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Does political risk undermine environment and economic development in Pakistan? Empirical evidence from China–Pakistan economic corridor

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Abstract
China–Pakistan Economic Corridor (CPEC) invests US$62 billion in Pakistan's energy, infrastructure, and other development projects to step toward Eurasia's economic integration. However, CPEC may exacerbate climate change vulnerabilities for Pakistan's struggling economy due to potential environmental hazards and consequences. In this context, the current study seeks to examine the impact of political risk on carbon emissions and economic growth in Pakistan while also considering the relevance of trade openness, Chinese outward Foreign Direct Investment (FDI), and One Belt One Road (OBOR) policy. To investigate this impact, we use the autoregressive distributed lag technique to cointegration and the fully modified ordinary least squares estimator for robustness results, using data spanning 2000 to 2020. Our empirical findings reveal that trade openness, FDI, and OBOR policy contribute to pollution and economic growth, but political stability slows the rate of environmental deterioration and increases economic growth. Furthermore, the existence of robust political stability mitigates the negative impacts of FDI and trade openness on the environment, while strong political stability aids the positive effects of FDI and trade openness on economic growth. Also, the findings confirmed that a better political environment promotes economic development while simultaneously lowering carbon emissions. Our results may assist the Government of Pakistan in transforming CPEC into a model green OBOR initiative in the region.

Keywords Carbon emissions · Economic development · Political risk · CPEC · OBOR · Pakistan

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1 Introduction

Political institutions are an essential factor in economic growth in both developing and developed countries. Powerful political stability mechanisms assist in fighting corruption, establishing the rule of law, and reducing the use of military force in politics, and they also improve the administration of public funds (Danish and Ulucak 2020). The character of political institutions in ecological sustainability is critical, and it supports the idea that nations may reduce the cost of future expansion while still enjoying high income through enhancing ecosystems (Hassan et al. 2020). In general, political quality is linked to the strategies that the county's institutions have implemented to establish cultural and legal frameworks that support socioeconomic and financial activities and have a direct effect on efforts to decrease environmental pollution (Salman et al. 2019). In contrast, poor political institutions (political instability) are a key restraint on the country's ability to build up productive components such as physical and human capital, which inhibits innovation and technology adoption; this also encourages expropriation and jurisdictional manipulation, resulting in deterioration of ecological quality by ignoring environmental externalities and consequences linked to economic growth (Slesman et al. 2015). Weak political institutions have a long-term influence on the economic progress of a nation (Kar et al. 2019). Ashraf et al. (2022a) argue that political institutions are critical to promoting economic development while simultaneously lowering the environmental pollution. So, the integrity of political institutions is crucial for reducing environmental damage and attaining long-term economic development objectives. Pakistan's growing environmental problems need attention, and enhancing political institutions' quality can help to reduce pollution. Pakistan has the lowest political institutions quality among developing nations, which harms economic development and environmental quality (Álvarez et al. 2018; Hassan et al. 2020). One of the key causes of its bad environmental policy might be an institutional failure that needs investigation.

The CPEC is a regional connectivity structure. The OBOR project consists of two trade routes for the economic unification of Eurasia: the Maritime Silk Road and the Silk Road Economic Belt. The CPEC was established in 2015 as part of the Silk Road Economic Belt. The CPEC includes infrastructure, energy, and other development projects in Pakistan worth US$62 billion (Waheed et al. 2021). It is seen as a game-changer for Pakistan's failing economy since it is expected to boost its economic growth to 7.5 percent between 2015 and 2030 (Mirza et al. 2019). Figure 1 depicts a time graph of GDP growth in Pakistan. Figure 1 clearly shows that during 2015–2018, the GDP growth is increasing, but during 2008–2010 and 2019–2020, the GDP growth rate has declined sharply due to the global financial crisis and the global COVID-19 epidemic, respectively. In addition, it's expected that CPEC would generate approximately 700, 000 new employment in Pakistan by accelerating mineral exploration and agricultural growth as well as the information technology revolution, commerce, and investment networks in Pakistan by 2030 (Kouser et al. 2020). The CPEC is crucial for China's economy since it will open up new markets for Chinese exports in the Middle East, Africa, and Europe by cutting travel time (Khursheed et al. 2019).

Fig. 1 GDP growth (annual %). Source world bank 2020

Apart from economic gains, the CPEC also holds enormous potential for addressing Pakistan's climate change concerns and environmental issues. The long-term global climate risk index in 2019 places Pakistan at number seven among the most susceptible nations to climate change (Eckstein et al. 2021). Furthermore, the nation is confronted with a variety of climate change-related problems, including flooding, droughts, heatwaves, illnesses, and a rise in poverty and hunger. In contrast to stricter environmental safeguards being used in development projects, Environmental Impact Assessment (EIA) has been neglected in the design of CPEC projects. According to recent research, the CPEC investments would harm Pakistan's water, air, and biodiversity in the long term (Huang et al. 2017; Zhang et al. 2017). Likely, environmental issues may severely limit the advantages of the CPEC.

The CPEC is Pakistan's largest investment project to date, valued at US$62 billion. Numerous environmental and climate change effects are expected to be linked with CPEC investment (Kouser et al. 2020; Waheed et al. 2021; Zubedi et al. 2018), particularly in conjunction with coal-based energy projects and infrastructural expansion. Figure 2 depicts a time graph of increasing carbon emissions in Pakistan. Pakistan would get 70% of total investment from CPEC as foreign direct investment (FDI) (Husain and Yasir, 2018). Similarly, international commerce and investment have an impact on the environment, although the consequences are mixed. This contradictory evidence has led to two competing theories: the pollution halo hypothesis and the pollution haven hypothesis. Following the pollution halo theory, trade and investment from other countries may enhance environmental quality by transferring new technologies and good management techniques (Birdsall and Wheeler 1993). In contrast, according to the pollution haven theory, FDI and trade have a detrimental impact on the environment because international companies relocate their polluting activities to other foreign nations, primarily developing ones (Pethig 1976; Walter and Ugelow 1979).

Given the above discussion, a deeper understanding of the relationship between OBOR policy, political risk, economic growth, and the environment must be needed, which has not yet to be done in Pakistan. In this scenario, there

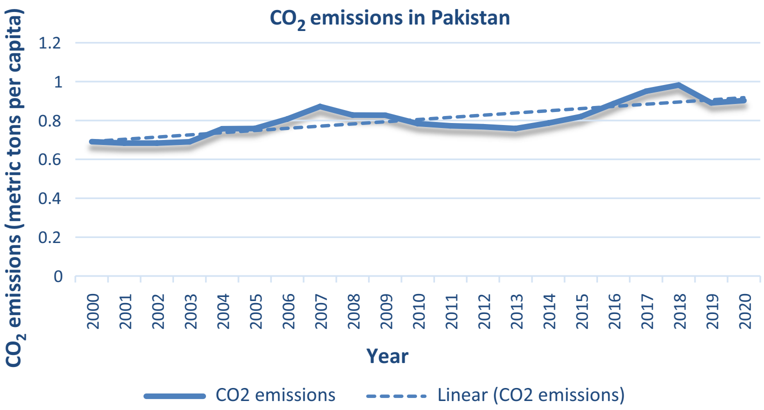

Fig. 2 Co_2 emissions (metric tons per capita). Source world bank 2020

are specific worries about the CPEC. This study will help policy analysts and government officials envisage long-term and short-term strategies for tackling mitigation climate change. On this note, this research explores the impact of OBOR initiative and political risk on economic development and environmental quality for Pakistan with the empirical evidence from CPEC. In terms of country development, political institutions are critical for both environmental and economic growth.

