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Quantile-based heterogeneous effects of nuclear energy and political stability on the environment in highly nuclear energy-consuming and politically stable countries

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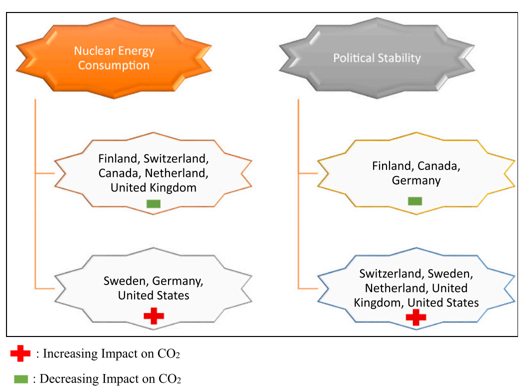
HIGHLIGHTS

- The study examines nuclear energy and political stability effect on CO_2 emissions.
- The study analyzes top eight politically stable nuclear power consuming countries.
- The study uses novel quantile based approaches for the period 1991/Q4–2021/Q4.
- Nuclear energy and political stability has a curbing effect on CO_2 emissions.
- Nuclear energy and political stability effects vary across quantiles and countries.

GRAPHICAL ABSTRACT



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ABSTRACT

The study analyzes the effects of nuclear energy and political stability (PS) on environmental degradation. For this aim, the study uses carbon dioxide (CO_2) emissions as the environmental degradation indicator, considers nuclear energy consumption (NEC) and political risk index (PRI) as explanatory variables, uses data between 1991/Q1 and 2021/Q4, and investigates eight highly politically stable countries in this way. Also, the study performs novel quantile-on-quantile regression and Granger causality-in-quantiles models as the fundamental models and applies the quantile regression model for robustness. The results reveal that (i) NEC has a mainly curbing effect on CO_2 emissions at higher levels of NEC and is beneficial for Finland, Switzerland, Canada, Netherlands, and United Kingdom; (ii) PS has a generally decreasing effect on CO_2 emissions at higher levels of

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CO_2
Quantile-based models

PS and is effective in Finland, Canada, and Germany; (iii) NEC and PS have a causal mainly effects on CO_2 emissions in the countries; (iv) the robustness of the results is verified through alternative approach. Overall, there are dependencies from NEC and PS to CO_2 emissions and the effects of both NEC and PS on CO_2 emissions vary across countries and quantiles. Hence, the results highlight the heterogeneous effects of NEC and PS on CO_2 emissions and underline the significance of quantile and country-based analyses for better empirical examination. Various policy caveats are discussed based on the fact that Finland and Canada can benefit from both NEC and PS in decreasing CO_2 emissions, whereas Sweden and the USA cannot, and the remaining countries have mixed results.

1. Introduction

Energy is the most basic and indispensable element of daily life and production for all societies. While the global population growth rate is increasing, research and investments to meet the global energy need have increased with the depletion of natural resources. However, the increase in cumulative consumption due to swift global population growth causes CO_2 emissions resulting in severe and irreversible environmental damage [5,11,29,40]. Several targets are set to compensate for damages to the environment at a global scale and ways to produce cleaner energy have been sought. An increase in CO_2 emissions and global temperature levels together with global climate change will seriously influence the life of the next generations. Hence, efforts have been made to prevent climate change and GHG effects through global and regional initiatives. Cooperation is carried out with actions, such as Paris Agreement and Sustainable Development Goals [51].

The world has engaged in total cooperation to combat global warming and to reduce the GHG effect. Because if the world continues to warm quickly, natural resources will be exhausted and the environment will be irreversibly destroyed. To reverse this negative environmental progress, global warming is aimed to be limited to an average of 1.5 °C and a net zero CO_2 emission target to be achieved by 2050 is set up with the decision taken at the COP21 meeting. It is aimed to reduce CO_2 emissions by half by 2030. With the most recent COP28 meeting, these targets are renewed. So, it is recently emphasized that the use of environmentally friendly clean energy sources should be expanded to reach the net zero target. For this purpose, using renewable sources and nuclear energy appears as a promising option instead of fossil fuel sources that harm the environment [1,3,24].

According to BP [13] statistics, a total of 33.8 billion tons of CO_2 emissions were globally emitted in 2021 due to energy consumption. Notably, most CO_2-emitting countries are generally composed of countries that make up a significant share of the world's population, such as India and China, and other countries with a high consumption and industrialization level, such as the USA, Russia, Japan, and Germany. Such highly populated and industrialized countries, which have the largest share in the world's CO_2 emissions, urgently need alternative ways to combat global warming and reduce the CO_2 emissions that they cause. In this context, clean energy production sources can be a significant alternative. That is why fossil fuel energy consumption damages the environment and increase CO_2 emissions [18].

As one of the important green energy sources, nuclear energy does not generally increase CO_2 emissions. However, it contributes to environmental pollution through radioactive waste. The cost advantage of nuclear power plants has led to the spread of this type of energy production globally. Recently, nuclear energy production at the global level has been in demand as an alternative energy source to fossil fuels. Although it is an attractive source of energy, it carries a significant risk due to the leaks after accidents (e.g., Chornobyl and Fukushima) in nuclear power plants and high installation costs. In response to the economic embargo and sanctions imposed on Russia after the recent Russia-Ukraine war, Russia's reduction of natural gas supply to European countries has brought nuclear energy production back to the agenda of countries as a potential alternative and solution to the current energy crisis. When the general condition is considered, it can be defined that the USA is the leading country followed by China, France, Russia, and South Korea in terms of NEC [13]. Therefore, it is noteworthy that developed and industrialized economies prefer nuclear energy production. Some research have examined the effect of NEC on the environment (e.g., [8,9]). Such studies have mainly stated that NEC is generally beneficial for the environment in countries, whereas some studies have concluded that NEC is ineffective (e.g., [42]).

It also should be stated that nuclear power countries have generally high PS. Hence, it is required to think about PS when dealing with the effect of nuclear energy on the environment. Different studies have investigated the effect of PS on the environment (e.g., [7,26,30,48,49,54]) by using CO_2 emissions as the environment indicator (e.g., [12,16,27,38,45,52,53,55,57]). Such studies have generally defined that PS is generally helpful in stimulating environmental quality by enabling eco-friendly decisions in developed countries, whereas it may cause adverse effects on the environment in emerging countries.

In the above-mentioned studies, there is no clear consensus about the effect of both NEC and PS on the environment in different countries. Hence, there is still a need for further examination. Also, mostly either a single (e.g., USA & France) or a small group (e.g., top 5 CO_2 emitting) countries have been considered for empirical examination. In light of the best knowledge, there is no study, which examines the effects of both NEC and PS on CO_2 emissions by applying novel quantile-based techniques. So, there is room for growth for new studies and they should have much more comprehensive content. By considering the environmental condition as well as energy structure and PS effect in the world, the study researches the relationship of NEC and PS on CO_2 emissions. In this context, the study considers eight countries (namely, Finland-FIN, Switzerland-CHE, Sweden-SWE, Canada-CAN, Germany-DEU, Netherlands-NLD, United Kingdom-GBR, and the United States of America-USA), which have used NEC and had higher PS ([13,39]. Focusing on such countries is important because they have significant levels of economic development, have high PS, and use nuclear energy. Also, some of these countries (e.g., the USA) take place among the most CO_2-emitting countries. So, the behaviors of these countries are seen as a lighthouse for other countries because of the fact that important efforts against global climate change are enabled by these countries. In the empirical investigation, the dataset covering the period 1991/Q1 and 2021/Q4 is analyzed with novel quantile-based models (QQ, GQ, QR). Empirical results mainly revealed that NEC and PS reduce CO_2 emissions, but the effects differ according to quantiles and countries.

The study has some contributions. Considering the recently proposed solution way to curb CO_2 emissions, which is supported by various parties (e.g., the International Energy Agency), the study examines the effect of NEC on CO_2 emissions in the countries that have both high NEC and PS, by using the most up-to-date dataset and applying novel quantile-based models. Hence, differently from the many studies in the current literature that made mean-based analysis, the study makes a country-based analysis by considering nonlinearity and quantile-based varying effects of NEC on CO_2 emissions. This is the main contribution of the study. Also, taking the recently developing literature about the effect of PS on CO_2 emissions into account, the study considers also PS in addition to NEC in investigating CO_2 emissions in the countries. Hence, differentiating from the present studies, the study investigates both the effect of NEC and PS on CO_2 emissions in the countries, which is the second contribution of the study. Hence, the study presents novel results by benefitting from novel quantile-based models, which enable researchers to make country and quantile-based analyses, and various policy caveats based on the results obtained can be argued for policymakers to prevent environmental degradation by truly using both NEC and PS.

The remaining parts are located as follows: Section 2 presents the theoretical framework and literature review; Section 3 details the methods; Section 4 gives the empirical findings of the novel models as well as presenting discussion and policy caveats; Section 5 includes a conclusion, limitations, and future directions.

