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Research article

Asymmetric and long-run impact of political stability on consumption-based carbon dioxide emissions in Finland: Evidence from nonlinear and Fourier-based approaches

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A B S T R A C T

The study investigates the asymmetric and long-run impact of political stability on consumption-based carbon dioxide (CCO_2) emissions in Finland. In this context, the study examines the impact of political stability, economic growth, renewable energy consumption, and trade openness; includes quarterly data between 1990/Q1 and 2019/Q4, and applies nonlinear and Fourier-based approaches. The empirical outcomes reveal that (i) there is a long-run cointegration between CCO_2 emissions and political stability as well as other controlling variables; (ii) positive changes in political stability have statistically significant impacts on CCO_2 emissions, whereas negative shocks in political stability are not statistically significant. Also, positive shocks are more powerful than negative shocks; (iii) positive shocks in economic growth have significantly increasing impacts; (iv) positive and negative shocks in renewable energy have decreasing impacts on CCO_2 emissions, while positive shocks are more powerful; (v) positive (negative) shocks in trade openness have decreasing (increasing) impacts on CCO_2 emissions. Overall, the empirical results highlight the role of political stability on CCO_2 emissions. Thus, consideration of political stability by policymakers of Finland in the policy development and implementation processes is highly recommended to achieve a carbon-neutrality target by 2035.

Author Contributions

Mustafa Tevfik Kartal: Conceptualization, Investigation, Methodology, Resources, Supervision, Writing – original draft, Writing – review & editing; Serpil Kılıç Depren: Formal analysis, Investigation, Methodology, Resources, Writing – original draft, Writing – review & editing; Derviş Kirikkaleli: Methodology, Software, Visualization; Özer Depren: Conceptualization, Investigation, Methodology, Resources, Writing – original draft, Writing – review & editing; Uzma Khan: Software, Analysis.

1. Introduction

As global warming and climate change increase, individual and societal interest in environmental degradation has been increasing (Kartal et al., 2022). For this reason, potential causes of environmental degradation have been intensively examined. While CO_2 emissions are evaluated as the main sources of global warming increase, CO_2 emissions also are used as one of the main indicators of environmental degradation (Angelevska et al., 2021; Kirikkaleli et al., 2022a). For this reason, the determination of influential factors on CO_2 emissions is quite significant to develop and implement policies by countries.

In the extant literature, a variety of factors like economic growth (Awosusi et al., 2022; Murshed et al., 2022b; Nurgazina et al., 2022), energy efficiency (Murshed et al., 2022a), energy consumption (Cheng and Yao, 2021; Li et al., 2021), renewable energy consumption (Murshed et al., 2021, 2022c; Tahiri et al., 2021; Adebayo et al., 2022a; Miao et al., 2022), and trade openness (Su et al., 2021; Adebayo, 2022a)

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have been examined in terms of their relationship with the CO_2 emissions. According to these studies in the current literature, such factors have a significant impact on CO_2 emissions that is a proxy for environmental degradation.

Moreover, the literature has been expanding on the impact of political instability on the environment. Although these studies that handle political stability are limited, they have been growing rapidly in recent times. For instance, Adebayo et al. (2022b), Kirikkaleli et al. (2022a), Peng et al. (2022), and Sohail et al. (2022) investigate how political stability has an impact on the environment for BRICS (Brazil, Russia, India, China, South Africa) countries, China, G-7 countries, and Pakistan, respectively. These studies reveal that political stability has an important impact on CO_2 emissions. Although a variety of countries have been examined in terms of the impact of political instability on CO_2 emission, however, some important countries that have high political stability, like Finland, have not been still uncovered. According to the political risk index that is developed by the Political Risk Services (PRS) Group, Finland has a quite high index implying that Finland has had a very low political risk since 1984/Q1 (PRS Group, 2022a).

Overall, whereas the extant literature contains a limited and increasing number of studies that investigate the impact of political stability on carbon emission, however, it does not get still rich enough to investigate the relationship between political stability and CO_2 emissions for politically stable countries like Finland that present a gap in the literature. Thus, new studies that investigate the impact of political stability on CO_2 emission for politically stable countries (i.e., Finland) while also considering well-known and common factors such as economic growth, renewable energy consumption, and trade openness can fill in the gap and contribute to the current literature.