Our study offers many significant additions to the literature. First, according to the best knowledge of the author, it is Pakistan's first empirical research on the effect of OBOR policy and political risk in economic development and environmental pollution reduction with the empirical evidence from CPEC. Second, to acquire more knowledge, the research also incorporates Chinese outward FDI into the model to address its effect on economic development and the environment. Third, furthermore, we investigate the indirect impact of political risk on CO_2 emissions through trade openness (TO) and FDI. This will help policymakers better grasp the interrelationship between institutions and CO_2 emissions, and it will make it easier to develop policies that take into account the combined impact of these factors. With the positive ecological consequences of political institutions, it may encourage growth that may reduce environmental strain. So, it would be beneficial to assess the indirect influence of political risk on CO_2 emissions through the channels of these factors. Fourth, we also investigated the political risk associated with the link between economic development and environmental deterioration. National institutions administer environmental regulations, and policymaking for the economic sector's sustainability is difficult without a prominent role for institutions. So, it is prudent to examine whether political institutions mitigate the negative environmental repercussions of economic growth. Lastly, a more robust strategy was utilized in the research; the ARDL limits testing approach employs the routes of (Kripfganz and Schneider, 2021) for critical value and p-value approximation, which produces more reliable estimates.

2 Literature review

This portion of the article provides an overview of research on the impact of FDI, economic growth, TO, and political risk, on CO_2 emissions. Numerous research (e.g., (Ahmad et al. 2021; Ashraf et al. 2021; Danish et al. 2019; Hassan et al. 2020; Hussain and Dogan, 2021; Ji et al. 2021; Khan and Rana, 2021; Salman et al. 2019; Su et al. 2021) investigating this connection have been undertaken over the last three decades; nonetheless, their conclusions are mixed. For example, He et al. (2021) examined the drivers of CO_2 emissions in Mexico using data from 1990*to*2018. The results of the dual method cointegration revealed that the variables move together over the long term. Moreover, the results of the dynamic ordinary least square (DOLS) and FMOLS revealed that trade openness, foreign investment, and economic development contributed to CO_2 emissions. In contrast, using meta-analysis, Demena and Afesorgbor, (2020) discovered that FDI enhances environmental sustainability, whereas economic expansion diminishes environmental sustainability. Moreover, Albulescu et al. (2019) examined data from 14 Latin American nations between 1980 and 2010 and found that FDI are no discernible effect on pollution.

Few studies have examined the link between CO_2 emissions and political risk (PR) recently. For instance, Vu and Huang (2020) investigated the impact of PR on CO_2 emissions in Vietnam using the ARDL technique. Their analyses demonstrated a statistically significant and positive relationship between CO_2 emissions and PR. The research of Zhang and Chiu (2020) on the influence of PR on CO_2 emissions in 111 countries between 1985 and 2014 refutes by Vu and Huang (2020) conclusion and demonstrating a statistically significant and negative relationship between PR and CO_2 emissions, Su et al. (2021) also confirm this view. This implies that a stable environment reduces environmental deterioration in the nations studied. Ashraf (2022a, 2022b) argues that political quality (lowering political risk) enhances environmental protection by minimizing environmental degradation.

Furthermore, few of the research looks at the indirect linear link between political institutions and the environment. For instance, Lau et al. (2014) investigated the influence of political institutions on the growth and CO_2 emissions relationship in Malaysia from 1984to2008. The findings of the ARDL bounds test indicated that neutral and efficient domestic political institutions are critical for mitigating carbon emissions throughout economic growth, Bhattacharya et al. (2017) and Ashraf et al. (2022a) also confirm this view. On the moderating impact of institutions emerging via TO and FDI channels, the proponents of the *pollution heaven theory* claim that free trade and FDI allow developed economies to shift their polluting industrial activity to developing nations where labour is cheaper and natural resources are more abundant (Solarin et al. 2017). In addition, political institutions influence the formulation of nations' internal environmental policies as well as their adherence to international environmental treaties (Congleton, 1992). Better political institutions also include appropriate fiscal measures in the energy industry, such as taxes and subsidies, which enhance the sustainability of the environment (Bhattacharya et al. 2017).

After summarizing the empirical studies described above, we may infer that, although there is an expanding body of literature investigating the influence of political risk on ecological deterioration and economic development, certain research gaps still remain. First, earlier research relied on single or conventional measures of political risk, which did not account for all aspects and sectors of the institution's system. Second, in addition to their direct influence, political institutions may indirectly impact the environment and economic growth through trade and OFDI. So, past research has not looked at such indirect effects. Also, such evidence was overlooked in the context of CPEC. In particular, inadequate research on underlying factors, inconsistent findings, and shortcomings in chosen techniques lead us to investigate the relationship between One Road One Belt, political risk, environment and economic development for Pakistan under the CPEC.

3 Theoretical framework and model construction

We explain first grasp the study's conceptual framework to comprehend the model's variables fully. Strong political quality (PQ) contributes significantly to the reduction of environmental degradation (ED) (Ahmad et al. 2021), because they decrease transaction costs, thus improving financial performance. Due to limited budgetary space and reliance on investment inflows, the quality of institutions is particularly essential for developing countries. However, the inconsistency of these transformative changes has created an ineffectual institutional environment. Pakistan's economic growth rate is decreasing day by day as a result of the country's poor PQ; therefore, appropriate institutional changes are required (Hassan et al. 2020). The quality of political institutions impacts nations' economies by their investment sectors. For example, strong institutions are seen as important in preventing market failure (Olson, 1996) and forcing companies to respect pollution emissions control practices (Welsch, 2004).

Moreover, PQ has a direct and indirect impact on pollution emissions via its impacts on growth, TO, and FDI factors. For example, poor political institutions enable governments to overlook environmental externalities, resulting in poorer environmental quality and slower development (López and Mitra, 2000). On the contrary, improved political institutions are associated with less ecological deterioration and foster economic development (Ashraf et al. 2022a; Bhattacharya et al. 2017). Kearsley and Riddel (2010) argue that emerging nations' lax rules would entice heavy industries, whereas established economies' strong regulations will keep light industries and service sectors afloat. Hence, institutions may assess the environmental quality of emerging economies to TO and FDI operations (Zakaria and Bibi, 2019).

Furthermore, Panayotou (1997) argued that political institutions are critical in enhancing environmental quality even in countries with low economic status. This indicates that effective institutions may assist lower the ecological cost of increased economic expansion, allowing nations to reduce pollution. According to Gagliardi (2008), improved PQ may help prevent exploitation, promote collaborative relationships among agents, and hence encourage agents to integrate externalities. As a result, improved PQ may give complete solutions for enhancing economic growth and improving environmental quality (Subramanian, 2007).

Our fundamental theoretical model is based on the framework described above: When CO_2 emission is included as a dependent, the model may be written as:

$$CO_2 = f(\text{GDP}, \ \text{FDI}, \ \text{TO}, \ \text{PR}) \tag{1}$$

Similarly, when economic growth is included as a dependent, the model may be written as:

$$\text{GDP} = f\left(CO_2, \ \text{FDI}, \ \text{TO}, \ \text{PR}\right) \tag{2}$$

Recent research has begun to show if OBOR has beneficial benefits. Ashraf et al. (2022a, b) predict that since 2013, OBOR policies in OBOR linked nations have encouraged more substantial economic development. The main goal of the OBOR strategy is to boost trade and investment on a bilateral and multilateral level (Buckley, 2020; Du and Zhang, 2018), thus boosting economic growth. OBOR policy in clustered nations will have multi-factor consequences on human activity, either openly or implicitly. There are two sides to every coin. Through bilateral cooperation and globalization, it will have positive impacts in contained economies on one corner. On the other side, it may have negative ones, such as ecological degradation resulting from large energy use, industrial expansion, mass communication and transportation, urbanization, and the clearance of forests to construct highways and rail lines. OBOR was included as a dummy variable and China outward FDI to examine the impact of OBOR policies on environment and economic development. According to this study Ashraf et al. 2022a; Liu et al. (2017) and Tian et al. (2019), we make this dummy; in years before 2013, it's 0; after 2013, it's 1 (including 2013). Their participation may boost trade activity and capital inflows, resulting in economic expansion (Ashraf et al. 2022b). According to all this in view, we apply the theoretical structure of the study as Fig. 3. Hence, re-write Eq. (1) and (2) as follows:

$$CO_2 = f(\text{GDP}, \ \text{FDI}, \ \text{TO}, \ \text{PR}, \ \text{BRI}) \tag{3}$$

$$\text{GDP} = f\left(CO_2, \ \text{FDI}, \ \text{TO}, \ \text{PR}, \ \text{BRI}\right). \tag{4}$$