2. Theoretical framework and literature review

2.1. Theoretical framework

In the area of energy economics, various studies have investigated the potential causes of environmental degradation by concentrating on energy consumption. So, many studies have considered CO_2 emissions as an environmental indicator on one hand. On the other hand, either aggregated level (i.e., total) energy consumption or disaggregated level (i.e., sub-groups) energy consumption has been considered in the investigation of environmental degradation over the years for various countries. So, a group of studies has used NEC for this aim. Some of these studies have determined that NEC has a declining effect on environmental degradation because nuclear energy does not cause high amounts of emissions (almost zero) at energy production processes. Nevertheless, some studies have defined that NEC has an increasing effect on environmental degradation (e.g., [23]). Also, some studies have defined that NEC is statistically insignificant in CO_2 emissions (e.g., [25]). In summary, it can be mainly stated that NEC has a contributing effect on the environment, but, the literature has not a consensus about this effect.

PS and political risks are important issues that economic agents give importance to in their decision-making processes. Investors evaluate the political risk indicators of the countries as well as other economic indicators. The expropriation risk, smooth profit transfer, corruption, rule of law, use of military force, bureaucratic obstacles, terrorism, and threatening democracy are among the political risk factors [15]. An increase in political risk factors means an increase in political instability. As increasing political risk causes uncertainty about the future, it deteriorates the investment environment by preventing investors from making investments. In case of increasing political risk factors and political instability, investors postpone investment decisions, and the country to be invested may be either changed or given up. In addition, there is a connection between PS and environmental degradation [43]. In the case of weak PS, expropriation, manipulation, abuse, and criminal activities can increase degradation in the environment [47]. Also, political instability prevents long-term environment-friendly decisions from being taken. Instead, policymakers tend to make short-term decisions, which disrupt the environment. Hence, political institutions and stability are important factors in reducing environmental degradation.

In addition to NEC, PS has been recently considered by scholars intensively in examining environmental degradation. Similar to the NEC, some studies have determined that PS has a curbing effect on the environment (e.g., [7,19,26,28,30]) by enabling eco-friendly decisions in the long-term. However, some studies have defined that PS has an increasing effect on environmental degradation (e.g., [2,54,58]), especially in emerging countries. Overall, it is mainly expected that PS has an increasing contribution to environmental quality, but, this is not the case for all countries. Overall, the effects of both NEC and PS on the environment have value to be researched further for countries.

2.2. Empirical literature

Nuclear energy generally reduces CO_2 emissions [8,32,33,35–37,41] and a causal relationship between NEC and CO_2 emissions appears. In some studies, a unidirectional causality is found from NEC to CO_2 emissions [8]. However, some other studies find a bidirectional causality between NEC and CO_2 emissions [33,37]. Moreover, there is no causal relationship according to some research [22,42]. On the contrary, Xu et al. [56] find that NEC causes fewer CO_2 emissions. Kartal [23] finds out that NEC increases CO_2 emissions.

In addition to NEC, PS is also considered. Based on the literature, PS is negatively related to CO_2 emissions [6,7,19,24,26,28,30,48,49], whereas some studies have a reverse conclusion, which is positively related with the CO_2 emissions ([2,54]). In other words, policymakers can adopt policies that decrease political risk factors and PS can be used as a tool to reduce CO_2 emissions and reverse the damage to the environment to tolerate environmental damages.

Table 1 presents a summary of the above-explained literature.

Table 1
Empirical Literature.

Authors (Years)	Countries	Period	Models	Results
Panel A: NEC and CO_2 Relationship				
Iwata et al. [21]	France	1960–2003	ARDL	NEC → CO_2
Menyah & Wolde-Rufael [34]	USA	1960–2007	VAR	NEC → CO_2
Saidi & Mbarek [42]	9 Developed	1995–2013	VECM	NEC ≠ CO_2
Dong et al. [18]	China	1993–2016	ARDL, CCR, FMOLS, DOLS, VECM	NEC ↓ CO_2
Azam et al. [8]	10 Leading	2000–2016	FE, RE, PE, PC	NEC → CO_2
Nathaniel et al. [35]	Group of Seven	1990–2017	AMG, CCEMG, DH	NEC ↓ CO_2
Özgür et al. [36]	India	1970–2016	FARDL	NEC ↓ CO_2
Majeed et al. [33]	Pakistan	1974–2019	ARDL, NARDL, FMOLS, DOLS, VECM	NEC ↓ CO_2
Pan et al. [37]	10 CO_2 Emitting	1990–2019	QQ	NEC ↓ CO_2
Sadiq et al. [41]	BRICS	1990–2020	Cross Sectional RDL, CCEMG, AMG	NEC ↓ CO_2
Kartal [23]	USA	1973/1–2022/4	DARDL	NEC ↑ CO_2
Panel B: PS and CO_2 Relationship				
Vu & Huang [54]	Vietnam	1990–2016	GC, ARDL	PS ↑ CO_2
Zhang & Chiu [58]	111 Selected	1985–2014	PSTRM	PS ↑ CO_2
Su et al. [49]	Brazil	1985–2018	FMOLS	PS ↓ CO_2
Khan et al. [26]	Morocco	1985–2020	ARDL	PS ↓ CO_2
Kirikkaleli et al. [30]	China	1990/Q1–2018/Q4	FMOLS, DOLS, CCR, GC	PS ↓ CO_2
Hassan et al. [19]	24 OECD	1990–2020	Cross Sectional ARDL, DH	PS ↓ CO_2
Sohail et al. [48]	Pakistan	1990–2019	ARDL, NARDL	PS ↓ CO_2
Ashraf [6]	Pakistan	2000–2020	ARDL, FMOLS	PS ↓ CO_2
Ayhan et al. [7]	Group of Seven	1997–2021	QQ	PS ↓ CO_2
Kartal et al. [24]	United Kingdom	1995/Q1–2018/Q4	NARDL	PS ↓ CO_2

Note: →: Unidirectional Causality; ↔: Bidirectional Causality; ≠: No causality; ↓: Decreasing Effect; ↑: Increasing Effect.

2.3. Evaluation of the literature

As presented in Table 1, a variety of studies have examined the effect

Table 2
Variables.

Variable	Explanation	Unit	Source
CO_2	CO_2 Emissions from Energy*	Tons	BP [13]
NEC	Nuclear Energy Consumption	Exajoules	BP [13]
PRI	Political Risk Index	Basis Point	PRS [39]

Note: * shows the dependent variables.

of either NEC or PS on the environment. While some of them have focused on a single country, some others prefer to examine a group of countries. Moreover, various econometric approaches (e.g., ARDL, cross sectional ARDL, AMG, CCEMG) have been frequently used in such studies for empirical examination. When all these issues are considered together, it is possible to conclude that the literature has a gap in that no study considers the effects of both NEC and PS in investigating CO_2 emissions by including eight leading politically stable countries, which use nuclear energy power. Also, the QQ model has been rarely used in the literature and has not been used for the aforementioned scope as well. By considering the literature gap, the study aims to close this gap in uncovering the effects of NEC and PS on CO_2 emissions for eight highly politically stable nuclear energy-consuming countries by using quantile-based novel models, which have been rarely used.

3. Methods

3.1. Data source

The study investigates the effects of NEC and PS on CO_2 emissions in high nuclear energy-consuming and highly politically stable countries for the period 1991/Q1–2021/Q4. The dataset of CO_2 and NEC are obtained from BP [13]. Also, data for PRI is obtained from the PRS [39]. Annual data is converted to quarterly data that is consistent with the latest research [10,44]. Moreover, this study transforms raw data into logarithmic difference series in line with the literature [4,7,17].

Table 2 presents the details of variables.

3.2. Empirical methodology

The flowchart of the empirical methodology is given in Fig. 1.

Descriptive Statistics: The first step in the empirical methodology is to examine descriptive statistics, which include the mean, median, the range of values of variables. In addition, the standard deviation demonstrates the amount of dispersion of data values from the mean. The measures of skewness and kurtosis are provided to characterize the location and variability of observation. Also, the Jarque-Bera (JB) test is a goodness of fit test of whether the data has a normal distribution or not.

Correlation Matrix: The second step is to examine the correlation between the variables. Hence, it can be examined how a nexus between the variables exists.

Nonlinearity Test: Followingly, this study continues to test stationarity or the presence of a unit root. Broock, Dechert, and Scheinkman (BDS) test is constructed within chaos theory and nonlinear dynamics [14]. Before the beginning of the advanced methods, the BDS test can be applied for the nonlinearity assumption.

Following the above-explained steps, the data characteristics of the variables are examined. Based on the data characteristics, which reveal mostly nonnormality and fully nonlinearity, it is highly appropriate to use nonlinear models. Accordingly, the study applies QQ, GQ, and QR models as novel nonlinear models for a quantile-based empirical investigation of both dependent and independent variables at the same time rather than making a mean-based analysis. Hence, the changing effects between the variables over quantiles can be analyzed for the countries.

3.3. Quantile-based models

QQ Model: The QQ model, which is developed by Sim & Zhou [46], determines the relationship between different quantiles of dependent (outcome) variables and each specific quantile of independent variables (covariates). It has been constructed by combining quantile regression and nonparametric models.

