Policy Uncertainty, Economic Activity And Carbon Emissions: A Nonlinear Autoregressive Distributed Lag Approach

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Research Article

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Policy uncertainty, economic activity and carbon emissions: A nonlinear autoregressive distributed lag approach

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Abstract

Over the last few years, economic uncertainty has become a global concern. Not only has its impact on economic activities, but there are pieces of evidence that show uncertainty can be the reason for CO_2 emissions. It is also expected that the economic policy uncertainty may decrease or delay economic production, which may lead to a reduction in carbon emissions. Furthermore, uncertainty may decrease friendly environment policies and budgets, which cause increase in carbon emissions. Thus, there may be an asymmetric relationship between economic uncertainty and the amount of CO_2 emissions. This study investigates the effects of economic policy uncertainty and economic activity on carbon emission applying a Nonlinear Autoregressive Distributive Lag (NARDL) cointegration approach in Iran between 1971 and 2018. Findings show that both policy uncertainty and economic growth contribute to CO_2 emissions. The negative and positive shocks of GDP and uncertainty index on CO_2 emissions in both the short-run and long-run are significant. It can be concluded that there is an asymmetric effect of economic production on CO_2 emissions in Iran. The results of analyzing asymmetric effects of economic uncertainty show a symmetric relationship between uncertainty index and CO_2 emissions. In a way that a shock in uncertainty index lowers carbon emission. To sum up, since uncertainty may affect the analysis of carbon emissions incorrectly, some environmental policies such as allocating a budget for R&D on clean energy, and environmental taxes must be implemented.

Keywords CO_2 emissions . Economic policy uncertainty . Economic growth . NARDL approach . Uncertainty Index.

1. Introduction

Climate change, global warming, and environmental problems are the most critical issues in the recent decade (Anser et al. 2020). These factors can easily lead to a rise in aerosols and air pollution (Anser et al. 2021.a). Air pollution can also have noticeable side effects on the national economy (Chang et al. 2020). Since climate change and environmental degradation can result in several human diseases (Shahpari et al. 2021), they attracted the attention of international agencies to mitigate Greenhouse Gas (GHG). Furthermore, the GHG level is the main reason for global warming. Carbon dioxide (CO_2) as a primary greenhouse gas consists around 80% of GHG emissions, which is emitted trough human activities (IPCC, 2013). Therefore, limiting and controlling carbon dioxide emissions can reduce the adverse effects of climate change (Kompas et al. 2018; Atsu and Adams 2020). Climate change is an important challenge that may threaten attaining sustainable development through economic and environmental aspects. Therefore, to achieve sustainable development, a decrease in CO_2 emission is a critical fact. The process of how GHG emissions can impact the environment and the importance of CO_2 emissions are illustrated in Fig. 1.

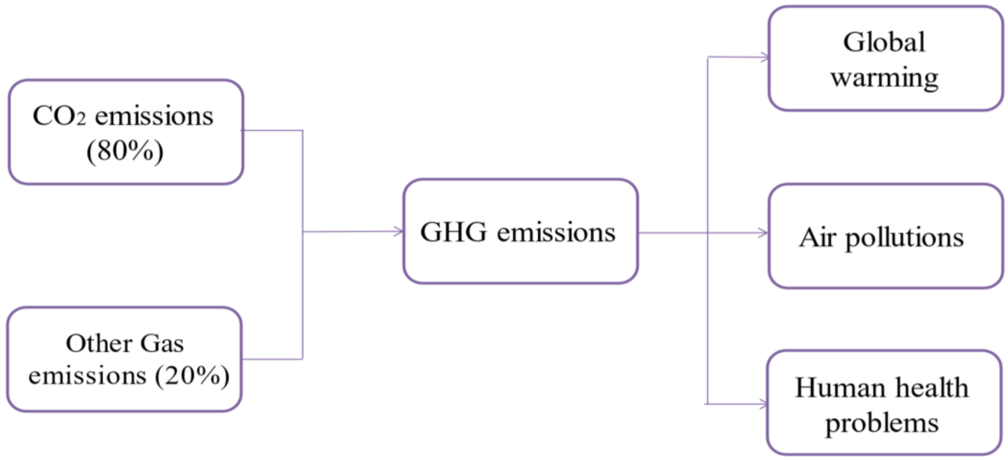


Fig. 1. The importance of CO_2 emissions

Simultaneously, concerns about Economic Policy Uncertainty (EPU) are another global concern. There are several literatures studying the effects of uncertainty on GDP or economic growth (Baker et al. 2016; Barrero et al. 2017; Wang and Sun 2017; Sahinoz and Erdogan Cosar 2018; Ghosh 2019; Altig et al. 2020; Alam and Istiak 2020; Razmi et al. 2020; Adedoyin and Zakari 2020; Anser et al. 2021.b). However, the critical point about economic uncertainty is that besides its economic consequences, it also has some environmental impacts implicitly (Atsu and Adams 2021; Reza Syed and Bouri 2021).

