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A nexus between the rule of law, green innovation, growth and sustainable environment in top Asian countries: fresh insights from heterogeneous panel estimation

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ABSTRACT

The intricacies revolving around Environmental Governance is the prime issue of this century. For this, researchers and practitioners have always strived for viable solutions that are not just efficient in terms of their productivity, but are also innovative in nature, so that they have the least possible repercussions to the ecological wellbeing. Therefore, the present study aims to explore the relevancy of the rule of law and green innovation, while also ascertaining the economic growth among the top Asian countries from 1995 to 2018. Moreover, the relevancy of the Environment Kuznets Curve (EKC) is also validated by the help of the advanced and latest estimation techniques; specifically, the Cross-section augmented autoregressive distributed lags test (CS-ARDL). Based on the findings from the CS-ARDL, the rule of law, and the concept of green innovation have been reported to have a negative association with each other. Additionally, the EKC hypothesis is found to be legitimate and relevant as well. Based on the findings, creating awareness has been recommended for establishing the rule of law. Whereas, more assistance and investments have also been recommended in order to achieve a higher level of Research and Development, which can then enhance the level of green innovation.

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1. Introduction

It does not come as a surprise that the climate of the earth is rapidly changing. This is essentially fast becoming a matter of serious concern for human beings, particularly in terms of meeting and fulfilling their indispensable, and basic needs and requirements, including water accessibility, production of food, land usage, environment, and human health (Bibi et al., 2021; Danish & Wang, 2019; Wang, Su, Hua, et al.,

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2021). Researchers, in this regard, have also urged that if the attention and consideration to this problem are defectively and inadequately given, then this problem can single-handedly lead to various other volatilities, risks, and destructions, which can be far more severe and destructive in terms of its magnitude, scale, and enormity (Guo et al., 2021; Ji et al., 2021; Umar, Ji, Mirza & Naqvi, 2021). Thus, in order to counter the destruction caused by climate change, the primary and crucial solution is pollution prevention, which is only probable by controlling and curtailing the emissions of greenhouse gases (Hao et al., 2021; Ji, Zhang, et al., 2021; Umar et al., 2021).

It should also be noted that the increase in the pollution and greenhouse gases is also because of the increased demand of products and services across the globe. Although this increased demand tends to improve the economic growth (GDP) of any economy, either due to regular increased population or improved lifestyle, the downsides that come with it must be addressed (Su et al., 2021; Umar, Ji, Kirikkaleli, Shahbaz, et al., 2020). However, at the same time, such growth or demand also increases the demand of the factors of production and influences the consumption of energies as well (Umar et al., 2021). This then tends to enhance the level of pollution and greenhouse emissions in general, and carbon emissions (CE) in particular (Song et al., 2020; Su et al., 2021; Wang, Su, Lobonț, et al., 2021). Moreover, the whole process of production and consumption is a source of pollution as well. During the production process, the consumption of resources and energy leads to increased CE and post-consumption; the mishandling of which, which mainly comprises of toxic waste, also impairs the ecology. Thus there is a need for the incorporation of sustainable business philosophies (Ahmed et al., 2020; Ielasi et al., 2018; Kaiser & Welters, 2019), including sustainable production, which govern the production stage, and propagate responsible consumption, which governs the consumption phase, and the "Extended Producers' Responsibility", which oversees the post-consumption (Najmi et al., 2021).

It is true that multiple arrangements have been made in order to govern and protect the ecological wellbeing of the environment and climate (Guo et al., 2022; Umar et al., 2021; Yan et al., 2021). One such initiative is the Kyoto Protocol of 1997. However, among them the most important, and one of the latest agreements which has been agreed upon, and endorsed by more than 190 countries, is referred to as the "Paris Agreement". In this particular agreement, all of the signatory countries have agreed to empirically eradicate global warming, by keeping the average rise of the temperature below to the threshold of 2 degree Celsius (Ji, Chen, et al., 2021; Rizvi et al., 2020; Yu et al., 2022). Hence, countries are now taking substantial and legitimate measures, in order to meet the desired threshold and ensure the shared objective of carbon neutrality (Ahmed et al., 2020). Precisely, for meeting the said target, economies are now making decisions and measures at all the relevant levels, including the individual level, organizational level and governmental level as well (Muhammad & Long, 2021). At the individuals' level, environmental sustainability can be ensured through responsible consumption (Najmi et al., 2021). This can primarily be achieved by, for instance, reducing the amount of plastics consumption (Khan et al., 2019), and through the efficient disposition of post-consumption waste (Khan, Ahmed, Najmi, et al., 2019). in precise terms, in their study (Najmi et al., 2019) have summarized some of the various factors from the literature, by the help of which the

responsible consumption among the consumers can be enhanced. This can also be undertaken by creating awareness, developing moral values and norms, and providing the most recent developments in terms of the available knowledge of the consumers (Umar et al., 2020).

At the organizational level, the eradication of CE by improving environmental sustainability can be undertaken through multiple improvements and operations (Su et al., 2020). For instance, by collaborating with the stakeholders at the stage of development of the product (Najmi & Khan, 2017), collaborating with the supply chain partners for a sustainable value chain (Ahmed et al., 2020), transforming processes towards green supply chain operations in general (Mirza et al., 2022; Naqvi et al., 2021), and by greening the suppliers in particular, as they are the main source of the raw material (Najmi et al., 2020), by having a quality infrastructure of reverse logistics (Najmi et al., 2014), and by conducting frequent orientations which comply to the ecology and environment (Ahmed et al., 2019). Among these, the most crucial factor which leads all of these operations is perhaps the level of innovation that an organization needs, in order to achieve environmental excellence (Ahmed et al., 2020; Umar et al., 2022).

At the governmental level, the pollution alleviation and reduction in the level of CE can be made by the efficient role of the institutions and law enforcement agencies, including social, governmental, and political institutions etc., (Goel et al., 2013). It should be noted that the role of these institutions should not be merely restricted to the formulation of rules and regulations that document the measures by which environmental protection can be governed (Muhammad & Long, 2021). However, the institutional pressure is extremely important to establish the rule of law, which forces the individuals or the organisations to have compliance with the rules (Ahmed et al., 2019) so that the possible consequences to the environment by the act of the parties are not just directed, but their level of compliance is ensured to establish the rule of law (Arminen & Menegaki, 2019; Welsch, 2004).

Therefore, in accordance with the discussion, it should be noted that controlling CE is inevitable without the support of the governmental agencies that ensure the rule of law to protect and preserve the quality of the environment. Furthermore, CE can also not be controlled by merely relying on the same conventional production operations and technologies that do not fulfil the required productivity criteria. Thus for the said purpose, the level of innovation is essential and the key to success in operations and environmental excellence. In contrast, the establishment of the rule of law is also reported to lead the improvement in environmental sustainability.