Based on the gap in the literature as well as considering its highly politically stable condition, this study examines the asymmetric and long-run impact of political stability on CCO_2 emissions in the Finland case. While most current studies use CO_2 emissions as a proxy for environmental degradation, however, they have missed out on an important point, which is that there is a huge amount of foreign trade activities between countries. As a result, some countries like China and Indonesia are net carbon emission exporters, whereas some others like Japan and South Korea are net carbon emission importers (Hassan et al., 2022). Hence, it is important to include international trade activities while examining CO_2 emissions. By considering this reality, instead of using solely CO_2 emissions, preferring to use CCO_2 that includes consumption impact resulting from the foreign trade activities can be much more appropriate. Therefore, this study uses CCO_2 emissions as the proxy for environmental degradation. Moreover, this study includes quarterly data between 1990/Q1 and 2019/Q4; uses the political risk index as an explanatory variable while controlling economic growth, renewable energy consumption, and trade openness; and applies a nonlinear autoregressive distributed lag (NARDL) approach for empirical examinations as the main model while considering also Fourier-based approach in examining the cointegration. Thus, this study investigates the asymmetric and long-run impact of political stability on CCO_2 emissions in Finland in a comprehensive manner, which fills in the literature gap at the same time that is the main novelty of the study. The empirical findings reveal that political stability has an important impact on CCO_2 emissions; positive shocks in political stability are more powerful than negative shocks, and negative shocks in political stability are not statistically significant on CCO_2 emissions in Finland case.

This study contributes to the current literature. Firstly, this study examines the impact of political stability on CCO_2 emissions for the first time in Finland case, which is a highly politically stable country. Second, this study performs the NARDL approach that has not been used to investigate the impact of political stability on CCO_2 emissions for the Finland case, although it has been rarely used to examine other country examples. Also, a Fourier-based approach is used in the examination of cointegration. Third, this study uses a very long and most accessible quarterly dataset for all variables included in the analysis, that is between 1990/Q1 and 2019/Q4.

The remaining of the study includes four sections: Section II reviews the literature regarding factors included in the analysis; Section III explains the data and methodology; Section IV presents the empirical results, discussion, and implications; and Section 5 provides a conclusion.

2. Literature review

Although the current literature has been growing recently, it still includes limited studies about the impact of political stability on CO_2 emissions. Some recent studies handle only a single country case. For instance, Su et al. (2021) investigate the relationship for Brazil from 1990 to 2018 by applying canonical cointegrating regression (CCR), dynamic ordinary least squares (DOLS), and Breitung & Candelon (BC) frequency-domain causality test approaches and determine that better political environment (political stability) decreases environmental pollution. The study of Adebayo (2022a) reveals that political stability mitigates CO_2 emissions covering the period 1990–2018 in Canada by using dynamic ARDL (DYNARDL) simulations and BC frequency-domain causality test approaches.

Kirikkaleli et al. (2022a) research China from 1990/Q1 to 2018/Q4 by performing CCR, DOLS, fully modified ordinary least squares (FMOLS), and BC frequency-domain causality test approaches and concluded that political stability has an important impact on CO_2 emissions. Sohail et al. (2022) argue that political instability leads to damage to environmental quality in the long run, whereas political stability improves environmental quality in the short run in the case of Pakistan from 1990 to 2019 by using ARDL and NARDL approaches.

On the other hand, some studies focus on a group of countries. For example, Rizk and Slimane (2018) study 146 countries for the period 1996–2004 and define that an increase in institutional quality leads to more protection of the environment by implying that political stability can lower environmental pollution. Purcel (2019) explores selected 47 low and lower-middle-income countries during 1990–2015 by using the panel vector error correction model (VECM) and concludes that political stability mitigates CO_2 emissions.

The studies that use political stability as an explanatory variable have been increasing more rapidly in 2021 and 2022. Mrabet et al. (2021) study 16 Middle East and North African (MENA) countries from 1990 to 2016 and defined that political stability reduces ecological footprint. Muhammad and Long (2021) investigate 65 Belt and Road Initiative (BRI) countries for the period between 2000 and 2016 and argue that institutional factors, including political stability, are highly significant in decreasing CO_2 emissions. Based on DOLS and panel VECM approaches, Sui et al. (2021) cover 124 countries from 2002 to 2018 and define that political stability improves environmental quality.

In the year 2022, interest in the impact of political stability on the environment has been developing. Adebayo et al. (2022b) study BRICS countries from 1990 to 2018 by using the moment's quantile regression (MMQR) approach and determined that political risk has an increasing impact on CO_2 emission. In the study of Ashraf (2022), it is defined that a better political environment enhances environmental quality in a total of 75 Belt and Road Initiative (BRI) countries between 1984 and 2019 by using the generalized method of moments (GMM) method. Benlemlih et al. (2022) uncover 145 countries from 1996 to 2015 by applying the ARDL approach and concluded that high political stability reduces CO_2 emissions significantly in the short run. Hassan et al. (2022) use panel data analysis to examine Regional Comprehensive Economic Cooperation (RCEP) economies between 1990 and 2020. Results indicate that less political risk help to mitigate CCO2 emissions.

