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Environmental Assessment of the Effect of CO2 Emissions on Economic Development in Iran

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Economic Growth, CO2 Emission, Iran

ABSTRACT

Financial development can significantly contribute to alleviating environmental pollution by providing access to modern technologies. However, it can also exacerbate pollution by increasing production activities. Since CO2 emissions are the primary driver of climate change, studying the factors affecting these emissions is crucial. This study aims to explore the impact of financial development, gross domestic product (GDP), and energy use on CO2 emissions in Iran's agricultural sector from an environmental economics perspective. The analysis of the financial index's impact on CO2 emissions is conducted using time-series data from Iran for the period 1991 to 2022, based on an autoregressive distributed lag (ARDL) model. The results show an inverse relationship between financial development and CO2 emissions, indicating that a 1 percent increase in financial development in the agricultural sector leads to a 0.27 percent reduction in CO2 emissions in the long run. Additionally, increases in the GDP of the agricultural sector and population growth lead to higher CO2 emissions. In the short run, financial development also has an inverse relationship with greenhouse gas emissions, while energy use and population growth are directly related to CO2 emissions. Therefore, reducing CO2 emissions requires the adoption of advanced technologies. Pollution control should be prioritized by planners and policymakers.

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INTRODUCTION

A key pillar of life and development is the environment, as it performs multiple functions to maintain balance in various aspects of life. However, the environment is currently being exploited freely and endlessly due to the lack of specific regulations and ownership. As a result, it is being degraded and contaminated with various pollutants (Ghorbani & Firuz Zare, 2010; Sardar Shahraki & Safdari, 2023). Public attention was drawn to environmental issues in the 1960s, primarily focusing on industrial pollution caused by the increasing use of fossil fuels (Amirtaimoori & Khalilian, 2009; Salatin & Ghaffari Somea, 2016; Haffman, 2017; Jahangir et al., 2020; Aliahmadi et al., 2023). Today, one of the primary concerns of policymakers is environmental conservation and pollution reduction alongside economic growth (Nasrollahi & Ghaffari Golak, 2009; Sadeghi & Ibrahimi, 2013; Cheol Hee, 2018). The most significant source of pollution, and a contributor to other environmental contaminants, is air pollution caused by emissions from industrial activities. These emissions, known as greenhouse gases (GHGs), include carbon dioxide (CO2), methane (CH4), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6) (Anonymous, 2012). Developed countries and emerging economies are primarily responsible for CO2-based GHG emissions, as they require increased energy use to sustain economic growth (Appiah et al., 2018; Salmani Bishak et al., 2017). CO2 is emitted through economic and social activities, and it can be controlled in two ways: by regulating economic activities or by implementing environmentally friendly and efficient technologies to meet energy demands with lower CO2 emissions (Amiri et al., 2016; Ghaffari Moghadam & SardarShahraki, 2023). Given humanity's reliance on energy production and consumption, the demand for energy continues to rise globally. Currently, 77 percent of global energy consumption is supplied by fossil fuels, which contribute to the emission of pollutants and GHGs. This process has also damaged the ozone layer, posing serious threats to the environment and contributing to global warming (Khoshakhlagh et al., 2002; Esmaeili & Fathi, 2012; Reza & Shah, 2018).

CO2 is a critical greenhouse gas (GHG) emitted by the energy sector, contributing significantly to climate change and global warming (Esmaeili & Fathi, 2012; Ramachandra et al., 2017). The environment and natural resources provide most production inputs. A production process generates not only optimal outputs (consumable goods) but also unfavorable outputs. If these unfavorable outputs are not controlled, the resulting environmental damage can outweigh production benefits, leading to irreparable losses and hindering sustainable development (Zeynaliyan, 2012). Environmental pollution is a major global issue, prompting countries to address it through international cooperation alongside national policies (Pajouyan & Moradhasel, 2007; Bahrami, 2016; Dawoudian et al., 2021). The relationship between economic growth and environmental pollution indicators has garnered significant attention in environmental economics. According to some economists, the environmental Kuznets curve theory posits that economic growth and environmental quality follow an inverse U-shaped relationship. Initially, economic growth degrades the environment in exchange for higher per capita income (PCI), but as

PCI improves, environmental degradation gradually decreases (Sadeghi, 2013; Khan et al., 2018). This bell-shaped curve is known as the environmental Kuznets curve (EKC).