Hence, the present study has the objective to explore the relevancy of the rule of law (LAW) and green innovation (GIN) while ascertaining the growth of the economies among the top Asian countries with the help of advanced and latest estimation technique namely "Cross-section augmented autoregressive distributed lags test" (CS-ARDL). Through this, the present study contributes to the literature in various ways. Firstly, through selecting the top Asian countries because these countries account for the majority of the global population, are key players in the global economic output, and at the same time also significantly contribute to emitting the CE. Secondly, through the statistical technique because since these countries reflect different cross-

sections, CS-ARDL is considered the advanced, legitimate, and robust technique for handling the panel data sets, especially when the cross-sections are heterogeneous (Ji, Umar, et al., 2021). Hence the application of CS-ARDL is made because of addressing various methodological concerns, including endogeneity, normality and capability of explaining more variances while comparing with the traditional statistical techniques (Ahmad et al., 2020). Thirdly, the present study also intends to evaluate the relevancy of the "Environment Kuznets Curve" (EKC) hypothesis, which reports that growth and pollution have a U-shaped relationship where growth tends to increase pollution. However, after reaching a certain limit, it starts decreasing (Grossman & Krueger, 1991). Lastly and most importantly, the current study is an attempt to validate the use of LAW and GIN as the potential solution to eradicate the CE, which, if found legitimate in terms of empirical evidence then can eventually attract the attention of the policymakers and academicians in further exploring its relevance and appropriateness.

The remainder of the study organisation is next section discusses the relevant literature, methodology followed by the estimated outcome through the application of the statistical techniques and in the last study is concluded, and recommendations are made.

2. Literature review

Since the ecological quality is regularly getting worse, therefore, academicians and environmental scientists have urged towards the relevancy of Green Innovation as the potential solution for the pollution alleviation and eradication of Carbon Emissions (Wang, Umar, et al., 2021). In this regard, the review of the literature leads to the summarization of the studies into two categories. The first group reflects the study area in which researchers have urged to opt for Green Innovation, as they are reported to be staunch advocates of Green Innovation initiatives, in order to successfully decrease the level of Carbon Emissions, and also suggest thorough guidelines, which Green Innovation initiative can be used productively and efficiently for this purpose (Batool et al., 2019; Danish, 2019; Haseeb et al., 2019). The second group represents those researchers who discard the deployment of Green Innovation initiatives, as they do not consider it to be a potentially viable solution for improving the environment quality, and empirically reported the absence of its role in minimizing the Carbon Emissions level. In fact, they consider it as an operation or activity which would further deteriorate the environment (Chien et al., 2021; Lee & Brahmasrene, 2013; Park et al., 2018; Razzaq et al., 2021a, 2021b; Salahuddin et al., 2016). Similarly, Fethi and Rahuma (2019), Mensah (2019) and Du et al. (2019) are also of the opinion that Green innovation has the capability of reducing the level of Carbon Emissions significantly. These findings were also reported in the other geographical settings such as ASEAN (Salman et al., 2019), for high income countries (Du et al., 2019), BRICS (Khattak et al., 2020) and also among the top polluted countries (Zhao et al., 2022). Since the contrasting evidence is always a relevant point to kick start an investigation, therefore, the current research has an objective to explore the said phenomena in the context of the top Asian countries.

The Rule of Law (LAW) refers to the perceived level of law abidance by the society, and their respective individuals, precisely with respect to the enforcement of regulation, rules, and their compliance (Greenidge et al., 2016). It is also considered as the key element of the institution, primarily due to its jurisdictions of law enforcement. In contrast, it is assumed that when a society has a high level of LAW, there is the highest probability of experiencing more compliance and abidance to the ecology and environment rules (Muhammad & Long, 2021). For instance, for the government to enforce the environmental wellbeing, there is a need to establish the rule of law, through which the environment can be safeguarded by multiple potential solutions, such as through awareness of sustainable consumption (Mohammed et al., 2022) and encouraging consumption of renewable sources (Mahmood et al., 20201). A limited number of studies directly discuss and analyze the level of association between LAW and Carbon Emissions. Some of the empirical findings include those of (Salman et al., 2019), who reported a negative relationship between LAW and Carbon Emissions, which essentially means that a higher level of LAW helps eliminate the level of Carbon Emissions. Similar findings were also reported by (Muhammad & Long, 2021) in the context of 65 countries participating in the Belt and Road Initiative. In contrast, the findings of (Abid, 2016) reported and concluded the stimulating role of LAW with Carbon Emissions. Therefore, the current research also aims to expand the literature by exploring the said phenomena in the context of top Asian countries.

3. Methodology

3.1. Data

The selection of an appropriate proxy from the reliable database in accordance with the objective of the research is extremely crucial. Therefore, as per the objective, the proxy of the rule of law (LAW) from the governance index was selected, GDP was selected to represent the growth, the number of patents registered for green was selected as the proxy for green innovation (GIN), and lastly, the level of carbon emissions (CE) was selected as the proxy of environment sustainability 1995–2018. In addition to this, as the study is based on the top Asian countries, therefore, the selected countries are mentioned in Table 5. All of the data comprised of time range of from 1995 to 2018 whereas, the data for LAW and GDP were extracted from the database of (World Bank, 2021), and GIN and CO2 were extracted from the database of OECD (2021). Additionally, for uniformity among the results, the natural log of the variables were taken.

3.2. Slope coefficients homogeneity and cross-section independence test

In contrast with the traditional techniques of econometrics and their respective methodologies, the current study firstly assesses the level of "Slope Coefficients Homogeneity" (SCH) followed by "Cross-Section Independence" (CSI) because if these concerns are not addressed at the earlier stage, then there will be a presence of inconsistency and the outcome will have biases. Therefore, for assessing SCH, the technique proposed by (Baltagi & Hashem Pesaran, 2007) was utilised as the assumption of coefficient's homogeneity is considered an essential pre-requisite while having

a possibility of its presence or absence. On the other hand, for assessment of CSI, technique by (Pesaran, 2004) was utilised because of having shocks that are local as well as global like the financial crises faced by Asia in 1997 and the financial crises witnessed by the countries worldwide in 2007-2008 (Ji, Umar, et al., 2021). The typical elaboration of SCH in mathematical form is represented as equations 1 and 2.

$$\tilde{\Delta}_{SCH} = (N)^{\frac{1}{2}}(2k)^{-\frac{1}{2}}\left(\frac{1}{N}\tilde{S} - k\right) \tag{1}$$

$$\tilde{\Delta}_{ASCH} = (N)^{\frac{1}{2}}\left(\frac{2k(T-k-1)}{T+1}\right)^{-\frac{1}{2}}\left(\frac{1}{N}\tilde{S} - 2k\right) \tag{2}$$

Referring equation 1 and 2, $\tilde{\Delta}_{SCH}$ represents the level of change in SCH and $\tilde{\Delta}_{ASCH}$ represents the level of change in Adjusted SCH.

3.3. Tests for unit root

In contrast to the test assessing stationarity that belongs to the first generation, for instance, (Im et al., 2003) and (Levin et al., 2002), the current study utilised the technique proposed by (Baltagi & Hashem Pesaran, 2007), which is referred to as "cross-section augment IMPS" (CSIMPS) test. This technique is considered consistent and vigorous against the coefficients of slope that are heterogeneous in nature and CSI. Precisely, this technique ascertains CSI by making an addition of lags and taking the difference at the first level by averaged and augmented cross-sections. The typical elaboration of CSIMPS in mathematical form is represented as equation 3.

$$\Delta Y_{i,t} = \gamma_i + \gamma_i Y_{i,t-1} + \gamma_i \overline{X}_{t-1} + \sum_{l=0}^{p} \gamma_{il} \Delta \overline{Y}_{t-1} + \sum_{l=1}^{p} \gamma_{il} \Delta Y_{i,t-1} + \varepsilon_{it} \tag{3}$$

Referring to equation 3, the averages at first differences and lagged are represented as $\Delta \overline{Y}_{t-1}$ and $\overline{Y}_{t-1}$. The test statistic for CSIMPS is represented as:

$$\widehat{CSIMPS} = \frac{1}{N}\sum_{i=1}^{n} CADF_i \tag{4}$$

Referring to equation 4, "cross-sectional augmented Dickey-Fuller," is represented by CADF, which is further utilised with equation 3. The statements of the hypothesis have been elaborated as non-stationarity is the reflection of acceptance of the null hypothesis. In contrast, the existence of stationarity is the reflection of acceptance of an alternate hypothesis.

