the dynamic ordinary least square (DOLS) method developed by Kao and Chiang. Both FMOLS and DOLS efficiently handle serial correlation and heterogeneity issues in panel data. FMOLS is a non-parametric procedure that controls autocorrelation and heterogeneity issues. In contrast, DOLS is a parametric method that handles the same problem with leads and lags of independent variables (Liu et al., 2020). More specifically, FMOLS and DOLS produce consistent, efficient and unbiased estimates in the long run.

4. Results and discussions

Table 4 presents the summary statistics of the study variables, climate change (CO₂ emission), governance index (GI), and economic growth (EG) of Asian countries from the period 2010 to 2020. The mean economic growth is 0.039 with a standard deviation of 0.059, which shows a 3.9% mean growth rate for Asian countries. Focus Economics (2017) indicated a 4.9% growth rate for Asian countries in the third quarter of 2018. World Bank (2017) predicts an average of 5.4% annual GDP growth for Asian countries compared to 3.1% average growth worldwide. The mean GI is 1.002 with a standard deviation of 2.176, which shows that Asian countries have feeble governance structures. The result is align with the findings

Table 4. Summary statistics and correlation matrix.

Panel A: Descriptive statistics and mean comparison												
Variables	Full sample			Developed countries			Developing countries			Shapiro Wilk test of normality z-Stat (<i>p</i> -value)	Wilcoxon Rank test z-Stat (<i>p</i> -value)	
	Mean	Median	St.Dev	Mean	Median	St.Dev	Mean	Median	St.Dev			
EG	0.039	0.044	0.059	0.025	0.028	0.069	0.044	0.051	0.054	10.348 (0.000)	6.295(0.000)	
CO2	0.11	0.027	0.386	0.331	0.122	0.711	0.033	0.018	0.039	13.597 (0.000)	−10.131(0.000)	
GI	1.002	−0.108	2.176	2.514	2.519	1.453	−0.883	−0.923	1.629	4.699 (0.000)	−15.3(0.000)	
Panel B: Correlation matrix and variance inflation factor (VIF)												
							EG			GI	CO2	VIF
EG							1					
GI							−0.118			1		1.05
CO2							0.354			0.225	1	1.05
Mean VIF												1.05

Table 5. Panel unit root test.

Variables	Levin, Lin and Chu Test			Im, Pesaran and Shin W-test			ADF-Fisher test			PP-Fisher test		
	Level	1st Diff	Decision	Level	1st Diff	Decision	Level	1st Diff	Decision	Level	1st Diff	Decision
EG	−0.096	−15.792***	I (1)	2.764	−7.102***	I (1)	105.798	262.22***	I (1)	109.214	269.134***	I (1)
CO2	−1.186	−7.837***	I (1)	3.707	−8.431***	I (1)	71.096	127.229***	I (1)	46.149	155.248***	I (1)
GI	1.352	−19.388***	I (1)	−1.13	−10.307***	I (1)	123.96	300.494***	I (1)	128.945	290.181**	I (1)

Note: ***, **represents $p < 0.01$ and $p < 0.05$.

of Gil et al. (2019), who stated that the governmental performance of Asian countries is inferior. Vadlamannati (2009) also reported poor governance quality in Asian countries. The mean CO₂ emissions is 0.11 with a standard deviation of 0.386. It shows that Asian countries contribute greatly to the world's greenhouse gas (GHG) emissions and are most vulnerable to climate change (Dolšák & Prakash, 2018).

Moreover, Table 4 also reports the mean comparison between developed and developing nations. The results of the Wilcoxon Rank test indicate a significant mean difference between the developed and developing countries for the study variables. From the results, we concluded that developed countries have better economic growth and governance and higher CO₂ emissions than developing countries in Asia. Our argument is supported by the view that developed countries use different energy resources to compete with developing countries' economic growth, which boosts CO₂ emissions (Cao et al., 2022).

Panel B of Table 4 illustrates the correlation matrix and variance inflation factor of economic growth, Governance Index, and CO₂ emissions. From the results, it is evident that the variables have less variability and no multicollinearity problem. The multicollinearity problem arises when the correlation is more than 0.8 (Gujarati et al., 2012). Also, the VIF values of GI and CO₂ support the findings of the correlational analysis of no multicollinearity problem among the variables because all variables have VIF values less than 5.