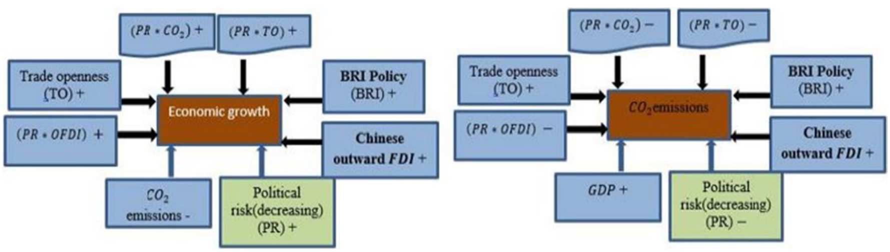

Fig. 3 The study's conceptual framework

Table 1 Variable measurement and data sources

Symbol	Variables	Measurement	Source
GDP	Economic growth	Real GDP growth rate per capita	World Bank
CO_2	CO_2 emissions	CO_2 emissions in metric tons per capita	World Bank
TO	Trade openness	Total trade as a percentage of GDP	World Bank
FDI	Chinese outward FDI	The value of Chinese FDI projects in Pakistan	
PR	Political risk	It is an index that examines the bureaucratic quality, law and order, internal conflicts, ethnic tensions, demographic accountability, corruption control, government stability, external conflicts, military involvement in politics, religious tension, socioeconomic conditions, and investment profile	PRS Group

Table 2 Descriptive statistics of variables

Variables/Statistics	GDP	CO_2	TO	FDI	PR
Mean	1.788776	0.804865	30.18195	27,013.39	47.28937
Median	2.223673	0.786821	30.43821	16,357.00	47.41667
Maximum	5.095223	0.981820	35.68173	101,426.0	51.37500
Minimum	− 1.443646	0.683731	25.30623	− 19,873.00	44.29167
SD	1.851540	0.085756	3.289271	33,627.54	2.132996

SD denotes by Standard Deviation

4 Methodology and data

4.1 Variable's description and study area

The current research relies on balanced time series data, covering the period of 2000–2020 for Pakistan. The experimental period chose because of the availability of data. Researchers have a strong motive to look at Pakistan because of the country's rapid economic growth during this period. GDP stands for economic growth and have been quantified as the GDP per capita growth rate (annual percent). CO_2 stands for CO_2 emissions, TO denotes trade openness, and FDI denotes Chinese outward FDI in Pakistan. PR stands for political risk and have been measured by 12 factors of political risk and institutions. Table 1 displays the variables' data sources and measurements, and Table 2 indicates the statistics descriptive of the variables.

Moreover, in the case of structural breakdowns, dummy variables (D_{2008} and D_{2018}) are included to reflect two structural breaks proposed by the Kapetanios (2005) unit-root test. D_{2008} is introduced to represent a negative structural break that occurred in 2008 due to the global financial crisis. To begin with, it is zero till 2008. After then, it is 1. According to the World Bank's study, Pakistan's *GDP* growth climbed from 5.4% in 2017 to 5.8% in 2018. This positive shock is backed up by large infrastructure investments and cheap financing rates. To account for this structural discontinuity, we introduce the D_{2018} dummy variable, which has a value of zero up to 2018 and a value of one after that.

We utilize both the variance inflation factor (*VIF*) and the correlation matrix to check for multicollinearity. Kennedy (2008, p. 199) and Wooldridge (2020, p. 92) argue that as rules of thumb, a pairwise Pearson correlation value > 0.80 or *VIF* value greater than 10 indicates significant multicollinearity. According to Marcoulides and Raykov (2019), a *VIF* value greater than 5 indicates significant multicollinearity. Table 3 shows that between the variables have no strong linear correlation.

A total area of 104.40×104 square kilometers is covered by the CPEC region, with 16.20×104 square kilometers lying inside Kashgar Prefecture and the other 88.20×104 square kilometers and center of the Eurasian continent $\left(2350'\text{-}4016'\text{N},\ 6100\right)$. The CPEC is bounded on the east by India, on the northwest by Tajikistan and Afghanistan, on the west by Iran, on the south by the Arabian Sea, and on the northeast by Kashgar Prefecture (China). The CPEC's geographical position emphasizes its significance as a land-sea waterway.

4.2 Unit root test

This article conducts the necessary unit root tests (URT) before beginning the estimate procedure. Many URT are widely used in the literature, including the PP test (Phillips and Perron, 1988), ADF test (Dickey and Fuller, 1981), which use nonparametric test statistics to account for autocorrelation and heteroscedasticity, the NGP test of (Pesaran et al. 2001), the KPSS test of (Kwiatkowski et al. 1992), and the ADF^{GLS} or ERS test of (Elliott et al. 1996), *among other things*. The significance of the test results in both the ADF and PP tests indicates a mixed flexible integration order between the variables. As indicated in Table 4, certain variables are stationary at level $I(0)$, while others are stationary at the 1st difference (i.e., one integrated order, $I(1)$).

4.2.1 Unit root test with structural breaks

All these tests have limited power if structural breakdowns are present in the data generation process (DGP), and they might cause us to draw incorrect and biased conclusions regarding time-series stationarity, as well as false cointegration and inaccurate estimations. Furthermore, when the first differenced series has a substantial and negative moving average (MA) component to the errors, several of these

Table 3 Multicollinearity among the variables

	GDP	CO_2	TO	FDI	PR	BRI	VIF	VIF
GDP	1						–	1.37
CO_2	0.0276	1					2.02	–
TO	0.1354	−0.0756	1				1.41	1.40
OFDI	0.1599	0.4156	−0.0684	1			1.07	1.24
PR	0.3256	0.1065	−0.5214	0.3319	1		1.85	1.95
BRI	0.05007	0.6323	0.38841	0.4608	0.54032	1	2.85	1.48

Table 4 Unit root test results

	ADFtest – statistics		PPtest – statistics		Decision
Variables	Level	Difference	Level	Difference	
GDP	−2.5349	−4.7994*	−2.0432	−4.7985*	$I(1)$
CO_2	−1.2015	−3.5603*	−1.2705	−3.5603*	$I(1)$
TO	−1.9906	−4.4054*	−1.9963	−4.4045*	$I(1)$
FDI	−4.0516*	-	−4.0448*	–	$I(0)$
PR	−3.0061**	−4.7004*	−3.0061**	−9.651*	$I(1)$

*Significant at 1% level, ** significant at 5% level

tests, particularly the PP test, suffer from severe size distortions. In addition, the PP, ADF, and KPSS all have distortions due to the use of tiny samples (Choi, 2015; Culver and Papell, 1997; Gregory et al. 1996; Ng and Perron, 2001; Perron and Serena, 1996; Schwert, 1989).

