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How Does Nuclear Energy Affect Environmental Pollution? Evidence from the United States

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Abstract

Research Originality: Nuclear power plant installation activities, which have gained momentum since the 1970s, have made nuclear energy widespread. The US ranks first in the world in nuclear energy use. This article contributes to the existing literature on environmental economics by incorporating environmental technologies and globalization into investigating the impact of nuclear energy on environmental pollution.

Research Objectives: This study aims to analyze the effects of nuclear energy consumption, environmental technologies, and globalization on environmental pollution in the US..

Research Methods: The paper use ARDL approach with the data of 1970-2018 period.

Empirical Results: According to the findings, nuclear energy consumption negatively affects environmental quality in the US both in the short and long run. On the contrary, environment-related technologies contribute positively to environmental quality, reducing carbon footprint in the long run. Also, globalization has an insignificant effect on the environment in both the short and long run.

Implications: Supporting environmental technologies and exchanging nuclear energy with renewable energy sources in the US is thought to improve environmental quality.

Keywords:

nuclear energy; ecological footprint; environmental technologies; ARDL approach

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INTRODUCTION

Economic growth, industrialization, urbanization, and population are key factors in increasing energy supply and demand. The energy that helps individuals carry out their daily activities also affects the socio-economic stability of a country (Sadiq et al., 2022b). On the other hand, environmental pollution is inevitable if increased energy consumption is welcomed by fossil energy sources such as coal, natural gas, and oil. Thus, environmental protection requires the widespread use of cleaner energy sources. One of these alternative sources is nuclear energy. Many studies in the literature have suggested that nuclear energy contributes to improving environmental quality in the fight against climate change (Hassan et al., 2020; Bandyopadhyay & Rej, 2021; Danish et al., 2021; Ali et al., 2022; Majeed et al., 2022; Ozgur et al., 2022; Sadiq et al., 2022a). For Pakistan, Majeed et al. (2022) investigated the asymmetrical effects of nuclear energy on carbon emissions. FMOLS and DOLS estimators showed that nuclear energy has a negative impact on both short-term and long-term carbon emissions. The VECM finds a two-way causal relationship between nuclear energy and carbon emissions. Ozgur et al. (2022) studied the relationship between nuclear energy consumption and CO2 emissions in India from 1970-2016 using the Fourier ARDL test. In India, nuclear energy consumption has been shown to contribute to improving environmental quality. Sadiq et al. (2022a) studied the relationship between nuclear energy and CO2 emissions in BRICS countries using second-generation forecasting approaches. As a result, a bilateral causal relationship has been found between carbon emissions and nuclear energy consumption.

Jahanger et al. (2023) studied the relationship between CO2 emissions, GDP, nuclear energy use, and technological innovation variables using the MMQR method with data covering the top 10 economies that generated the most electricity using nuclear resources from 1990 to 2017. The empirical findings show that nuclear energy has reduced environmental pollution in the lower, middle, and upper percentages. With data covering 1993-2020 for BRICS countries, Hassan et al. (2024) examined the impact of GDP, renewable energy, geopolitical risk, environmental technologies, and nuclear energy consumption on greenhouse gas emissions using the Panel Quantile Regression method. The study's findings indicate that the use of nuclear energy negatively impacts greenhouse gas emissions. Furthermore, the papers of Baek (2015) for the top nuclear-producing countries, Jin & Kim (2018) for the 30 countries using nuclear energy, Saidi & Omri (2020) for the OECD countries, Azam et al. (2021) for China, Bandyopadhyay et al. (2022) for the top nine nuclear energy consuming economies (Canada, China, France, Germany, Japan, South Korea, Sweden, Russia, and the United States), Pata & Samour (2022) for France have proven the negative association between nuclear energy and environmental pollution.

