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Does institutional quality matter for environmental sustainability?

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The prime objective of the study is to examine the asymmetric effect of institutional quality and other control variables on environmental sustainability in G7 economies. The study examined data from 1986 to 2020 using a nonlinear ARDL (NARDL) technique. The outcomes of the study show heterogeneous results for the sampled economies. The findings confirm the asymmetric relationship between institutional quality, foreign direct investment, trade openness, and economic growth, and environmental sustainability in G7 countries. Furthermore, the study finds that neglecting the series' inherent nonlinearities may lead to misleading inferences. The findings suggest that policies should be based on individual country characteristics and that no single policy can be a good fit for devising environmental sustainability measures.

KEYWORDS

environmental sustainability, institutional quality index, hidden cointegration, NARDL, G7 countries

Introduction

In the near future, the biggest goal and challenge is to attain sustainable environmental quality (Ridzuan et al., 2020). In 2015, the United Nations set 17 sustainable development goals (SDGs), to be achieved by member nations by 2030 under the United Nations umbrella. In the 1990s, carbon dioxide (CO_2) emission had surpassed allowable thresholds according to the report of the National Development goals of 2017. Over the last 3 decades, the amount of carbon dioxide has rapidly increased. Basically, CO_2 emission is the main cause of environmental degradation in both developed and developing countries. Further, greenhouse gases have an adverse effect on environmental quality (Nazar et al., 2020; Ullah et al., 2020). These emissions have an extremely adverse effect on the climate globally. In addition, natural disasters, such as floods and forest fires, contribute to the degradation of the environment all over the world (Khan et al., 2019). CO_2 emissions are extensively affecting agricultural land, the natural resources as well as the health of people. Many policymakers, researchers, economists, and environmental experts are taking a great interest in this most critical problem (Teng et al., 2021).

Extant literature on sustainable environment has looked into factors which have a relationship with environmental sustainability, like corporate social responsibility, globalization, renewable energy, industrialization, tourism, poverty, energy prices, internal trade, economic freedom, technology, human capital, health expenditure, remittance inflows, innovation, population, temperature, water scarcity, institutional quality, foreign direct investment, trade openness, and economic growth, among others (Meo et al., 2021; Sarkodie and Adams, 2018; Chishti et al., 2021). The last four factors are considered highly important factors for the growth of any country. Economic growth in the G7 region ("United Kingdom, United States, Canada, France, Italy, Japan, and Germany") has been fueled by the abundance of natural resources. Therefore, the current study the examines relationship between, institutional quality, foreign direct investment, trade openness, and economic growth, and environmental sustainability.

As far as environmental sustainability is concerned, institutional quality has a significant impact (Sarkodie and Adams, 2018; Hameed et al., 2019). Abid (2016), Salman et al. (2019), and Wang et al. (2018) showed that institutional quality can reduce CO_2 emissions. One of the most important factors in economic progress is the quality of the country's institutions. This guarantees that funds are allocated to the most efficient and ecologically-friendly initiatives. High-quality institutions provide an ecosystem in which all parties may successfully play their role in environmental protection.

The impact of foreign direct investment is very important for the global environment. Many studies have examined its impact on CO_2 emissions in developed and developing countries. Xin-gang et al. (2019) and Chishti et al. (2021) found a positive relationship between foreign direct investment and CO_2 emissions in developing countries. Jalal et al. (2011) also found positive effects of foreign direct investment on CO_2 emissions. Furthermore Haughton (2014) discovered a positive relationship between foreign direct investment and CO_2 emissions. Economic growth in the G7 region has been fueled by the abundance of natural resources. Economically advanced economies (G7) control global trade and the international financial system as well as foreign direct investment. As a result, the region's environment has had to bear a significant price in terms of its ability to sustain its growth.

Trade openness has been emphasized in current environmental quality studies; however, these studies have reached contradictory outcomes. Ferrantino (1997), Antweiler et al. (2001), and Khan et al. (2021) found that openness to international trade is a crucial economic growth predictor. However, in some countries, openness through import and export activity, contributes to pollution and diminishes environmental quality, which is a problem. Increasing trade, foreign direct investment, and financial globalization are degrading the environment, particularly in developing nations where ineffective policies are being implemented in an effort to spur economic growth (Khan et al., 2021). The increasing number of economic activities across different countries, as well as changes in environmental quality, have prompted debates about the impact of trade on the environment. Like other factors, various researchers have found that economic growth positively affects CO_2 emissions (Kongkuah et al., 2022; Mujtaba et al., 2022).

After a thorough literature review, we find that the early studies on institutional quality-carbon emissions (IQ-ES) nexus have shown a linear relationship. Several macroeconomic factors, particularly business cycles, have been shown to exhibit nonlinear properties, despite the fact that the factors driving CO_2 emissions have been investigated in a linear framework (Neftçi, 1984). The main problem of linear time series models is that variables are regarded as linear, although in reality, most of the series demonstrate nonlinear features (Anoruo, 2011). Meo et al. (2020) found that ignoring the intrinsic nonlinearities may lead to misinformed inferences. Hence, considering the importance of nonlinearities among the series, there is a dire need to examine the asymmetric relationship between institutional quality, foreign direct investment, trade openness, and economic growth, and environmental sustainability. The comprehensive analyses of the current study will be very helpful for the policy-makers to devise efficient policies to enhance economic growth without scarifying environmental quality.