We use the (Kapetanios, 2005) test to look for unit roots in our time series where structural discontinuities exist. It checks for stationarity in the existence of up to five structural discontinuities in the intercept and/or trend that is unknown or data-dependent. In other words, by minimizing the sum of squared residuals, this test endogenously derives the structural break's dates and predicts the structural break's position. According to Kapetanios (2005) notation, the following formula applies to this test

$$y_t = a_0 + a_1 t + \rho y_{t-1} + \sum_{i=1}^{k} \lambda_i \Delta y_{t-i} + \sum_{i=1}^{m} \varphi_i DU_{i,t} + \sum_{i=1}^{m} \gamma_i DT_{i,t} + \varepsilon_t \tag{5}$$

Here,ρ shows the parameter of the first-order autoregressive term; a_0 represents intercept, and a_1 represent a trend. $DU_{i,t}$ and $DT_{i,t}$ represent a trend representing the intercept and trend break dummy variables, respectively. This test's null hypothesis is $H0 : \rho = 1$, which indicates that the series has a unit root or is non-stationary with m structural breakdowns. These dummies, $DU_{i,t}$ and $DT_{i,t}$ may be used to demonstrate $DU_{i,t} = 1$ if $\left(t > T_{b,i}\right)$, 0 otherwise and $DT_{i,t} = \left(t - T_{b,j}\right)\text{if}\left(t > T_{b,i}\right)$, 0 otherwise. Here, $T_{b,i}$ denotes the date on which the structural break. In the case of a single unknown structural break in the intercept or trend, the Kapetanios test will become equal to the (Zivot and Andrews, 1992) unit root test if we set $m = 1$. This test is limited to two structural fractures because of the short sample size. Kapetanios (2005) argue that the power of this test decreases as the number of breaks rises. Table 5 displays the Kapetanios (2005) unit root test that at the 5% significance level, all variables are $I(1)$, and none of them is $I(2)$. Specifically, all variables of order one are stable around two structural breaks, suggesting that these series match the key criteria for applying the ARDL model and bounds testing technique to cointegration (Pesaran et al. 2001).

The literature heavily relies on data-dependent criteria to determine the ideal lag length such as Schwarz Bayesian information criterion (*SBC*) of (Schwarz, 2007),

Table 5 Result of unit root test with structural breaks

	Test statistics			Break dates	
Variables	Level	Difference	Decision	1st break date	2nd break date
GDP	−3.0449*	−5.0042*	$I(1)$	2008	2018
CO_2	−3.1798*	−6.5248*	$I(1)$	2008	2018
TO	−2.9927*	−5.0812*	$I(1)$	2007	2010
FDI	−3.2695*	−5.4403*	$I(1)$	2006	2008
PR	−3.7724*	−5.3400*	$I(1)$	2006	2017

*Significant at 1% level

Akaike information criterion (*AIC*) of (Akaike, 1973) and Hannan and Quinn information criterion (*HQ*) of (Hannan and Quinn, 1979). Among these criteria, the findings of the *SBC* are chosen since they are believed to be a consistent model selection, particularly in small sample sizes (Pesaran and Shin, 2012; Potscher, 2007). These selection criteria pick the ideal lag time based on their lowest value. All of our variables' information requirements indicate a single lag time. Hence, for the *ARDL* model, we used one lag value.

4.3 Cointegration tests

4.3.1 Johansen cointegration test

The number of cointegration equations in the CO_2 and *DGP* are determined by using the Johansen (1991, 1988) cointegration test. Gonzalo (1994) contends that this test offers superior qualities over other methods. It is necessary for all variables to be $I(1)$. This approach is based on the error correction form's unconstrained vector autoregressive (*VAR*) model (Lütkepohl et al. 2001).

$$\Delta y_t = \Pi y_{t-1} + \sum_{m=1}^{p-1} \Gamma_m \Delta y_{t-m} + \xi_t \tag{6}$$

y_t denotes by $I(1)$ variables vector, Γ and Π are matrices of unknown parameters that must be calculated, and ξ_t represent the white noise random error vector. Here, the rank of Π is equal to the number of independent cointegrating vectors (r) of y_t. The Johansen process examines pairs of hypotheses using both the trace test $\left(\lambda_{trace}\right)$ and the maximum eigenvalue test $\left(\lambda_{\max}\right)$. The first null hypothesis (*NH*), which is validated by the trace test, claims that $H\left(r_o\right) : \Pi = r_o$, alternative $H\left(r_o\right) : \Pi > r_o$. The second null hypothesis, which is validated by the maximum eigenvalue test, claims that $H\left(r_o + 1\right) : \Pi = r_o + 1$, alternative $H\left(r_o + 1\right) : \Pi > r_o + 1$.

If the results of both tests on small samples contradict, both Lütkepohl et al. (2001) and Cheung and Lai (1993) suggest doing a trace analysis. They argue that skewness or excess kurtosis is present, the test indicates a minor bias, but overall, it is more resilient and better than the equivalent maximum eigenvalue test.

Table 6 Result of Johansen cointegration test

Maximum rank (*r*)	λ_{trace}	Critical values	λ_{max}	Critical values
None	135.2484	83.93712*	62.14448	36.63019*
At most 1	73.10390	60.06141*	41.08785	30.43961*
At most 2	32.01605	40.17493	19.78616	24.15921
At most 3	12.22988	24.27596	8.632051	17.79730

*Show that significance at 1% level. We employ one lag with intercept and no trend restriction suggested by the *SBC* in the *VAR* system

Table 6 displays the results of the two tests. According to both tests, only two cointegrating associations exist between our variables at a 1% significance level.

4.3.2 Phillips–Ouliaris cointegration test

To ensure that the regressors in our CO_2 and GDP are not cointegrated with one another, we apply the (Phillips and Ouliaris, 1990) cointegration test. This technique is based on residuals and has improved power qualities when testing for cointegration in small samples (Haug, 1992; Maher and Zhao, 2021). The multivariate Phillips–Ouliaris technique examines the null hypothesis, which says that the variables do not include a cointegrating vector under the $\check{Z}\alpha$ test (Haug, 1992).

Table 7 shows that there is a cointegration relationship when CO_2 and GDP are used as the dependent variable. However, when the other four variables are used as the dependent variable, cointegration does not occur, suggesting that the regressors are not cointegrated among themselves. When CO_2 and GDP are used as the dependent variable, both Johansen and Phillips-Ouliaris cointegration tests show a cointegrating connection. This allows us to use the ARDL technique to deal with these equation models.

Table 7 Result of Phillips–Ouliaris cointegration test

Dependent variables	Z_a Statistic	Critical values at 5%	Decisions
GDP	−40.0698**	−33.73	Cointegration
CO_2	−37.2517**	−33.73	Cointegration
TO	−12.8731	−33.73	No
FDI	−23.2014	−33.73	No
PR	−22.1607	−33.73	No
BRI	−12.6168	−33.73	No

The asterisk (**) denotes statistical significance at the 5% level. We take into account both the constant and the absence of a trend. We used Table 3 in Haug (1992) to get the critical values for small samples since the Phillips-Ouliaris value has been determined using a large sample size ($T = 500$)

4.4 Estimation technique

Many cointegration strategies, such as those developed by Johansen (1991), (Phillips and Ouliaris (1990) and Engle and Granger (1987), investigate the long-run connection between variables. These strategies need the integration of the underlying time series in the same order, which is generally $I(1)$. The ARDL technique and bounds testing for cointegration established by (Pesaran and Shin, 2012) and (Pesaran et al. 2001), on the other hand, are not constrained by such constraints. This method examines the presence of long-run (LR) and short-run (SR) correlations regardless of whether the variables are purely $I(0)$, simply $I(1)$, or mutually cointegrated, as long as no variables are $I(2)$ (Pesaran et al. 2001). Furthermore, when compared to previous cointegration strategies, this strategy produces superior results for small sample sizes (Haug, 2002; Narayan and Narayan, 2005). According to Shmueli (2010), lower sample size is associated with a larger bias in predictive modelling, which is not the case in explanatory modelling. *ARDL* model enables to account for residual autocorrelation and endogeneity in the regressors by using the proper lag structure (Pesaran, 2016; Pesaran and Shin, 2012; Sam et al. 2019).