3.4. Test for panel cointegration

The cointegration relationships among the studied variables, the rule of law, green innovation, growth, and carbon emissions in a longer period of time, were assessed

by the utilisation of technique by (Westerlund, 2007), which is founded on an error correction framework. The said is superior and rigorous while comparing it with the technique of assessing cointegration by (Khan et al., 2020) and is extremely helpful in employing error irrespective of their CSI and SCH. The typical elaboration of this test in mathematical form is represented as equations 5 to 8.

$$G_t = \frac{1}{N}\sum_{i-1}^{N}\frac{\acute{a}_i}{SE(\acute{a}_i)} \tag{5}$$

$$G_a = \frac{1}{N}\sum_{i-1}^{N}\frac{T\acute{a}_i}{\acute{a}_i(1)} \tag{6}$$

$$P_T = \frac{\acute{a}_i}{SE(\acute{a}_i)} \tag{7}$$

$$P_a = T\acute{a} \tag{8}$$

Referring to equation 5 and 6, they are for estimating the mean statistics for the group like G_t and G_a, whereas on the other hand, equations 7 and 8 are for estimating the mean statistics for the panel like P_t and P_a. The hypothesis statement for this test states that the null hypothesis means there is no existence of the cointegration, whereas the alternate hypothesis states the presence of cointegration.

3.5. Cross-section augmented autoregressive distributed lags test

In order to assess the relationship for both longer and shorter periods of time, the current study utilises the "Cross-section augmented autoregressive distributed lags test" (CS-ARDL), which is a quite recent technique proposed by (Chudik et al., 2016). This test is considered rigorous, robust, and efficient while comparing it with the other techniques that are based on "common correlated effect mean group," "augmented mean group," "pooled mean group," and "mean group" (Danish, 2019; Li et al., 2020). In addition to this, the CS-ARDL is not just capable of addressing CSI and SCH but is also efficient against other issues, including non-stationary (mixed order of integration too), endogeneity, and other un-observed variances or common factors which can be statistically significant as ignoring them will lead to the computation of biased and ambiguous outcome (Khan et al., 2020). The typical elaboration of CS-ARDL in mathematical form is represented as equation 9.

$$CE_{it} = \alpha_0 + \sum_{j=1}^{p}\lambda_{it}CE_{it-j} + \sum_{j=0}^{p}\acute{a}_{it}W_{t-j} + \sum_{j=0}^{3}\overline{Z}_{it,t-j} + \mu_{it} \tag{9}$$

Referring equation 9, $\overline{Z}_t = \left(\Delta\overline{CE}_{it}, \overline{W}_t'\right)'$ and $W_{it} = (LAW_{it}, GIN_{it}, GDP_{it})'$, whereas the predictor variables are represented as W, which are Rule of Law, Green Innovation, and Growth. To evaluate the quality, whether the test is robust and

rigorous or not is ensured by the help of the "augmented mean group test" suggested by (Eberhardt, 2012). This test is far superior to the other techniques like "pooled mean group" and "mean group" in the presence of the methodological issues discussed and mentioned earlier. In addition to this, for assessing the direction of causality, the test proposed by (Dumitrescu & Hurlin, 2012) is utilised, which is helpful to be applied when the value of T exceeds N or T is below N. In addition to this, this technique is also recommended when the dataset is balanced. There is heterogeneity in the panel dataset, whereas it can also efficiently handle the level of CSI. The typical elaboration of this technique in mathematical form is represented as equation 10.

$$z_{i,t} = \alpha_i + \sum_{j=1}^{p} \beta_i^j z_{i,t-j} + \sum_{j=1}^{p} \gamma_i^j T_{i,t-j} \tag{10}$$

Referring to equation 10, j represents the length of lag whereas $\beta^j(j)$ is for the computation of autoregressive parameters. As per the hypothesis statements of this test, when there is an absence of causality, it means accepting the null hypothesis, whereas when there is a presence of causality, it represents the rejection of null and acceptance of an alternative hypothesis.

4. Estimations and results

First and foremost, the assessment of CSI was done because of its propensity to lead to inferior and problematic outcomes if not ascertained rightfully. As already discussed, the statement of null and alternate hypothesis reflects the absence and existence of "cross-section dependence" (CD) (Pesaran, 2015). In contrast, the assessment of CD should be made variable wise as done in the current study. Although the significance level could be 10%, 5%, or 1%, which is normally accepted in the related studies, the outcome mentioned in Table 1 reported the existence of CD at a 1% level of significance for all of the studied variables.

In the next step, the level of stationarity was assessed, which is also essential to be gauged, whereas failure to ascertain could have inferior and problematic outcomes. Moreover, the stationarity was assessed with the help of two tests which are far superior to other conventional tests, namely the test by (Pesaran, 2007) and (Bai & Carrion-I-Silvestre, 2009). Based on the hypothesis statements, the outcome generated through the application of these two tests confirms the presence of stationarity. It discards the likelihood of having unit root issues in accordance with their computation framework. Precisely, the outcome reported by the test of (Pesaran, 2007) confirms that to ascertain the structural breaks, all of the studied variables are stationary at a

Table 1. Results of cross-sectional dependence analysis.

Variable	Test Statistics (p-values)
CE	38.010*** (0.000)
LAW	19.547*** (0.000)
GIN	12.981*** (0.000)
GDP	27.040*** (0.000)

"Note: ***, ** & * explain the level of significance at 1%, 5% and 10% respectively, whereas the values are in parentheses contains P-values".
Source: Author's Estimation.

Table 2. Results of Unit root test with & without structural break Pesaran (2007).

	Level I(0)			First Difference I(1)		
Variables	CIPS	M-CIPS		CIPS	M-CIPS	
CE	−3.011***	−4.010**		–	–	
LAW	−5.010***	−6.011**		–	–	
GIN	−3.001***	−4.005**		–	–	
GDP	−6.009***	−7.015**		–	–	
	Bai and Carrion-i-Silvestre (2009)					
	Z	P_m	*P*	*Z*	P_m	*P*
CE	0.301	0.245	18.001	−5.010***	6.010***	68.019***
LAW	0.150	0.141	21.010	−3.011***	4.011***	49.014***
GIN	0.204	0.102	19.101	−6.021***	7.019***	81.016***
GDP	0.175	0.160	17.103	−4.002***	5.013***	57.010***

"Note: The level of significance is determined by 1, 5, and 10% indicated through ***, ** and * respectively. For Bai & Carrion-i-Silvestre (2009) test, 1, 5, and 10% critical values (CV) for *Z* and *Pm* statistics are 2.326, 1.645 and 1.282, while the critical values (CV) for *P* are 56.06, 48.60 and 44.90, separately.".
Source: Author's Estimation.