The model for the θ-quantile of the dependent function as a function of the independent variable is stated in Eq. 1.

$$Y_t = \beta^\theta(X_t) + \alpha^\theta Y_{t-1} + v_t^\theta \tag{1}$$

where the X and Y are independent and the dependent variables, respectively. v_t^θ is the error term. Eq. 1 is linearized using the first-order Taylor expansion of $\beta^\theta(X_t)$ in Eq. 2.

$$\beta^\theta(X_t) \approx \beta^\theta(X^\tau) + \beta^{\theta}(X^\tau)(X_t - X^\tau) \tag{2}$$

Also, Eq. 2 can be rewritten in Eq. 3 because $\beta^\theta(X^\tau)$ and $\beta^{\theta'}$ are the function of θ and τ.

$$\beta^\theta(X_t) \approx \beta_0(\theta,\tau) + \beta_1(\theta,\tau)(X_t - X^\tau) \tag{3}$$

Eq. 4 is obtained when Eq. 3 is substituted in Eq. 1.

$$Y_t = \beta_0(\theta,\tau) + \beta_1(\theta,\tau)(X_t - X^\tau) + \alpha(\theta)Y_{t-1} + v_t^\theta \tag{4}$$

Finally, to estimate Eq. 5, $\widehat{X}_t$ and $\widehat{X}^\tau$ are replaced by their estimated

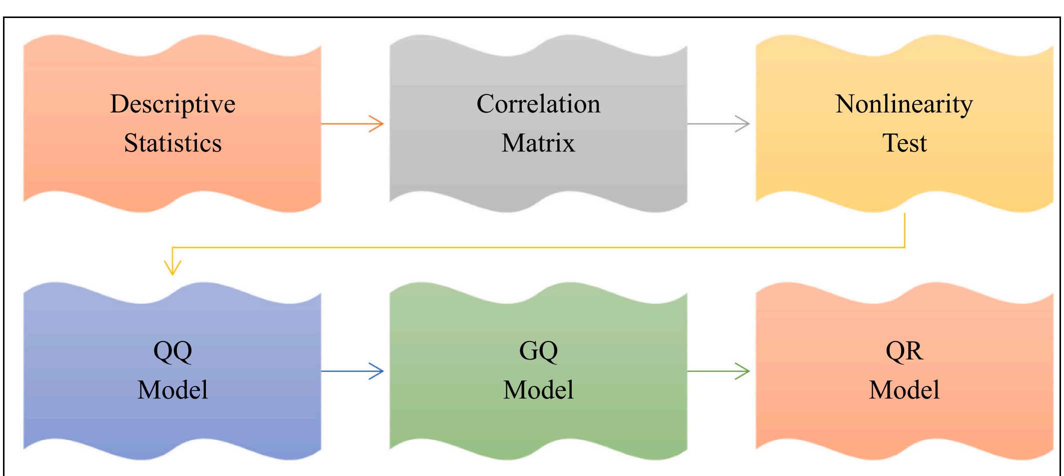

Fig. 1. The Flowchart of the Methodology.

Table 3
Preliminary Statistics.

Country	Variable	Mean	Median	Maximum	Minimum	SD	Skewness	Kurtosis	JB	JB Prob.
	CO_2	14.12	14.48	18.87	8.96	2.33	−0.35	2.55	3.57	0.1676
FIN	NEC	0.05	0.06	0.06	0.05	0.00	−0.62	2.26	10.72	0.0047
	PRI	22.27	22.05	23.69	20.32	0.99	−0.28	1.95	7.26	0.0265
	CO_2	10.42	10.74	11.61	8.00	0.82	−1.19	3.96	34.01	0.0000
CHE	NEC	0.06	0.06	0.07	0.04	0.01	−1.24	4.23	39.67	0.0000
	PRI	21.98	21.91	23.40	21.14	0.56	0.78	3.04	12.47	0.0020
	CO_2	13.95	14.70	17.25	9.80	1.97	−0.37	1.87	9.42	0.0090
SWE	NEC	0.16	0.16	0.20	0.11	0.02	−0.31	2.48	3.41	0.1821
	PRI	21.65	21.71	23.05	19.85	0.82	−0.64	2.83	8.59	0.0136
	CO_2	131.98	136.39	145.05	106.71	10.68	−1.04	2.89	22.42	0.0000
CAN	NEC	0.22	0.22	0.28	0.18	0.02	−0.09	2.83	0.30	0.8599
	PRI	21.34	21.49	22.51	19.96	0.62	−0.88	3.01	15.99	0.0003
	CO_2	203.80	206.52	246.30	148.56	21.12	−0.64	3.23	8.77	0.0125
DEU	NEC	0.33	0.38	0.44	0.14	0.10	−0.55	1.66	15.45	0.0004
	PRI	20.89	20.87	23.10	17.57	0.80	−1.08	5.99	70.22	0.0000
	CO_2	53.05	53.72	58.30	43.07	3.67	−0.72	3.21	10.84	0.0044
NLD	NEC	0.01	0.01	0.01	0.01	0.00	−1.44	4.92	62.03	0.0000
	PRI	21.29	21.17	24.15	18.11	1.38	−0.05	3.01	0.06	0.9714
	CO_2	128.61	139.24	151.69	77.97	20.03	−1.09	2.95	24.73	0.0000
GBR	NEC	0.19	0.18	0.26	0.10	0.04	−0.07	1.97	5.56	0.0622
	PRI	20.56	20.36	22.60	19.04	1.02	0.43	2.13	7.76	0.0207
	CO_2	1334.19	1318.08	1474.66	1094.21	90.61	−0.39	2.77	3.38	0.1849
USA	NEC	1.92	1.95	2.08	1.62	0.13	−0.86	2.56	16.17	0.0003
	PRI	20.51	20.42	22.40	18.68	0.80	0.10	3.15	0.32	0.8512

Note: SD: Standard Deviation; JB: Jarque-Bera; Prob: Probability.

counterpart $\widehat{X}_t$ and $\widehat{X}^\tau$, respectively.

$$\min_{b_0,b_1}\sum_{i=1}^{n}\rho_\theta[Y_t-b_0-b_1(\widehat{X}_t-\widehat{X}^\tau-\alpha(\theta)Y_{t-1})]K\left(\frac{Fn(\widehat{X}_t)-\tau}{h}\right) \quad (5)$$

$$Fn(\widehat{X}_t)=\frac{1}{n}\sum_{k=1}^{n}I(\widehat{X}_k<\widehat{X}_t) \quad (6)$$

where ρ_θ is the absolute value function that supplies *the* θ-quantile value of r_t. $K(.)$ represents the Gaussian Kernel function I refer to as an indicator function, and r_t is the independent variable at time t [46].

GQ Model: After defining the nonlinearity characteristic and performing QQ, the heterogeneity dependence structure within GQ was developed by Troster [50]. In this sense, the causal relation between NEC and PRI on environmental degradation in different conditional distributions is investigated by the GQ model so that is possible to distinguish between causality affecting the conditional distribution's median and tails.

QR Model: To estimate the connection between independent variables and any quantile of the dependent variable rather than the mean, QR has been provided without using a specific conditional distribution assumption. With the help of this model, it is possible to analyze a diverse variety of conditional quantiles, deal with various types of conditional heterogeneity, and allow for unobserved heterogeneity effects [20,31]. QR model is estimated by $Q_y(\tau|x)$:

$$Q_y(\tau|x)=x^T\beta(\tau) \quad (7)$$

$$y=x^T\beta(\tau)+u(\tau) \quad (8)$$

$$Q_{u(\tau)}(\tau|x)=0 \quad (9)$$

where τ is the conditional quantile ($for\ 0<\tau<1$), y and x stand for dependent and independent variables, respectively [31].

4. Empirical results and discussion

4.1. Descriptive statistics

Table 3 presents the summary statistics for the variables of each country. According to Table 3, CO_2 and NEC have the highest mean and median in the USA and DEU. This is followed by CO_2 in CAN (131.98), and NEC in CAN (0.22). PRI has the highest mean and median in FIN (22.27), CHE (21.98), and SWE (21.65), respectively. Based on skewness statistics, all variables have a left-skewed distribution, except for PRI in CHE, GBR, and the USA. In addition, all variables in FIN, SWE, GBR, and NEC in DEU have less kurtosis than the normal distribution but the kurtosis value disclosed that all variables in CHE and NLD, and PRI in CAN, and the USA are leptokurtic. JB test statistics confirm the normality assumption for only a few variables in some countries, whereas most of the variables have a nonnormal distribution. It can be clearly stated that the data of the variables in CHE and DEU do not come from the normal distribution.

Table 4
Correlation Matrix.

Country	Variable	CO_2	NEC	PRI
	CO_2	1.00		
FIN	NEC	0.26	1.00	
	PRI	0.45	0.89	1.00
	CO_2	1.00		
CHE	NEC	0.72	1.00	
	PRI	0.31	0.21	1.00
	CO_2	1.00		
SWE	NEC	0.78	1.00	
	PRI	−0.02	−0.03	1.00
	CO_2	1.00		
CAN	NEC	−0.06	1.00	
	PRI	0.77	−0.47	1.00
	CO_2	1.00		
DEU	NEC	0.86	1.00	
	PRI	−0.10	0.06	1.00
	CO_2	1.00		
NLD	NEC	0.26	1.00	
	PRI	0.44	0.29	1.00
	CO_2	1.00		
GBR	NEC	0.72	1.00	
	PRI	0.12	0.43	1.00
	CO_2	1.00		
USA	NEC	0.52	1.00	
	PRI	0.16	0.32	1.00

Note: Values indicate coefficients.

Table 5
BDS Test Results.