4.1. Results of panel unit root and panel cointegrations

We test the stationarity of variables via widely known unit root test such as LLC, IMP, ADF-Fisher, and PP-Fisher to determine the order of stationarity of variables. The reported in results in Table 5 suggest that all the variables are stationary at order 1, I (1). Afterward, we employed the cointegration tests such as Pedroni test and Kao test to examine the long run association among the variables and the results are reported in Table 6. The findings reveal that there exists a long run relationship between climate change and economic growth in Asia region.

4.2. Long-run relationship

Table 7 shows of FMOLS and DOLS estimates of model 1 produce similar results for CO₂ emissions regarding sign and significance for all the sample Asian countries. A positive relationship is found between CO₂ emissions and economic growth. From FMOLS, the coefficient of CO₂ is 0.277, which

Table 6. Panel cointegrations.

Pedroni cointegration tests									
Within-dimension			Between-dimension			Kao cointegration test			
Test		<i>p</i> -Value	Test		<i>p</i> -Value	Test		<i>p</i> -Value	Decision
Model-1 EG← CO ₂ , GI									
V	3.763	0.000	Rho	2.251	0.987	ADF	−2.348	0.009	Cointegrated
Rho	−2.413	0.008	PP	−9.956	0.000				
PP	−11.2	0.000	ADF	−5.6	0.000				
ADF	−4.553	0.000							
Model-2 CO ₂ ← EG, GI									
V	−502.88	1.000	Rho	4.668	1.000	ADF	2.535	0.005	Cointegrated
Rho	0.702	0.758	PP	−6.701	0.000				
PP	−7.653	0.000	ADF	−2.14	0.016				
ADF	−1.755	0.039							

Table 7. Long run relationship.

Dependent variables	Independent variables	FMOLS			DOLS		
		Coefficient	Std. Error	t-State	Coefficient	Std. Error	t-State
Model 1: EG	CO ₂	0.277	0.042	6.634***	0.035	0.011	3.114***
	GI	-0.012	0.004	-2.67***	-0.007	0.002	-3.554***
Model 2: CO ₂	EG	1.436	0.411	3.495***	1.119	0.382	2.929***
	GI	0.055	0.013	4.238***	0.045	0.011	4.058***

Note: ***represents significance at a 1% level.

means that a rise in CO₂ emissions resulted in a 0.277 increase in EG. Similarly, DOLS results reveal that the coefficient of CO₂ in relation to EG is 0.045, indicating that an increase in CO₂ emissions increases EG by 0.035. This long-run positive relation between CO₂ emission and economic growth aligns with the results of Destek et al. (2020); Shahbaz et al. (2013), who documented a long-run positive association between economic growth and climate change. Our results also support the pessimistic view that the growth process uses the environment as a source of raw material and energy and as a sink for waste that damages the environment.

Furthermore, the FMOLS results illustrate a negatively significant effect of GI on EG, indicating that an increase in governance structure reduces economic growth by 0.012. Likewise, the DOLS results report that the influence of GI on EG is -0.007, which shows that an increase in governance structure brings a reduction of 0.007 in economic growth. In a nutshell, the results show that a rise in the quality of governance reduces economic growth in the Asian region. Our results are supported by the findings of Musa et al. (2023), who argued that restrictions and strict rules sometimes slow economic growth. This result also aligns with the finding of Fraj et al. (2018), who documented a negative relation between governance and economic growth for 50 developed and developing countries. Our results also support the Keynesian theory that government interventions are necessary for sustained and stable economic growth in the long run.

From model 2, the study used CO₂ emissions as a dependent variable and examined the long-run association between the variables. The FMOLS and DOLS estimates produced similar signs and significance levels for economic growth and governance in relation to CO₂ for the sample countries. The findings depict there exist a long run positive relationship of carbon emissions with EG and GI. In other words, one-unit increase in EG and GI upsurge the carbon emissions by 1.436 and 0.055 respectively. Similarly, the DOLS results also complement the positive impact of EG and GI on carbon emissions in Asia. The results are consistent with the notion that rapid economic development with weak governance further deteriorate the environmental quality thereby increasing the GHG emissions (Alvarado et al., 2022). Empirically, the finding shared common grounds with Majeed and Mazhar (2019), they established the disastrous role of unregulated economic development in shaping environmental quality. Similarly, in context of Pakistan, Khan et al. (2020) concluded that positive association of economic progress with carbon emissions.

Ironically, the findings suggest that a positive impact of governance on carbon emissions, suggesting that increase in governance quality further deteriorate the environmental quality in Asia. This result supports the views of Halkos and Tzeremes (2013), who argued that variations in countries' regional and

Table 8. Panel causality test.