To look into the links between *BRI* policy, political risk, GDP growth, and CO_2 emissions in Pakistan, we use the ARDL technique and perform bounds testing for the cointegration framework. Figure 4 depicts the analytical flow. The regressors' lags and the regressands' lags are also included in this model, in addition to their contemporaneous values. It is a specification for dynamic single-equation error correction. The $ARDL(p, q)$ model's general formula (including the deterministic components) may be stated as

$$y_t = a_0 + \delta t + \sum_{i=1}^{p} a_i y_{t-i} + \sum_{j=0}^{q} \beta_j x_{t-j} + \varepsilon_t \tag{7}$$

Here i and j represent lags of the variables included: $i = 1, 2, \ldots, p; j = 0, 1, 2, \ldots, q$; y_t denotes the dependent variables; y_{t-i} and x_t represent the independent variables, where the former indicates the dependent's lagged values and is included as an independent variable. a_i and β_j are the parameters; a_0 and δt the intercept and trend; and ε_t is the error term. Equations (1)

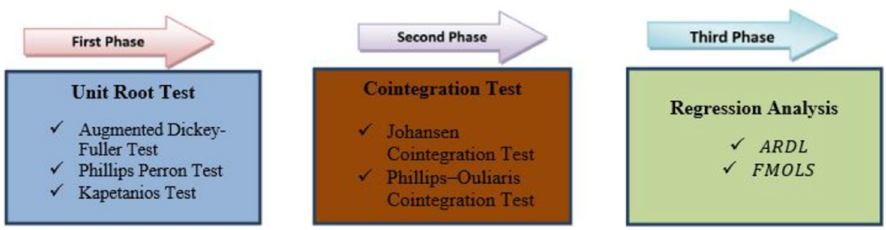

Fig. 4 Graph of a flow

and (2) may be turned into an unconstrained error correction model (*UECM*) for determining the *SR* dynamics and *LR* equilibrium route at the same equation as shown below

$$\begin{aligned}\Delta \ln \mathrm{CO}_{2t} &= a_0 + \sum_{i=1}^{p} a_1 \Delta \ln \mathrm{CO}_{2\,t-i} + \sum_{n=0}^{k} a_2 \Delta \ln \mathrm{GDP}_{t-n} + \sum_{c=0}^{s} a_3 \Delta \ln \mathrm{TO}_{t-c} + \sum_{l=0}^{r} a_4 \Delta \ln \mathrm{FDI}_{t-1} \\ &+ \sum_{j=0}^{q} a_5 \Delta \ln \mathrm{GPR}_{t-j} + \sum_{g=0}^{m} a_6 \Delta \mathrm{BRI}_{t-g} + \beta_1 \ln \mathrm{CO}_{2\,t-1} + \beta_2 \ln \mathrm{GDP}_{t-1} + \beta_3 \ln \mathrm{TO}_{t-1} \\ &+ \beta_4 \ln \mathrm{FDI}_{t-1} + \beta_5 \ln \mathrm{PR}_{t-1} + \beta_6 \mathrm{BRI}_{t-1} + \eta_1 D_8 + \eta_2 D_{18} + \varepsilon_t \end{aligned} \tag{8}$$

Similarly,

$$\begin{aligned}\Delta \ln \mathrm{GDP}_t &= a_0 + \sum_{i=1}^{p} a_1 \Delta \ln \mathrm{GDP}_{t-i} + \sum_{n=0}^{k} a_2 \Delta \ln CO_{2\,t-n} + \sum_{c=0}^{s} a_3 \Delta \ln \mathrm{TO}_{t-c} + \sum_{l=0}^{r} a_4 \Delta \ln \mathrm{FDI}_{t-1} \\ &+ \sum_{j=0}^{q} a_5 \Delta \ln \mathrm{GPR}_{t-j} + \sum_{g=0}^{m} a_6 \Delta \mathrm{BRI}_{t-g} + \beta_1 \ln \mathrm{GDP}_{t-1} + \beta_2 \ln \mathrm{CO}_{2\,t-1} + \beta_3 \ln \mathrm{TO}_{t-1} \\ &+ \beta_4 \ln \mathrm{FDI}_{t-1} + \beta_5 \ln \mathrm{PR}_{t-1} + \beta_6 \mathrm{BRI}_{t-1} + \eta_1 D_8 + \eta_2 D_{18} + \varepsilon_t \end{aligned} \tag{9}$$

Here Δ indicate the first-difference; i, n, c, l, j, and g represent of lags of the each variable; $\alpha 1, \ldots, \alpha 6$ indicate the *SR* paraments; $\beta 1, \ldots, \beta 6$ represent the *LR* parameters; η_1 and η_2 denotes the dummy variables and ε_t is the error term. If cointegration connection, we can derive an *ECM* model that may be used to calculate short-term elasticities, as following

$$\begin{aligned}\Delta \ln \mathrm{CO}_{2t} &= a_0 + \sum_{i=1}^{p} a_1 \Delta \ln \mathrm{CO}_{2\,t-i} + \sum_{n=0}^{k} a_2 \Delta \ln \mathrm{GDP}_{t-n} + \sum_{c=0}^{s} a_3 \Delta \ln \mathrm{TO}_{t-c} + \sum_{l=0}^{r} a_4 \Delta \ln \mathrm{FDI}_{t-1} \\ &+ \sum_{j=0}^{q} a_5 \Delta \ln \mathrm{GPR}_{t-j} + \sum_{g=0}^{m} a_6 \Delta \mathrm{BRI}_{t-g} + \eta_1 D_8 + \eta_2 D_{18} + \varphi \mathrm{ECT}_{t-1} + \varepsilon_t \end{aligned} \tag{10}$$

Similarly,

$$\begin{aligned}\Delta \ln \mathrm{GDP}_t &= a_0 + \sum_{i=1}^{p} a_1 \Delta \ln \mathrm{GDP}_{t-i} + \sum_{n=0}^{k} a_2 \Delta \ln \mathrm{CO}_{2\,t-n} + \sum_{c=0}^{s} a_3 \Delta \ln \mathrm{TO}_{t-c} + \sum_{l=0}^{r} a_4 \Delta \ln \mathrm{FDI}_{t-1} \\ &+ \sum_{j=0}^{q} a_5 \Delta \ln \mathrm{GPR}_{t-j} + \sum_{g=0}^{m} a_6 \Delta \mathrm{BRI}_{t-g} + \eta_1 D_8 + \eta_2 D_{18} + \varphi \mathrm{ECT}_{t-1} + \varepsilon_t \end{aligned} \tag{11}$$

Here φ indicates the ECT_{t-1}‘s parameter. It shows the *LR* equilibrium adjustment speed following an *SR* shock. It specifically looks for convergence to the *LR* equilibrium route. So, it is expected that its coefficient will be negative (Gyimah-Brempong and Traynor, 1999).

Pesaran et al. (2001) identify two degenerate situations in the context of the ARDL model. The first instance occurs when both the overall $F-$ bounds test for assessing the significance of all variables' lagged values and the $t-$ bounds test for testing the significance of the regressand's lagged values are significant. Two sets of asymptotic critical values are presented by Pesaran et al. (2001), one for the *I*(0) variables and one for the *I*(1) variables. The relevance of the overall *F*− bounds test and *t*− bounds test is tested using these key values.

5 Results and discussion

Table 8 displays the estimates for the ARDL model. which reveal that GDP is positively linked with the CO_2 in both the short-run (*SR*) and long-run (*LR*). The positive GDP coefficient indicates that GDP impedes environmental sustainability through increasing CO_2 emissions. These findings show that economic activity in Pakistan economy is not ecologically friendly. This economy is sacrificing environmental quality for a false sense of luxury to achieve quick economic expansion. As a result of economic activity, there is an increase in energy use and environmental deterioration (Khan and Hou, 2021; Sharma et al. 2020). This finding is coherent with those of (Su et al. 2021; Zhang et al. 2021).