Table 3. Results of slope heterogeneity analysis.

Dependent Variable: CE	
Statistics	Test value (P-value)
Delta tilde	62.047*** (0.000)
Delta tilde Adjusted	84.039*** (0.000)

"Note: ***, ** & * explain the level of significance at 1%, 5% and 10% respectively, whereas the values are in parentheses contains P-values".
Source: Author's Estimation.

1% level of significance. On the other hand, the outcome generated through the application of the test by (Bai & Carrion-I-Silvestre, 2009) also supported the findings of (Pesaran, 2007) and reported that the data is supposed to have unit root issues at the level. In contrast, it becomes stationary when their first difference is considered. The outcome generated from both tests confirming the stationarity of the data set variables wise is depicted in Table 2.

After ascertaining the level of CD and ruling out the propensity of having the unit root problems, in the later stage, the level of SCH was assessed in the data set through the revised version of (Swamy, 1970), which was done and discussed by (Pesaran & Yamagata, 2008) and is accordingly recommended for generating the rigorous and robust outcome (Alam et al., 2018). The hypothesis statements of this test state the presence and absence of SCH with the acceptance of null hypothesis and rejection of null hypothesis, respectively. The results generated through the application of (Pesaran & Yamagata, 2008) reported the absence of SCH. They concluded that the slope is heterogeneous, which is statistically significant, and the outcome is reported significant at a 1% level of significance (Table 3).

In the next stage, the level of cointegration was assessed with the help of (Westerlund & Edgerton, 2008). As discussed, this test has the hypothesis which is if it is found to have significance, then it means the cointegration is present. In contrast, if it is found to be insignificant, then it means the cointegration is absent. The outcome generated through (Westerlund & Edgerton, 2008) acknowledges the cointegration as the outcome reported is statistically significant at a 1% significance level. The outcome generated through (Westerlund & Edgerton, 2008) is mentioned in Table 4.

Table 4. Results of Westerlund and Edgerton (2008) panel cointegration analysis.

Dependent Variable: CE			
Test	No break	Mean shift	Regime shift
$Z_{\varphi}(N)$	−5.135***	−5.013***	−6.025***
P_{value}	0.000	0.000	0.000
$Z_{\tau}(N)$	−7.117***	−7.100***	−6.043***
P_{value}	0.000	0.000	0.000

"Note: ***, ** & * explain the level of significance at 1%, 5% and 10% respectively, whereas the values are in parentheses contains P-values.".
Source: Author's Estimation.

Table 5. Results of Banerjee and Carrion-i-Silvestre (2017) cointegration analysis.

Dependent Variable: CE			
Countries	No deterministic specification	With constant	With trend
Full Sample	−8.010***	−8.002***	−9.011***
China	−11.046***	−11.011***	−11.013***
Japan	−6.012***	−6.003***	−6.001***
South Korea	−7.010***	−7.010***	−7.012***
Russia	−9.041***	−9.006***	−9.022***
Indonesia	−10.011***	−10.021***	−10.002***
Malaysia	−12.021***	−12.030***	−12.005***
Singapore	−8.016***	−8.014***	−8.002***
Philippines	−8.012***	−8.002***	−8.016***
Vietnam	−20.018***	−20.042***	−20.004***
Thailand	−6.031***	−6.001***	−6.030***

Note: Critical Value (CV) at 5%** and 10% *with constant is −2.32, −2.18 and with the trend is −2.92 and − 2.82.
Source: Author's Estimation.

In addition to this, the level of cointegration is also assessed by applying the test discussed by (Banerjee & Carrion-i-Silvestre, 2017). This test is different from the test of (Westerlund & Edgerton, 2008) in terms of generating in-depth outcomes from this test. Precisely, the earlier reported test only ascertains the level of cointegration for the whole data set. In contrast, this test can ascertain the level of cointegration for every single sub-section, which in the present study is every single Asian Country. Despite the difference with respect to the depth of the ascertaining the cointegration, the current test also reported that the data set as a whole and countries as a separate section, all are reported to possess the cointegration as the outcome values for all of them are statistically significant at 1% level of significance. The outcome generated through the (Banerjee & Carrion-i-Silvestre, 2017) is mentioned in Table 5.

Once all of the required and suggested quality parameters were met, finally, the application of CS-ARDL was made. The outcome of CS-ARDL is generated for both longer and shorter periods of time. Firstly, while discussing the outcome in a longer period of time, the LAW was reported to have a negative and significant association with CE ($\beta = -0.346,\ p < 0.01$) at 1% level of significance. This statistical interpretation of the outcome means that a 1% increase in LAW will improve the sustainability of the environment as it will decrease the level of CE by 34.6%. This relationship signifies the importance of the rule of law for the regular extermination of CE. Furthermore, it also highlights the importance of having the rule of law or compliance, which means that in addition to making the environment-oriented and preservation focused legislation which normally every government or law-making institutions do for the wellbeing of the environment, however, they also need to have

an implementation of those rules at just, as the results revealed that there is not just need to have rules. However, there is also a need to have assurance on the level of compliance that is being made for enabling the rule of law. These findings also support the existing but limited literature covering and reporting similar relationships in the context of countries forming the BRICS region (Danish & Wang, 2019) and 65 countries participating in the belt and road initiative (Muhammad & Long, 2021).

Secondly, while discussing the outcome in a longer period of time, the GIN was also reported to have a negative and significant association with CE ($\beta = -0.218,\ p < 0.01$) at 1% level of significance. This statistical interpretation of the outcome means that a 1% increase in GIN will improve the sustainability of the environment as it will decrease the level of CE by 21.8%. This outcome highlights the importance of GIN for the regular extermination of CE. Furthermore, it highlights that with the help of investing in GIN, economies can exterminate the level of CE and urge the utilisation of the GIN as one of the potential solutions for the betterment and wellbeing of the environment. These findings also support the existing literature covering and reporting similar relationships, including (Ali et al., 2021; Álvarez-Herránz et al., 2017; Balsalobre-Lorente et al., 2018; Guo et al., 2021; Khan et al., 2020).

Lastly, for assessing the relevancy of the EKC curve for which the GDP and its square were included in the analysis. The outcome reported having a positive and significant association of GDP with CE ($\beta = 0.354,\ p < 0.05$) at 5% level of significance. This statistical interpretation of the outcome means that a 1% increase in GDP will impair the sustainability of the environment as it will increase the level of CE by 35.4%. On the other hand, for the square of GDP, the outcome reported having a negative and significant association with CE ($\beta = -0.193,\ p < 0.01$) at 1% level of significance. This statistical interpretation of the outcome means that a 1% increase in the square of GDP will improve the sustainability of the environment as it will decrease the level of CE by 21.8%. These two relationships form a U-shaped association between GDP and CE as GDP will increase the CE to a point where it starts to diminish and eventually reports a negative association. This justifies the relevancy and legitimacy of the EKC curve in the context of top Asian Countries. These results findings also support the existing literature that covers and reported the similar relationships and legitimacy ok EKC, including (Esso & Keho, 2016; Hanif, 2018; Hanif & Gago-de-Santos, 2017; Kais & Sami, 2016; Saidi & Hammami, 2015; Saleem et al., 2020; Wang et al., 2016). The outcome generated through the CS-ARDL for the long run is mentioned in Table 6.