It is expected that policy uncertainty increases the cost of production. Uncertainty can easily encourage firms to compensate modern technology with an unfriendly environment and old production lines to decrease their cost of production. This change undoubtedly leads to an increase in the amount of CO_2 emissions. In addition, the budget allocated to renewable energy's R&D and innovation methods may reduce in uncertain circumstances. This could also result in a rise in fossil fuel consumption, leading to increased CO_2 emissions. Adams et al. (2020) stated that economic policy uncertainty might increase CO_2 emissions, especially in resource-rich countries, because policy uncertainty may limit innovations to reduce energy consumption and carbon emissions. On the other hand, policy uncertainty may decrease or delay economic production, which in turn will cause a reduction in carbon emissions (Chen et al. 2021).

Economic uncertainty is a helpful index to forecast a recession because as the uncertainty increase, firms decrease or delay their consumption and investment (Ercolani and Natoli 2020; Adedoyin and Zakari 2020). Therefore, it can be concluded that economic uncertainty will affects the investment plans.

Based on the above description of how uncertainty may have a relationship with the amount of CO_2 emissions, it can be concluded that economic uncertainty can either lead to a decrease or even an increase in CO_2 emissions. In other words, there can be an asymmetric relationship between economic uncertainty and the amount of CO_2 emissions. These consequences have been summarized in Fig. 2.

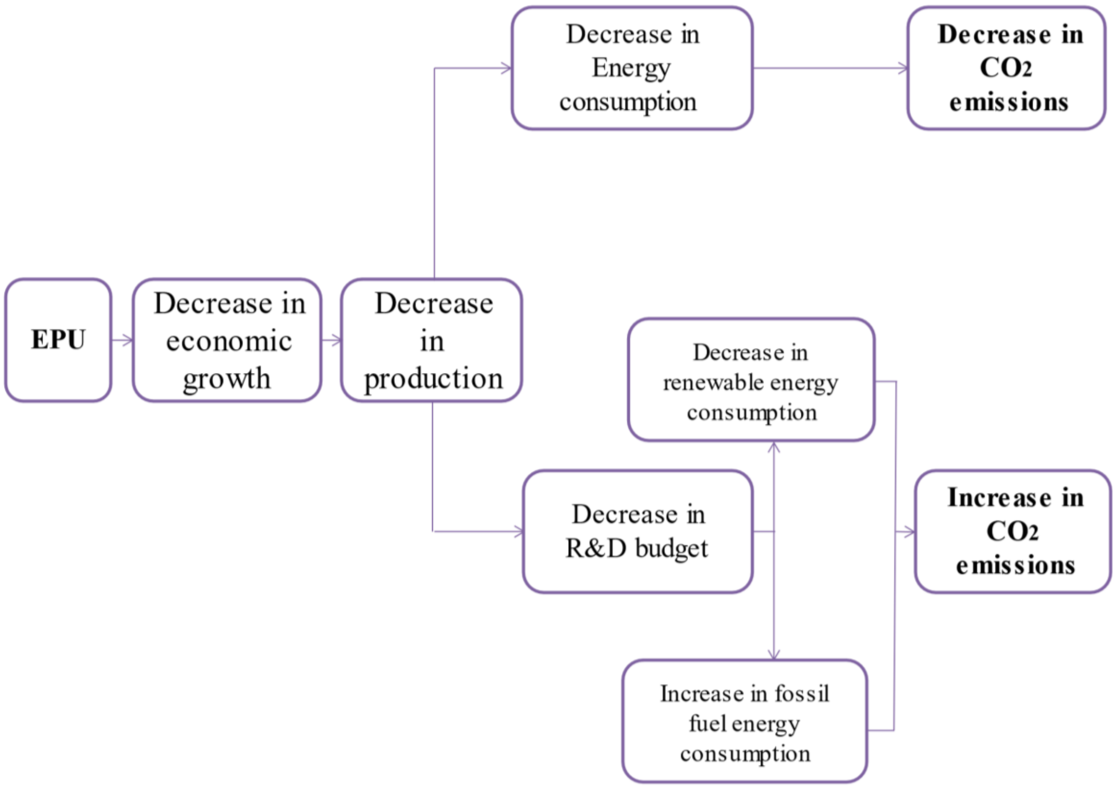


Fig. 2. The asymmetric effect of economic uncertainty on the amount of CO_2 emissions

Thus, studying policy uncertainty is essential to evaluate environmental effects and to provide policymakers with more robust information for reducing CO_2 emissions. This study tries to add new insights to the existing studies by exploring an index that incorporates the uncertainty condition of economics, which affects carbon emissions via economic activity changes. Specifically, the current research applies the asymmetric approach of the ARDL model to determine the effects of uncertainty index and GDP on CO_2 emissions.

Economic growth is the most significant phenomenon that can lead to environmental pollution and CO_2 emissions. In fact, in the initial steps of economic growth, countries pay more attention to production and less attention to environmental issues. The production methods and processes are not high-tech and efficient enough to prevent environmental problems (Dinda 2004; Pata et al. 2018). During economic growth time, the increase in the use of natural resources is inevitable. Indeed, during these years, natural resources consumption will be more than production capacity. Therefore, the amount of GHG emissions would be at higher levels (Pata et al. 2018). Increasing GHG emissions is a worldwide issue whose effect is not limited to a specific part of the world. This issue needs tackling instantly and globally (Hosseini et al. 2019).