There are certain knowledge gaps in the litrature about how institutional quality affects CO_2 emissions, and this study fills them. As a starting point, this study adds to the growing body of knowledge about the relationship between institutional quality and CO_2 emissions by constructing an institutional quality index utilizing principal component analysis (PCA) and six indicators of institutional quality: "control of corruption, government effectiveness, political stability and absence of violence, regulatory quality, rule of law, and voice and accountability". Secondly, it is important to note that this study is primarily focused on the G7 economies; this is because we evaluated numerous factors in G7 countries before selecting the sample. This group of seven large economies accounts for more than half of the world's gross domestic product (GDP) (JinRu and Qamruzzaman, 2022). Further, Canada has the greatest per capita greenhouse gas emissions among the G7 countries. Due to its non-homogeneous characteristics, the sample is intriguing. It is possible that the outcomes of this research could help the largest and most powerful economies to better understand how to implement ecologically-friendly policies. Thirdly, most research on the relationship between institutional quality and emissions have been conducted in a linear paradigm. However, structural changes and short-term volatility, cannot be studied using linear models (Po and Huang, 2008). Furthermore, one of the primary problems with linear models is that they presume that variables or series are linear, whereas macroeconomic variables exhibit nonlinear characteristics (Anoruo, 2011).

TABLE 1 Description of variables.

Variables	Symbols	Units of measurement	Data-source
Environmental—sustainability	ES	CO_2 emissions (cubic per meter)	WDI
Institutional quality	IQ	Institutional quality index	WGI
Foreign direct investment	FDI	Foreign direct investment net inflow (% annual GDP)	WDI
Trade openness	TOP	Import goods and services (%GDP)	WDI
		Export goods and services (%GDP)	
Economic growth	EG	GDP per capita growth (annual %)	WDI

Furthermore, CO_2 emissions in actuality are prone to asymmetries (Chen et al., 2022). The findings suggest that ignoring fundamental nonlinearities may lead to incorrect inferences. Given the significance of nonlinearities or asymmetries, the current study investigates the asymmetric impact of institutional quality, foreign direct investment, trade openness, and economic growth on environmental sustainability.

The rest of the paper is structured as follows: The second section contains data and methods. The findings and discussion are presented in *Findings and discussion* Section. The fourth section continues with policy implications.

Data, model, and econometric techniques

Data

We used the annual data from 1986 to 2020. We designed an institutional quality index based on six indicators ("control of corruption, government effectiveness, political stability and absence of violence, regularity quality, rule of law, and voice and accountability"). We extracted the data from two indicators: "World Development Indicators" and "Worldwide Governance Indicators (WGI)". Further details are given in Table 1.

Model specification

To evaluate the asymmetric impact of institutional quality, foreign direct investment, trade openness, and economic growth on environmental sustainability, the study postulated the following linear equation.

$$ES_t = \alpha_0 + \alpha_1 IQ_t + \alpha_2 FDI_t + \alpha_3 TOP_t + \alpha_4 EG_t + \mu_t \tag{1}$$

Where ES, IQ, FDI, TOP and EG, refer to environmental sustainability, institutional quality, foreign direct investment, trade openness and economic growth, respectively. As mentioned above, most of studies on the IQ-ES nexus have been based on the linear framework, while we conducted this research in nonlinear settings because of the nonlinearities in time series. There are various reasons for nonlinearities, such as structural breaks in data, sudden changes or policy shocks (Chowdhury et al., 2021). As the prime objective of the study is to check the asymmetric relationship between institutional quality, foreign direct investment, trade openness, and economic growth and environmental sustainability, we formulated the following long-run asymmetric model:

$$ES_t = \alpha_0 + \alpha_1 IQ_i^+ + \alpha_2 IQ_i^- + \alpha_3 FD_i^+ + \alpha_4 FD_i^- + \alpha_5 TOP_i^+ + \alpha_6 TOP_i^- + \alpha_7 EG_i^+ + \alpha_8 EG_i^+ + \mu_t \tag{2}$$

Where $ES_t, IQ_i^+, IQ_i^-, FD_i^+, FD_i^-, TOP_i^+, TOP_i^-, EG_i^+, EG_i^+$ denote environmental sustainability, partial sums of positive and negative changes in institutional quality, foreign direct investment, trade openness, and economic growth, respectively; while, $\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6, \alpha_7$ *and* α_8 are the long-run parameters of the model. Equation 1 only gives the long-run effect of predictors. Therefore, to examine the short-run impact of institutional quality, foreign direct investment, trade openness, and economic growth on environmental sustainability, we re-specified Equation 1 as follows:

$$\Delta ES_t = \varphi_0 + \sum_{k=1}^{n} \varphi_{1k} \Delta ES_{t-k} + \sum_{k=1}^{n} \varphi_{2k} \Delta IQ_{t-k} + \sum_{k=1}^{n} \varphi_{3k} \Delta FDI_{t-k} + \sum_{k=1}^{n} \varphi_{4k} \Delta TOP_{t-k} + \sum_{k=1}^{n} \varphi_{5k} \Delta EG_{t-k} + \gamma_6 ES_{t-1} + \gamma_7 IQ_{t-1} + \gamma_8 FDI_{t-1} + \gamma_9 TOP_{t-1} + \gamma_{10} EG_{t-1} + \mu_t \tag{3}$$