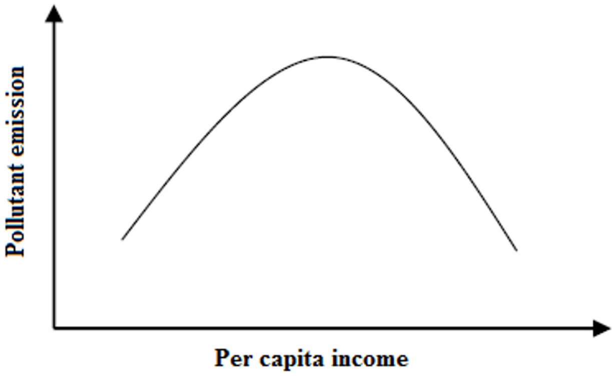

Figure 1. The Environmental Kuznets Curve (Source: Cole, 2007)

On the other hand, the optimistic approach to the relationship between commerce and the environment suggests that the increase in trade enhances the environmental quality in developing countries. The proponents of this view argue that trade liberalization allows more efficient allocation and use of resources and thereby enables countries to specialize in the production of the goods and services in which they have an advantage; so, they can maximize production at certain levels of energy and material use (Barghi Oskoei, 2008). This argument emphasizes the ability of trade liberalization in raising available funds for environmental protection through enhancing the production capacity, and the argument has been put forth to justify the EKC hypothesis (Taskin & Zaim. 2001).

Research on some pollutants has shown a positive relationship between pollution and the income of countries. Accordingly, pollution is initially aggravated by the increase in income, but then it starts to follow a descending trend. The proponents of the EKC hypothesis argue that at high levels of development, the economic structure moves towards modern industries, technologies, and services, and the mix of inputs and polluting energies is adjusted. Additionally, environmental awareness gradually increases, more environmentally-friendly regulations are enacted, and the expenditures on environment conservation and improvement are increased.

Theoretically, three mechanisms explain how economic growth affects environmental quality: increased production scale, technical growth, and structural changes. In the production scale mechanism, higher GDP leads to greater demand for inputs, resulting in more intensive use of natural resources to boost production. The technical growth mechanism refers to more efficient input use, replacing inputs or production processes with less polluting alternatives, shifting towards local crops, and reducing waste or converting it into less harmful forms (Orubo & Omotor, 2011).

The third mechanism involves structural changes in the economy. In the early stages of development, production shifts from agriculture to industry, worsening pollution and environmental degradation. However, as industrialization continues, inputs improve, consumer demands evolve, and production gradually transitions from energy-intensive industries to knowledge-based industries and the service sector (Chen, 2007). This structural shift helps curb pollution.

While production scale expansion negatively impacts the environment, the other two mechanisms—technical growth and structural changes—enhance environmental quality by reducing pollutants. The ascending part of the EKC reflects the dominance of production scale expansion, which worsens pollution. In contrast, the descending part shows the dominance of technical growth and structural changes, which reduce emissions and improve environmental conditions (Grossman & Krueger, 1995; Vukina et al., 1999).

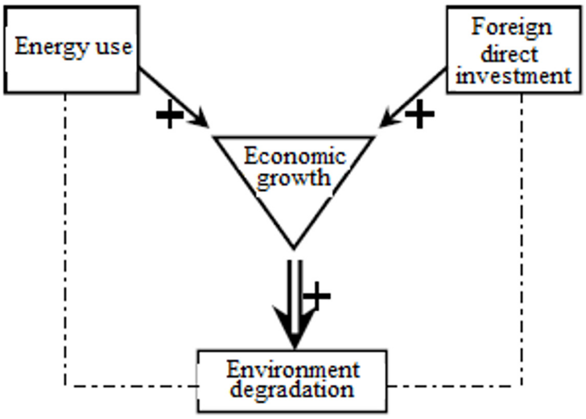

Figure 2. The Dynamic Relationship Between Economic Growth, Foreign Trade, and Energy Use (Source: Feqhi Kashani, 2007)

Since attracting foreign direct investment and increasing energy use in developing countries often lead to the emission of environmental pollutants, the economic growth driven by these factors contributes to further environmental degradation. Within the theoretical framework, the relationships between environmental quality and its influential factors can be depicted schematically, as shown in Figure 2 (Feqhi Kashani, 2007; Torkan et al., 2023). Figure 3 further elaborates on the dynamic relationships among economic growth, financial development, foreign trade, and energy use, providing a more detailed illustration of their interconnectedness.