Dependent Variables	Causation (independent variables)			Long-run (t-statistics)	Direction
	Short-run (F-statistics)				
	ΔEG	ΔGI	ΔCO2		
ΔEG	–	4.142**	3.624**	–0.662***	GI→EG, CO2→EG
ΔCO2	0.011	2.097	–	–0.007**	No causality

economic development shape the way and the number of governance indicators influence the emission of CO₂. Our results align with Lau et al. (2014), who documented a long-run association between Governance, CO₂ emissions, and economic growth. Therefore, quality governance is essential for controlling CO₂ emissions in economic development. Overall, the study found a long-run association between climate change, governance, and economic growth for the entire sample.

Table 8 illustrates the results of the Granger causality test among EG, GI, and CO₂ emissions. The second column's result shows that GI Granger causes EG at a 5% significance level. The study found a unidirectional causal relationship between GI and EG. The result aligns with the outcomes of Emara and Jhonsa. The first and second columns show that EG and GI do not Granger cause CO₂. The third column shows that CO₂ causes EG, but EG does not Granger causes CO₂ emission at a 5% significance level. Thus, a unidirectional causal association exists between CO₂ emissions and EG. This result aligns with the findings of Khurshid et al. (2022); Lau et al. (2014), who found a unidirectional short-run association between EG and CO₂ emissions. Likewise, Abbasi et al. (2021) found a short-run causal relationship between CO₂ emission and economic growth. For the dependent variable EG, the coefficient of the error correction term ECT_{it-1} is significantly negative at a 1% level, indicating a high 66.2% speed of adjustment to the long-run equilibrium. However, for the dependent variable CO₂, the coefficient of ECT_{it-1} is negatively significant and denotes a slow speed of adjustment to the long-run equilibrium.

5. Conclusion and policy implications

The study investigated the long-run causal nexus between CO₂ emissions, GI, and EG for 47 Asian countries from 2010 to 2020. For this purpose, advanced panel data framework of panel unit root tests, panel cointegration procedures consisting of Pedroni and Kao (1999), and FMOLS and DOLS for long-term association were applied. Our results illustrate the long-run causal association between CO₂ emissions and EG. In the long run, the results demonstrate that CO₂ emissions positively affect EG, while GI adversely affects EG. Furthermore, both EG and GI positively affect CO₂ in the long run. Moreover, we also found a unidirectional causal link between GI and EG, and between CO₂ emissions and EG, and no causal relation between GI and CO₂ emissions.

Our study has some policy and practical implications as well. First, the positive relation between CO₂ emissions and economic growth implies that Asian governments should further enhance green investment and innovations to reduce CO₂ emissions without reducing economic growth. Moreover, policymakers should evolve stringent policies to force the governments to ensure that the likelihood of a green growth narrative has been achieved.

Second, the antagonistic relation between governance and economic growth implies that the disciplinary influence of quality governance only enhances economic growth in countries with proper structure and function of market mechanisms. Therefore, Asian countries should strengthen suitable market mechanism functions to ensure the quality of governance in general and institutions in particular. Moreover, Asian countries should enhance their governance system to implement environmental regulations and policies to mitigate CO₂ emissions.

Third, the positive association between governance and CO₂ emissions does not support the government's effectiveness in reducing CO₂ emissions in the Asian region. The government's effectiveness and efficiency in governance quality consist of environmental protection and sustainable implementation of resources. The more governance effectiveness, especially in implementing environmental laws and regulations, the more environmental protection. Therefore, policymakers should design effective government policies to increase the implementation of environmental regulation, which leads to a further reduction

in CO2 emissions. Moreover, policy regarding the decline in CO2 emissions should align with governance indicators specific to countries' development and unique regional factors.

Finally, it is recommended that in the long run, proper governance should be warranted not only to enhance economic development and the needs of society but also to maintain environmental sustainability in the Asian region.

The study has some limitations that need further investigation. As the study did not consider the non-linear nexus between governance, climate change, and economic growth, future studies should be augmented for the non-linear relationship in the Asian region. The study is limited to panel data; future studies could analyze time series data by considering other institutional variables. In addition, our data time frame is limited to 11 years; future research can take a more extended time frame and reanalyze the same panel procedure in the sampled Asian countries. Moreover, our study is limited to a single control variable; future studies explore the nexus using the same methodology by including other control variables. Finally, future studies can validate this study in different groups of panel countries for more generalizability.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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