Jiang et al. (2022) cover G-7 countries from 1990 to 2020 by using panel ARDL and define that the political risk index significantly lessens the environmental quality by disrupting the detrimental impact of CO_2 emissions. Similarly, Peng et al. (2022) investigate G-7 countries over the 1994–2018 period by applying the second generation panel test and define that deducing political risk boosts green energy consumption.

Also, Pata et al. (2022) apply the Stochastic Impacts by Regression on Population, Affluence, and Technology model in Pakistan, India, Sri Lanka, and Bangladesh from 2002 to 2016, and discovered that political stability helps to reduce environmental degradation.

Moreover, some studies in the current literature conclude with opposite results. For instance, Zhang and Chiu (2020) analyze 111 countries between 1985 and 2014 by using panel regression and define that political stability has an increasing impact on CO_2 emissions. Dong et al. (2021) examine 66 countries between 2003 and 2018 by using panel analysis methods and defined that although the political risk increases CO_2 emissions for the global panel by promoting the structure effect, however, the scale and technique effects of political risk can ease the greenhouse gas effect. Awosusi et al. (2022) use panel quantile regression and Dumitrescu-Hurlin panel causality test approaches in the BRICS countries between 1990 and 2017, and underline that there exists a one-way causality from ecological footprint to political risk.

Such studies, as mentioned above, generally conclude that political stability has a decreasing impact on CO_2 emissions. By considering these studies, political stability is included as an explanatory indicator, the political risk index is used as the proxy of political stability, and it is expected that the political risk index has a negative (decreasing) impact on CO_2 emissions.

Apart from the political stability, this study also controls three important indicators. The first indicator considered is economic growth. In the extant literature, a variety of studies have considered either economic growth itself or proxies in examining CO_2 emission. For instance, Katrakilidis et al. (2016) uncover Greece's example between 1960 and 2012 through the Granger causality test; Pata (2018) examine Turkey over the period between 1971 and 2014 by the ARDL approach; Işık et al. (2019) study the United States (US) from 1980 to 2015 by panel estimation methods; Koç and Buluş (2020) investigate South Korea between 1971 and 2017 by ARDL approach; Ali et a. (2022) examine China from 1990 to 2019 by DYNARDL and Nurgazina et al. (2022) research China between 1979 and 2019 by DYNARDL simulations. All these studies show that economic growth is an important and increasing impact on CO_2 emission. In line with these studies, economic growth is also included as an explanatory indicator, Gross Domestic Product (GDP) is used as the proxy of economic growth, and it is expected that economic growth has an increasing impact on CO_2 emissions.

The second indicator considered is renewable energy consumption. With the increasing harmful impacts of fossil fuels on the environment, studies regarding renewable energy consumption have been increasing (Kartal, 2022). The current literature includes various studies like Sharif et al. (2020), Qerimi et al. (2020), Sharif et al. (2021), Yuping et al. (2021), Zhan et al. (2021), Adebayo (2022b), Adebayo et al. (2022c), Kartal et al. (2022), and Kirikkaleli et al. (2022b) for top ten polluted countries, Kosovo, US, Argentina, Pakistan, Spain, Portugal, US, and Chile, respectively. These studies mainly determine the lowering impact of renewable energy consumption contributes on CO_2 emission. By considering these studies, renewable energy consumption is included as an explanatory indicator and it is expected that it has a negative (decreasing) impact on CO_2 emissions.

The third indicator considered is trade openness. Trade openness is used in studies of Koç and Buluş (2020) for South Korea; Kwakwa et al. (2018) for three African countries (Ghana, Kenya, South Africa); Kirikkaleli et al. (2021) for Turkey; Adebayo et al. (2022d) for Sweden. They reach similar results that trade openness can contribute to decreasing CO_2 emissions. In line with these studies, trade openness is included as an explanatory variable and it is expected that trade openness has a negative (decreasing) impact on CO_2 emissions.