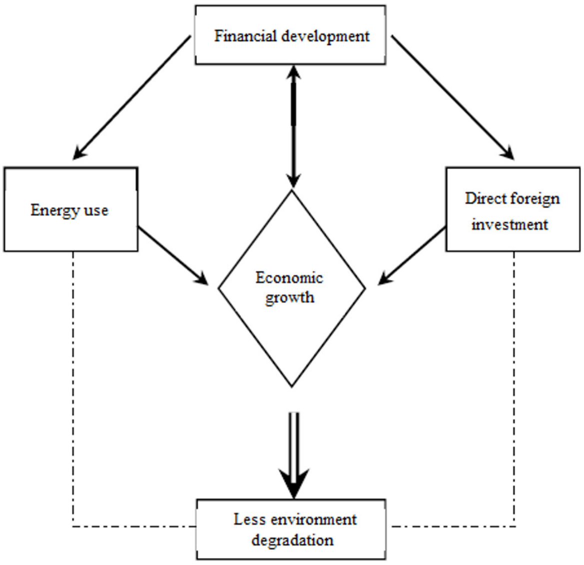

Figure 3. The Dynamic Relationship among Financial Development, Economic Growth, Foreign Trade, and Energy Use (Source: Mahdavi and Amirbabaei, 2016)

Financial development can attract more foreign direct investment with reduced pollution by offering financial support for establishing advanced R&D departments and accessing environmentally friendly, efficient technologies, which often require significant financial resources (Stern, 2004). This accelerates economic growth while generating less pollution at each level of growth. Additionally, by providing the financial means to adopt more efficient energy technologies, financial development reduces energy intensity and improves energy efficiency, further promoting economic growth with lower pollution. Thus, financial development helps mitigate environmental degradation by fostering economic growth through foreign investment and more efficient energy use (Copeland & Taylor, 2003).

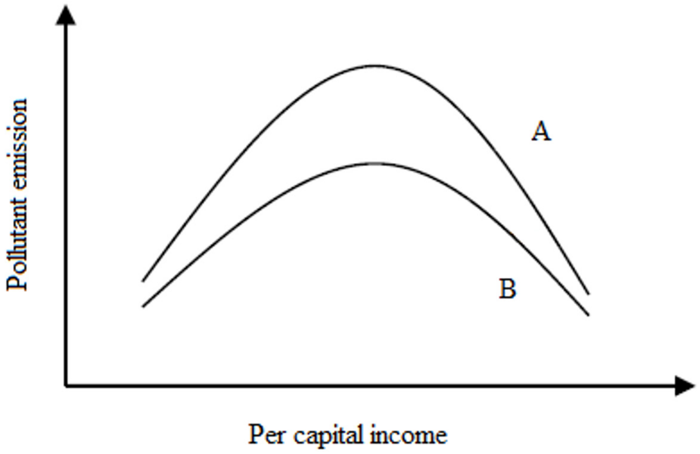

Figure 4. The Environmental Kuznets Curve with The Inclusion of Financial Development (Source: Dinda, 2004)

This claim can be explained within the EKC hypothesis by the fact that as the economic growth rate increases, less pollution is emitted per unit of growth, causing the slope of the EKC to decline. This results in a shift from curve a to curve b, as depicted in Figure 4 (Mahdavi & Amirbabaei, 2016).

Environmental pollution and rising GHG concentrations are among the major contributors to global climate change. Air pollution, a significant form of environmental pollution, poses a serious threat to future generations. CO2 is one of the most critical GHGs, and energy consumption contributes to increasing its concentration in the atmosphere, with widespread global consequences.

Financial development facilitates access to modern technologies, particularly in the energy sector, thereby helping to reduce CO2 emissions. However, it can also intensify production activities and, in turn, exacerbate environmental degradation. Studies in both developed and developing countries demonstrate the influence of financial markets on economic growth. The agricultural sector, a key part of any economy, including Iran's, plays a significant role in driving societal development. However, economic growth, though often prioritized by governments, typically leads to environmental damage. This raises concerns regarding the sustainability of global development, as it risks inflicting irreparable harm on the environment.