According to the above discussion, developing countries choose higher production levels to achieve higher levels of economic growth, considering environmental pollution. According to the inverted U-shaped of Kuznets curve, the relationship between economic growth and environmental pollution depends on the development levels. When a developing country faces an increase in income per capita and welfare, economic growth and environmental pollution will negatively affect it. Thus, there would be a change in the relationship between economic growth and environmental degradation at the developed stages. Finally, as the development process continues, countries start to improve their production technologies, and the environmental degradation reduces (Stern 2004).

Iran is a developing country and one of the top 10 countries of CO_2 emitters (Ashena et al. 2020). Iran has been faced with different kinds of economic sanctions, providing economic uncertainty in recent decades. Therefore, it is an important issue to study how the economy reacts aftermath of such shocks. To the best of our knowledge, this is the first study that considers the impacts of uncertainty on CO_2 emissions in Iran. Furthermore, this study employs a nonlinear ARDL approach, which yields reliable results as it incorporates asymmetric effects. This study differs from previous papers in terms of the type of indicators, time series of a single country, and the method.

The rest of this article is organized as follows. In section 2, the background of study and study area has been expanded. Section 3 explains the methodology. Data and results are provided in section 4, while this article is concluded in section 5.

2. Literature Review

2.1. Previous Studies

Some studies show that economic growth is directly related to the increase in CO_2 emissions (Apergis and Payne 2010; Nejat et al. 2015; Xu et al. 2018). Other studies such as Shahbaz et al. (2020) determined the validity of the EKC hypothesis, indicating that economic growth can produce solutions to environmental problems in the long run. To sum up, most empirical assessment of the nexus between carbon emissions and GDP shows mixed outcomes.
Table 1 summarizes studies about the relationship between CO_2 emissions, economic growth, and EPU.

Table 1 Lists of previous studies

Authors	Findings	Methodology	Region of study
Shafiullah et al. (2021)	Using data from 1986 to 2019, they tried to model the consequences of economic policy uncertainty on renewable energy consumption. They showed that there is a negative long-run relationship between EPU and renewable energy consumption.	Nonlinear economic approaches	USA
Atsu and Adams (2021)	Throughout 1984-2017, they found fossil fuel consumption and EPU stirring up CO_2 emissions. However, renewable energy along with financial development mitigate CO_2 emissions. Therefore, they suggested promoting an economic policy to	Cross-sectional augmented ARDL model	Five selected countries

	stimulate investment in energy efficiency technology to reduce CO_2 emissions.		
Sohail et al. (2021)	They found that monetary policy uncertainty can negatively affect renewable energy consumption in the short run and long run.	ARDL model	USA
Reza Syed and Bouri (2021)	They find that in the short run, EPU intensifies CO_2 emissions. However, in the long run, EPU decreases CO_2 emissions, and therefore, higher levels of EPU can improve environmental quality.	A bootstrap ARDL approach	USA
Zakari et al. (2021)	From 1985 to 2017, they found a positive relationship between energy consumption and EPU with CO_2 emissions. However, this study also showed a negative relationship between renewable energy and CO2 emissions in the long run.	Pooled Mean Group (PMG) ARDL approach	OECD countries
Anser et al. (2021.a)	They studied the WUI on CO_2 emissions. For 1990-2015, they showed that an increase in WUI could decrease CO_2 emissions both in the short and long run.	a PMG-ARDL approach	Top ten carbon emitter countries
Anser et al. (2021.b)	They showed that EPU and non-renewable energy consumption could lead to environmental degradation. However, on the other hand, renewable energy consumption can result in a better ecological situation.	OLS and Dynamic Regression	Selected emerging economics
Razmi et al. (2020)	Their findings showed that EPU could play a vital role in forcing investors to transfer their investment to other sectors of the economy with more stability from 2009 to 2017.	GARCH-MIDAS approach	Iran
Pirgaip and Dincergok (2020)	From 1998 to 2018, they showed unidirectional causality from EPU to energy consumption in Japan. However, the same causality was found from EPU to CO_2 emissions in the USA and Germany. On the other hand, Canada has a unidirectional causality from EPU to CO_2 emissions and energy consumption.	A bootstrap panel, Grenger causality test	G7 countries
Adedoyin and Zakari (2020)	Based on their study on annual data from 1985-2017, EPU is more important in the short run and can increase CO_2 emissions. Nevertheless, on the other hand, in the long run, EPU reduces CO_2 emissions. The Granger causality showed that there is a one-way causality between: Energy consumption and CO_2 emission, CO_2 emission and EPU, Energy consumption and EPU.	ARDL model	UK