The outcome generated through CS-ARDL for the shorter period of time reported similar findings as reported in the longer period of time for all of the studied relationships except for LAW and CE. Unlike the long-run association, the outcome of the relationship of LAW is reported to have a positive and significant association with CE ($\beta = 0.050,\ p < 0.01$) at 1% level of significance. This statistical interpretation of the outcome means that a 1% increase in LAW will impair the sustainability of the environment as it will increase the level of CE by 5%. The magnitude of the path coefficient in the shorter period of time indicates that since compliance towards the rule of law is impossible despite the efforts put by the law enforcement agencies, the non-compliance leads to impair the environment quality further. This relationship

Table 6. Results of CS-ARDL analysis (Long run CS-ARDL Results).

Variables	Coefficients	t-statistics	p-values
LAW	−0.346***	−6.812	0.000
GIN	−0.218***	−5.085	0.000
GDP	0.354***	3.201	0.000
GDP^2	−0.193**	−2.511	0.035
CSD-Statistics	–	0.057	0.321

"Note: ***, ** & * explain the level of significance at 1%, 5% and 10% respectively.".
Source: Author's Estimation.

Table 7. Results of CS-ARDL analysis (Short-run CS-ARDL Results).

Variables	Coefficients	t-statistics	p-values
LAW	0.050***	4.562	0.000
GIN	−0.120***	−6.101	0.000
GDP	0.083***	5.694	0.000
GDP^2	−0.041***	−1.979	0.048
ECT(-1)	−0.234***	−9.624	0.000

"Note: ***, ** & * explain the level of significance at 1%, 5% and 10% respectively.".
Source: Author's Estimation.

Table 8. Results of AMG & CCEMG for robustness check.

Dependent Variables CE	Augmented Mean Group (AMG)			Common Correlated Effect Mean Group (CCEMC)		
	Coefficients	t-statistics	p-values	Coefficients	t-statistics	p-values
LAW	−0.070***	−5.543	0.000	−0.078***	−4.021	0.000
GIN	−0.186***	−4.001	0.000	−0.132***	−6.030	0.000
GDP	0.212***	8.256	0.000	0.368***	6.844	0.000
GDP2	−0.058***	−3.240	0.000	−0.093***	−3.924	0.000
Wald test	–	81.03	0.000	–	72.038	0.000

"Note: ***, ** & * explain the level of significance at 1%, 5% and 10% respectively.".
Source: Author's Estimation.

was found negative in the longer period of time, but due to the variation in the time period and the perceived or expected outcome for LAW is not possible, and having high compliance towards LAW requires time. The outcome generated through the CS-ARDL for the short run is mentioned in Table 7.

In the last stage, the robustness and rigorousness of the generated output through CS-ARDL was confirmed by the application of Augmented Mean Group" (AMG) and "Common Correlated Effect Mean Group" (CCEMG). The outcome generated through both of these tests validates the findings of CS-ARDL by generating similar results for all of the studied associations of the current study. For instance, LAW and GIN were reported to have a negative association. In contrast, the EKC hypothesis was found to be legitimate and relevant through the application of CS-ARDL and outcome generated through Augmented Mean Group" (AMG) and "Common Correlated Effect Mean Group" (CCEMG) have reported identical results. The outcome generated through the AMG and CCEMG is mentioned in Table 8.

5. Conclusion and recommendations

The climate of the earth is rapidly changing, and researchers urged that if the attention and consideration to this problem are defectively and inadequately given, then

this problem can single-handedly lead to various other volatilities, risks, and destructions. For countering the destruction caused by climate change, the essential solution is pollution prevention which is possible by controlling the emissions of greenhouse gases. It should also be noted that the increase in pollution and greenhouse gases is also because of the increased demand for products across the globe, which also leads to an increase in the level of GDP. Hence, a balance of equilibrium needs to be achieved as controlling the production will worsen the economy, and improved production will impair the environment. This equilibrium can be achieved by having a sufficiency of GIN and improving compliance to establish the LAW.

Therefore, the present study aims to explore the LAW and GIN's relevancy while ascertaining the economies' growth among the top Asian countries. Through the application of CS-ARDL, LAW and GIN were reported to have a negative association, whereas the EKC hypothesis was legitimate and relevant. Although the EKC is found relevant empirically, its relevancy needs to be supported by the proposed recommendation, following which the EKC can be made relevant practically. For that, GIN can play an efficient role. In order to improve the level of GIN, there is a need to have more investments in Research and Development by which more GIN can be made. Moreover, GIN will also be needed in transforming the existing operations towards sustainable and environment-friendly operations. For instance, to have clean input, there is a need to have GIN which makes it useful for clean energy to be used as input resources. Similarly, GIN will need GIN to develop vehicles that consume less energy and produce greater mileage to have an environment-friendly transport infrastructure. Moreover, adequate channelising of the investments will be needed for an improved level of GIN which can also be possible by attracting collaboration among the private and public stakeholders.

On the other hand, EKC can also be made relevant practically by establishing the LAW and improving the governance infrastructure. For said purpose, government institutions should not just be making regulations and rules for pollution alleviation. However, they also need to improve the level of compliance. Such compliance can be made by creating proper awareness among the individuals and organisations that comply with the proposed regulations. In addition to this, creating the habits and norms of following certain initiatives similar to other cultural norms like the Japanese culture of lean and 5S could also play the role. Lastly, the government needs to introduce a proper governance system in which non-compliance to the LAW is strictly monitored, and in the worst scenario, parties are penalised to ensure LAW.

Similar to any other study, there are also certain limitations that this research possesses. Based on these limitations, there are also future directions to the researchers for further expanding the literature. Firstly, there is a need to revisit the same relationships by the techniques which can provide more insights from the data like quantiles based QARDL. Secondly, the same relationships need to be explored in other geographical contexts like European Countries, BRICS, and other income and development-based groups of the economies. Thirdly, LAW has the propensity to modify and transform the strength of the relationship between predictor and criterion; therefore, its exploration as a moderator can also enrich the literature. Lastly, there is a need to explore the determinants of GIN and LAW by which the level of CE is eventually controlled.

Disclosure statement

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References

Abid, M. (2016). Impact of economic, financial, and institutional factors on CO2 emissions: Evidence from sub-Saharan Africa economies. *Utilities Policy*, *41*, 85–94. https://doi.org/10.1016/j.jup.2016.06.009

Ahmad, M., Jiang, P., Majeed, A., Umar, M., Khan, Z., & Muhammad, S. (2020). The dynamic impact of natural resources, technological innovations and economic growth on ecological footprint: An advanced panel data estimation. *Resources Policy*, *69*, 101817. https://doi.org/10.1016/j.resourpol.2020.101817

Ahmed, Z., Ali, S., Saud, S., & Shahzad, S. J. H. (2020). Transport CO 2 emissions, drivers, and mitigation: An empirical investigation in India. *Air Quality, Atmosphere & Health*, *13*(11), 1367–1374. https://doi.org/10.1007/s11869-020-00891-x

Ahmed, W., Najmi, A., Arif, M., & Younus, M. (2019). Exploring firm performance by institutional pressures driven green supply chain management practices. *Smart and Sustainable Built Environment*, *8*(5), 415–437. https://doi.org/10.1108/SASBE-04-2018-0022