Today, GHG emissions, particularly CO2, are a major global challenge. The agricultural sector is a notable emitter of CO2 in Iran. A primary objective of Iran's socioeconomic development plans is to achieve high economic growth rates. One solution is to direct financial and capital resources toward productive economic activities and develop financial markets (Wang et al., 2018). Financial development refers to the factors, policies, and institutions that enable efficient financial intermediaries and markets and broaden access to financial services (Pilbeam, 2018). It occurs in two sectors: banking and non-banking.

In developed countries, financial innovations and developments tend to occur outside the banking sector, while in developing countries, financial development mainly relies on reforms in the banking sector (Nazifi, 2004). Thus, financial development—realized through various policies and support for firms, industries, and manufacturers—can either alleviate or exacerbate environmental pollution (Kazemi et al., 2013).

Given the central role of the financial sector in economic growth and development, this study aimed to examine the impact of the financial index on CO2 emissions in Iran's agricultural sector. Using the autoregressive distributed lag (ARDL) model and time-series data from 1991-2023, the study sought to explain this relationship.

LITERATURE REVIEW

Economic growth is widely considered one of the key contributors to environmental impacts, as it necessitates greater use of natural resources and leads to higher emissions of pollutants, which negatively affect environmental quality. The interaction between economic growth and environmental quality has been a subject of extensive study by economists and environmentalists, both theoretically and empirically, in recent years.

Sadeghi (2013) applied the Johansen-Juselius cointegration method to examine the relationship between CO2 emissions and water pollution in Iran from 1980 to 2009. The findings supported the EKC hypothesis for both CO2 emission rates and water pollution, indicating a long-term relationship between environmental quality indices and factors like population density and urban population growth. Alipour et al. (2014) analyzed the costs of CO2 emissions caused by the development of Iran's agricultural sector between 1992 and 2010, using the shadow price of CO2 emissions. Their results showed a significant increase in the average cost of CO2 emissions during this period.

Najimeydani & Davodi (2015) conducted a decomposition analysis of CO2 emissions in Iran's transportation sector from 1999 to 2011. They found that economic scale and growth had the most significant impact on CO2 emissions, while factors like emission intensity and fuel composition varied in influence over the years. Ghaffari et al. (2016) used panel data and an error correction model (ECM) to investigate the impact of wind energy on economic growth and CO2 emissions. They confirmed a long-term relationship, noting that while wind energy positively affected economic growth, it had no impact on CO2 emissions. Their panel Granger causality test showed a short-term bidirectional relationship between CO2 emissions and economic growth, as well as between CO2 emissions and urban population growth.

Salatin & Ghaffari Somea (2016) examined the effect of nuclear energy on environmental quality using a panel data approach. Their fixed effects model for selected countries from 2004 to 2014 demonstrated that nuclear energy had a significant negative impact on CO2 emissions. Sadeghi et al. (2017) analyzed the influence of renewable energy on Iran's economic growth and environmental quality over 1980-2012, using the SVAR method. Positive shocks in renewable energy usage were found to enhance both economic growth and CO2 emissions, though renewable energy accounted for only a small part of the variance in GDP and CO2 forecast errors.

Salmani Bishak et al. (2017) explored the economic factors influencing CO2 emissions in Iran from 1972 to 2000, using the ARDL model. Their results indicated that all variables except for trade openness positively affected CO2 emissions, while trade openness had a negative effect. Shahnazi et al. (2017) studied the causal relationships between energy carrier use, economic growth, and CO2 emissions across Iran's economic sectors from 1982 to 2012, applying the Toda and Yamamoto causality method. They identified unidirectional causality from energy carrier use to economic growth but found no causal link with CO2 emissions. However, bidirectional causality was found between economic growth and energy use in the residential, commercial, and transportation sectors. In the industrial sector, there was unidirectional causality from economic growth to gas use and from electricity use to economic growth, alongside a bidirectional relationship between economic growth and coal use. Zhang & Xu (2012) examined the relationship between economic growth and energy use in China from 1975 to 2010, finding a bidirectional causal relationship between energy consumption and GDP at both national and regional levels. Wolde-Rufael (2014) used a bootstrap panel causality approach to explore the connection between economic growth and energy use in 15 developing countries from 1975 to 2010. Their findings indicated unidirectional causality from electricity use to economic growth in Belarus and Bulgaria, from economic growth to electricity use in the Czech Republic, Latvia, Lithuania, and Russia, and bidirectional causality in Ukraine. However, no Granger causality was detected in Albania, Macedonia, and other countries.