Equation 3 error correction terms provide the coefficients of long-run and short-run, which are represented by (Δ), indicating the short-term coefficient; while (γ) provides the long-term coefficient. However, the prime objective of this study is to examine asymmetric impact of institutional quality, foreign direct investment, trade openness, and economic growth on environment sustainability in G7 countries. Hence, to achieve the objective of the study, we followed the asymmetric cointegration regression as below:

$$b_t = \theta^+ \alpha_t^+ + \theta^- \alpha_t^- + \mu_t \tag{4}$$

Where, θ^{+} *and* θ^{-} refer to the long-term coefficient; while α_t is decomposed vector regressor:

$$\alpha_t = \alpha_t^{+} + \alpha_t^{-} \tag{5}$$

In Equation 5, α^{+} and α^{-} represent the independent variables, which are decomposed into partial sum of positive and negative changes. The following Equations 6–13 indicate the partial sum of positive and negative changes in institutional quality, foreign direct investment, trade openness, and economic growth:

$$IQ^{+} = \sum_{i=1}^{t} \Delta IQ^{+} = \sum_{i=1}^{t} max\left(\Delta IQ_i,\ 0\right) \tag{6}$$

$$IQ^{-} = \sum_{i=1}^{t} \Delta IQ^{-} = \sum_{i=1}^{t} min\left(\Delta IQ_i,\ 0\right) \tag{7}$$

$$FDI^{+} = \sum_{i=1}^{t} \Delta FDI^{+} = \sum_{i=1}^{t} \max\left(\Delta FDI_i,\ 0\right) \tag{8}$$

$$FDI^{-} = \sum_{i=1}^{t} \Delta FDI^{-} = \sum_{i=1}^{t} min\left(FDI_i,\ 0\right) \tag{9}$$

$$TOP^{+} = \sum_{i=1}^{t} \Delta TOP^{+} = \sum_{i=1}^{t} max\left(TOP_i, 0\right) \tag{10}$$

$$TOP^{-} = \sum_{i=1}^{t} \Delta TOP^{-} = \sum_{i=1}^{t} min\left(TOP_i,\ 0\right) \tag{11}$$

$$EG^{+} = \sum_{i=1}^{t} \Delta EG^{+} = \sum_{i=1}^{t} max\left(EG_i, 0\right) \tag{12}$$

$$EG^{-} = \sum_{i=1}^{t} \Delta EG^{-} = \sum_{i=1}^{t} min\left(EG_i,\ 0\right) \tag{13}$$

In the succeeding stage, the study replaced IQ, FDI, TOP, and EG in Equation 3 with IQ^{+}, IQ^{-} $FDI^{+}, FDI^{-}, TOP^{+}, TOP^{+}, EG^{+}$ *and* EG^{-}. By incorporating partial sum of positive and negative changes of the above-mentioned variables into Equation 3, we formulated the following nonlinear Equation 14 known as asymmetric/nonlinear ARDL approach to cointegration.

$$\begin{aligned}\Delta ES_t = {} & \varphi_0 + \sum_{k=1}^{n} \varphi_{1k} \Delta ES_{t-k} \\ & + \sum_{k=1}^{n} \varphi_{2k} \Delta IQ^{+}_{i\,t-k} + \sum_{k=1}^{n} \varphi_{3k} \Delta IQ^{-}_{i\,t-k} + \sum_{k=1}^{n} \varphi_{4k} \Delta FDI^{+}_{i\,t-k} + \\ & \sum_{k=1}^{n} \varphi_{5k} \Delta FDI^{-}_{i\,t-k} + \sum_{k=1}^{n} \varphi_{6k} \Delta TOP^{+}_{i\,t-k} + \\ & \sum_{k=1}^{n} \varphi_{7k} \Delta TOP^{-}_{i\,t-k} + \sum_{k=1}^{n} \varphi_{8k} \Delta EG^{+}_{i\,t-k} + \sum_{k=1}^{n} \varphi_{9k} \Delta EG^{-}_{i\,t-k} + \gamma_1 ES_{t-1} + \\ & \gamma_2\, IQ^{+}_{i\,t-1} + \gamma_3\, IQ^{-}_{i\,t-1} + \gamma_4\, FDI^{+}_{i\,t-1} + \gamma_5\, FDI^{-}_{i\ t-1} + \gamma_6\, TOP^{+}_{i\,t-1} + \\ & \gamma_7 TOP^{-}_{i\,t-1} + \gamma_8\, EG^{+}_{i\,t-1} + \gamma_9\, EG^{-}_{i\,t-1} + \mu_t\end{aligned} \tag{14}$$

After the estimation of Equation 14, we applied the Shen (2014) bounds testing approach which was established by Pesaran et al. (2001). The bounds testing approach of Pesaran et al. (2001) is equally appropriate to Equation 14. The inclusion of decomposed positive and negative series of institutional quality, foreign direct investment, trade openness, and economic growth into Equation 3 makes the model non-linear ARDL (14), hereafter the NARDL model. The ARDL approach has several advantages over conventional cointegration approaches. For instance, it is possible to use the ARDL approach regardless of whether the variables are I (0), I (1), or a mixture of I (0) and I (1), which is different from traditional cointegration techniques that require all variables to be stationary in the same order (Engle and Granger, 1987; Khan et al., 2020; Fatima et al., 2021). This method's most alluring feature is that it performs admirably even with a small sample size. However, this technique cannot be employed in the presence of a variable that is stationary at I (2).