As a result of the literature review, it can be concluded that the current literature has a limited but growing number of studies regarding the impact of political stability on CO_2 emissions. In these studies, a limited number of single countries (e.g., Brazil, Canada, China, Sweden) or country groups (e.g., BRI, BRICS, G-7) are examined and various econometric techniques (e.g., ARDL, BC frequency-domain causality test, CCR, DOLS, Dumitrescu-Hurlin panel causality test, DYNARDL, FMOLS, GMM, Granger causality, MMQR, NARDL, panel ARDL, panel quantile regression, panel regression, panel VECM, regression) are applied for empirical analysis. As far as it is known, the literature does not include any study that examines Finland's case which is a highly politically stable country. Moreover, the NARDL approach that has a high capacity in prediction has been rarely used for examination, like the Pakistan case by Sohail et al. (2022). Hence, it can state that there is a gap in the literature and this study aims to fill in the gap by focusing on Finland's case to investigate the asymmetric and long-run impact of political stability on CCO_2 emissions by using nonlinear and Fourier-based approaches.

3. Data and methodology

3.1. Data

The study aims to examine whether the impacts of the political risk index on CCO_2 emissions are statistically significant by controlling economic growth, renewable energy consumption, and trade openness. The dataset used in the study is provided by a variety of sources: The data for CCO_2 is collected from Our World in Data (OWID, 2022), the data for the political risk index is obtained from PRS Group (2022b), the data for economic growth and trade openness are also obtained from World Bank (WB-2022), the data for renewable energy consumption is obtained from British Petroleum (BP-2022).

A quarter-based dataset is used in the study because GDP, which is the indicator of economic growth, is announced on a quarter based. Also, data from 1990/Q1 to 2019/Q4 is included in the analysis because, in this period, there is the most available data for all variables. Before conducting the empirical model, all variables are transformed into logarithm series.

In the study, CCO_2 emission is used as the dependent variable by considering studies of independent variables. Details of all used variables are explained in Table 1.

3.2. Methodology

The flowchart of empirical methodology is presented in Fig. 1.

The seven-step methodology is followed up to capture the asymmetric and long-run impact of political stability on CCO_2 emissions in Finland as follows:

- The first step is the data gathering from different sources. Data for the variables are obtained from BP (2022), OWID (2022), PRS Group (2022b), and WB (2022) sources.
- Descriptive statistics such as mean, standard deviation, skewness, kurtosis, etc. are given in step 2.
- In the third step, the BDS test is used to test the stationary of variables (Broock et al., 1996; Kim et al., 2003).

Table 1
Details of the variables.

Symbols	Descriptions	Units	Sources
CCO_2	Consumption-Based CO_2 Emissions	Millions Tons	OWID (2022)
PRI	Political Risk Index (0 shows a high risk, 100 denotes a low risk)	Bps	PRS Group (2022b)
GDP	Economic Growth (GDP Constant)	USD	WB (2022)
RE	Renewable Energy Consumption	%	BP (2022)
TRO	Trade Openness (Average of Import and Export)	USD	WB (2022)

Notes: Bps denotes basis points; % denotes percentage; USD denotes United States Dollar.

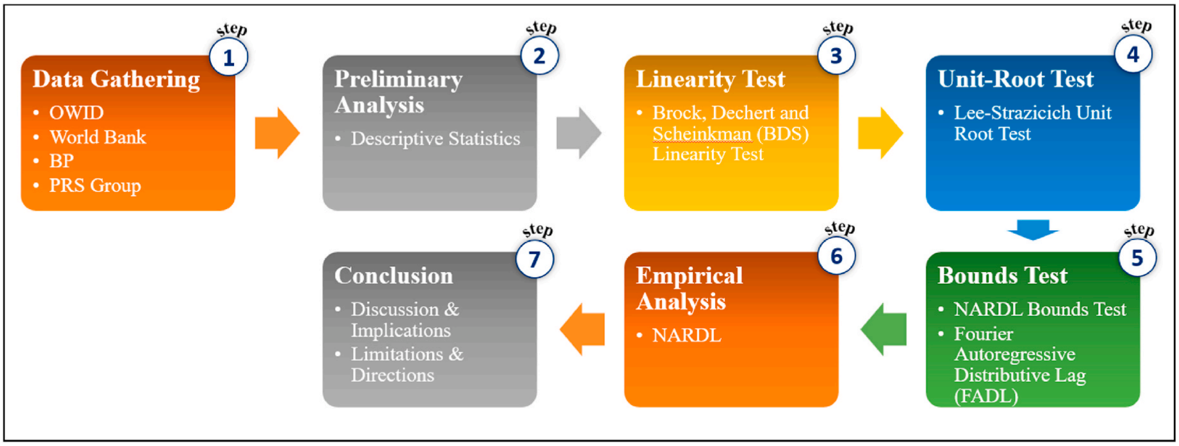

Fig. 1. The methodology of study.