On the other hand, the contribution of nuclear energy to environmental quality has yet to be established. In other words, the environmental impact of nuclear energy is still a subject of debate (Çakar et al., 2022). The negative environmental impact of nuclear energy is caused by radioactive waste. However, there is little evidence that

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nuclear energy pollutes the environment. Bian et al. (2021) focus on the relationship between climate change and earthquakes in Taiwan's nuclear power plants. The findings of the OLS method show that nuclear power plants have a positive relationship between risk perception, climate change, and the presence of earthquakes. Sadiq et al. (2022b) analyzed the impact of nuclear energy consumption on the country's environmental footprint, with the top ten ecological footprints from 1990-2017. The authors used Driscoll-Kraay Standard Errors, FGLS, and Panel Adjusted Standard Errors (PCSE) methods for long-term coefficient estimation. The findings revealed that nuclear energy consumption, environmental technology, and population density have significant negative effects on the ecological footprint and that globalization and economic growth have significant positive impacts on the environmental footprint.

Another important point in this study is investigating the source of environmental pollution in the context of technological innovations related to the environment. Environmental technology reduces the negative environmental impact of human activities through practices that protect natural resources and the environment. Environmental technologies, such as wind stations and photovoltaics, are also used to identify energy generation equipment (Usman et al., 2022). In recent years, developed countries have implemented environmental and technological developments in order to achieve their targets of reducing greenhouse gas emissions (Ahmed et al., 2020). Therefore, the relationship between environmental technology and environmental problems is an issue of interest to many academics and researchers (Usman & Hammar, 2021). Since the late 1950s, the relationship between environmental quality and technological progress has been investigated (Dietz & Rosa, 1997).

However, the study of the relationship between environmental technological innovations and environmental pollution is more recent. Ahmed et al. (2020) analyzed the relationship between environmental technological change, CO2 emissions, fossil and renewable energy consumption, and economic growth in Brazil, India, China, and South Africa. They found that developments in environmental technology could reduce CO2 emissions. Bai et al. (2020) determined that renewable energy technologies increase CO2 emissions in China. Alataş (2022) found that environmental-related technologies did not significantly impact CO2 emissions from the transportation sector between 1977 and 2015 for 15 EU countries. Hussain et al. (2022) concluded that environmental technologies reduced carbon emissions for E-7 countries. Fatima et al. (2023) examined the relationship between foreign direct investment inflows, trade openness, environmental technologies, environmental taxes, economic growth, and environmental pollution using data covering 1990-2020 for 36 OECD countries using the Panel ARDL method. Environmental technologies have a negative impact on CO2 emissions both in the long term and short term.

Another factor that contributes to economic growth is globalization (Panayotou, 2000). Globalization affects the environment through economic, political, and social integration (Kalaycı & Hayaloğlu, 2019). The environmental impacts of globalization

can be positive or negative. The positive effects of globalization on the environment can be reflected in the study of the ozone layer and the promotion of environmental norms and standards in the management of climate change issues (Kirkman, 2015). Moreover, globalization contributes to developing new technologies and raises environmental standards by improving the environmental awareness of individuals in countries that apply environmentally friendly production methods. One recent study that identified the positive impact of globalization on the environment was carried out by Aluko et al. (2021). Aluko et al. (2021) studied the relationship between globalization and environmental degradation in 27 selected industrialized countries and found that economic globalization reduces environmental deterioration.

Farooq et al. (2022) studied the relationship between globalization and environmental degradation using the panel's quantile regression method for 180 countries. General and political globalization help improve environmental degradation, while economic globalization pollutes the environment. Mehboob et al. (2024) examined the CS-ARDL method, which consists of nuclear energy consumption, environmental taxes, globalization of trade, economic growth, population density, and consumption-based CO2 emissions in the five countries with the highest carbon emissions between 1990 and 2020. According to the findings, globalization has contributed to improving environmental quality. Despite these positive effects, globalization can also cause an explosion. Globalization can undermine the quality of the environment by increasing production, energy consumption, international transport, and the use of natural resources (Kalaycı & Hayaloğlu, 2019).