Wang et al. (2020)	From 1960 to 2016, they showed that per capita income increases CO_2 emissions in the long run. They used WUI as a proxy for EPU. Based on their findings, in the long run, WUI increases CO_2 emissions.	ARDL model	USA
Adams et al. (2020)	From 1996 to 2017, they find that in the short run, EPU intensifies CO_2 emissions. However, in the long run, EPU decreases CO_2 emissions, and therefore, higher levels of EPU can improve environmental quality. To study countries with high geopolitical risk, their results showed that in the long run; there is a significant relationship between economic uncertainty and CO_2 emissions.	A PMG-ARDL model	A group of high geopolitic al countries
Yu et al. (2020)	They estimated the effects of EPU on manufacturing firms' CO_2 emissions. They showed that an increase in EPU could increase carbon emission intensity for firms. They even concluded that firms try to use cheap and dirty fossil fuels to respond to this rising by an increase in uncertainty.	An unbalanced panel data	China

2.2. Theoretical background

In the 2015 United Nations Climate Change Conference in Paris, Iran made an international commitment in order to reduce CO_2 emissions. According to this commitment, Iran has to reduce 8-12% of the CO_2 emissions from its level in 2005 by 2030 as its long-run development plan (Hosseini et al. 2019; Ashena et al. 2020). In Fig. 3, the Iran CO_2 emissions rate of growth from 2001 to 2019 has been illustrated. From Fig. 3, it is evident that during this time interval, the rate of growth is always positive except for 2015, when the commitment was signed.

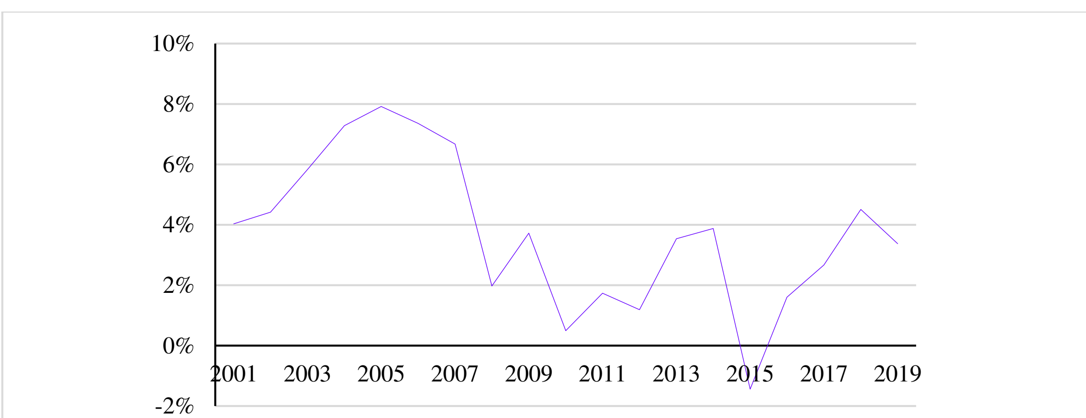


Fig. 3. CO_2 emissions rate of growth from 2001 to 2019 in Iran

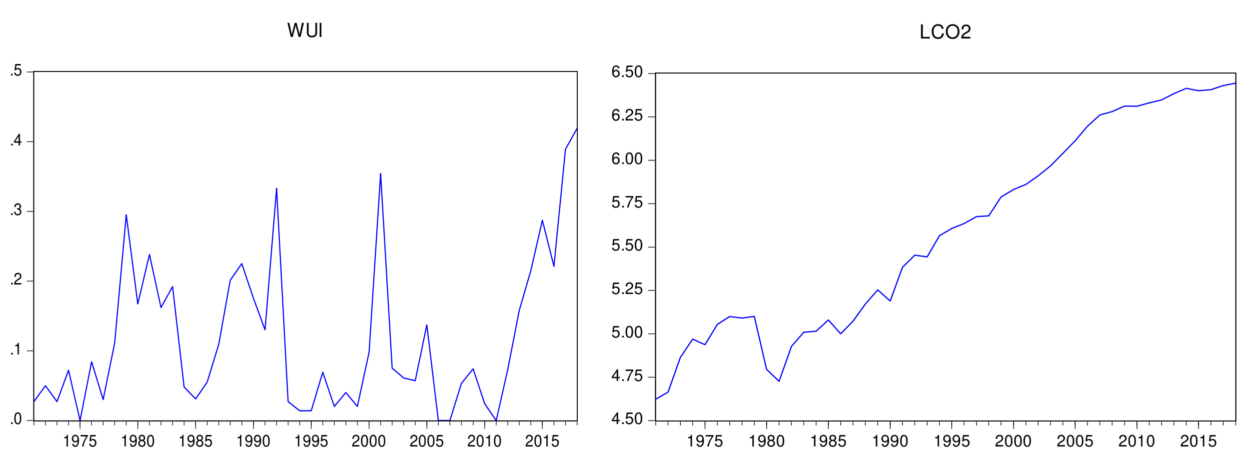
There is not a single definition for economic uncertainty, according to the literature. In other words, there is no agreed-upon unique definition for the concept of economic uncertainty (Al-Thaqeb and Algharabali 2019). However, Jin and Wu (2021) explained EPU as the uncertainty associated with signs in monetary and fiscal policies and government regulations that influence how people and firms have their economic activities. In general, economic uncertainty can be categorized into different groups:

1. Uncertainty contributes to market volatility such as regulatory or monetary policies
2. Unexpected changes contribute to the economic ecosystems (Al-Thaqeb and Algharabali 2019).