Country	Variable	Dimensions				Decision
		2	3	4	5	
FIN	CO_2	0.0000	0.0000	0.0000	0.0000	NL
	NEC	0.0000	0.0000	0.0000	0.0000	NL
	PRI	0.0000	0.0000	0.0000	0.0000	NL
	CO_2	0.0000	0.0000	0.0000	0.0000	NL
CHE	NEC	0.0000	0.0000	0.0000	0.0000	NL
	PRI	0.0000	0.0000	0.0000	0.0000	NL
	CO_2	0.0000	0.0000	0.0000	0.0000	NL
SWE	NEC	0.0000	0.0000	0.0000	0.0000	NL
	PRI	0.0000	0.0000	0.0000	0.0000	NL
	CO_2	0.0000	0.0000	0.0000	0.0000	NL
CAN	NEC	0.0000	0.0000	0.0000	0.0000	NL
	PRI	0.0000	0.0000	0.0000	0.0000	NL
	CO_2	0.0000	0.0000	0.0000	0.0000	NL
DEU	NEC	0.0000	0.0000	0.0000	0.0000	NL
	PRI	0.0000	0.0000	0.0000	0.0000	NL
	CO_2	0.0000	0.0000	0.0000	0.0000	NL
NLD	NEC	0.0000	0.0000	0.0000	0.0000	NL
	PRI	0.0000	0.0000	0.0000	0.0000	NL
	CO_2	0.0000	0.0000	0.0000	0.0000	NL
GBR	NEC	0.0000	0.0000	0.0000	0.0000	NL
	PRI	0.0000	0.0000	0.0000	0.0000	NL
	CO_2	0.0000	0.0000	0.0000	0.0000	NL
USA	NEC	0.0000	0.0000	0.0000	0.0000	NL
	PRI	0.0000	0.0000	0.0000	0.0000	NL

Note: Values indicate the p-values. NL denotes the nonlinear.

4.2. Correlation matrix

Table 4 demonstrates the correlations between the variables.

According to Table 4, there is a positive correlation between NEC and CO_2 as well as between PRI and CO_2 in FIN, CHE, NLD, GBR, and USA. Also, CO_2 has a positive (negative) correlation with NEC (PRI) in SWE and DEU. Moreover, CO_2 has a negative (positive) correlation with NEC (PRI) in CAN. When the power of correlation is examined, it can be seen that NEC has a much higher correlation with CO_2 in some countries, whereas PRI has a much more powerful correlation with CO_2 in other countries.

4.3. Nonlinearity test

To test the nonlinearity features of the variables, the BDS test is performed and the results are shown in Table 5.

The nonlinearity of the variables is defined because the null hypotheses of being independently distributed residuals cannot be accepted for all variables.

4.4. The QQ results

The quantile-based effects of NEC on CO_2 emissions are measured for each country by using the QQ approach, which is illustrated in Fig. 2.

Although the effect of NEC is positive for each quantile combination in SWE, DEU, and the USA, the magnitude of the effect is differentiated by quantiles. On the contrary, in CHE, CAN, and GBR, the effect of NEC is negative for each quantile combination. Also, it is revealed that the effect of NEC can be positive or negative based on the quantiles' combination in FIN and NLD. In detail, the effect of NEC is strong and

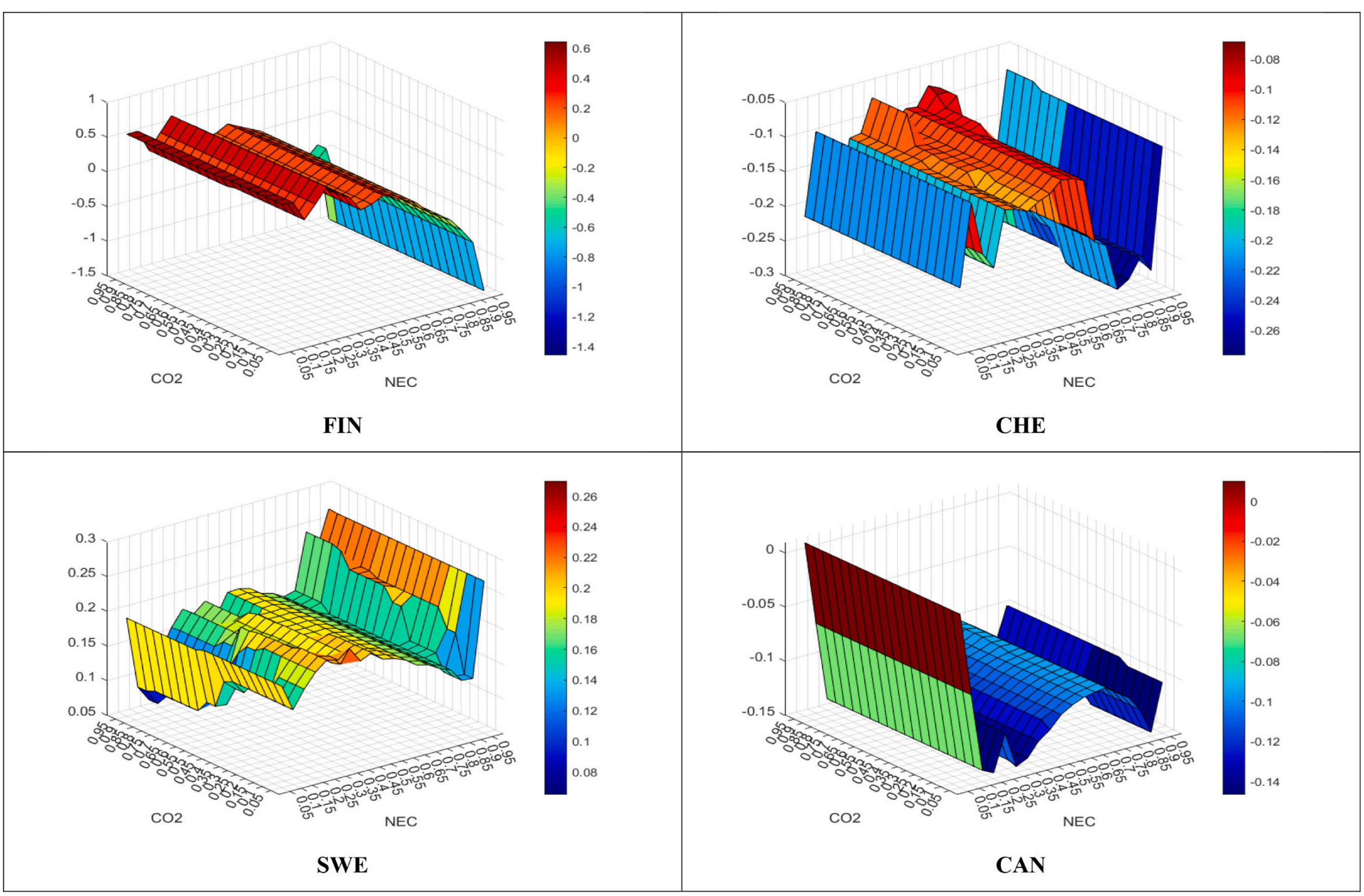

Fig. 2. The QQ Results of NEC Effect on the CO_2.