Furthermore, liberalization of globalization trade can increase environmental pollution in these countries, causing polluting-intensive firms to move their investments to countries with weaker environmental laws (Gallagher, 2009). Empirical studies have also concluded that globalization increases environmental pollution. Pata (2021) found that globalization increased CO2 emissions in BRIC countries. Using the ARDL approach, Yurtkuran (2021) identified that globalization increased CO2 emissions for Türkiye. Globalization has deteriorated the quality of the environment, identified the MENA countries in their study by Heidary et al. (2021). One recent study by Haq et al. (2024) found that globalization increases environmental pollution in SAARC countries.

Nuclear energy is a source of energy that contributes to the solution of countries' energy supply problems (Ozgur et al., 2022). Thus, it may be interesting to discuss determining the environmental impact of nuclear energy compared to other environmentally friendly sources. Previous studies focused on the impact of nuclear energy consumption on economic growth, and research on the environmental effects of nuclear power has remained limited. It addresses the research gap by analyzing the impact of nuclear energy and other factors on environmental quality, particularly in the US. This study aims to investigate the relationship between nuclear energy consumption, environmental technologies, globalization, and environmental

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pollution in the United States during the 1970-2022 period by applying the ARDL method.

This study has some contributions to the current literature. The first is that while studies investigate the relationship between nuclear energy consumption and environmental pollution, research into environmental technologies and the impact of globalization should be more noticed. Globalization, on the one hand, promotes resource consumption and increases environmental pollution by increasing production, while on the other hand, it promotes environmentally friendly solutions by promoting technological advances. As environmental technologies evolve, cleaner energy production is also encouraged, and the risk of environmental pollution can be reduced. That is why we have incorporated the indicator of technological innovation and globalization into the relationship between nuclear energy consumption and environmental quality. Secondly, it is worth studying the environmental impact of nuclear energy on the US. As the world's richest and most developed country, the US economy depends on fossil-fuel energy sources, which are responsible for significant global carbon emissions. The US economy is one of the countries with the largest share in nuclear energy consumption. The third contribution of the study concerns the method. Using the ARDL method, our research analyses the short and long-term impact of nuclear energy, globalization, and environmental technologies on environmental quality. This study provides valuable insights into how the environmental quality of the US economy is developing.

The relationship between the quality of nuclear energy and the environment in the US (Pan & Zhang, 2020; Hassan et al., 2020; Hassan et al., 2023; Kartal et al., 2023), the relationship between environmental technologies and environmental quality (Adebayo & Özkan, 2024; Chien et al., 2021; You et al., 2022) and the relation between globalization and quality of the environment (Sun et al., 2021; Usman et al., 2020; Gangopadhyay et al., 2023) have been studied separately in the literature. As far as we know, no other study in the US examines the impact of nuclear energy consumption, environmental technologies, and globalization on environmental pollution (ecological footprint). So, this study can fill this gap in the literature.

METHODS

This section describes the sources of the relevant data by describing the data set using the study. The basic econometric model standing for the relationship was then introduced. Methodological information on the econometric method used to test this relationship has been provided and the test results have been. The study examines the relationship between environmental quality, globalization, environmental technologies, and nuclear energy consumption with data from the 1970-2022 period for the United States. For this purpose, the data set used in the study and the source of the related data are shown in Table 1.

Table 1. Used Variables and Resources

Variable	Description	Explanation	Resource
ECF	Ecological footprint	Carbon footprint per person (Gha)	Global Footprint Network
GDP	Economic growth	GDP per capita (2015 constant)	WDI
NUC	Nuclear energy consumption	Nuclear energy consumption per capita (kWh))	Our World in Data
TEC	Environmental technologies	Total number of patents for environmental technologies	OECD statistics
GLOB	Globalization	Globalization Index	KOF Swiss Institute of Economics
URB	Urbanization	Proportion of total urban population	WDI
TRA	Trade	Total trade share in GDP	WDI