- LS Unit Root test is performed in the fourth step to determine the existence of a unit root (Lee and Strazicich, 2003).
- In the fifth step, the NARDL bounds test (Pesaran and Shin, 1995; Pesaran et al., 2001) and FADL cointegration test (Banerjee et al., 2017) are used to examine cointegration between variables in the long run.
- In the empirical analysis, which is the sixth step, the NARDL approach (Shin et al., 2014) is performed to measure the impact of the independent variables on CCO_2 emissions by positive and negative changes. The NARDL approach is selected by considering the current literature about the impact of political stability on CO_2 emissions as well as the characteristics of the dataset used in this study that has a nonlinear structure based on the BDS nonlinearity test results.
- In the last step, according to the empirical findings, discussion, implications, limitations, and directions are discussed.

By following up on the methodology above, this study applies the empirical model as follows:

$$CCO_2 = \beta_0 + \beta_1 PRI_t + \beta_2 GDP_t + \beta_3 RE_t + \beta_4 TRO_t + \varepsilon_t \quad (1)$$

In Equation (1), CCO_2, PRI, GDP, RE, TRO, β_0, ε, and t represent CCO_2 emissions, political risk index, GDP constant, renewable energy consumption, and the average of imports and export, intercept, error-term, and times, respectively. For the empirical analysis, Equation (1) is modified as follows by considering transforming the series into the logarithmic form:

$$LnCCO_2 = \beta_0 + \beta_1 LnPRI_t + \beta_2 LnGDP_t + \beta_3 LnRE_t + \beta_4 LnTRO_t + \varepsilon_t \quad (2)$$

$LnCCO_2$, $LnPRI$, $LnGDP$, $LnRE$, $LnTRO$ represents the logarithm series of all variables. An increase in the political risk index can make a decreasing impact on CCO_2 emissions ($\beta_1 = \frac{\partial CO_2}{\partial PS} < 0$). In addition, GDP can make an increasing impact on CCO_2 emissions ($\beta_2 = \frac{\partial CO_2}{\partial GDP} > 0$). Renewable energy consumption can make a decreasing impact on CO_2 emissions ($\beta_3 = \frac{\partial CO_2}{\partial RE} < 0$). Similarly, the average of imports and export can make an increasing impact on CO_2 emissions ($\beta_4 = \frac{\partial CO_2}{\partial TO} > 0$).

4. Empirical analysis

4.1. Preliminary statistics

The central tendency and variation statistics are calculated and interpreted in detail to understand the distribution of data used in the study. Besides, the Jarque-Bera (JB) test is performed to understand the theoretical distribution of variables (Jarque and Bera, 1980).

According to Table 2, $LCCO_2$ values differ from 0.86 to 1.15, LPRI varies from 4.39 to 4.56, LGDP ranges from 11.15 to 11.41, and LRE ranges from 1.11 to 1.42, and LTRO varies from 10.56 to 11.19. In all variables, the mean and median values are too close to each other, except LTRO. Besides, the coefficient of variation statistics is too low, which means that the dispersion of data points around the mean is relatively small. Based on skewness statistics, it is shown that LCCO2, LPRI, LGDP, and LTRO have a slightly right-skewed distribution, while RE has a left-skewed distribution. Besides, kurtosis statistics of all variables are lower than 3, which is the kurtosis value of the normal distribution. Thus, it can be said that all variables have a lower peak and light tails than the normal distribution. Furthermore, based on the JB Test, there is no significant evidence to accept the null hypothesis, which is assumed the data is normally distributed for all variables.

Table 2
Descriptive statistics.

	LCCO2	LPRI	LGDP	LRE	LTRO
Mean	1.03	4.49	11.31	1.26	10.95
Median	1.05	4.49	11.34	1.24	11.03
Maximum	1.15	4.56	11.41	1.42	11.19
Minimum	0.86	4.39	11.15	1.11	10.56
Standard Deviation	0.07	0.05	0.09	0.08	0.19
Coefficient of Variation	6,80	1,11	0,80	6,35	1,74
Skewness	−0.64	−0.39	−0.63	0.49	−0.76
Kurtosis	2.44	2.01	1.89	2.27	2.21
Jarque-Bera	9.88	7.86	14.20	7.47	14.69
Jarque-Bera Probability	0.0072	0.0196	0.0008	0.0239	0.0006
Observations	120	120	120	120	120

4.2. Linearity test

The linearity of variables is tested via the BDS test, and the results are given in Table 3.