Principal component analysis

Previous studies have used various factors as a proxy for institutional quality, such as government stability (Habib et al., 2017), corruption (Lv and Xu, 2017), and law and order (Moyo and Ziramba, 2013). However, there are other indicators of institutional quality as well, such as "control of corruption, government effectiveness, political stability and absence of violence, regulatory quality, rule of law, and voice and accountability". Therefore, other factors of IQ had to be included as well to get more information about IQ and its impact on environmental sustainability. To get a thorough knowledge about IQ, we composed an index of institutional quality based on the above-mentioned indicators using PCA. We generated an IQ index using the PCA approach as follows: $IQ_j = z_{j1}y_1 + z_{j2}y_2 + z_{j3}y_3 \ldots\ldots\ldots\ldots + z_{jp}x_p$, where the IQ_j represents institutional quality and z_j shows a parameter of an equation. Also, "x" is denoted as an indicator and "p" evaluate as no variables exist.

Findings and discussion

Table 2 shows the results of the descriptive statistics, which was used to analyze the nature of the data in G7 economies. The Jarque-Bera test results demonstrate that all of the series are normally distributed. Furthermore, one of the major preconditions of the NARDL model is that there should be no variables that are stationary at the I (2). Ibrahim (2015) found that in the presence of any variable which is stationary at I (2), cointegration F-statistics value becomes invalid. Therefore, to avoid this series issue, we applied different time series unit root test, such as the Dickey–Fuller (ADF) and Phillips–Perron (PP) tests. The results of the unit root test as in Table 3 reveal that there is no variable that is stationary at I (2), and so, we proceeded with the Dynamic NARDL long-run and short-run estimations.

After confirming that none of the series is stationary at I (2), we proceeded with the bounds testing approach. Table 4 shows the results of asymmetric cointegration based on the bounds

TABLE 2 Descriptive statistics.

	Mean	Median	Max	Min	Std. Dev	Skewness	Kurtosis	Jarque-bera	Prob
Model 1(UK)									
ES	2.056	2.186	2.295	1.578	0.212	0.942	2.521	4.731	0.093[a]
IQ	0.345	0.090	0.773	2.588	1.182	0.977	2.447	1.893	0.388
FDI	1.052	0.985	2.479	2.555	1.056	1.243	5.754	1.636	0.214
TOP	6.911	6.890	7.071	6.742	0.009	0.164	2.045	1.275	0.528
EG	28.536	28.589	28.791	28.208	0.176	0.491	2.084	2.252	0.324
Model 2 (USA)									
ES	2.884	2.945	3.019	2.691	0.114	0.519	1.667	3.575	0.167
IQ	0.956	0.248	0.7441	6.195	1.958	1.557	4.878	7.167	0.073[a]
FDI	0.366	0.398	1.225	0.766	0.497	0.302	2.567	0.690	0.708
TOP	4.201	4.181	4.412	4.026	0.124	0.259	1.869	1.935	0.379
EG	30.324	30.388	30.624	29.912	0.211	0.465	2.078	2.143	0.324
Model 3 (Canada)									
ES	2.766	2.760	2.854	2.689	0.045	0.253	2.172	1.176	0.555
IQ	0.701	0.047	0.827	4.435	1.351	1.408	4.762	1.898	0.320
FDI	0.779	0.828	2.216	-1.955	0.823	1.152	5.467	1.250	0.324
TOP	7.638	7.608	7.911	7.321	0.142	0.025	2.502	0.313	0.855
EG	27.810	27.869	28.159	27.310	0.261	0.404	1.864	2.429	0.296
Model 4 (France)									
ES	1.712	1.762	1.872	1.524	0.114	0.470	1.708	3.193	0.202
IQ	−0.597	−0.165	0.561	−3.886	1.116	1.837	5.793	1.208	0.883
FDI	0.505	0.455	1.354	-1.591	0.626	1.279	5.560	1.382	0.231
TOP	6.959	6.994	7.131	6.706	0.122	0.694	2.507	2.714	0.257
EG	28.394	28.441	28.593	28.148	0.138	0.508	1.926	2.7350	0.254
Model 5 (Italy)									
ES	1.917	1.960	2.103	1.659	0.149	0.586	1.889	3.261	0.196
IQ	0.052	0.293	0.657	1.321	0.612	1.215	3.415	2.785	0.248
FDI	0.506	0.257	2.093	6.394	1.416	2.578	11.721	0.756	0.812
TOP	7.219	7.222	7.441	6.824	0.152	0.827	3.624	3.911	0.141
EG	28.226	28.250	28.319	28.089	0.067	0.795	2.467	3.518	0.172
Model 6 (Japan)									
ES	2.221	2.229	2.292	2.135	0.037	0.406	2.709	0.929	0.628
IQ	0.574	0.242	0.723	4.011	1.418	1.329	3.759	4.142	0.126
FDI	2.086	1.639	0.215	7.198	1.685	1.307	4.611	1.615	0.125
TOP	5.586	5.616	5.943	5.204	0.267	0.093	1.431	3.122	0.209
EG	29.047	29.063	29.155	28.923	0.073	0.265	1.996	1.612	0.447
Model (Germany)									
ES	2.282	2.283	2.456	2.118	0.086	0.067	2.306	0.624	0.232
IQ	0.389	0.118	0.579	2.023	0.878	0.625	2.136	1.348	0.509
FDI	0.350	0.619	2.546	3.765	1.616	1.583	6.965	1.044	0.220
TOP	6.848	6.940	7.157	6.317	0.393	0.525	1.748	3.337	0.188
EG	28.720	28.708	28.911	28.532	0.115	0.015	1.881	1.567	0.456

[a]refers to 10% level of significance.

testing approach. The findings show that the F-test value exceeds the upper bounds value, which confirms rejection of the null hypothesis of no asymmetric cointegration at the 1% level of significance for all the sampled G7 economies. Hence, the findings of the nonlinear bounds test confirm the existence of asymmetric cointegration or hidden cointegration.