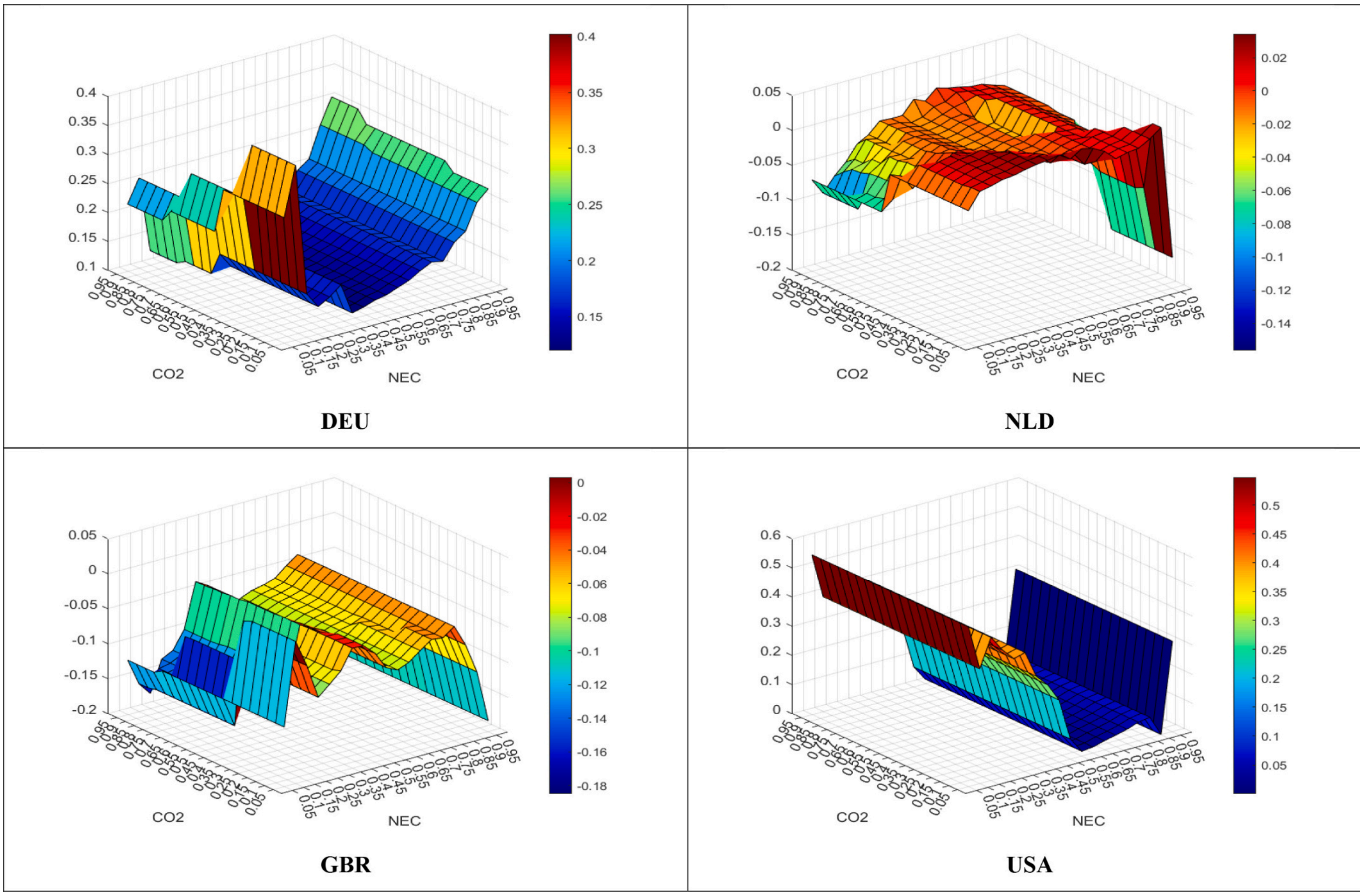

Fig. 2. (*continued*).

positive in the area, where the quantiles of NEC are lower than 0.50, but this effect turns strongly negative in the area, where the quantiles of NEC are higher than 0.50. Moreover, at the lowest and highest quantiles of NEC, the effect is relatively strong. In the NLD, the effect of NEC on CO_2 emissions is around 0.02 almost in all quantile combinations. There are only two areas, where the effect is significantly negative, at which the quantiles of NEC are lower than 0.20 and the quantiles of CO_2 higher than 0.80, or the quantiles of NEC higher than 0.80 and the quantiles of CO_2 lower than 0.20.

In CHE, the effect is negative but the magnitude of the effect is around −0.10 in the middle quantiles of NEC, whereas the magnitude of the effect is significantly increased and reached −0.26 in the lowest and the highest quantiles of NEC. On the contrary, in SWE, the effect is positive but the magnitude of the effect is between 0.16 and 0.18 in the area, where the NEC quantiles are lower than 0.80. However, this effect increases and reaches a 0.24 level in the area, where the NEC quantiles are higher than 0.80. Similarly, the effect of NEC is negative in all quantile combinations in CAN. Also, the effect of the NEC is differentiated between −0.08 and − 0.14 in the area, where the quantiles of NEC are higher than 0.20. In DEU and the USA, the effect of NEC on CO_2 emissions is positive and also it has similar characteristics. In detail, NEC quantities increase from 0.05 to 0.30 in DEU and from 0.05 to 0.50 in the USA, whereas the positive effect of NEC on CO_2 emissions is decreasing. Nevertheless, this effect is significantly increasing in the area, where the NEC quantiles are higher than 0.30 in DEU and higher than 0.80 in the USA. Once this effect is examined in GBR, it can be seen that the effect of NEC on CO_2 emissions is differentiated from −0.14 to −0.04. Also, it is revealed that the lowest and the highest quantiles of NEC are important in terms of the magnitude of the effect of NEC on CO_2 emissions. In these areas, the effect is significantly negative and at a − 0.16 level.

The quantile-based effects of PRI on CO_2 emissions for each country are demonstrated in Fig. 3.

The effect of PRI on CO_2 emissions can be positive or negative based on the quantile combination in each country, except in FIN, and the magnitude of the effect is differentiated by quantiles. In FIN, contrary to other countries, the effect of PRI on CO_2 emissions is negative in all quantile combinations and ranges from −0.05 to −3.00. Also, the effect is increasing from lower quantiles to higher quantiles of PRI. In all countries, except SWE, the effect has a threshold, which changes the sign of the effect at a certain quantile of PRI. These thresholds are 0.35 in CHE, 0.25 in CAN, 0.20 in DEU, 0.60 in the NLD, 0.85 in GBR, and 0.40 in the USA. More specifically in SWE, the effect is positive in all quantile combinations, and also the magnitude of the effect increases from lower quantiles to higher quantiles of PRI (the effect increases from 1.00 to 2.80).

NLD and GBR have a similar pattern in terms of the effect of PRI on CO_2 emissions. The magnitude of the effect of PRI on CO_2 emissions increases when the quantiles are from 0.65 to 0.95 in NLD, and from 0.75 to 0.95 in GBR. Moreover, CHE, CAN, and the USA have a similar pattern in terms of the effect of PRI on CO_2 emissions as well. It starts with a negative effect in the lowest quantiles of PRI, except in CHE, and decreases from lower quantiles to certain quantiles of PRI, which are 0.35 for CHE, 0.25 for CAN, and 0.40 for the USA. After these critical thresholds, the effect of PRI on CO_2 emissions turns positive and generally stays stable in these countries. Moreover, it is revealed that the effect of PRI on CO_2 emissions in the lowest and the highest quantiles are significantly higher than in other areas. Finally, in DEU, the effect of PRI on CO_2 emissions differs from −0.14 to 0.02, and also the negative effect of PRI on CO_2 emissions is increasing from lower quantiles to higher quantiles of PRI.

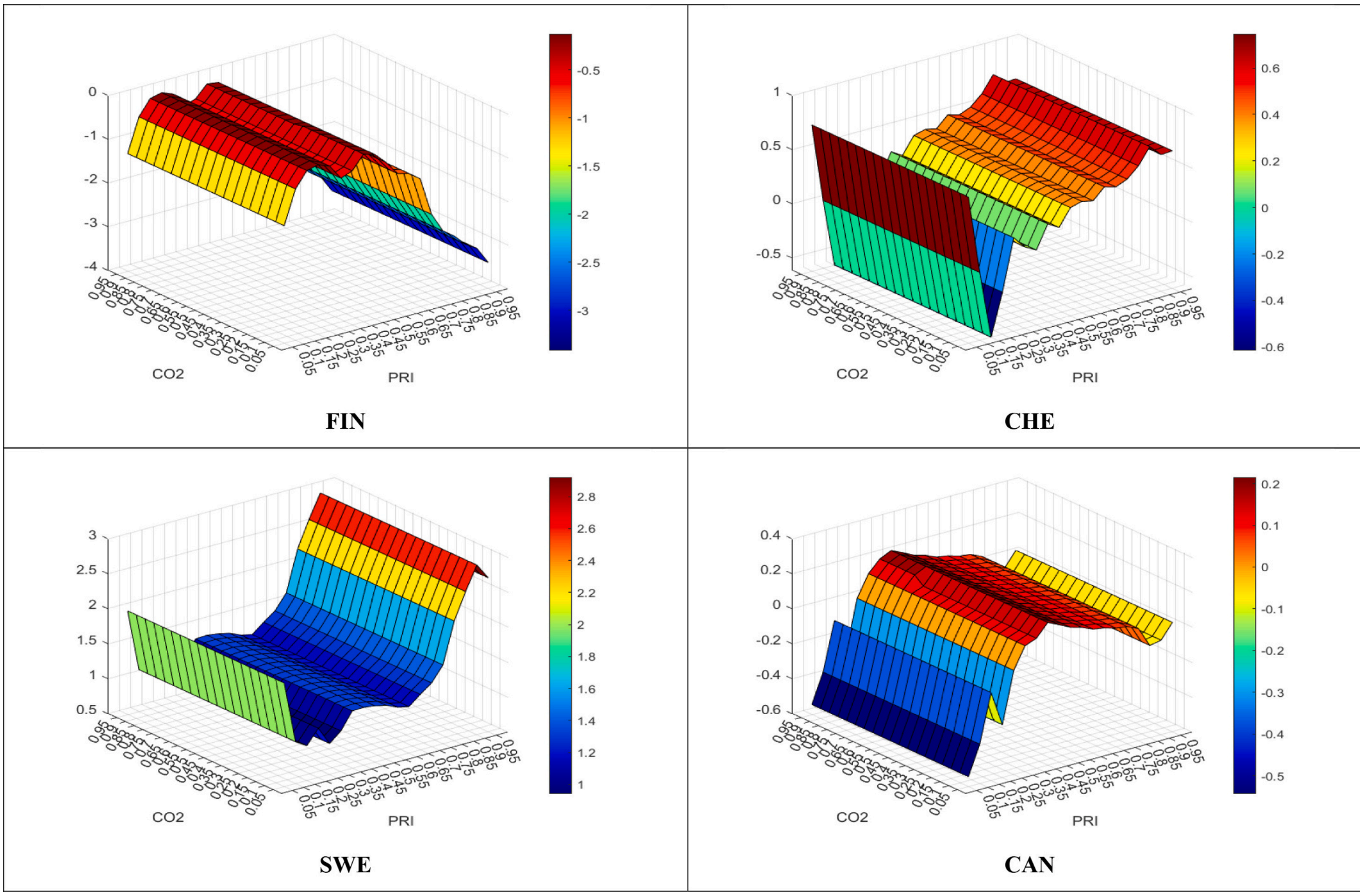

Fig. 3. The QQ Results of PRI Effect on the CO_2.