Alam, M. S., Miah, M. D., Hammoudeh, S., & Tiwari, A. K. (2018). The nexus between access to electricity and labour productivity in developing countries. *Energy Policy*, *122*, 715–726. https://doi.org/10.1016/j.enpol.2018.08.009

Ali, S., Dogan, E., Chen, F., & Khan, Z. (2021). International trade and environmental performance in top ten-emitters countries: The role of eco-innovation and renewable energy consumption. *Sustainable Development*, *29*(2), 378–387. https://doi.org/10.1002/sd.2153

Álvarez-Herránz, A., Balsalobre, D., Cantos, J. M., & Shahbaz, M. (2017). Energy innovations-GHG emissions nexus: Fresh empirical evidence from OECD countries. *Energy Policy*, *101*, 90–100. https://doi.org/10.1016/j.enpol.2016.11.030

Arminen, H., & Menegaki, A. N. (2019). Corruption, climate and the energy-environment-growth nexus. *Energy Economics*, *80*, 621–634. https://doi.org/10.1016/j.eneco.2019.02.009

Bai, J., & Carrion-I-Silvestre, J. L. (2009). Structural changes, common stochastic trends, and unit roots in panel data. *Review of Economic Studies*, *76*(2), 471–501. https://doi.org/10.1111/j.1467-937X.2008.00530.x

Balsalobre-Lorente, D., Shahbaz, M., Roubaud, D., & Farhani, S. (2018). How economic growth, renewable electricity and natural resources contribute to CO2 emissions? *Energy Policy*, *113*, 356–367. https://doi.org/10.1016/j.enpol.2017.10.050

Baltagi, B. H., & Hashem Pesaran, M. (2007). *Heterogeneity and cross section dependence in panel data models: Theory and applications introduction*. Wiley Online Library.

Banerjee, A., & Carrion-i-Silvestre, J. L. (2017). Testing for panel cointegration using common correlated effects estimators. *Journal of Time Series Analysis*, *38*(4), 610–636. https://doi.org/10.1111/jtsa.12234

Batool, R., Sharif, A., Islam, T., Zaman, K., Shoukry, A. M., Sharkawy, M. A., Gani, S., Aamir, A., & Hishan, S. S. (2019). Green is clean: The role of ICT in resource management. *Environmental Science and Pollution Research*, *26*(24), 25341–25358. https://doi.org/10.1007/s11356-019-05748-0

Bibi, A., Zhang, X., & Umar, M. (2021). The imperativeness of biomass energy consumption to the environmental sustainability of the United States revisited. *Environmental and Ecological Statistics*, *28*(4), 821–841. https://doi.org/10.1007/s10651-021-00500-9

Chien, F., Sadiq, M., Nawaz, M. A., Hussain, M. S., Tran, T. D., & Le Thanh, T. (2021). A step toward reducing air pollution in top Asian economies: The role of green energy, eco-innovation, and environmental taxes. *Journal of Environmental Management*, *297*, 113420.

Chudik, A., Mohaddes, K., Pesaran, M. H., & Raissi, M. (2016). *Long-run effects in large heterogeneous panel data models with cross-sectionally correlated errors*. Emerald Group Publishing Limited.

Danish. (2019). Effects of information and communication technology and real income on CO2 emissions: The experience of countries along Belt and Road. *Telematics and Informatics*, 45. https://doi.org/10.1016/j.tele.2019.101300

Danish, & Wang, Z. (2019). Investigation of the ecological footprint's driving factors: What we learn from the experience of emerging economies. *Sustainable Cities and Society*, *49*.

Du, K., Li, P., & Yan, Z. (2019). Do green technology innovations contribute to carbon dioxide emission reduction? Empirical evidence from patent data. *Technological Forecasting and Social Change*, *146*, 297–303.

Du, Y., Li, Z., Du, J., Li, N., & Yan, B. (2019). Public environmental appeal and innovation of heavy-polluting enterprises. *Journal of Cleaner Production*, *222*, 1009–1022.

Dumitrescu, E.-I., & Hurlin, C. (2012). Testing for Granger non-causality in heterogeneous panels. *Economic Modelling*, *29*(4), 1450–1460. https://doi.org/10.1016/j.econmod.2012.02.014

Eberhardt, M. (2012). Estimating panel time-series models with heterogeneous slopes. *The Stata Journal: Promoting Communications on Statistics and Stata*, *12*(1), 61–71. https://doi.org/10.1177/1536867X1201200105

Esso, L. J., & Keho, Y. (2016). Energy consumption, economic growth and carbon emissions: Cointegration and causality evidence from selected African countries. *Energy*, *114*, 492–497. https://doi.org/10.1016/j.energy.2016.08.010

Fethi, S., & Rahuma, A. (2019). The role of eco-innovation on CO_2 emission reduction in an extended version of the environmental Kuznets curve: evidence from the top 20 refined oil exporting countries. *Environmental Science and Pollution Research*, *26*(29), 30145–30153.

Goel, R. K., Herrala, R., & Mazhar, U. (2013). Institutional quality and environmental pollution: MENA countries versus the rest of the world. *Economic Systems*, *37*(4), 508–521. https://doi.org/10.1016/j.ecosys.2013.04.002

Greenidge, K., McIntyre, M. M. A., & Yun, H. (2016). *Structural reform and growth: What really matters? Evidence from the Caribbean*. International Monetary Fund.

Grossman, G. M., & Krueger, A. B. (1991). *Environmental impacts of a North American free trade agreement*. National Bureau of economic research.

Guo, X., Liang, C., Umar, M., & Mirza, N. (2022). The impact of fossil fuel divestments and energy transitions on mutual funds performance. *Technological Forecasting and Social Change*, *176*, 121429. https://doi.org/10.1016/j.techfore.2021.121429

Guo, J., Zhou, Y., Ali, S., Shahzad, U., & Cui, L. (2021). Exploring the role of green innovation and investment in energy for environmental quality: An empirical appraisal from provincial data of China. *Journal of Environmental Management*, *292*, 112779.

Hanif, I. (2018). Impact of fossil fuels energy consumption, energy policies, and urban sprawl on carbon emissions in East Asia and the Pacific: A panel investigation. *Energy Strategy Reviews*, *21*, 16–24. https://doi.org/10.1016/j.esr.2018.04.006

Hanif, I., & Gago-de-Santos, P. (2017). The importance of population control and macroeconomic stability to reducing environmental degradation: An empirical test of the environmental Kuznets curve for developing countries. *Environmental Development*, *23*, 1–9. https://doi.org/10.1016/j.envdev.2016.12.003

Hao, L.-N., Umar, M., Khan, Z., & Ali, W. (2021). Green growth and low carbon emission in G7 countries: How critical the network of environmental taxes, renewable energy and human capital is? *The Science of the Total Environment*, *752*, 141853 https://doi.org/10.1016/j.scitotenv.2020.141853

Haseeb, A., Xia, E., Saud, S., Ahmad, A., & Khurshid, H. (2019). Does information and communication technologies improve environmental quality in the era of globalization? An empirical analysis. *Environmental Science and Pollution Research International*, *26*(9), 8594–8608.