TABLE 3 Unit root tests.

Tests	ES	IQ	FDI	TOP	EG
UK					
ADF unit root test (1981)					
I (0)	0.001**	0.003**	0.273	0.1932	0.996
I (1)	0.000***	0.000***	0.004**	0.094*	0.000***
PP unit root test (1988)					
I (0)	0.491	1.000	0.294	0.208	0.881
I (1)	0.000***	0.000***	0.004**	0.091*	0.001**
USA					
ADF unit root test (1981)					
I (0)	0.088*	0.078*	0.739	0.035**	0.053**
I (1)	0.000***	0.000***	0.004***	0.086*	0.000***
PP unit root test (1988)					
I (0)	0.293	0.721	0.392	0.002**	0.061*
I (1)	0.000***	0.041**	0.035**	0.031**	0.001***
Canada					
ADF unit root test (1981)	0.493	0.053**	0.146	0.078*	0.043**
I (0)	0.000***	0.000***	0.032**	0.002**	0.001**
I (1)					
PP unit root test (1988)					
I (0)	0.294	0.034**	0.245	0.091*	0.054**
I (1)	0.000***	0.001**	0.000***	0.041**	0.000***
France					
ADF unit root test (1981)					
I (0)	0.792	0.130	0.432	0.045**	0.032**
I (1)	0.000***	0.000***	0.031**	0.002**	0.000***
PP unit root test (1988)					
I (0)	0.392	0.367	0.521	0.034**	0.041**
I (1)	0.002**	0.000***	0.001**	0.000***	0.004**
Italy					
ADF unit root test (1981)					
I (0)	0.976	0.052**	0.268	0.312	0.005**
I (1)	0.018**	0.000***	0.001**	0.003**	0.000***
PP unit root test (1988)					
I (0)	0.521	0.031**	0.314	0.412	0.031**
I (1)	0.000***	0.000***	0.041**	0.002**	0.000***
Japan					
ADF unit root test (1981)					
I (0)	0.137	0.698	0.503	0.039**	0.632
I (1)	0.007**	0.000***	0.006**	0.001**	0.001**
PP unit root test (1988)					
I (0)	0.120	0.587	0.402	0.002**	0.597
I (1)	0.001**	0.000***	0.002**	0,000***	0.002**
Germany					
ADF unit root test (1981)					
I (0)	0.003**	0.031**	0.042**	0.032**	0.012**
I (1)	0.000***	0.001**	0.000***	0.002**	0.000***
PP unit root test (1988)					
I (0)	0.001**	0.021**	0.021**	0.041**	0.022**
I (1)	0.000***	0.000***	0.003**	0.004**	0.005**

Note: ***, ** and* refers to 1,5 and 10% level of significance respectively.

TABLE 4 Bounds test for nonlinear/asymmetric/hidden cointegration.

Models	F-statistic
$ES = f(IQ^{+}, IQ^{-}, FDI^{+}, FDI^{-}, TOP^{+}, TOP^{-}, EG^{+}, EG^{-})$ (UK)	5.095***
$ES = f(IQ^{+}, IQ^{-}, FDI^{+}, FDI^{-}, TOP^{+}, TOP^{-}, EG^{+}, EG^{-})$ (USA)	5.688***
$ES = f(IQ^{+}, IQ^{-}, FDI^{+}, FDI^{-}, TOP^{+}, TOP^{-}, EG^{+}, EG^{-})$ (Canada)	8.188***
$ES = f(IQ^{+}, IQ^{-}, FDI^{+}, FDI^{-}, TOP^{+}, TOP^{-}, EG^{+}, EG^{-})$ (France)	7.821***
$ES = f(IQ^{+}, IQ^{-}, FDI^{+}, FDI^{-}, TOP^{+}, TOP^{-}, EG^{+}, EG^{-})$ (Italy)	3.547***
$ES = f(IQ^{+}, IQ^{-}, FDI^{+}, FDI^{-}, TOP^{+}, TOP^{-}, EG^{+}, EG^{-})$ (Japan)	6.745***
$ES = f(IQ^{+}, IQ^{-}, FDI^{+}, FDI^{-}, TOP^{+}, TOP^{-}, EG^{+}, EG^{-})$ (Germany)	4.055***

Note: ***, **, and * denote the rejections of the null hypothesis of no cointegration at the 1, 5, and 10% significance levels, respectively. F-statistic refers to the calculated F-state value of the test. The bound testing approach is evaluated by the F-statistic values by (Pesaran et al., 2001) and the joint of no co-integration null hypothesis is $p = \theta^{+} = \theta^{-} = 0$.

TABLE 5 Dynamic asymmetric ARDL estimation.