Overall, the power effects of NEC on CO_2 emissions are differentiated across quantiles and countries.

4.5. GQ results

After the power of the effects, the causal effects, of which the direction is from NEC and PRI to CO_2 emissions, are investigated across quantiles. The results of the analysis are presented in Table 6.

According to Table 6, in CHE, SWE, GBR, and the USA, it can be said that there are two areas, where the causality from NEC and PRI to CO_2 emissions are statistically significant. These areas are the quantiles from 0.15 to 0.45 and from 0.70 to 0.85 for CHE, from 0.10 to 0.35, and from 0.50 to 0.85 for SWE, from 0.10 to 0.40 and from 0.60 to 0.85 for GBR, from 0.05 to 0.40 and from 0.55 to 0.80 for the USA. In FIN and NLD, there are three significant areas, where the causality from NEC and PRI to CO_2 emissions is statistically significant. These areas' quantiles are from 0.15 to 0.20, 0.30, and 0.65 to 0.90 in FIN, while 0.05, from 0.15 to 0.40, and 0.70 to 0.75 in NLD. Furthermore, in CAN and DEU, there are four significant areas, where the causality from NEC and PRI to CO_2 emissions is statistically significant as well. These areas' quantiles are 0.10, from 0.20 to 0.45, 0.60 to 0.75, and 0.85 in CAN, while from 0.10 to 0.15, 0.25 to 0.40, 0.60 to 0.65, and 0.95 in DEU. As a result of the causality in quantiles analysis, it is revealed that the effects of both NEC and PS should be taken into consideration in the areas, where the causality is statistically significant.

4.6. Robustness analysis

Lastly, the robustness of the results is controlled by applying the QR model. The results are detailed in Annexes 1–2 and summarized in Table 7.

Based on Table 7, it is revealed that the correlation between the QQ and QR coefficients is relatively at a high level. Also, it is higher than 0.99, which shows the high correlation between the two results. In NLD, the correlation between the QQ and QR coefficients for NEC and CO_2 is around 0.72, which also means an acceptable relationship between the two results.

4.7. Discussion and policy caveats

The study follows a comprehensive empirical methodology to uncover the effects of NEC and PS on CO_2 emissions in a total of eight highly nuclear energy-consuming and politically stable countries. The findings of the novel models unveil the heterogeneous (i.e., changing) effects of NEC and PS on CO_2 emissions over the countries and quantiles. So, it is highly critical to think about why the effects of NEC and PS differ over the countries as well as quantiles.

NEC has a generally declining effect on CO_2 emissions at higher levels of NEC and is beneficial for FIN, CHE, CAN, NLD, and GBR. However, NEC does not help decrease CO_2 emissions in SWE, DEU, and USA. This determination highlights some critical points. The first reason is that some countries (e.g., the USA) have relied on highly NEC in total energy mix. So, there is a saturation for these countries, which means that increasing NEC further cannot be beneficial for such countries (e.g., USA) in curbing CO_2 emission. Instead, they should focus on using further renewable sources and decreasing the use of fossil fuel sources. The second reason is that some countries (e.g., SWE & DEU) have very little amount of NEC in the total energy mix. So, NEC has been in a

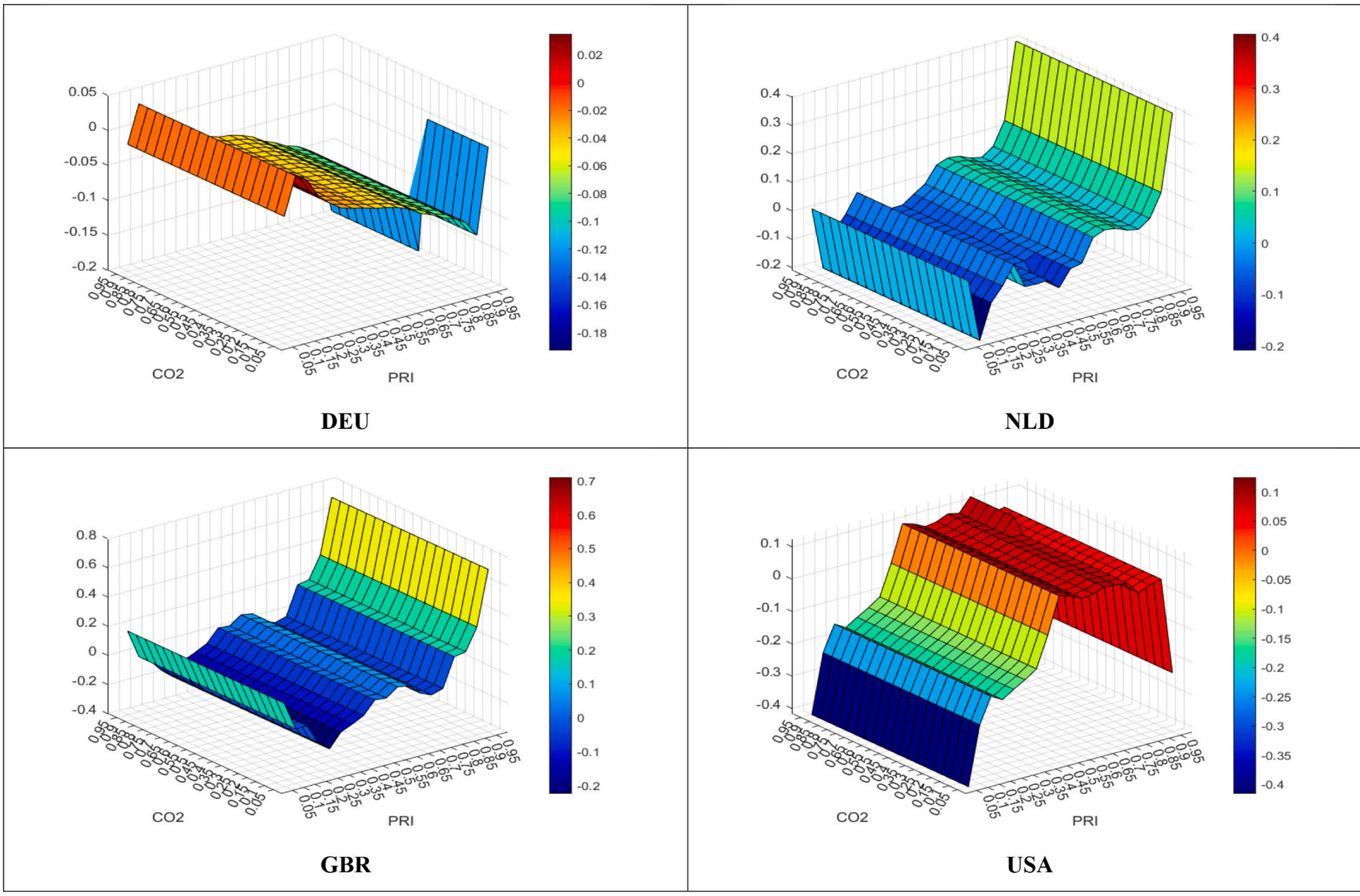

Fig. 3. (*continued*).

growing stage and has not reached a level that it can provide to curb impact. This shows that such countries (e.g., SWE & DEU) should either increase NEC further to make them efficient on CO_2 emissions or fully phase out NEC as in the case of DEU and allocate their efforts and sources to renewable sources.

PS has a generally decreasing effect on CO_2 emissions at higher levels of PS and is effective in FIN, CAN, and DEU. On the other hand, PS does not make a curbing impact on CO_2 emissions in CHE, SWE, NLD, GBR, and USA. This finding demonstrates some critical perspectives. The leading reason is that some countries (e.g., FIN, CAN, and DEU) have a relatively higher PS than other countries. So, these countries can have a much more long-term point of view than other countries. Hence, they can make long-term based decisions, which support the progress of the environmental quality by benefitting from the PS in reshaping the behaviors of citizens in a much eco-friendlier manner. Another reason is that although some other countries (e.g., CHE, SWE, NLD, GBR, and USA) have also higher PS, they have failed to construct eco-friendly decision-making processes at policymaker levels as well as eco-friendly manner in both society and individual level of citizens. Hence, although these countries have higher PS, unfortunately, they cannot benefit from higher PS in curbing CO_2 emissions. That is why high PS causes a harmful effect on the environmental quality by supporting higher consumption due to PS, not considering eco-friendly approaches at individual and policymaker levels.

When the results of this study are considered, it can be stated that the study validates the findings of most of the studies in the literature (e.g., [7,19,24,37] for the effect of PS on CO_2). However, by differentiation from such studies, this study provides quantile-based results for each country for the effects of NEC and PS on CO_2 emissions by considering quantiles of both independent and dependent variables at the same time. Hence, the nonnormal and nonlinear structures of the variables are considered and the current literature has been enriched the literature further.

Considering both NEC and PS together in examining CO_2 emissions, an argument can be developed for policymakers to prevent environmental degradation by increasing clean energy use and reducing political risk factors. So, some policy caveats can be discussed based on the outcomes.