The basic function adopted to describe the relationship using the variables in Table 1 is as follows:

$$ECF_t = f\ (GDP_t,\ NUC_t,\ TEC_t,\ GLOB_t,\ URB_t,\ TRA_t) \quad (1)$$

A time series model created around this model is as follows:

$$ECF_t = \beta_0 + \beta_1 GDP_t + \beta_2 NUC_t + \beta_3 TEC_t + \beta_4 GLOB_1 + \beta_5 URB_t + \beta_6 TRA_t + \mu_t \quad (2)$$

In the model, the ECF represents the ecological footprint per capita, is adopted as an environmental quality indicator, and constitutes the model's dependent variable. As independent variables, it represents GDP per capita, NUC per person consumption of nuclear energy, TEC environmental technologies, the degree of globalization of the GLOB, the urban population of the URB, and the share of total trade in GDP. μ_t is included in the model as an error term, while t corresponds to the time dimension of the study (1970-2022).

The analysis phase of the study was primarily tested with Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests. The different degrees of stability of the series depending on the unit root results obtained from both test results required the adoption of the Autoregressive Distributed Lag (ARDL) approach in the subsequent phase of co-integration and for the estimation of the short- and long-term ratio.

This approach, introduced by Pesaran & Shin (1995) and Pesaran et al. (2001), supplies consistent estimates of asymptotically normal long-term coefficients, regardless of whether they are series I (0) or I (1). The ARDL boundary test equation is formulated as follows (Pesaran & Shin, 1995):

$$\Delta ECF_t = \alpha + \sum_{i=1}^{z} \beta_{1i} \Delta(ECF)_{t-i} + \sum_{i=0}^{z} \beta_{2i} \Delta(GDP)_{t-i} + \sum_{i=0}^{z} \beta_{3i} \Delta(NUC)_{t-i} + \sum_{i=0}^{z} \beta_{4i} \Delta(\mathrm{TEC})_{t-i} + \sum_{i=0}^{z} \beta_{5i} \Delta(GLOB)_{t-i} + \sum_{i=0}^{0} \beta_{6i} \Delta(URB)_{t-i} + \sum_{i=0}^{z} \beta_{7i} \Delta(TRA)_{t-i} + \beta_8 ECF_{t-1} + \beta_9 GDP_{t-1} + \beta_{10} NUC_{t-1} + \beta_{11} TEC_{t-1} + \beta_{12} GLOB_{t-1} + \beta_{13} URB_{t-1} + \beta_{14} TRA_{t-1} + \varepsilon_t \quad (3)$$

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Where Δ represents the difference between the delays of the dependent and independent variables. The difference between each delay of dependent and independent variables represents the short-term dynamics. The ratio of each delay value of the variables that may occur in the dependent variables to the relative variable shows the long-term dynamics.

Long-term co-integration is calculated using F statistics, and the test results are evaluated on the critical values developed by Pesaran et al. (2001). These critical values are divided into two sections. First, all series are assumed to be I (1). The second assumption is that the variables are I (0). If the statistical value of F remains above the upper limit, the empty hypothesis of non-compliance is rejected. This results analysis, which indicates the existence of synchronization, takes it to the next stage, enabling the obtaining of an error correction model where short-term dynamics are obtained. This error correction model, calculated using the ARDL boundary test, can be formulated in equation 4. A negative and statistically significant ECT coefficient means that short-term imbalances in explanatory variables are balanced over the long term.

$$\Delta ECF_t = \alpha + \sum_{i=1}^{z} \beta_{1i} \Delta(ECF)_{t-i} + \sum_{i=0}^{z} \beta_{2i} \Delta(GDP)_{t-i} + \sum_{i=0}^{z} \beta_{3i} \Delta(NUC)_{t-i} + \sum_{i=0}^{z} \beta_{4i} \Delta(\mathrm{TEC})_{t-i} + \sum_{i=0}^{z} \beta_{5i} \Delta(GLOB)_{t-i} + \sum_{i=0}^{\mho} \beta_{6i} \Delta(URB)_{t-i} + \sum_{i=0}^{z} \beta_{7i} \Delta(TRA)_{t-i} + \sum_{i=0}^{z} + \beta_{8i} ECT_{t-1} + \vartheta_t \quad (4)$$