The other important point is that many factors can be the reason for uncertainty. Moreover, some of these factors have both short-run and long-run effects. Therefore, to study the effects of economic uncertainty, it is essential to consider the time horizon.

There are some indices to measure uncertainty; for instance, the Chicago Board Options Exchange has been used the volatility index (VIX) for many years as an accepted proxy for firm uncertainties in the equity market (Al-Thaqeb and Algharabali 2019). However, VIX works best for mature markets and is not appropriate for all countries. Methods of text-mining and word counting are usual ways to measure economic uncertainty: keyword-based methods. Regarding these methods, some keywords identify the index, such as "uncertain" and "uncertainty." Thus, uncertainty index is measured by news containing these keywords (Al-Thaqeb and Algharabali 2019; Kaveh-Yazdy and Zarifzadeh 2021). Economic Policy uncertainty (EPU) is an uncertainty index calculated based on text-mining in newspaper articles of leading newspapers. World Uncertainty Index (WUI) is another measure of uncertainty, which uses a single source for all countries to compare the level of uncertainty across countries. This index captures uncertainty related to economic and political events.

Fig. 4. shows the time trend of the carbon emissions, GDP, and economic uncertainty for Iran during the research period. As it is shown, GDP and CO_2 variables have been increasing, while economic uncertainty fluctuates during the research period. Meanwhile, WUI has been experiencing a positive upward trend since 2011.



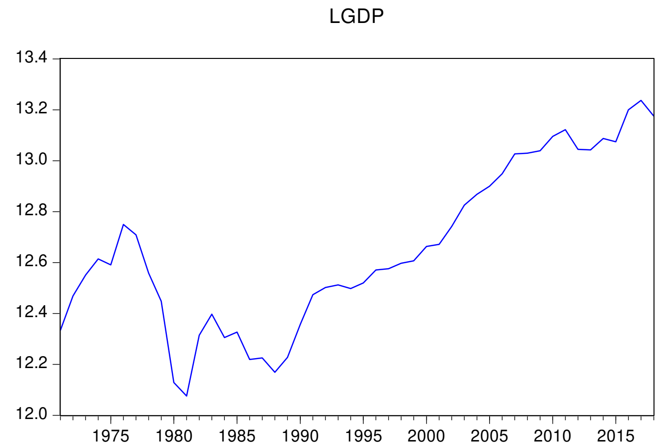


Fig. 4. Trends in CO_2 emission, GDP, and WUI from 1971 to 2018.

Source: Authors compilation

3. Methodology and Model Specification

Since ARDL is a strong approach for short-run and long-run analysis, it has become a popular and widely used approach, especially for time series analysis (for example, for Irans' economy, Shahpari and Davoudi 2014 and Shahpari et al. 2020 used ARDL). This study uses yearly data for Iran in the 1971-2018 period. In this study, uncertainty index for Iran is obtained from a database of policy uncertainty of WUI based on Ahir at al. (2018). Other data are obtained from database of World Development Indicators (WDI).

Based on Shin et al. (2014) and Hatemi-j (2012), the nonlinear and asymmetric cointegration tests are applied in investigating the cointegration and long-run relationship between the dependent variable (CO_2) and the explanatory variables (GDP, energy intensity, and economic uncertainty). The nonlinear ARDL is considered in this study because of its advantage over other time series approaches.

The nonlinear ARDL approach of cointegration does not need a particular order of integration for cointegration analysis, and a mixed order of integration I(0) and I(1) could be applied.

This study assesses whether the uncertainty index could affect CO_2 emissions. Based on the research variables, the generalized form of the study model can be represented as follows:

$$\mathrm{LCO}_{2t} = \beta_0 + \beta_1 \mathrm{LGDP}_t + \beta_3 \mathrm{UI}_t + \beta_2 \mathrm{LEI}_t + \varepsilon_t \qquad (1)$$

where LCO_2, LGDP, UI, and LEI represent the natural logarithm of carbon emission (million-ton carbon equivalent), the natural logarithm of GDP (million $ US), economic uncertainty index, the natural logarithm of energy intensity, and ε is the error correction term.