Ielasi, F., Rossolini, M., & Limberti, S. (2018). Sustainability-themed mutual funds: An empirical examination of risk and performance. *The Journal of Risk Finance*, *19*(3), 247–261. https://doi.org/10.1108/JRF-12-2016-0159

Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, *115*(1), 53–74. https://doi.org/10.1016/S0304-4076(03)00092-7

Ji, X., Chen, X., Mirza, N., & Umar, M. (2021). Sustainable energy goals and investment premium: Evidence from renewable and conventional equity mutual funds in the Euro zone. *Resources Policy*, *74*, 102387. https://doi.org/10.1016/j.resourpol.2021.102387

Ji, X., Umar, M., Ali, S., Ali, W., Tang, K., & Khan, Z. (2021). Does fiscal decentralization and eco-innovation promote sustainable environment? A case study of selected fiscally decentralized countries. *Sustainable Development*, *29*(1), 79–88. https://doi.org/10.1002/sd.2132

Ji, X., Zhang, Y., Mirza, N., Umar, M., & Rizvi, S. K. A. (2021). The impact of carbon neutrality on the investment performance: Evidence from the equity mutual funds in BRICS. *Journal of Environmental Management*, *297*, 113228 https://doi.org/10.1016/j.jenvman.2021.113228

Kais, S., & Sami, H. (2016). An econometric study of the impact of economic growth and energy use on carbon emissions: Panel data evidence from fifty eight countries. *Renewable and Sustainable Energy Reviews*, *59*, 1101–1110. https://doi.org/10.1016/j.rser.2016.01.054

Kaiser, L., & Welters, J. (2019). Risk-mitigating effect of ESG on momentum portfolios. *The Journal of Risk Finance*, *20*(5), 542–555. https://doi.org/10.1108/JRF-05-2019-0075

Khan, F., Ahmed, W., & Najmi, A. (2019). Understanding consumers' behavior intentions towards dealing with the plastic waste: Perspective of a developing country. *Resources, Conservation and Recycling*, *142*, 49–58. https://doi.org/10.1016/j.resconrec.2018.11.020

Khan, F., Ahmed, W., Najmi, A., & Younus, M. (2019). Managing plastic waste disposal by assessing consumers' recycling behavior: The case of a densely populated developing country. *Environmental Science and Pollution Research International*, *26*(32), 33054–33066.

Khan, Z., Ali, M., Jinyu, L., Shahbaz, M., & Siqun, Y. (2020). Consumption-based carbon emissions and trade nexus: Evidence from nine oil exporting countries. *Energy Economics*, *89*, 104806. https://doi.org/10.1016/j.eneco.2020.104806

Khattak, S. I., Ahmad, M., Khan, Z. U., & Khan, A. (2020). Exploring the impact of innovation, renewable energy consumption, and income on CO2 emissions: new evidence from the BRICS economies. *Environmental Science and Pollution Research*, *27*(12), 13866–13881.

Lee, J. W., & Brahmasrene, T. (2013). Investigating the influence of tourism on economic growth and carbon emissions: Evidence from panel analysis of the European Union. *Tourism Management*, *38*, 69–76. https://doi.org/10.1016/j.tourman.2013.02.016

Levin, A., Lin, C.-F., & Chu, C.-S J. (2002). Unit root tests in panel data: Asymptotic and finite-sample properties. *Journal of Econometrics*, *108*(1), 1–24. https://doi.org/10.1016/S0304-4076(01)00098-7

Li, J., Zhang, X., Ali, S., & Khan, Z. (2020). Eco-innovation and energy productivity: New determinants of renewable energy consumption. *Journal of Environmental Management*, *271*, 111028.

Mensah, J. (2019). Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review. *Cogent Social Sciences*, *5*(1), 1653531.

Mirza, N., Abbas Rizvi, S. K., Saba, I., Naqvi, B., & Yarovaya, L. (2022). The resilience of Islamic equity funds during COVID-19: Evidence from risk adjusted performance, investment styles and volatility timing. *International Review of Economics & Finance*, *77*, 276–295. https://doi.org/10.1016/j.iref.2021.09.019

Mohammed, A. I., Yunos, N. F. M., Idris, M. A., Najmi, N. H., Jamal, Z. A. Z., & Nomura, T. (2022). Phase transformations of Langkawi ilmenite ore during carbothermal reduction using palm char as renewable reductant. *Chemical Engineering Research and Design*.

Muhammad, S., & Long, X. (2021). Rule of law and CO2 emissions: A comparative analysis across 65 belt and road initiative (BRI) countries. *Journal of Cleaner Production*, *279*, 123539. https://doi.org/10.1016/j.jclepro.2020.123539

Najmi, A., Haq, M. A., Majeed, S., & Khan, N. R. (2014). Effects of product's warranty on customers'preferences: Empirical findings on reverse logistics models. *LogForum*, *10*(3), 305–317.

Najmi, A., Kanapathy, K., & Aziz, A. A. (2019). Prioritising factors influencing consumers' reversing intention of e-waste using analytic hierarchy process. *International Journal of*

Electronic Customer Relationship Management, *12*(1), 58–74. https://doi.org/10.1504/IJECRM.2019.098981

Najmi, A., Kanapathy, K., & Aziz, A. A. (2021). Understanding consumer participation in managing ICT waste: Findings from two-staged Structural Equation Modeling–Artificial Neural Network approach. *Environmental Science and Pollution Research International*, *28*(12), 14782–14796.

Najmi, A., & Khan, A. A. (2017). Does supply chain involvement improve the new product development performance? A partial least square-structural equation modelling approach. *International Journal of Advanced Operations Management*, *9*(2), 122–141. https://doi.org/10.1504/IJAOM.2017.086680

Najmi, A., Maqbool, H., Ahmed, W., & Rehman, S. A. U. (2020). The influence of greening the suppliers on environmental and economic performance. *International Journal of Business Performance and Supply Chain Modelling*, *11*(1), 69–90. https://doi.org/10.1504/IJBPSCM.2020.108888

Naqvi, B., Mirza, N., Rizvi, S. K. A., Porada-Rochoń, M., & Itani, R. (2021). Is there a green fund premium? Evidence from twenty seven emerging markets. *Global Finance Journal*, *50*, 100656. https://doi.org/10.1016/j.gfj.2021.100656

OECD. (2021). https://www.oecd.org/economic-outlook/

Park, Y., Meng, F., & Baloch, M. A. (2018). The effect of ICT, financial development, growth, and trade openness on CO 2 emissions: An empirical analysis. *Environmental Science and Pollution Research*, *25*(30), 30708–30719. https://doi.org/10.1007/s11356-018-3108-6

Pesaran, H. M. (2004). *General diagnostic tests for cross-section dependence in panels. Fac Econ*. Institute for the Study of Labor.

Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics*, *22*(2), 265–312. https://doi.org/10.1002/jae.951

Pesaran, M. H. (2015). Testing weak cross-sectional dependence in large panels. *Econometric Reviews*, *34*(6–10), 1089–1117. https://doi.org/10.1080/07474938.2014.956623

Pesaran, M. H., & Yamagata, T. (2008). Testing slope homogeneity in large panels. *Journal of Econometrics*, *142*(1), 50–93. https://doi.org/10.1016/j.jeconom.2007.05.010

Razzaq, A., Ajaz, T., Li, J. C., Irfan, M., & Suksatan, W. (2021a). Investigating the asymmetric linkages between infrastructure development, green innovation, and consumption based material footprint: Novel empirical estimations from highly resource-consuming economies. *Resources Policy*, *74*, 102302.