Furuoka (2015) explored the link between CO2 emissions and economic development through cross-sectional, cointegrating, and threshold regressions, confirming the inverted U-shaped EKC. Inglesi-Lotz (2016) focused on OECD countries from 1990 to 2010, discovering that increasing the share of renewable energy in the total energy mix positively influenced economic growth. Reza & Shah (2018) examined the relationship between financial development, economic growth, and energy use in Pakistan from 1972 to 2014, concluding that all variables significantly contributed to environmental degradation.

Khan et al. (2018) applied the STIRPAT model to Asian countries from 1980 to 2014, finding that income inequality reduced CO2 emissions in Pakistan and India, though this was not true for Bangladesh. Energy use significantly impacted CO2 emissions in Bangladesh, Pakistan, and India. Ramachandra et al. (2017) analyzed economic inequality's effect on CO2 emissions in Bangalore, India, finding that per capita energy use increased with family income, making economic status a key factor in energy consumption and GHG emissions.

Hosseini et al. (2019) used time series and regression analysis to predict CO2 emissions in Iran for 2030 under two scenarios, BAU and SDP, applying MLR and MPR techniques. Jahangir & Cheraghi (2020) evaluated the economic and environmental aspects of a hybrid solar-wind-biomass energy system for rural areas, showing that such systems could drastically reduce CO2 emissions and save substantial costs annually. Finally, Dawoudian et al. (2021) studied the environmental effects of the cement industry, revealing that 70 percent of the most damaging impact was water pollution, with the most destructive interaction effects stemming from excavation and land deformation.

Most recent studies have concentrated on

Table 1

Some Other Relevant Literature.

Source	**Country/ location**	**Modeling method**	**Objectives**
Verbeke et al., 2006	29 countries	Monte Carlo	The presence of environmental Kuznets curve
Akbostanci et al., 2009	Turkey	Johansen-Juselius cointegration	To study the relationship between per capita income and environmental pollution
Chiang Lee et al., 2010	Africa, Asia, Oceania, America, Europe	Generalized method of moment (GMM)	To study the relationship between water pollution and economic growth
Pao et al., 2011	Russia	Cointegration and causality test	To study the relationship between CO_2 emission, energy use, and economic growth
Jalil and Feridun, 2011	China	ARDL	To study the effect of economic growth, energy use and financial development on environmental pollution
Nasir and Rahman, 2011	Pakistan	Johansen convergence test	To study the relationship between carbon emission, income level, energy use, and foreign trade
Zaman et al., 2012	Pakistan	Granger causality test and variance analysis	To study the relationship between agricultural technologies and CO_2 emission
Robaina Alves and Moutinho, 2013	Portugal	Complete analysis	Analysis of CO_2 emitted by energy use in the industrial sectors
Elgin and Oztunali, 2014	152 countries	Panel method	To study the relationship between informal economy size and environmental pollution level and energy use
Cowana et al., 2014	BRICS countries	Granger causality test	To study the causality of electricity and economic growth with CO_2 emission
Ara Begum et al., 2014	Malaysia	ARDL	To study CO_2 emission and its relationship with energy use, economic growth, and population growth
ESlamloueyan and Jokar, 2014	Middle Eastern and North African countries	Multivariate causality test and VECM	To study the relationship between energy use and economic growth
Saidi and Hammami, 2015	Europe, North Asia, Africa	Simultaneous equations	To study the relationship between economic growth, energy use, and CO_2 emission
Dogan and Turkekul, 2016	US	Granger causality test	CO_2 emission, actual production, energy use, commerce, urbanization, and financial development
Sarkodie and Owusu, 2016	Seri Lanka	ARDL and neural network	To study the relationship between energy, CO_2 emission, GDP, industrialization, financial development, and population with a forecast of energy use with a neural network

Table 1
Continue

Katircioğlu and Taşpinar, 2017	Turkey	Main impacts and interactive impacts models	The effective role of financial development in the EKC
Sarkodie and Owusu, 2017	Senegal	Nonlinear iterative partial least square (NIPALS) regression	Multivariant analysis of CO_2 emission, electricity use, economic growth, financial development, industrialization, and urbanization
Al-mulali and Binti Che Sab, 2018	UAE	VAR	The relationship between energy use, CO_2 emission, and development
Ali et al., 2018	Nigeria	ARDL	Financial development and CO_2 emisison

the relationship between environmental pollution and economic growth. However, the impact of financial development on environmental pollution, particularly CO2 emissions, has not been thoroughly explored. Research in Iran and other regions indicates that financial development can influence the environment in multiple ways. Therefore, this study employs the autoregressive distributed lag (ARDL) model and time-series data from 1991 to 2023 to examine the relationship between the financial development index, population, energy use, and gross domestic product (GDP) of the agricultural sector on CO2 emissions.