Then, the nonlinear bound test approach is applied to investigate the cointegration relationship. This bound test is developed by Shin et al. (2014) as an extended version of Pesaran et al. (2001). Decomposing selected independent variables can extend the linear version of the Unrestricted Error Correction Model (UECM) into positive and negative shocks (Shin et al. 2014). The ARDL (p, q) is converted to the NARDL (p, q) by considering the positive and negative components as follows:

$$\mathrm{LCO}_{2t} = \sum_{j=1}^{p} \varphi_j \mathrm{LCO}_{2t-j} + \sum_{j=0}^{q} (\beta_{1j}^{+} \mathrm{LGDP}_{t-j}^{+} + \beta_{2j}^{-} \mathrm{LGDP}_{t-j}^{-} + \beta_{3j}^{+} \mathrm{UI}_{t-j}^{+} + \beta_{4j}^{-} \mathrm{UI}_{t-j}^{-} + \beta_5 \mathrm{LEI}_{t-j}) + \varepsilon_t \quad (2)$$

So that p and q are the optimal number of lags, φ_j are the coefficients of the dependent variable lags, β_{ij} are the coefficients of the independent variables lags. According to the following relation, the selected independent variables are decomposed into positive and negative components:

$$LGDP_t^{+} = \sum_{j=1}^{t} \Delta LGDP_t^{+} = \sum_{j=1}^{t} \max(\Delta LGDP_t^{+}, 0)$$

$$LGDP_t^{-} = \sum_{j=1}^{t} \Delta LGDP_t^{-} = \sum_{j=1}^{t} \min(\Delta LGDP_t^{-}, 0)$$

$$UI_t^{+} = \sum_{j=1}^{t} \Delta UI_t^{+} = \sum_{j=1}^{t} \max(\Delta UI_t^{+}, 0)$$

$$UI_t^{-} = \sum_{j=1}^{t} \Delta UI_t^{-} = \sum_{j=1}^{t} \min(\Delta UI_t^{-}, 0) \quad (3)$$

Where $LGDP_t^{+}, UI_t^{+}$ are partial sum processes of positive changes and $LGDP_t^{-}, UI_t^{-}$ are partial sum processes of negative changes.

The model of NARDL(p,q) with the asymmetric error correction is presented as follows:

$$\Delta LCO_{2t} = \gamma_0 + \gamma_1 LCO_{2t-1} + \gamma_2^{+} LGDP_{t-1}^{+} + \gamma_3^{-} LGDP_{t-1}^{-} + \gamma_4^{+} UI_{t-1}^{+} + \gamma_5^{-} UI_{t-1}^{-} + \gamma_6 LEI_{t-1} + \sum_{j=0}^{p-1} \alpha_{1j} \Delta LCO_{2t-i} + \sum_{j=0}^{q-1} \alpha_{2j}^{+} \Delta LGDP_{t-i}^{+} + \sum_{j=0}^{q-1} \alpha_{3j}^{-} \Delta LGDP_{t-i}^{-} + \sum_{j=0}^{q-1} \alpha_{4j}^{+} \Delta UI_{t-i}^{+} + \sum_{j=0}^{q-1} \alpha_{5j}^{-} \Delta UI_{t-i}^{-} + \sum_{j=0}^{q-1} \alpha_6 \Delta LEI_{t-i} + \varepsilon_t \quad (4)$$

Where α, γ represent the short-run and long-run effects of variables. The short-run and long-run analysis investigate the effect of independent variables shock on CO_2 emissions and assess the adjustment speed.

The bound-test is done on all the lagged levels of the independent variables. The null hypothesis, no cointegration against the existing cointegration, is investigated by F-statistics. The null hypothesis is rejected where estimated F-statistics are more significant than the upper bound and vice versa (Pesaran et al. 2001). If the values of the F-statistics lie between the upper and lower bounds, no precise decision can be made. Based on the results of the cointegration, the null hypotheses of symmetric coefficients in long-run or short-run can be tested using the Wald statistic following an asymptotic χ^2distribution.

4. Data and estimation results

4.1. Data

In this study, CO_2 emissions is considered as the dependent variable, and the influence of uncertainty index and GDP is investigated. Moreover, energy intensity is considered as a control variable in the model. Likewise, although there are several uncertainty indices, this study uses the world uncertainty index. It should be noted that the research variables are transformed into logarithmic forms.

Approaches such as Dickey-Fuller (DF 1979); and Philips-Perron (PP 1990) methods were applied in this study for the test of a unit-root. The unit-root test results are presented in table 2, in which both tests indicate that variables including LCO_2 and LGDP have a unit root in the level form and are stationary in the first-difference form. While UI and LEI variables are stationary in the level form. As stated before, the NARDL approach could be used for variables with mixed order of integration I(0) and I(1).

Table 2 Unit root test for variables

ADF unit root test				
Variable	levels		First difference	
	Without trend	With trend	Without trend	With trend
LCO_2	-0.76(0/81)	-2.02(0/57)	-5.75(0.00) *	-5.67(0.00) *
LGDP	-0.48(0/88)	-2.16(0.49)	-4.75(0/00) *	-4.85(0.00) *
UI	-3.09(0.03) **	-3.22(0.05)	-	-
LEI	-3.53(0.01) *	-4.00(0.01) *	-	-
PP Unit Root Test				
LCO_2	-0.76(0/81)	-2.13 (0.51)	-6.18(0.00) *	-6.13(0.00) *
LGDP	-0.50(0/88)	-1.78(0.69)	-4.93(0/00) *	-4.85(0.00) *
UI	-2.98(0.04) **	-3.18(0.09)	-	-
LEI	-5.04(0.00) *	-2.98 (0.00) *	-	-

Notes: (**) and (*) denote significance at 5% and 1% significance level, respectively
Source: Authors estimation

4.2. Estimation results

Table 3 shows the results of the asymmetric cointegration test. Based on the bounds test approach, the long-run cointegration is confirmed, as F-statistic is greater than the critical value of the upper bound.