Further, the regression results show that trade openness (TO) positively and significantly impacts the CO_2 in both the *SR* and *LR*. This shows that an increase in TO decreases environmental sustainability. Pakistan's environmental damage is increasing as a result of TO. Most developing nations, including Pakistan, depend on imported resources, such as electronic trash and used items. Despite the fact that these items or commodities improve living standards and economic progress in developing countries, but the increased energy consumption they entail exacerbates CO_2 emissions. This finding supports the 'pollution haven hypothesis' (*PHH*) of a pollution haven theory, demonstrating that TO damages environmental sustainability. Our result coherent with those of Ashraf et al. (2022a), Khan and Rana (2021) and Salman et al. (2019), who discovered a positively significant link between TO and CO_2 emissions. However, it contrasts the results of Tachie et al. (2020), Zeren and Akkuş (2020) and Adebayo (2020), who discovered a negatively significant relationship CO_2 emissions and trade openness.

Our results on the *PHH* are further reinforced by the fact that the FDI variable's coefficient is positively significant in all models in Table 8. More foreign direct investment (*FDI*) in developing countries is seen as necessary for the transfer of technology and know-how, but this also increases pollution emissions because of the movement of polluting businesses (Birdsall and Wheeler, 1993; Long et al. 2017). Numerous research in current literature indicates the increasing environmental degradation due to the FDI. Included in these instances is studies by Abbasi and Riaz (2016) for Pakistan, Le et al. (2020) for 31 Asian economies, and Salahuddin et al. (2018) for Kuwait. Recent research by Phuc Nguyen et al. (2020) suggests that FDI and CO_2 emissions in developing countries are directly linked.

The coefficient of *BRI* policy is positively and significantly impact on CO_2 emissions in both the *SR* and *LR*. The main goal of the OBOR strategy is to boost trade and investment on a bilateral and multilateral level (Buckley, 2020; Du and Zhang, 2018), thus boosting economic growth. Economic growth impedes environmental sustainability by increasing CO_2 emissions.

Table 8 The result of ARDL long run and short run

Variables	Model 1	Model 2	Model 3	Model 4
Dependent variable CO_2				
Long – runresults				
GDP	0.1489** (0.013)	0.1287** (0.018)	0.2271** (0.019)	0.8399*** (0.060)
TO	0.2859* (0.007)	0.0647*** (0.082)	7.0105*** (0.055)	0.9089* (0.006)
FDI	0.2085* (0.007)	0.0147*** (0.083)	0.04972** (0.037)	0.9972* (0.004)
PR	−1.7207** (0.036)	−1.6863 (0.046)	6.1928*** (0.059)	−0.5920* (0.005)
BRI	0.1408* (0.083)	0.1337** (0.012)	0.6480* (0.024)	1.5776 (0.612)
ln(***PR*GDP***)		−0.04475*** (0.079)		
ln(***PR*TO***)			−0.0520*** (0.055)	
ln(***PR*FDI***)				0.7293* (0.004)
Short – runresults				
GDP	0.0344* (0.0006)	0.0312*** (0.063)	0.0321* (0.000)	0.0408* (0.003)
TO	0.3744* (0.001)	0.3681* (0.003)	10.629* (0.002)	0.5320* (0.002)
OFDI	0.0148** (0.013)	0.01431** (0.015)	0.0705** (0.038)	0.0484** (0.029)
PR	−0.0325** (0.0146)	−0.4095*** (0.087)	−9.8051* (0.002)	0.2719** (0.032)
BRI	0.3259** (0.014)	0.3249** (0.017)	0.07013** (0.033)	0.0767** (0.041)
D_8	−0.0358** (0.036)	−0.0380*** (0.064)	−0.0168 (0.203)	−0.0274 (0.121)
D_{18}	0.007512 (0.7860)	0.009562 (0.7543)	0.0425*** (0.069)	0.0442 (0.166)
ln(***PR*GDP***)		−0.01087*** (0.080)		
ln(***PR*TO***)			0.07373* (0.002)	
ln(***PR*FDI***)				−0.0368** (0.026)
Constant	−1.3997* (0.000)	−1.4548* (0.000)	6.5006* (0.000)	−0.2055 (0.000)
ECT_{t-1}	−0.2314* (0.000)	−0.2428* (0.000)	−0.1417* (0.000)	−0.0486* (0.000
Adj. R^2	0.98	0.98	0.99	0.99
Diagnostic tests				
Heteroscedasticity (BPG test)	0.7146 (0.696)	0.9442 (0.547)	0.3656 (0.937)	1.3190 (0.405)

Table 8 (continued)

Variables	Model 1	Model 2	Model 3	Model 4
Autocorrelation (LM test)	0.0182 (0.895)	0.0031 (0.956)	1.3322 (0.312)	1.2724 (0.322)
Normality (JB test)	1.221 (0.452)	1.839 (0.398)	0.2407 (0.886)	0.8707 (0.647)
RESET (Ramsey test)	0.0494 (0.961)	0.2340 (0.821)	1.0660 (0.346)	1.5762 (0.190)

The significance levels of 1%, 5%, and 10% are denoted by *, **, and *** respectively. Bartlett kernel function and *HAC* Newey-West robust standard errors are used

Political stability (meaning a decrease in political risk) is negatively and significantly correlated to CO_2 emissions in both the *SR* and *LR*. Political stability helps to reduce corruption and ease the road for severe environmental legislation to be implemented. Thus, political stability makes a huge impact in mitigating climate change and its consequences via economic preparedness, social, and governance. Therefore, before adaption choices can be implemented, competent political institutions need strict economic changes and policies, social, and governance.

Furthermore, the interaction term is utilized to evaluate the combined influence of GDP and PR, shown in *Model*2. The interaction term's negative coefficient explains GDP decreases environmental deterioration when combined with decreasing political risk (meaning an increase in political stability). Political stability allows governments to enforce strong economic institution legislation and pave the road for green initiatives. So, when PR interacts with GDP, it reduces the adverse effects of GDP and enhances environmental quality. Thus, Models 3 and 4 show the moderating impacts of political risk by trade openness and FDI. Overall, these findings confirm our contention that the presence of the '*PHH* ' is significant only for countries with high political risk.

Table 9 shows the ARDL estimation when the dependent variable is economic growth. It demonstrates that political stability (meaning a decrease in political risk) is significant and positive correlated to GDP growth in both the *SR* and *LR*. This implies that efficient and neutral domestic political institutions boost economic development, thus crediting the "hierarchy of institutions theory" in Pakistan. The findings are backed by (Salman et al. 2019). The variable of coefficient CO_2 and interaction term $\left(PR * CO_2\right)$ are positive and negative, respectively. This significantly supports the notion that environmental contamination in Pakistan may be decreased, if the political institutions reach a certain degree of development. In other words, Pakistan may simultaneously enjoy a higher growth rate and reduce the deteriorating impact of CO_2 emissions under strong political stability. The coefficients of trade and FDI have a positive impact on GDP growth. Thus, Models 3 and 4 show the moderating impacts of political risk by trade openness and FDI. Political stability has been proven to improve the economic growth impact of trade openness because it accelerates trade benefits such as specialization and economies of scale in advanced countries. Furthermore, political stability may boost the economic growth