First, at higher levels of NEC, it has mainly a curbing effect on CO_2 emissions. In detail, it is defined that NEC is beneficial for FIN, CHE, CAN, NLD, and GBR. Consistent with this determination, these countries should increase the level of NEC in meeting total energy needs and they can lower CO_2 emissions in this way while contributing to achieving carbon neutrality targets. On the other hand, NEC does not help curb CO_2 emissions in SWE, DEU, and USA. Therefore, these three countries should search for new ways and initiate new approaches, such as accelerating nuclear energy-related R&D budgets, to make NEC much more efficient and helpful in declining CO_2 emissions. That is why an increase in NEC causes a stimulating effect on CO_2 emissions in these countries.

Second, at higher levels of PS, it has a generally declining effect on CO_2 emissions. Specifically, it is determined that PS helps curb CO_2 emissions in FIN, CAN, and DEU. So, these countries can continue to rely on PS to decrease CO_2 emissions. Differently, the effect of PS on CO_2 emissions is not effective in making a decreasing effect in CHE, SWE, NLD, GBR, and the USA. Hence, these five countries should search for new ways, such as R&D investment in energy technologies.

Third, there are different effects of both NEC and PS on CO_2 emissions across quantiles and countries. In other words, there is not a linear either increasing or decreasing effect of these variables on CO_2

Table 6
GQ Results.

Country	Causality	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
FIN	NEC⇒CO_2	0.84	0.27	0.01	0.01	0.13	0.02	0.33	0.06	0.36	0.65	0.26	0.07	0.01	0.01	0.01	0.01	0.01	0.01	0.35
	PRI⇒CO_2	0.84	0.27	0.01	0.01	0.13	0.02	0.33	0.06	0.36	0.65	0.26	0.07	0.01	0.01	0.01	0.01	0.01	0.01	0.35
CHE	NEC⇒CO_2	1.00	0.24	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.07	0.86	0.10	0.09	0.01	0.01	0.01	0.01	0.28	1.00
	PRI⇒CO_2	1.00	0.24	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.07	0.86	0.10	0.09	0.01	0.01	0.01	0.01	0.28	1.00
SWE	NEC⇒CO_2	0.73	0.01	0.01	0.01	0.01	0.01	0.01	0.56	0.85	0.02	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.60	0.08
	PRI⇒CO_2	0.73	0.01	0.01	0.01	0.01	0.01	0.01	0.56	0.85	0.02	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.60	0.08
CAN	NEC⇒CO_2	1.00	0.01	0.15	0.05	0.01	0.01	0.01	0.01	0.03	0.34	0.72	0.02	0.01	0.02	0.01	0.49	0.01	0.15	0.41
	PRI⇒CO_2	1.00	0.01	0.15	0.05	0.01	0.01	0.01	0.01	0.03	0.34	0.72	0.02	0.01	0.02	0.01	0.49	0.01	0.15	0.41
DEU	NEC⇒CO_2	0.34	0.01	0.01	0.11	0.02	0.03	0.01	0.02	0.15	0.78	0.09	0.02	0.01	0.24	0.16	0.48	0.23	0.61	0.06
	PRI⇒CO_2	0.34	0.01	0.01	0.11	0.02	0.03	0.01	0.02	0.15	0.78	0.09	0.02	0.01	0.24	0.16	0.48	0.23	0.61	0.06
NLD	NEC⇒CO_2	0.01	0.09	0.02	0.01	0.01	0.05	0.01	0.01	0.27	0.77	0.31	0.43	0.11	0.05	0.01	0.15	0.75	0.20	1.00
	PRI⇒CO_2	0.01	0.09	0.02	0.01	0.01	0.05	0.01	0.01	0.27	0.77	0.31	0.43	0.11	0.05	0.01	0.17	0.75	0.20	1.00
GBR	NEC⇒CO_2	0.18	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.18	0.67	0.32	0.01	0.01	0.01	0.02	0.01	0.05	0.19	1.00
	PRI⇒CO_2	0.18	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.18	0.67	0.32	0.01	0.01	0.01	0.02	0.01	0.05	0.19	1.00
USA	NEC⇒CO_2	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.27	0.38	0.01	0.01	0.01	0.01	0.01	0.01	0.07	0.75	1.00
	PRI⇒CO_2	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.27	0.38	0.01	0.01	0.01	0.01	0.01	0.01	0.07	0.75	1.00

Note: Numbers represent p-values.

Table 7
Correlations between the QQ & QR Coefficients.

	NEC Effect on CO_2	PRI Effect on CO_2
FIN	99.98	99.99
CHE	99.24	99.99
SWE	92.53	99.99
CAN	99.65	99.94
DEU	99.16	93.95
NLD	72.38	99.96
GBR	92.59	99.97
USA	99.99	99.97

emissions. Also, the causal effects on CO_2 emissions vary according to the quantiles (levels) of both NEC and PS. So, all the countries should monitor the changing effect of both NEC and PS on CO_2 emissions across quantiles and times. When the effects of both NEC and PS turn harmful, additional steps should be taken by the countries so that the adverse effects of NEC and PS can be prevented. Otherwise, although NEC and PS have been increasing, they may cause an increasing effect on CO_2 emissions, which result in increasing environmental degradation, global warming, and climate change in turn.

To sum up, FIN and CAN benefit from both NEC and PS in directing CO_2 emissions into a decreasing path, which enables these countries to rely on both NEC and PS in achieving carbon neutrality targets, whereas SWE and USA can benefit from neither NEC nor PS. Also, the remaining countries have mixed results in terms of the effects of NEC and PS. So, policymakers of these countries should take into account their conditions as well as quantile and country-based varying effects of NEC and PS in the development of policies.

By benefitting from the case of developed countries, it can be argued for policymakers to prevent environmental degradation in emerging countries with higher CO_2 emissions and high populations. Hence, the contribution of the study can be inclusive for developed and developing countries to combat environmental degradation.

5. Conclusion

This study investigates the effect of NEC and PS on environmental degradation. So, the study empirically analyzes eight highly politically stable countries, uses the most recent data between 1991/Q1 and 2021/Q4, and performs novel quantile-based approaches. The empirical investigation shows that (I) NEC has a mainly curbing effect on CO_2 emissions at higher levels of NEC; (ii) PS decreases CO_2 emissions at higher levels of PS; (iii) NEC and PS are causally effective on CO_2 emissions; (iv) the QR results confirmed the robustness of the findings. Overall, both NEC and PS effects on CO_2 emissions are non-homogeneous and vary according to quantiles and countries. The study highlights the importance of quantile and country-based analyses for a better empirical examination. Also, the empirical outcomes confirm the previous studies' findings and present that NEC and PS have important effects on CO_2 emissions.

There is a dilemma for policymakers between meeting increasing energy demand and reducing environmental damage. To find a solution, the usage of clean energy sources (nuclear), which is a certain alternative to fossil fuels, has been tried to increase in countries. In addition to this, PS (i.e., reduction of political risk) can be a tool that countries could use as a strong argument for reducing environmental damage in terms of enacting and enforcing environmental laws. Hence, to reduce environmental damage and CO_2 emissions, the results of the research show that policymakers should focus on measures that will increase PS and they can find solutions with the use of nuclear energy because there are almost no CO_2 emissions.

Both NEC and PS offer a compelling opportunity to combat environmental pollution. The contribution of the study is that it uses up-to-date data, applies up-to-date models gives individual results for eight countries with the highest PS stability, and is the first to test the effect of

NEC and PS together on the environment. Moreover, the findings and recommendations of this study can also be a good gauge for other countries to combat environmental hazards.

In the study, nuclear energy-consuming countries with the highest PS are included. So, future studies can be conducted on less politically stable nuclear energy-consuming countries. Also, new studies can be prepared for examination from the other types of clean energy, such as hydro, solar, and wind. Hence, not only developed countries, but also emerging countries can be investigated. Moreover, new studies could use both aggregated and disaggregated level data on energy consumption and PS. Furthermore, recently developed other novel models (e.g., wavelet local multiple correlations) can be used for empirical uncovering. The literature can be enriched much more in this way.

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Consent for publication

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

Acronyms

AMG	Augmented Mean Group
ARDL	Autoregressive Distributed Lag
BP	British Petroleum
CCEMG	Common Correlated Effects Mean Group
CCR	Canonical Cointegration Regression
CO_2	Carbon Dioxide
COP	Conference of Parties
DH	Dumitrescu Hurlin
DOLS	Dynamic Ordinary Least Squares
DARDL	Dynamic ARDL
FARDL	Fourier ARDL
FE-OLS	Fixed Effect OLS
FMOLS	Fully Modified OLS
GC	Granger Causality
GQ	Granger Causality-in-Quantiles
GHG	Green House Gas
NARDL	Nonlinear ARDL
NEC	Nuclear Energy Consumption
PC	Panel Causality
PPE	Panel Pooled Estimation
PRI	Political Risk Index
PRS	Political Risk Services
PS	Political Stability
PSTRM	Panel Smooth Transition Regression Model
QQ	Quantile-on-Quantile Regression
QR	Quantile Regression
RE-OLS	Random Effect OLS
TY	Toda Yamamoto
VECM	Vector Error Correction Model

CRediT authorship contribution statement

Mustafa Tevfik Kartal: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Serpil Kılıç Depren:** Writing – original draft. **Fatih Ayhan:** Writing – original draft. **Talat Ulussever:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no competing interests.

Data availability

Data will be made available on request.