In BDS Test, the null hypothesis is set as "the variable is linearly distributed", and the alternative hypothesis is vice versa. Based on Table 3, there is no statistically significant evidence at a 95% of confidence level to accept the null hypothesis for all variables, which means that all variables have a nonlinear distribution.

4.3. Stationarity test

The minimum Lagrange Multiplier unit root test, which can take into consideration two endogenous breaks of the null and the alternative hypothesis, is applied (Lee and Strazicich, 2003). Thus, the false rejection of the null hypothesis of a unit root is prevented. The LS unit root test results are presented in Table 4.

According to the LS unit root test results, which are given in Table 4,

Table 3
Linearity test results.

Variables	Dimensions					Results
	2	3	4	5	6	
$LCCO_2$	0.17882 [0.0000]	0.29601 [0.0000]	0.37296 [0.0000]	0.42371 [0.0000]	0.45896 [0.0000]	Nonlinear
LPRI	0.16169 [0.0000]	0.26904 [0.0000]	0.34017 [0.0000]	0.38651 [0.0000]	0.41421 [0.0000]	Nonlinear
LGDP	0.204226 [0.0000]	0.346408 [0.0000]	0.445223 [0.0000]	0.513588 [0.0000]	0.560792 [0.0000]	Nonlinear
LRE	0.174583 [0.0000]	0.285761 [0.0000]	0.356612 [0.0000]	0.401346 [0.0000]	0.429528 [0.0000]	Nonlinear
LTRO	0.205523 [0.0000]	0.349784 [0.0000]	0.451254 [0.0000]	0.522572 [0.0000]	0.572747 [0.0000]	Nonlinear

Notes: Values denote t-statistics and [ ] denote p-values.

Table 4
Stationarity test results.

At Level						
		LCCO2	LPRI	LGDP	LRE	LTRO
LS	t-Statistic (tau)	−4.81	−4.89	−3.84	−4.45	−3.94
	Break Points	2004/Q4 2009/Q4	1994/Q2 2001/Q4	1996/Q1 2010/Q1	1994/Q4 2005/Q4	1996/Q1 2010/Q4
Test critical values	1% level	−6.04	−5.75	−6.13	−5.95	−6.01
	5% level	−5.34	−5.25	−5.52	−5.45	−5.43
	10% level	−5.09	−4.98	−5.24	−5.16	−5.15
At First Difference						
		LCCO2	**LPRI**	**LGDP**	**LRE**	**LTRO**
LS	t-Statistic (tau)	−5.79	−10.46	−7.85	−6.60	−5.63
	Break Points	2004/Q3 2010/Q4	1996/Q3 1997/Q3	1996/Q1 2010/Q1	2002/Q4 2005/Q4	1993/Q3 2010/Q4
Test critical values	1% level	−6.03	−5.74	−6.13	−6.04	−6.01
	5% level	−5.48	−5.24	−5.52	−5.34	−5.43
	10% level	−5.23	−4.98	−5.24	−5.09	−5.15

Table 5
Bounds test results.

NARDL Bounds Test				
F-Bounds Test		Null Hypothesis: No levels of relationship		
Test Statistic	Value	Significance	I(0)	I(1)
F-statistic	6.69	10%	1.85	2.85
K	8	5%	2.11	3.15
		1%	2.62	3.77
FADL Cointegration Test				
Test-Statistic		Frequency	Min. AIC	
−6.32***		2	−6.26	
Critical Values				
1%		5%	%10	
−4.79		−4.10	−3.73	

Notes: *, **, and *** denote statistically significant at the 10%, 5%, and 1% significance level, respectively. The decisions are taken based on the critical values of Banerjee et al. (2017).

Table 6
NARDL results.

Variables	Coefficient	Std. Error	t-Statistic	Prob.
LPRI_POS	−0.21*	0.11	−1.82	0.0715
LPRI_NEG	0.16	0.17	0.91	0.3633
LGDP_POS	1.79***	0.61	2.92	0.0044
LGDP_NEG	−1.44	1.09	−1.33	0.1880
LRE_POS	−0.93***	0.08	−11.30	0.0000
LRE_NEG	−0.75***	0.12	−6.26	0.0000
LTRO_POS	−0.39*	0.23	−1.71	0.0915
LTRO_NEG	0.81*	0.45	1.80	0.0758
C	1.15***	0.02	74.57	0.0000
CointEq(-1)*	−0.40***	0.05	−8.59	0.0000

Notes: *, **, and *** denote statistically significant at the 10%, 5%, and 1% significance level, respectively.

it can be said that there is no statistically significant evidence at a 95% of confidence level to reject the null hypothesis for all variables at the I(0) level. However, it is revealed that all variables are stationary at the I(1) level based on the LS unit root test.