RESULTS AND DISCUSSION

In the analysis part of the study, a unit root test of the series was first performed. Both ADF and PP unit root tests were used. The results of both tests for both level and differential variables are summarized in Table 2. When examining Table 2, the ECF, GDP, TEC, GLOB, URB, and TRA variables remained stable at the first difference from both test results. However, results have been obtained that the NUC variable is stable. So, it can be said that the variables in the model have different degrees of integration. In this case, it is considered appropriate to adopt an ARDL approach, which is a time series analysis technique. In this context, co-integration tests were first conducted with the ARDL (3,3,0,4,3,0,4) model (see Table 3).

Table 2. Unit Root Test

	ADF		PP	
Variables	**Level**	**1 Difference**	**Level**	**1 Difference**
ECF	-0.013	-6.265***	-0.118	-6.214***
GDP	-1.528	-6.324***	-1.954	-6.307***
NUC	-2.657*	-4.436***	-10.596***	-4.750***
TEC	-0.596	-7.070***	-0.659	-7.070***
GLOB	-1.934	-5.992***	-1.934	-5.994***
URB	-0.341	-3.711**	0.967	-5.101***
TRA	-1.880	-6.104***	-1.912	-7.360***

* and *** indicate the statistical significance levels of %10 and %1 respectively.
Source: Data processing

Table 3. Co-Integration Relationship Results

		%10		%5		%1	
k	**F statistic**	**I (0)**	**I (1)**	**I (0)**	**I (1)**	**I (0)**	**I (1)**
6	11.923	1.99	2.94	2.27	3.28	2.55	3.61

According to Table 3, the F-statistical value was calculated at 11.923, showing that there is a long-term correlation between the series since the result is greater than the critical value at the 1 percent significance level. After the long-term co-integration relationship has been identified, the short- and longer-term ratio of the ARDL is moved to the stage of obtaining predictive results. Table 4 shows the results of the ARDL short-term error correction model.

The results of the analysis of short-term dynamics are in Table 4. Firstly, the result for the ECM coefficient, which stands for the ARDL model error correction ratio, is negative and statistically significant. This result means that short-term deviations recover rapidly over the long term. Nuclear energy consumption has a negative short-term impact on environmental quality in the United States. So, an increase in US nuclear energy consumption increases the carbon footprint by about 0.08 percent in the short term. Similarly, short-term economic growth, technology, and overall trade impact the carbon footprint, negatively affecting environmental quality in the US.

Analysis findings show that although nuclear energy is an important source of pollution in both the long and short run, this effect becomes more evident in the long run. This significant effect in the long run may be considered because of neglecting the environmental damage of nuclear energy in the short run. Therefore, the damage caused to sustainability over time by measures not taken in the short run for the negative impact of this energy source is remarkable. While the results of environmental technologies produce positive environmental effects with a delay of one, two, and three periods, this effect disappears in the long run. This result emphasizes the importance of patents, which are indicators of environmental technology, in areas that serve sustainability in the long run.

According to the ARDL's long-term ratio estimates, the impact of nuclear energy consumption on environmental pollution is not to be underestimated. The long-term effect is stark: an increase in nuclear energy consumption leads to a 0.47 percent rise in environmental pollution. While trade and globalization ratios show a negative trend, the environmental pollution reduction effect of GDP is statistically insignificant in the long term. Urbanization, on the other hand, has a significant long-term impact on environmental pollution. However, environmental technologies don't have a long-term positive impact.