Variables	UK	USA	Canada	France	Italy	Japan	Germany
ES (-1)	−0.613***	−0.168**	−0.787**	−0.476**	−0.137***	−0.684**	−0.347**
	(0.000)	(0.035)	(0.002)	(0.011)	(0.001)	(0.031)	(0.022)
IQ_POS	−0.732 **	−0.542 **	−2.476 **	−0.316 **	−0.019 ***	−0.622 **	−0.627* *
	(0.015)	(0.025)	(0.046)	(0.037)	(0.000)	(0.001)	(0.021)
IQ_NEG	−0.288 **	-0.414 **	−1.476 **	−0.056 **	−0.005 *	−0.452 **	−0.495* *
	(0.051)	(0.011)	(0.046)	(0.003)	(0.081)	(0.003)	(0.025)
FDI_POS (-1)	0.491 *	0.121 **	0.543 *	0.732 *	0.295 **	0.642 **	0.943 **
	(0.073)	(0.034)	(0.071)	(0.071)	(0.011)	(0.013)	(0.002)
FDI_NEG	0.281 **	0.022 *	0.412 **	0.432 **	0.031 **	0.392 **	0.743 *
	(0.012)	(0.093)	(0.008)	(0.035)	(0.051)	(0.005)	(0.063)
TOP_POS	0.243 *	0.311 ***	1.927 **	0.855 *	0.139 **	0.599 **	0.827 **
	(0.083)	(0.003)	(0.023)	(0.061)	(0.095)	(0.031)	(0.013)
TOP_NEG	0.096 *	0.111 **	1.927 **	0.855 **	0.043 **	0.599 **	0.067 **
	(0.062)	(0.018)	(0.013)	(0.022)	(0.005)	(0.057)	(0.041)
EG_POS	−0.263 **	−0.203 **	−0.334 **	−0.964 **	−0.114 **	−1.569 **	−0.405 **
	(0.011)	(0.015)	(0.002)	(0.049)	(0.037)	(0.016)	(0.004)
EG_NEG	−0.075 **	−0.023 **	−0.078 ***	−0.651 **	−0.089 **	−0.789 **	−0.536 **
	(0.042)	(0.049)	(0.000)	(0.010)	(0.016)	(0.047)	(0.021)
C	0.914 **	0.294***	0.704*	1.809***	0.114**	−.655**	−0.851***
	(0.021)	(0.000)	(0.084)	(0.000)	(0.031)	(0.009)	(0.000)

Note: ***, ** and * denoted the significance levels at 1, 5, and 10%, respectively.

After confirming asymmetric cointegration, we proceeded with the dynamic estimation of the NARDL model. We followed a general-to-specific approach, like Shin et al. (2014) by taking $p = q = 2$ as optimal lags. We dropped all the insignificant lagged regressors because Katrakilidis and Trachanas (2012) argued that it is very important to drop all the insignificant lagged regressors because insignificant lagged regressors create noise in dynamic multipliers. Moreover, we checked for other major regression issues, for instance, normality of residuals based on the Jarque-Bera test, heteroskedasticity based on the Breusch–Godfrey test, serial correlation based on the LM test, and stability of the model based on CUSUM and CUSUMSQ. Table 5 (Panel B) shows the results of the above-mentioned diagnostic tests, confirming that the model does not suffer from any of the above-mentioned regression problem, and, hence, we moved forward to the dynamic estimation of NARDL model. Table 5 contains the results of the dynamic estimation of the NARDL model.

The current study investigated the long-run asymmetric relationship between institutional quality, foreign direct investment, trade openness, and economic growth, and

TABLE 6 Long-run asymmetric relationship.

Variables	UK	USA	Canada	France	Italy	Japan	Germany
CointEq (-1)	−0.388***	−0.836***	−0.281**	−0.560***	−0.135***	−0.612***	−0.658***
	(0.012)	(0.000)	(0.048)	(0.002)	(0.000)	(0.000)	(0.000)
IQ_POS	−1.194 ***	−3.226 **	−3.146 **	−0.664 ***	−0.138 ***	−0.909 ***	−1.807 **
	(0.025)	(0.041)	(0.045)	(0.004)	(0.003)	(0.001)	(0.047)
IQ_NEG	−0.470 ***	−2.464 ***	−1.875 **	0.118	−0.037 **	−0.661 **	−1.427 **
	(0.012)	(0.003)	(0.062)	(0.430)	(0.007)	(0.053)	(0.032)
FDI_POS	0.801 *	0.720 **	0.690 **	1.538 ***	2.153 *	0.939 **	2.718 **
	(0.073)	(0.042)	(0.027)	(0.003)	(0.090)	(0.004)	(0.046)
FDI_NEG	0.458 *	0.131 *	0.524 ***	0.908 **	0.226 ***	0.573 *	2.141 **
	(0.086)	(0.091)	(0.013)	(0.037)	(0.000)	(0.091)	(0.051)
TOP_POS	0.396 **	1.850 ***	2.449 **	1.796 **	1.014**	0.876 **	2.383***
	(0.031)	(0.000)	(0.031)	(0.052)	(0.032)	(0.042)	(0.003)
TOP_NEG	0.157 ***	0.660 ***	0.863 **	1.420 **	0.313***	0.539 **	0.193 **
	(0.029)	(0.006)	(0.018)	(0.031)	(0.008)	(0.012)	(0.025)
EG_POS	−0.429 ***	−1.208 ***	−0.424 ***	2.025 ***	0.832 ***	2.294 ***	−1.167 ***
	(0.014)	(0.021)	(0.045)	(0.032)	(0.041)	(0.062)	(0.032)
EG_NEG	0.122 ***	0.137 ***	0.032 ***	1.368 ***	0.650 ***	1.154 ***	0.855 ***
	(0.013)	(0.016)	(0.052)	(0.083)	(0.000)	(0.021)	(0.043)