4.4. Bounds test

To determine the long-run relationship among variables, the ARDL bounds test is applied (Pesaran et al., 2001) followed by the Fourier ADL cointegration test testing the long-run relationship among variables is performed as a robustness check. The results of the NARDL bounds test and FADL cointegration test are presented in Table 5.

Based on Table 5, it is revealed that there is significant evidence (F statistics < critical thresholds, and FADL test statistics < min. AIC) at a 95% of confidence level to reject the null hypothesis of no long-run cointegration between variables. Thus, it is accepted that the long-run relationship between variables is significant and can't be ignored.

4.5. NARDL estimation

The long-term coefficients and the error correction coefficients are calculated using the NARDL model after the determination of the long-run cointegration among variables. The results of the NARDL model are given in Table 6.

According to Table 6, it is revealed that all variables have a significant impact on CCO_2 emissions. In detail, a 1% positive shock to PRI causes a 0.21% point decrease in CCO_2 emissions, whereas negative shocks do not have a statistically significant impact on CCO_2 emissions. This result shows that CCO_2 decreases as PRI increases, which is named as a negative correlation between two variables. Also, especially the expectation of positive shocks should be taken seriously by policy-makers. On the other hand, it seems that there is no need to take action if there is an expectation of negative shocks on PRI because it has no statistically significant impact on CCO_2.

Unlike PRI, a 1% positive shock to GDP causes a 1.79% increase in CCO_2 emissions, whereas negative shocks do not have a statistically significant impact on CCO_2 emissions. With this result, it is revealed that GDP is a variable that positively affects CCO_2. Similar to PRI, policy-makers should have ready plans for positive shocks to GDP while there is no need to take serious action if there is an expectation of negative shocks to GDP.

Moreover, a 1% positive shock to RE causes a 0.93% decrease in CCO_2 emissions, while a 1% positive shock to RE causes a 0.75% decrease in CCO_2 emissions. This finding shows that unlike the effect of PRI and GDP on CCO_2, both positive and negative shocks had a statistically significant effect on CCO_2. Thus, policymakers should strictly monitor RE, make an estimation of increase or decrease, and create action plans for significant changes positively or negatively in RE.

Unlike other indicators, the impact of TRO on CCO_2 emissions is significant at a 90% of confidence level. It is revealed that the magnitude and direction of the impact differ according to the positive or negative shocks to TRO, which is also defined as asymmetric impact. 1% positive shock to TRO causes a 0.39% decrease in CCO_2 emissions, while a 1% negative shock to TRO causes a 0.81% increase in CCO_2 emissions. Therefore, when the impacts of shocks on CCO_2 are examined, it can be said that the effect of negative shocks is stronger than the effect of positive shocks. Since the significant increase or decrease in TRO causes a different impact on CCO_2, policymakers should create different action plans for negative or positive shocks in TRO. Furthermore, the coefficient of CointEq(-1) is statistically significant and negative at 95% of the confidence level. This means a previous correction can be fixed in the following periods (i.e., 2.5 quarters). The value of R^2 is 0.814 and diagnostic tests show that the model meets the criteria that it needs.[1] Moreover, it is concluded that 81.4% of the variation in CCO_2 emissions is explained by PRI, GDP, RE, and TRO.

4.6. Discussion and Implications

The results obtained are generally consistent with expectations and also similar to the current literature. Once the aforementioned results about the impact of the political risk index on CCO_2 emissions that are obtained in this study are similar to the study of Adebayo (2022a), Adebayo et al. (2022b), Ashraf (2022), Benlemlih et al. (2022), Kirikkaleli et al. (2022a), and Sohail et al. (2022). However, these results are not consistent with the studies of Zhang and Chiu (2020) and Dong et al. (2021). Moreover, it is seen that GDP has an increasing impact on CCO_2 emissions, that are consistent with the studies of Işık et al. (2019), Koç and Buluş (2020), Ali et al. (2022), Kirikkaleli et al. (2022a), and Nurgazina et al. (2022). Renewable energy has a decreasing impact on CCO_2 in the literature, which is similar to the results obtained by the NARDL model in this study (Adebayo, 2022b; Adebayo et al., 2022c; Kartal, 2022; Kartal et al., 2022; Kirikkaleli et al., 2022b). Besides, trade openness has a mixed impact on CCO_2 emissions in the current literature, which is also similar to the results in this study (Kwakwa et al., 2018; Adebayo et al., 2022d).