Table 3 Asymmetric Cointegration test results

F-statistic	Critical Value at %1 Significance Level	
Null Hypothesis: No long-run relationships exist	Bottom Bound	Upper Bound
6.69	3.06	4.15

Source: Source: Authors estimation

These results established a long-run relationship among the variables. The estimate of the long-run coefficients is reported in table 4. The optimal lag length is selected based on the Akaike Information Criterion (AIC). Furthermore, the error correction form is estimated to distinguish the short-run effects of the descriptive variables from their long-run effects (Table 5).

The long-run and short-run NARDL results show a significant relationship between CO_2 emissions and descriptive variables. According to table 4, positive and negative shocks in the partial sum of LGDP increases CO_2 emissions, and the relationship is not symmetric. This conclusion is in line with theoretical foundations and expected results. According to the previous studies (Lotfalopour et al. 2010; Ghorashi and Alavi Rad 2017; Solaymani 2020), there is a positive relationship between increasing production and CO_2 emissions in Iran. The effect of adverse shocks of GDP on carbon emissions in the long-run and short-run is also positive. LGDP has the most significant effect on CO_2 emission. Based on the results, a one percent positive shock to LGDP causes a 1.1 percent increase, and a one percent negative shock causes a 0.71 percent increase in CO_2 emissions. In justifying this result, it can be mentioned that due to the low energy price and low environmental regulation in Iran, energy is not used optimally and efficiently.

The results of positive and negative shocks of UI on CO_2 emissions show negative relationship. In other words, a positive or negative shock in UI will decrease CO_2 emissions. This implies that higher levels of economic policy uncertainties adversely affect CO_2 emissions in Iran. This results implying that policy uncertainty may decrease or delay economic production, which in turn will cause a reduction in carbon emissions (Chen et al. 2021). This result, especially for countries that have fossil fuel as a natural resource, is expected. Because usually, in such countries, energy consumption is based on fossil fuel usage. Therefore, when the production decreases, CO_2 emission definitely decreases due to the decline in fossil fuel usage.

LEI, which is regarded as a control variable in the model, shows a positive relationship with CO_2 emissions. So that increasing energy intensity will raise CO_2 emissions.

Table 4 long-term coefficient estimates of ARDL model (2, 4, 3, 4, 4, 3)

Variables	coefficient	t-statistics
$LGDP^+$	1.10*	11.24
$LGDP^-$	0.71*	4.80
UI^+	-0.86*	-6.09
UI^-	-.099*	-5.86
LEI	0.26**	2.19
C	6.90*	6.13

Notes: (**) and (*) denote significance at 5% and 1% significance level, respectively
Source: Authors estimation

Table 5 short-term coefficient estimates of ARDL model (2, 4, 3, 4, 4, 3)

Lag order	0	1	2	3
ΔLCO_2		-0.74(0.00) *		
Δ $LGDP^+$	1.45(0.00) *	-0.08(0.50)	0.40(0.00) *	0.28(0.05) **
Δ $LGDP^-$	0.64(0.00) *	0.08(0.61)	0.79(0.00) *	
Δ UI^+	0.32(0.00) *	1.82(0.00) *	1.06(0.00) *	1.71(0.00) *
Δ UI^-	0.00(0.96)	1.05(0.00) *	1.44(0.00) *	
LEI	0.66(0.00) *	0.39(0.00) *	0.38(0.00) *	0.12(0.05) **
ECM	-0.66(0.00) *	R^2 =0.94	$AdjR^2$=0.90	

Notes: (**) and (*) denote significance at 5% and 1% significance level, respectively
Source: Authors estimation

Finally, the asymmetric impact, in the long run, is examined by the Wald test. The results presented in table 6 show the significance of asymmetry in the long-run parameter of LGDP. Moreover, the null hypothesis of a symmetric long-run relationship for UI is not rejected and suggests symmetric effects of UI on carbon emission.

Table 6 Long-run asymmetries (WALD test)

Variables	x2Chi-Square [Prob]	Asymmetry
LGDP	5.65(0.01) *	yes
UI	1.41(0.23)	no

Notes: (*) denote significance at 1% significance level.
Source: Authors estimation

Table 7 reports the model residual diagnostic tests, including autocorrelation, heteroscedasticity, Ramsey RESET, and normality tests. The results of these residual diagnostic tests indicate that the null hypothesis of autocorrelation, heteroscedasticity, model stability, and normality cannot be rejected. Furthermore, Fig. 5 represents CUSUM and CUSUMSQ tests of the model. The figures show stability in the model, as the significant lines lie between the critical lines.