Note: ***, ** and * denotes significance levels at 1, 5, and 10%, respectively. *p*-values are contained within parentheses.

environmental sustainability. Table 6 shows the results of the long-run asymmetric relationship. The findings confirm that there is an asymmetric relationship between institutional quality and environmental sustainability in all G7 economies. The findings confirm that one unit increase in institutional quality (IQ_POS) decreases CO_2 emissions by 1.194, 3.226, 3.146, 0.664, 0.138, 0.909, and 1.807 units for the UK, the USA, Canada, France, Italy, Japan, and Germany, respectively, which ultimately increases the sustainability of the environment; while a one unit decrease in institutional quality (IQ_NEG) leads to an increase in CO_2 emissions by 0.470, 2.464, 1.875, 0.037, 0.661, and 1.427 units for the UK, USA, Canada, Italy, Japan and Germany, respectively. However, we find no significant relationship between negative shock in institutional quality (IQ_NEG) and environmental sustainability in France. We also discover that positive changes in institutional quality (IQ_POS) have a greater impact on CO_2 emissions than negative changes in institutional quality (IQ_NEG). The findings are aligned with Bernauer and Koubi (2009), Ibrahim and Law (2016), and Mehmood et al. (2021), who found that institutional quality negatively affects CO_2 emissions, which ultimately improves environmental sustainability. All the aforementioned studies have advocated the importance of antinutritional quality in improving environmental sustainability.

Furthermore, we confirm the asymmetric relationship between foreign direct investment and environmental sustainability. The findings confirm that one unit increase in foreign direct investment (FDI_POS) leads to an increase in CO_2 emissions (worsens environmental sustainability) by 0.801, 0.720, 0.690, 1.538, 2.153, 0.939, and 2.718 units in the UK, the USA, Canada, France, Italy, Japan, and Germany, respectively; while, a one unit decrease in foreign direct investment (FDI_NEG) leads to a decrease in CO_2 emissions by 0.458, 0.131, 0.524, 0.908, 0.226, 0.573, and 2.141 units in the UK, the USA, Canada, France, Italy, Japan, and Germany, respectively. We find that FDI_POS has a larger effect on environmental sustainability compared to FDI_NEG. The findings are supported by Mujtaba and Jena (2021), who also found an asymmetric relationship between FDI and CO_2 emissions. Jafri et al. (2022) found an asymmetric relationship between FDI and CO_2 emission as well, confirming that a positive change in FDI has a greater effect on CO_2 emission.

We also find similar results for trade openness and environmental sustainability, whereby an asymmetric relationship exists between trade openness and environmental sustainability. We confirm that a one unit increase in trade openness (TOP_POS) leads to a positive change in CO_2 emissions (worsens environmental sustainability) by 0.396, 1.850, 2.449, 1.796, 1.014, 0.876, and 2.383 in the UK, the USA, Canada, France, Italy, Japan, and Germany, respectively; while a one unit decrease in trade openness leads to a reduction in CO_2 emission by 0.157, 0.660, 0.863, 1.420, 0.313, 0.539, and 0.193. It is confirmed that positive shock in trade openness has a larger effect on environmental sustainability than negative shock. Our findings are aligned with studies which have also found