Table 9 The result of ARDL long run and short run

Variables	Model 1	Model 2	Model 3	Model 4
Dependent variable GDP				
Long − run results				
CO_2	−6.0899** (0.050)	−1.9322* (0.063)	−4.1451** (0.043)	−1.5999** (0.049)
TO	0.30273*** (0.098)	1.6114** (0.046)	2.0148** (0.016)	5.2964*** (0.071)
,OFDI	0.0166*** (0.068)	0.0947*** (0.082)	0.0288** (0.027)	1.0802** (0.039)
PR	9.5242** (0.012)	1.9468* (0.008)	3.1692** (0.018)	5.4940** (0.041)
BRI	1.0516*** (0.074)	0.9737** (0.049)	2.7913* (0.0085)	1.7589** (0.026)
$\ln(\boldsymbol{PR*CO_2})$		6.7151* (0.005)		
ln(***PR*TO***)			0.2061* (0.001)	
ln(***PR*OFDI***)				0.7835** (0.0422)
Short − runresults				
CO_2	−5.9588** (0.019)	−1.3696* (0.005)	−4.4081** (0.033)	−1.9080** (0.047)
TO	7.3645** (0.039)	9.8632** (0.024)	2.5587** (0.012)	6.3164*** (0.0891)
OFDI	0.1762** (0.050)	0.4966** (0.019)	0.0891*** (0.063)	1.2883*** (0.056)
PR	9.3191** (0.011)	2.6665*** (0.088)	2.5042** (0.014)	6.5520** (0.041)
BRI	0.3259** (0.014)	1.3336*** (0.082)	2.1977** (0.011)	0.7327 (0.265)
D_8	−0.8722 (0.265)	−1.8776*** (0.096)	−0.5840 (0.265)	−1.4001 (0.117)
D_{18}	0.7612 (0.1549)	0.5294 (0.324)	1.5964* (0.097)	0.7853 (0.124)
$\ln(\boldsymbol{PR*CO_2})$		9.1975*** (0.061)		
ln(***PR*TO***)			0.2192** (0.012)	
ln(***PR*OFDI***)				0.9735*** (0.053)
Constant	34.539* (0.000)	52.361* (0.000)	−18.262* (0.000)	2.9664 (0.000)
ECT_{t-1}	−0.9784* (0.000)	−1.3696* (0.000)	−1.0634* (0.000)	−1.1925* (0.000)
Adj. R^2	0.92	0.96	0.98	0.98
Diagnostic tests				
Heteroscedasticity (BPG test)	1.585 (0.26)	1.225 (0.44)	0.449 (0.88)	1.368 (0.92)

Table 9 (continued)

Variables	Model 1	Model 2	Model 3	Model 4
Autocorrelation (LM test)	0.066 (0.80)	0.766 (0.43)	0.799 (0.43)	1.352 (0.30)
Normality (JB test)	0.931 (0.62)	2.06 (0.35)	0.787 (0.67)	0.380 (0.32)
RESET (Ramsey test)	1.550 (0.17)	0.274 (0.79)	0.629 (0.57)	0.537 (0.61)

The significance levels of 1%, 5%, and 10% are denoted by *, ** and *** respectively. Bartlett kernel function and *HAC* Newey-West robust standard errors are used

benefit of FDI by improving the facilitation of technology transfer and knowledge spill-over processes (Jude and Levieuge, 2017). The *BRI* coefficient has a significantly positive impact on GDP growth. The outcome is matched with (Ashraf et al. 2022a).

Furthermore, in Tables 8 and 9, the ECT_{t-1} is significantly negative at a 1% level, indicating that *SR* aberrations are corrected towards the *LR* equilibrium relationship within a year. The adjusted R^2 shows that our models explain almost above 90 per cent of the total variations in CO_2 and GDP growth rate in Pakistan. The Breusch–Godfrey–Lagrange multiplier (*LM*) test is used to verify that the estimate residuals are free of autocorrelation. According to the *LM* test, which asserts that there is no autocorrelation, the associated probabilities of the $F-$ statistics surpass the 5% significance threshold, which means we fail to reject the null hypothesis (*NH*) of the *LM* test. The Breusch–Pagan–Godfrey (*BPG*) test is used to look for heteroscedasticity in the data. Since the $F-$ statistics' corresponding probability are above the 5% significance threshold for homoscedasticity, we fail to reject its NH. Moreover, the Ramsey regression equation specification error (*RESET*) test fails to reject the NH, which claims that our model has no identification issues, and the functional form is correct. The $F-$ statistic's probability surpasses the 5% significance threshold. Jarque–Bera (*JB*) testing is used to determine if regression residuals are regularly distributed. Since the *JB* test statistic exceeds the 5% significance threshold in Tables 8 and 9, we fail to reject the *NH* that the residuals follow a normal distribution.

We employ the bounds testing technique to cointegration to look for a *LR* equilibrium connection (cointegration) between the variables. The *LR* cointegration relationship is seen in Table 10. The aggregate $F-$ statistic exceeds the upper limit, $I(1)$, of the critical values at all significant levels, indicating that the variables are cointegrated. We thus reject $H0$, which asserts that there is no cointegration, in favour of $H1$. Furthermore, it is clear from $table8$ that a cointegration connection exists at all significant levels, and so we may reject the *NH* that there is no cointegration, given that the $t-$ statistic surpasses the upper limit of the critical values.

We employ the FMOLS estimator developed by Phillips and Hansen (1990) to ensure the robustness of our findings. As a result of this method, asymptotically median-unbiased estimators are produced, which yield optimal long-run estimates

Table 10 Result bounds testing method to cointegration analysis

Models				F − Bounds Test	t − Bounds Test t −Bounds Test
$\boldsymbol{Ln\ CO_2} = \mathrm{f}\left[\mathrm{lnGDP},\ \boldsymbol{lnTO}, \mathrm{lnFDI}, \mathrm{FR}, \mathrm{BRI},\ \boldsymbol{D_8},\ \boldsymbol{D_{18}}\ \right]$				11.432*	– 10.329*
$\boldsymbol{Ln\ CO_2} = \mathrm{f}\left[\mathrm{lnGDP},\ \boldsymbol{lnTO}, \mathrm{lnFDI}, \mathrm{lnFR}, \mathrm{BRI},\ \boldsymbol{D_8},\ \boldsymbol{D_{18}},\ \boldsymbol{ln(PR*GDP)}\right]$				7.396*	– 10.672*
$\boldsymbol{Ln\ CO_2} = \mathrm{f}\left[\mathrm{lnGDP},\ \boldsymbol{lnTO}, \mathrm{lnFDI}, \mathrm{lnFR}, \mathrm{BRI},\ \boldsymbol{D_8},\ \boldsymbol{D_{18}},\ \boldsymbol{ln(PR*TO)}\right]$				46.816*	– 26.850*
$\boldsymbol{Ln\ CO_2} = \mathrm{f}\left[\mathrm{lnGDP},\ \boldsymbol{lnTO}, \mathrm{lnFDI}, \mathrm{lnFR}, \mathrm{BRI},\ \boldsymbol{D_8},\ \boldsymbol{D_{18}},\ \boldsymbol{ln(PR*OFDI)}\right]$				15.841*	– 15.619*
$\boldsymbol{Ln\ CO_2} = \mathrm{f}\left[\mathrm{lnCO_2},\ \boldsymbol{lnTO}, \mathrm{lnFDI}, \mathrm{lnFR}, \mathrm{BRI},\ \boldsymbol{D_8},\ \boldsymbol{D_{18}}\ \right]$				8.5120*	– 9.1100*
$\boldsymbol{Ln\ GDP} = \mathrm{f}\left[\mathrm{lnCO_2},\ \boldsymbol{lnTO}, \mathrm{lnFDI}, \mathrm{lnFR}, \mathrm{BRI},\ \boldsymbol{D_8},\ \boldsymbol{D_{18}},\ \boldsymbol{ln\left(PR*CO_2\right)}\right]$				9.3886*	– 12.024*
$\boldsymbol{Ln\ GDP} = \mathrm{f}\left[\mathrm{lnCO_2},\ \boldsymbol{lnTO}, \mathrm{lnFDI}, \mathrm{lnFR}, \mathrm{BRI},\ \boldsymbol{D_8},\ \boldsymbol{D_{18}},\ \boldsymbol{ln(PR*TO)}\right]$				21.786*	– 19.526*
$\boldsymbol{Ln\ GDP} = \mathrm{f}\left[\mathrm{lnCO_2},\ \boldsymbol{lnTO}, \mathrm{lnFDI}, \mathrm{lnFR}, \mathrm{BRI},\ \boldsymbol{D_8},\ \boldsymbol{D_{18}},\ \boldsymbol{ln(PR*OFDI)}\right]$				24.464*	– 19.482*
F – ***Critical Value Bound***	$I(0)$	$I(1)$	t – *CriticalValueBound*	$I(0)$	$I(1)$
1%	3.15	4.43	1%	– 3.43	– 4.99
5%	2.45	3.61	5%	– 2.86	– 4.38
10%	2.12	3.23	10%	– 2.57	– 4.04