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Table 4. ARDL Short and Long-term Analysis Results

ARDL Short-term Analysis Results			
Variable	**Coefficient**	**t-statistic**	**Prob.**
Δ(ECF (-1))	-0.190	-2.014	0.057
ΔNUC	0.083	3.043	0.006
Δ(NUC(-1))	-0.012	-0.488	0.630
Δ(NUC(-2))	0.080	3.325	0.003
Δ(NUC(-3))	0.079	2.897	0.008
ΔTEC	0.013	14.067	0.000
Δ(TEC(-1))	-0.047	-10.797	0.000
Δ(TEC(-2))	-0.055	-11.716	0.000
Δ(TEC(-3))	-0.053	-10.802	0.000
ΔGDP	0.930	9.141	0.000
Δ(GDP(-1))	0.566	3.144	0.005
Δ(GDP(-2))	-0.451	-3.681	0.001
Δ(GDP(-3))	0.281	2.535	0.019
ΔGLOB	0.001	1.320	0.201
Δ(GLOB(-1))	0.004	2.586	0.017
Δ(GLOB(-2))	0.000	0.286	0.777
Δ(GLOB(-3))	0.006	5.248	0.000
ΔTRA	0.000	1.432	0.167
Δ(TRA(-1))	0.003	3.987	0.000
Δ(TRA(-2))	0.004	7.616	0.000
Δ(TRA(-3))	0.003	4.574	0.000
ECM(-1)	-0.234	-11.347	0.000
ARDL Long-term Analysis Results			
NUC	0.474	3.797	0.001
TEC	0.262	1.718	0.101
GDP	-1.167	-1.155	0.261
GLOB	-0.022	-1.942	0.066
URB	0.085	4.347	0.000
TRA	-0.023	-4.708	0.000
C	-1.313	-0.394	0.697

Source: Data processing

Table 5. Diagnostic Test Results

Test	F statistic	Prob.
Breusch-Godfrey Serial Correlation LM Test	7.204	0.147
Heteroskedasticity Test: Breusch-Pagan-Godfrey	0.628	0.873
Ramsey RESET Test	1.069	0.314
	Jarque-Bera	Prob.
Normality Test	1.747	0.417

Source: Data processing

Considering the positive and long-run negative impact of GDP on environmental pollution in the short run, the importance of technology may be understood more clearly. The development of technology, whose importance in growth is undeniable, towards more environmentally friendly areas in the long run may reverse the environmental damage of economic growth. The increasing effect of urbanization on environmental pollution is a predictable result when considered on the axis of technology and growth. Although globalization and trade variables have a positive but insignificant effect on environmental degradation in the short run, both variables have a reduction in environmental pollution in the long run. It is a known fact that these two variables are complementary due to the increasing trade volume caused by globalization. Thus, the positive contribution of the US's trade as a developed country with developing countries specializing in pollution-intensive production to the US's carbon emissions is understood.

While nuclear energy contributes to environmental quality according to the widespread literature (Hassan et al., 2020; Bandyopadhyay & Rej, 2021; Danish et al., 2021; Ali et al., 2022; Majeed et al., 2022; Ozgur et al., 2022; Sadiq et al., 2022a), the opposite results are obtained in this study. The empirical outcome of both the long and short-term environmental impact of nuclear energy consumption is consistent with the results of studies by Bian et al. (2021). In fact, the operation of nuclear power plants without harming the environment is a hot topic. This underscores the need for further research and policy development in the field of nuclear energy. Although the use of nuclear power plants is an effective method for clean energy production, these power plants also have environmental risks. Radiation from nuclear plants pollutes water, air and soil. This brings negative effects on people and natural life.

Therefore, radiation and nuclear waste density are the biggest environmental disadvantages of nuclear power plants. On the other hand, since this study focuses on nuclear energy consumption, it reveals that the environmental aspects of the usage areas of this energy source should be investigated. The result means that nuclear energy, which the US economy considers an environmentally friendly energy source, is part of the country's environmental degradation. The results on the positive contribution of environmental technologies to the environment in the short run are like those of Ahmed et al. (2020) and Fatima et al. (2023). Thus, the findings on the environmental impact of nuclear energy consumption overlap with the limited number of studies in the literature that

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revealed this negative impact. In contrast, the results on environmental technology are consistent with widespread literature that reached similar findings.