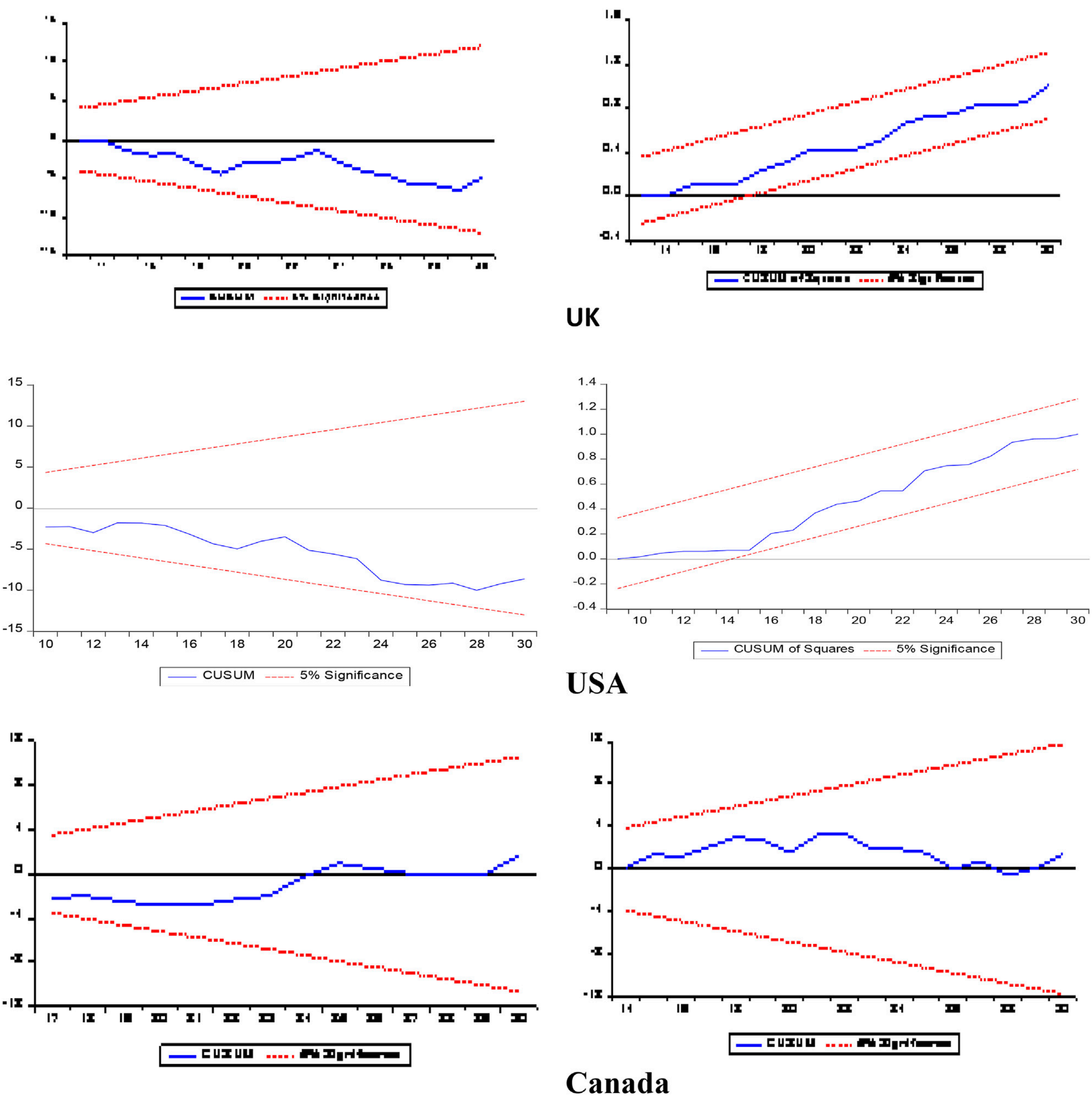

FIGURE 1
Parameters stability.

similar outcomes, for example, Ertugrul et al. (2016) and Dou et al. (2021), which found that an increase in international trade leads to an increase in CO_2 emission. A heavy dependence on coal-powered technology for production, domestic energy use, and the various polluting businesses found in these regions, could be some of the reasons for the environmental impact of trade. However, we find heterogenous findings related to economic growth and environmental sustainability relationship. We find that a positive change in economic growth reduces CO_2 emissions (improves environmental sustainability) in the UK, the USA, Canada and Germany. Various studies have supported these findings, for example, Aye and Edoja (2017) and Liobikienė and Butkus (2019), among others, that have found that an increase in GDP leads to a reduction in CO_2 emissions. A one unit increase in positive shock of economic growth (EG_POS) improves environmental sustainability by 0.429, 1.208, 0.424, and 1.167, respectively. However, we confirm that a one unit increase in positive shock of economic growth leads to an increase in CO_2 emissions (worsens environmental sustainability) by 2.025, 0.832, and 2.294 units in France, Italy, and Japan, respectively; while a one unit decrease in economic growth (EG_NEG) improves environmental sustainability by 0.122, 0.137, 0.032, 1.368, 0.650, 1.154, and 0.855 units in the UK, the USA, Canada, France, Italy, Japan, and Germany, respectively. The asymmetric relationship between economic growth and environmental sustainability suggests that positive change in economic growth has a larger effect on environmental sustainability than negative change in economic growth.

The findings also confirm the speed of adjustment for the UK, the USA, Canada, France, Italy, Japan, and Germany at 38, 83, 56, 13, 61 and 65%, respectively.

After examining the long-run asymmetric relationship between the proposed variables, we further enriched our analysis by checking parameters stability based on CUSUM or CUSUMSQ. After long-run and short-run estimations, Brown et al. 1975) suggested using CUSUM or CUSUMSQ tests to verify the robustness of any statistical analysis. The following Figure 1 confirms the stability of parameters for all the countries.

Conclusion and policy implications

The findings confirm that there is an asymmetric relationship between institutional quality, foreign direct investment, trade openness, and economic growth and environmental sustainability in all G7 economies. We find inverse relationship between institutional quality and CO_2 emissions; increase in institutional quality reduces CO_2 emissions which ultimately increases environmental sustainability. There are direct relationships between foreign direct investment and trade openness, and environmental sustainability. However, we find heterogenous findings related to the economic growth-environmental sustainability relationship.

The findings of the study have some policy implications for decision-makers. According to research, trade openness raises CO_2 emissions in G7 nations. Institutional quality promotes ecological sustainability (reduction in CO_2 emissions), which becomes the basis to regulate and strengthen the function and efficacy of local institutions in order to reduce carbon emissions during economic development. Without a doubt, foreign direct investment and trade openness are necessary for growth, but growth at the expense of environmental degradation is extremely bad; thus, policymakers should encourage environmentally-friendly projects, such as solar panel energy projects, green transportation, and so on.

Furthermore, this study can be expanded by considering other important factors that are innovative and important in eliminating environmental pollution, such as green financing, solar energy, technological innovation, and so on.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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