The significance levels of 1% is denoted by ∗

of cointegrating regressions. All variables must be $I(1)$ for the FMOLS estimator. According to Phillips (1995), the FMOLS uses semi-parametric corrections to correct serial correlation and long-run endogeneity. Based on the results of the Johansen and Phillips-Ouliaris cointegration tests, as shown in Tables 6 and 7, we may infer that our variables have just two cointegrating relationships. After confirming that these two requirements are satisfied, we may use the FMOLS estimator (Narayan and Narayan, 2005). “Appendix” (Tables 11 and 12) shows the long-term estimates from the FMOLS model, which are consistent with those from the ARDL model.

6 Conclusion and policy implications

Since the China–Pakistan Economic Corridor (*CPEC*) is a step toward Eurasia’s economic integration, it is critical to study the impact of political risk (*PR*) on ecological deterioration and economic growth and examine trade openness (TO), China OFDI, and OBOR policy. In this context, the current study seeks to examine the impact of PR on CO_2 emissions and economic growth in Pakistan while also taking into account the relevance of TO, China OFDI, and OBOR policy. Furthermore, we examine the moderating impacts on CO_2 emissions of political risk appearing through trade openness, GDP growth and FDI channels. Similarly, we also examine the moderating impacts on GDP growth of political risk appearing through trade openness, CO_2 emissions and FDI channels. To investigate this impact, we use the ARDL technique to cointegration, and the FMOLS estimator for robustness results, using data spanning 1990 to 2018. We find that political risk has a significantly positive influence on CO_2 emission in both the *SR* and *LR* and a negative on economic growth in both the *SR* and *LR*. Our empirical results, based on the ARDL model, reveal that GDP, trade openness, FDI, and OBOR policy contribute to pollution, but political stability slows the rate of environmental deterioration. Furthermore, the existence of robust political stability mitigates the negative impacts of GDP, FDI, and trade openness. Also, the findings confirmed that impartial domestic political stability is critical to promoting economic development while simultaneously lowering CO_2 emissions at the same time.

These findings have important policy implications for our sample economy. First, the positive impact of GDP, *TO*, and FDI demonstrates that the Pakistan region's GDP growth is not environmentally friendly, and policymakers must keep a careful eye on the ecological repercussions of trade and FDI activities, as well as economic development in general. In reality, Asian economies significantly expand their worldwide share in international commerce and FDI (Khan and Rana, 2021; Nasreen and Anwar, 2014). Therefore, the governments of the regions that receive trade and FDI inflows should enforce strict environmental restrictions. For example, they may employ trade subsidies (taxes) for both local and international enterprises that respect environmental quality without jeopardizing their goals of trade liberalization; investments in energy-efficient manufacturing and consumption technology might benefit from similar policies that encourage foreign direct investment.

Second, our findings on the importance of indices of political stability suggest that strong political institutions may mitigate the detrimental effects of *GDP*, *FDI* and *TO* on ecological deterioration. Indeed, the presence of political stability generates demand for improved environmental standards and drives legislators to implement more environmental legislation. Strong political structures are necessary for effective environmental control. To do this, regional governments should raise public awareness to build strong institutions and reduce pollution. Furthermore, political stability would guarantee property rights and encourage both people and companies to participate in renewable energy initiatives. It is only feasible for *R&D* in renewable energy technology to take place when the governance framework guarantees that property rights are protected. There has been a long-standing debate on the direct positive impacts of political stability on economic development in the academic literature. However, our results point to certain indirect consequences of political stability on long-term economic growth, manifesting as a decrease in pollution. Analysing the efficacy of both direct and indirect political stability impacts for diverse areas and nations is a viable future study path.

Appendix

See Tables 11, 12.

Table 11 Long-run FMOLS estimates

Variables	Model 1	Model 2	Model 3	Model 4
Dependent variable CO_2				
GDP	0.0949*** (0.062)	0.09585* (0.045)	0.0507*** (0.081)	0.1806 (0.014)
TO	0.7436*** (0.069)	0.05514*** (0.077)	4.6381** (0.045)	0.3342** (0.026)
FDI	0.0304** (0.020)	0.02747* (0.002)	0.0406** (0.018)	0.1308* (0.000)
PR	−0.6788** (0.020)	−0.6935** (0.020)	−3.8378*** (0.055)	−0.5941*** (0.075)
BRI	0.15041** (0.0147)	0.1046*** (0.093)	0.17015** (0.011)	0.0432 (0.228)
D_8	−0.3559** (0.039)	−0.0702** (0.014)	0.0198 (0.655)	−0.0026 (0.918)
D_{18}	0.04280 (0.565)	0.01552 (0.8356)	0.322*** (0.068)	0.0644 (0.162)
ln(***PR*GDP***)		−0.0254*** (0.0457)		
ln(***PR*TO***)			−0.0318** (0.045)	
ln(***PR*FDI***)				−0.0988* (0.0000)
Constant	−2.0832** (0.040)	−2.5729** (0.030)	26.303*** (0.051)	−3.227** (0.049)
Adj. R^2	0.51	0.59	0.49	0.77
Normality (JB test)	0.2068 (0.901)	1.3696 (0.504)	1.0069 (0.604)	1.3220 (0.516)

The symbols ***, **, and * represent significance at the 10%, 5%, and 1% levels, respectively. We use the Newey-West fixed bandwidth and the Bartlett kernel function to compute the long-run covariances

Table 12 Long-run FMOLS estimates

Variables	Model 1	Model 2	Model 3	Model 4
Dependent variable GDP				
CO_2	−0.8851*** (0.064)	3.0470** (0.020)	0.1081*** (0.099)	−2.4670* (0.034)
TO	0.2406*** (0.089)	1.7787** (0.038)	1.8756* (0.009)	1.4994* (0.056)
FDI	0.0406*** (0.086)	0.5157** (0.032)	0.0403** (0.010)	0.5941** (0.022)
PR	5.9828** (0.029)	13.114** (0.013)	1.3991** (0.048)	6.2976** (0.028)
BRI	0.7254** (0.021)	0.8695** (0.010)	0.9355*** (0.098)	0.8800*** (0.093)
D_8	−0.5898 (0.1498)	−0.6038*** (0.099)	−0.6077 (0.1186)	−0.4488 (0.2346)
D_{18}	0.35229 (0.623)	0.5368 (0.264)	2.5663* (0.000)	0.4173 (0.236)
$\ln\left(PR * CO_2\right)$		11.604** (0.020)		
$\ln(PR * TO)$			0.0525* (0.009)	
$\ln(PR * FDI)$				0.4121** (0.025)
Constant	22.058* (0.004)	1.4352*** (0.095)	−1.8534* (0.000)	27.511* (0.003)
Adj. R^2	0.63	0.66	0.63	0.66
Normality (JB test)	1.2766 (0.528)	0.8807 (0.643)	1.9920 (0.369)	2.1064 (0.348)

The symbols ***, **, and * represent significance at the 10%, 5%, and 1% levels, respectively. We use the Newey-West fixed bandwidth and the Bartlett kernel function to compute the long-run covariances

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