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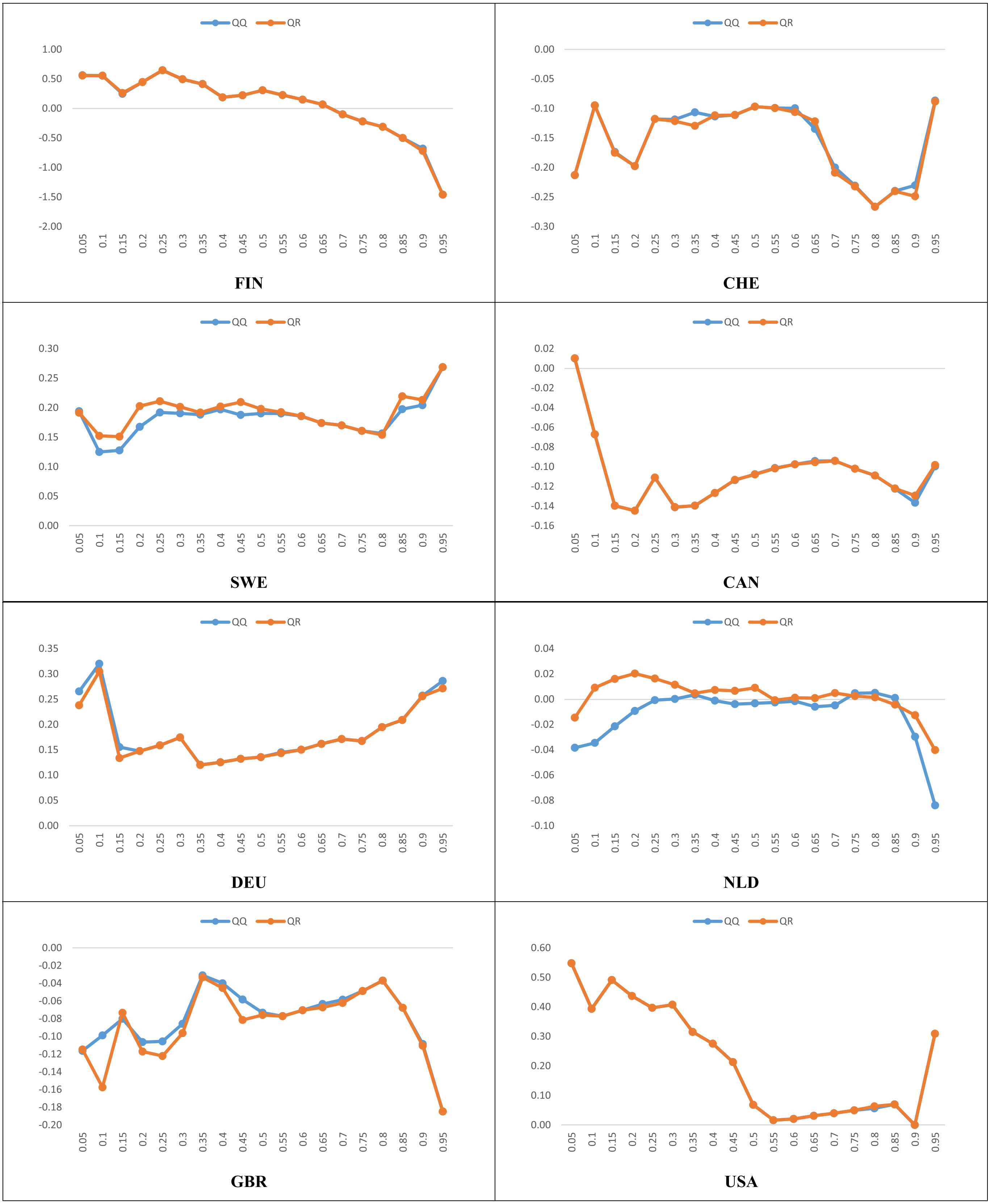
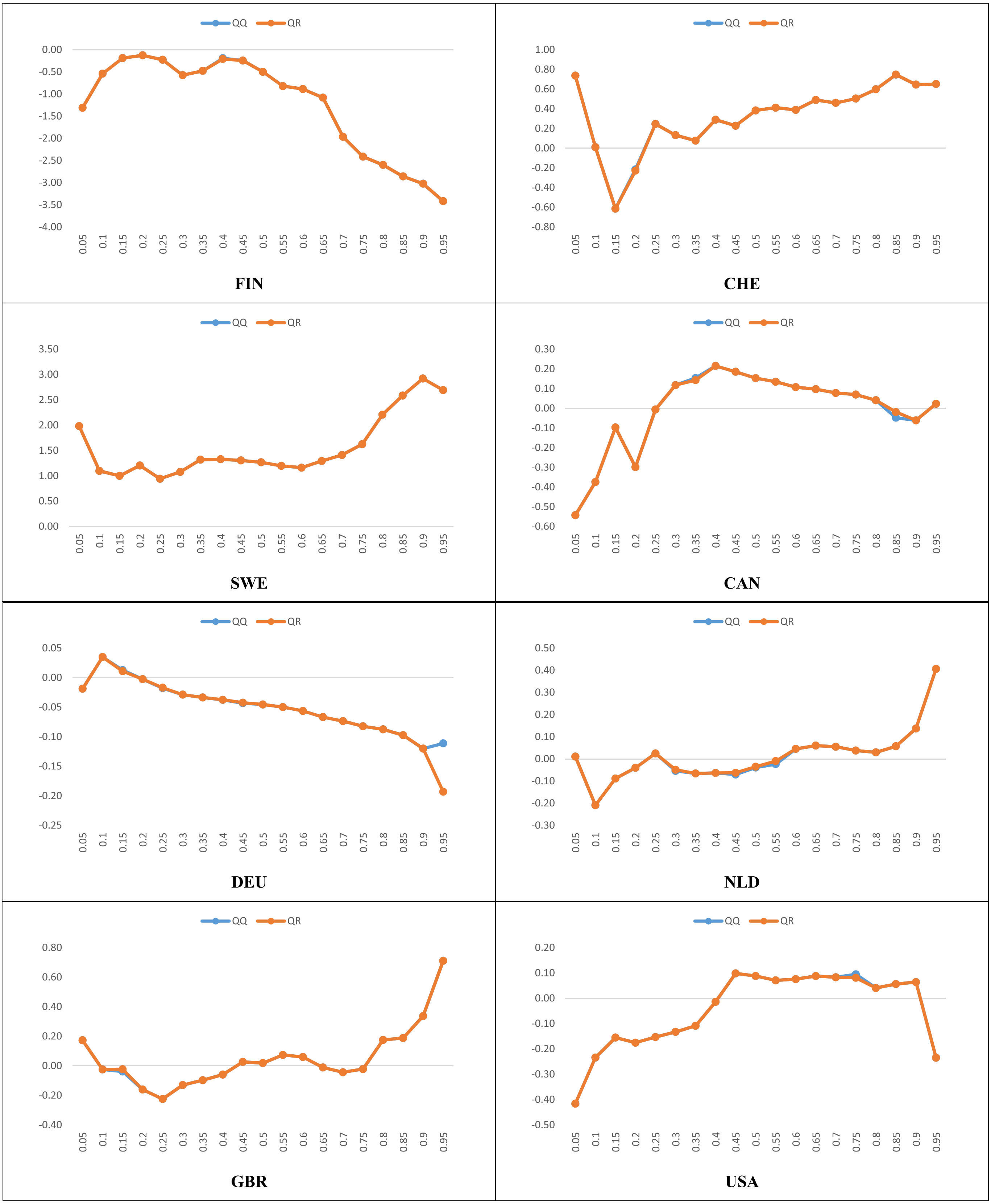
Not applicable.

Appendix A. Annex 1. Comparison of the QQ and QR Coefficients for NEC Effect on the CO_2


QQ
QR
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45 0.5 0.55 0.6 0.65 0.7 0.75 0.8 0.85 0.9 0.95
FIN
QQ
QR
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30
0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45 0.5 0.55 0.6 0.65 0.7 0.75 0.8 0.85 0.9 0.95
CHE
QQ
QR
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45 0.5 0.55 0.6 0.65 0.7 0.75 0.8 0.85 0.9 0.95
SWE
QQ
QR
0.02
0.00
-0.02
-0.04
-0.06
-0.08
-0.10
-0.12
-0.14
-0.16
0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45 0.5 0.55 0.6 0.65 0.7 0.75 0.8 0.85 0.9 0.95
CAN
QQ
QR
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45 0.5 0.55 0.6 0.65 0.7 0.75 0.8 0.85 0.9 0.95
DEU
QQ
QR
0.04
0.02
0.00
-0.02
-0.04
-0.06
-0.08
-0.10
0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45 0.5 0.55 0.6 0.65 0.7 0.75 0.8 0.85 0.9 0.95
NLD
QQ
QR
0.00
-0.02
-0.04
-0.06
-0.08
-0.10
-0.12
-0.14
-0.16
-0.18
-0.20
0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45 0.5 0.55 0.6 0.65 0.7 0.75 0.8 0.85 0.9 0.95
GBR
QQ
QR
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45 0.5 0.55 0.6 0.65 0.7 0.75 0.8 0.85 0.9 0.95
USA

Appendix B. Annex 2. Comparison of the QQ and QR Coefficients for PRI Effect on the CO_2



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