Figure 1. Result of CUSUM and CUSUM of Squares

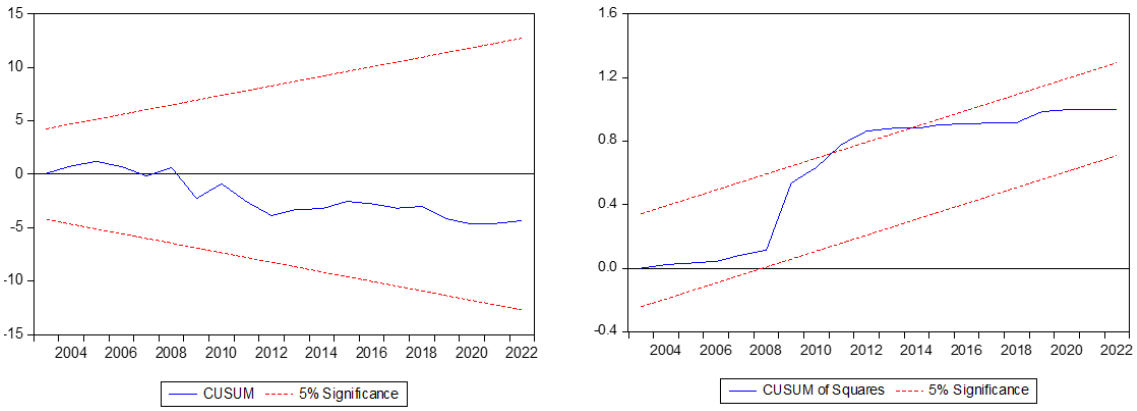

Table 5 displays the results of diagnostic tests aimed at identifying any potential econometric issues with the study model. The Breusch-Godfrey autocorrelation test, the Breusch–Pagan variable variance test, and the Ramsey RESET stability test were all conducted, and the model was found to be free of any statistical problems. The normality test further supported these results. Figure 1 provides a visual representation of the model's stability and any structural changes. The conclusion drawn from the CUSUM and CUSUMQ tests was that the model remained stable throughout the review period, without any structural alterations, thereby instilling confidence in the reliability of our results.

CONCLUSION

The study aims to analyze the impact of nuclear energy consumption, environmental technologies, and globalization on environmental pollution in the United States. The study used the ecological carbon footprint indicator as an indicator of environmental pollution. According to the findings, nuclear energy consumption has a negative impact on environmental quality in the United States, both in the short and long term. On the contrary, while long-term environmental technologies positively contribute to environmental quality with a reduced carbon footprint, globalization has not been seen to have a significant effect in the short or long term. The results show that the US is the world's leading source of nuclear energy consumption and faces environmental costs.

In light of the findings, US nuclear energy consumption is a significant threat to the environment, while developments in environmental technologies contribute positively to the country's environmental quality. Considering that nuclear energy consumption is a widely used energy source for electricity generation, minimizing pollution caused by nuclear energy use is vital for sustainable energy production. On the other hand, the view that nuclear power plants do not emit greenhouse gases has appeared today,

especially in the United States, which has a significant capacity to use nuclear energy, because the negative impact on environmental quality is essentially inevitable in nuclear power plant installation activities. Thus, exchanging nuclear energy with renewable energy sources will be a significant environmental breakthrough in all economic production and consumption processes. At the same time, all technological innovations that contribute to environmental quality in the environment and fields should be encouraged and adopted in all sectors of the economy that are environmentally relevant. There are precautions to be taken to prevent environmental risks. These measures include educating industrial waste, transitioning to clean energy production, recycling, and using waste management systems.

However, many studies are being carried out to reduce the environmental risks of nuclear power plants. For example, special storage facilities are built for nuclear waste management to ensure that waste is controlled. However, it is not possible to eliminate the environmental risks of nuclear power plants. Therefore, precautions must be taken, and the environmental impacts of nuclear power plants must be constantly inspected. Also, policies supporting investments in environmental technologies may be complementary to these measures. Environmental damage may be minimized with patent applications that contribute to the development of environmentally friendly technologies in waste management.

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