Table 7 Diagnostic Test

Serial correlation (LM) Test	2.24(0.11)
Heteroskedasticity Test (BPG)	2.54(0.25)
RESET Test	0.93(0.34)
Normality Test	1.52(0.46)

Notes: (*) denote significance at 1% significance level.
Source: Authors estimation

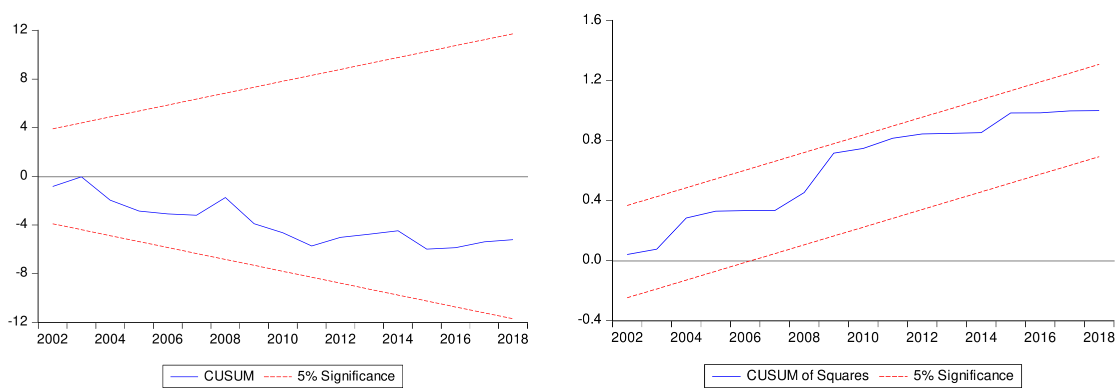


Fig. 5. The CUSUM and CUSUMSQ tests for residuals, obtained by the ARDL approach
Source: Authors estimation

5. Conclusion and policy implications

In recent decades, Economic uncertainty has increased rapidly. Economic uncertainty can delay the investment plans directly and, therefore, decreases production. Results of previous research confirmed that uncertainty is a reason for sharp recessions (Bloom 2017; Kaveh-Yazdy and

Zarifzadeh 2021). In addition to this economic consequences, economic uncertainty can also have environmental impacts (Anser et al. 2021.a;b). For countries such as Iran, which use fossil fuel as their energy resource in the production process, this decreases fossil fuel energy consumption and CO2 emission.

This study analyzed policy uncertainty and economic growth on carbon dioxide emissions in one of the most carbon dioxide emitter countries, Iran. Applying NARDL approach, the cointegration tests revealed a long-run relationship for all variables. The findings of the study suggest that policy uncertainty and economic growth contribute to CO_2 emissions. The negative and positive shocks of LGDP and UI on CO_2 emissions in both the short-run and long-run are statistically significant. The coefficients of LGDP indicate a positive effect of economic production on carbon emission in Iran. These findings are consistent with those of Lotfalopour et al. (2010), Ghorashi and Alavi Rad (2017), and Solaymani, 2020 as economic growth is associated with more energy consumption and CO_2 emissions. It should be noted that the estimated results indicate an asymmetric effect of economic production on carbon emission in Iran, implying to different responses to the negative and positive shocks.

The results of analyzing asymmetric effects of UI show a symmetric relationship between UI and CO_2 emissions. In a manner that a shock in policy uncertainty lowers the carbon emission. Similar to Pirgaip and Dincergok (2020), mitigating CO_2 emissions in Iran may occurs at the cost of uncertainty increasing. Meanwhile, Kaveh-Yazdy and Zarifzadeh (2021) also found that EPU can be the reason for higher unemployment rates which is also a signal of decrease in production levels. Ercolani and Natoli (2020) also used economic uncertainty to forecast recession periods, another definition for the decrease in production levels.

Therefore, if policymakers are tend to mitigate environmental pollution and economic uncertainty simultaneously, some complementary policies are needed. In other word, to decouple economic growth from CO_2 emissions, it is required to invest in R&D, applying low-carbon technologies and energy efficiency targets.

The implication of the relationship between policy uncertainty and CO_2 emission is that uncertainty makes it challenging to decide on economic activity, and it cannot be ignored in the GDP–CO_2 emissions relationship. Furthermore, although policy uncertainty will reduce CO_2 emissions in Iran, it should be noted that this result may cause locking into the existing fossil-fuel-based economy structure. Therefore, it is reasonable for the countries to promote economic policy that encourages innovation and stimulates capital investment in energy efficiency equipment or appliances. R&D budget should be raised to find new methods of clean production. Allocating subsidies for clean production methods is another practical policy to reduce fossil fuel consumption and encourage firms to apply modern technologies. Finally, political uproar and unrest should be adequately addressed to reduce its effect on emissions.

Declarations

Ethics approval and consent to participate Not applicable

Consent for publication Not applicable

Availability of data and materials All data generated or analyzed during this study are included in the reference list of this article. Data will be available upon request.

Competing interests The authors declare no competing interests.

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Authors' contributions MA analyzed data and developed the model regarding the relationship between economic uncertainty and CO2 emissions. GS prepared the historical literature and introduction part of the manuscript. Both authors read and approved the final manuscript.

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