With all of these empirical findings, various policy implications can be suggested. First of all, Finland policymakers should monitor and take action regarding the impact of the political risk on CCO_2 emission. Once the political risk is taken into consideration in Finland, political stability can be also defined as an important factor in managing CCO_2 emissions. Thus, the relationship between political stability and CCO_2 emissions and potential actions can be included in policy development and implementation processes to achieve the carbon-neutrality target of Finland by 2035.

Secondly, by considering that the political risk index has an asymmetric impact on CCO_2 emissions, policymakers should consider this impact during policy development and implementation steps.

Thirdly, positive shocks are relatively more important than negative shocks in all variables except trade openness. Thus, policymakers should work on preventing the positive shocks in political risk index, economic growth, and renewable energy consumption to manage CCO_2 emissions. While policymakers in Finland deal with the influential factors to reduce the CCO_2 emissions, a complementary approach should be run at the same time.

Fourthly, Finland policymakers should keep on running the initiatives and policies about moving from fossil fuel sources to renewable sources because renewable energy consumption is highly influential in decreasing CCO_2 emissions. Thus, Finland can benefit much more from renewable energy consumption in declining CCO_2 emissions that result from energy.

Finally, since the data obtained from different sources are quarterly, Finland policymakers should take into consideration publishing these data on a higher frequency (e.g., monthly) to perform a more robust analysis. Thus, more detailed results can be obtained and various policy recommendations can be proposed by using high-frequency data in empirical analysis. In addition, Finland policymakers should allocate their valuable efforts to strengthening political stability to support environmental investment, innovation, and technologies by limiting the adverse impacts of political instability. Hence, Finland as a country, Finnish citizens as a society living in Finland as well as Europe and the World can benefit from the increasing positive contributions of political stability in limiting environmental degradation and stimulating environmental technologies that can be achieved through political stability in turn.

5. Conclusion

This study investigates Finland's case as a highly politically stable country in terms of the asymmetric and long-run impact of political stability on CCO_2 emissions by applying nonlinear and Fourier-based approaches for the period 1990/Q1-2019/Q4. The asymmetric analysis results reveal that political stability and other explanatory indicators included have an important impact on CCO_2 emissions in the long-run; political stability, economic growth, and trade openness have an asymmetric impact in the long run; positive changes in political stability, economic growth, and renewable energy consumption are much more powerful. Hence, empirical results highlight the importance of positive shocks in political stability, economic growth, renewable energy consumption, and trade openness in terms of their impacts on CCO_2 emissions in Finland. Also, empirical results are consistent with the current literature that underscore the applicability of the findings obtained in this study for future studies. Furthermore, some policy recommendations are proposed. Hence, the study contributes to the current literature by examining Finland and Finland's policymakers in the policy development and implementation to control CCO_2 emissions by considering the asymmetric and long-run impact of political stability.

The main contribution of this study is to focus on Finland's case as a highly politically stable country that has not never been examined comprehensively. Also, this study uses the NARDL approach, which has been rarely used to examine the impact of political stability on CO_2 emissions as well as a Fourier-based approach for cointegration. Moreover, this study uses whole accessible data between 1990/Q1 and 2019/Q4. Hence, it is thought that this study fills in the gap in the literature by presenting a comprehensive examination of the asymmetric and long-run impact of political stability on CCO_2 emissions for Finland. It is evaluated that this study contributes to the current literature focusing on Finland's case that can be a lighthouse for other highly politically stable countries.

On the other hand, focusing on only the Finland case can also be evaluated as the main shortcoming of the study. By considering that a limited number of countries have been examined in the current literature and this study examines Finland, future studies can examine much more countries that are politically stable. Even politically stable and unstable countries can be compared in future studies as well. Moreover, future studies can use machine learning algorithms and novel econometric techniques to examine the impact of political stability on the environment. Furthermore, future studies can use more high-frequency data, if it can be available to the public. Although there are monthly data

[1] *According to diagnostics tests, there are no modeling errors like serial correlation, heteroscedasticity, misspecification, and non-normal distribution of residuals. The details are available from the authors upon reasonable request.*

for political stability indicators, this is not valid for other explanatory variables economic growth most of the time. This is the cause of quarter-based dataset usage in this study.

Disclosure statement

The authors certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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Availability of data and materials

The data that support the findings of this study are available in World Bank at https://data.worldbank.org, OECD at https://data.oecd.org/energy/renewable-energy.htm, Our World in Data at https://ourworldindata.org/co2/country/finland, and obtained from the PRS Group via e-mail.

Ethics approval and consent to participate

Not applicable.

Consent for publication

The authors are willing to permit the Journal to publish the article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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