Razzaq, A., An, H., & Delpachitra, S. (2021b). Does technology gap increase FDI spillovers on productivity growth? Evidence from Chinese outward FDI in Belt and Road host countries. *Technological Forecasting and Social Change*, *172*, 121050.

Rizvi, S. K. A., Mirza, N., Naqvi, B., & Rahat, B. (2020). Covid-19 and asset management in EU: A preliminary assessment of performance and investment styles. *Journal of Asset Management*, *21*(4), 281–291. https://doi.org/10.1057/s41260-020-00172-3

Saidi, K., & Hammami, S. (2015). The impact of CO2 emissions and economic growth on energy consumption in 58 countries. *Energy Reports*, *1*, 62–70. https://doi.org/10.1016/j.egyr.2015.01.003

Salahuddin, M., Alam, K., & Ozturk, I. (2016). The effects of Internet usage and economic growth on CO2 emissions in OECD countries: A panel investigation. *Renewable and Sustainable Energy Reviews*, *62*, 1226–1235. https://doi.org/10.1016/j.rser.2016.04.018

Saleem, H., Khan, M. B., & Shabbir, M. S. (2020). The role of financial development, energy demand, and technological change in environmental sustainability agenda: Evidence from selected Asian countries. *Environmental Science and Pollution Research International*, *27*(5), 5266–5280.

Salman, M., Long, X., Dauda, L., & Mensah, C. N. (2019). The impact of institutional quality on economic growth and carbon emissions: Evidence from Indonesia, South Korea and Thailand. *Journal of Cleaner Production*, *241*, 118331. https://doi.org/10.1016/j.jclepro.2019.118331

Song, Y., Chen, B., Tao, R., Su, C.-W., & Umar, M. (2020). Too much or less? Financial development in Chinese marine economic growth. *Regional Studies in Marine Science*, *37*, 101324. https://doi.org/10.1016/j.rsma.2020.101324

Su, C.-W., Qin, M., Tao, R., & Umar, M. (2020). Financial implications of fourth industrial revolution: Can bitcoin improve prospects of energy investment? *Technological Forecasting and Social Change*, *158*, 120178.

Su, C.-W., Song, Y., & Umar, M. (2021). Financial aspects of marine economic growth: From the perspective of coastal provinces and regions in China. *Ocean & Coastal Management*, *204*, 105550. https://doi.org/10.1016/j.ocecoaman.2021.105550

Su, Z.-W., Umar, M., Kirikkaleli, D., & Adebayo, T. S. (2021). Role of political risk to achieve carbon neutrality: Evidence from Brazil. *Journal of Environmental Management*, *298*, 113463 https://doi.org/10.1016/j.jenvman.2021.113463

Swamy, P. A. (1970). Efficient inference in a random coefficient regression model. *Econometrica*, *38*(2), 311–323. https://doi.org/10.2307/1913012

Umar, M., Farid, S., & Naeem, M. A. (2022). Time-frequency connectedness among clean-energy stocks and fossil fuel markets: Comparison between financial, oil and pandemic crisis. *Energy*, *240*, 122702. https://doi.org/10.1016/j.energy.2021.122702

Umar, M., Ji, X., Kirikkaleli, D., & Alola, A. A. (2021). The imperativeness of environmental quality in the United States transportation sector amidst biomass-fossil energy consumption and growth. *Journal of Cleaner Production*, *285*, 124863. https://doi.org/10.1016/j.jclepro.2020.124863

Umar, M., Ji, X., Kirikkaleli, D., Shahbaz, M., & Zhou, X. (2020). Environmental cost of natural resources utilization and economic growth: Can China shift some burden through globalization for sustainable development? *Sustainable Development*, *28*(6), 1678–1688. https://doi.org/10.1002/sd.2116

Umar, M., Ji, X., Kirikkaleli, D., & Xu, Q. (2020). COP21 Roadmap: Do innovation, financial development, and transportation infrastructure matter for environmental sustainability in China? *Journal of Environmental Management*, *271*, 111026.

Umar, M., Ji, X., Mirza, N., & Naqvi, B. (2021). Carbon neutrality, bank lending, and credit risk: Evidence from the Eurozone. *Journal of Environmental Management*, *296*, 113156.

Umar, M., Ji, X., Mirza, N., & Rahat, B. (2021). The impact of resource curse on banking efficiency: Evidence from twelve oil producing countries. *Resources Policy*, *72*, 102080. https://doi.org/10.1016/j.resourpol.2021.102080

Wang, Y., Chen, L., & Kubota, J. (2016). The relationship between urbanization, energy use and carbon emissions: Evidence from a panel of Association of Southeast Asian Nations (ASEAN) countries. *Journal of Cleaner Production*, *112*, 1368–1374. https://doi.org/10.1016/j.jclepro.2015.06.041

Wang, Q.-S., Su, C.-W., Hua, Y.-F., & Umar, M. (2021). Can fiscal decentralisation regulate the impact of industrial structure on energy efficiency? *Economic Research-Ekonomska Istraživanja*, *34*(1), 1727–1751. https://doi.org/10.1080/1331677X.2020.1845969

Wang, K.-H., Su, C.-W., Lobonț, O.-R., & Umar, M. (2021). Whether crude oil dependence and CO2 emissions influence military expenditure in net oil importing countries? *Energy Policy*, *153*, 112281. https://doi.org/10.1016/j.enpol.2021.112281

Wang, K.-H., Umar, M., Akram, R., & Caglar, E. (2021). Is technological innovation making world "Greener"? An evidence from changing growth story of China. *Technological Forecasting and Social Change*, *165*, 120516. https://doi.org/10.1016/j.techfore.2020.120516

Welsch, H. (2004). Corruption, growth, and the environment: A cross-country analysis. *Environment and Development Economics*, *9*(5), 663–693. https://doi.org/10.1017/S1355770X04001500

Westerlund, J. (2007). Testing for error correction in panel data. *Oxford Bulletin of Economics and Statistics*, *69*(6), 709–748. https://doi.org/10.1111/j.1468-0084.2007.00477.x

Westerlund, J., & Edgerton, D. L. (2008). A simple test for cointegration in dependent panels with structural breaks. *Oxford Bulletin of Economics and Statistics*, *70*(5), 665–704. https://doi.org/10.1111/j.1468-0084.2008.00513.x

World Bank. (2021). *World Development Report 2021: Data for better lives*. The World Bank.
Yan, L., Mirza, N., & Umar, M. (2021). The cryptocurrency uncertainties and investment transitions: Evidence from high and low carbon energy funds in China. *Technological Forecasting and Social Change*, 121326. https://doi.org/10.1016/j.techfore.2021.121326
Yu, B., Li, C., Mirza, N., & Umar, M. (2022). Forecasting credit ratings of decarbonized firms: Comparative assessment of machine learning models. *Technological Forecasting and Social Change*, *174*, 121255. https://doi.org/10.1016/j.techfore.2021.121255
Zhao, L., Zhang, L., Sun, J., & He, P. (2022). Can public participation constraints promote green technological innovation of Chinese enterprises? The moderating role of government environmental regulatory enforcement. *Technological Forecasting and Social Change*, *174*, 121198.