MATERIALS AND METHODS

Autoregressive distributed-lagged model (ARDL)

To examine cointegration and estimate the long-term and short-term relationships between variables, the ARDL model proposed by Pesaran & Shin (2001) is employed. This model offers several advantages over conventional methods and has been widely used in empirical studies. One key advantage is its applicability regardless of whether the variables are I(0) or I(1), though it cannot be used when variables are I(2). Additionally, ARDL is more efficient for small or limited samples and can estimate both long-term and short-term dynamics. The model also calculates the adjustment rate towards long-term equilibrium after short-term shocks through the error correction model (ECM). Furthermore, endogeneity issues are avoided as the ARDL approach ensures no correlation between the error terms (Pesaran & Shin, 1999; Sadeghi & Ibrahimi, 2013).

The general form of an ARDL dynamic model in which the variables are lagged is as follows:

To reduce the bias of calculating model coefficients in smaller samples, it is better to use a model in which there are a higher number of lags for the variables.

$$Y_t = aX_t + bX_{t-1} + cY_{t-1} + u_t \qquad (1)$$

$$\phi(L,P)Y_t = \sum_{i=1}^{k} b_i(L,q_i)X_{it} + c'w_t + u_t \qquad (2)$$

In Eqs. (1) and (2), Y_t represents the dependent variable and X_{it} represents the independent variables. The term L is the lag operator, and w_t is an S × 1 vector that shows the predetermined variables of the model including the y-intercept of dummy variables, temporal trend, and other exogenous variables. P is the number of lags applied to the dependent variable, and q is the number of lags applied for independent variables (X_{it}). This is an ARDL model in which we have (Tashkini. 2005; Elkadhi et al.. 2017):

$$\phi(L,P) = 1 - \phi_1 L^2 - \ldots - \phi_P L^P \qquad (3)$$

$$b_i(L,q_i) = b_{i0} + b_{i1}L + \ldots + b_{iq}L^q \qquad (4)$$
$$i=1,2,\ldots,k$$

The optimal number of lags for each explanatory variable can be selected using criteria such as Akaike's Information Criterion (AIC), Schwarz-Bayesian Criterion (SBC), Hannan-Quinn Criterion (HQC), or the adjusted coefficient of determination (R-bar^2) (Pesaran & Shin, 1996). The same dynamic model is then used to calculate the long-term coefficients. The ARDL model follows a two-step procedure for estimating long-term relationships. In the first step, the existence of long-term relationships between the variables is tested (Pesaran & Shin, 2001). To ensure that the long-term relationships are not spurious, two methods are commonly employed.

In the first way, after the dynamic ARDL model is estimated, the null hypothesis holds that there is no cointegration or long-term relationship. To test the hypothesis as described by Banerji et al. (1993), the test statistic should be of t-statistic type:

$$t = \frac{\sum_{i=1}^{P} \hat{\phi}_i - 1}{\sum_{i=1}^{P} S\hat{\phi}_i} \qquad (5)$$

If the magnitude of the t-statistic exceeds the critical values presented by Banerji et al. (1993) at a 95 percent confidence level, the null hypothesis, which posits the absence of cointegration, is rejected, and the presence of long-term relationships is confirmed (Pesaran & Shin, 1996; Fotros & Karimi, 2017; Tashkini, 2005; Gulzar & Zhahua, 2018).

In the second method, the first step of ARDL estimation involves testing for a long-term relationship between all the model variables using the F-test. In this test, the null hypothesis states that no long-term relationship exists between the variables, while the alternative hypothesis suggests the presence of such a relationship, as defined below:

$$\begin{gathered} H_0: \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 \\ H_1: \lambda_1 \neq \lambda_2 \neq \lambda_3 \neq \lambda_4 \neq \lambda_5 \end{gathered} \qquad (6)$$

The F-statistic is compared with two critical values: the lower value with the assumption of all variables being I(0), and the upper value with the assumption of all variables being I(1). If the calculated F-value is greater than the upper critical value, the null hypothesis is refuted; if it is smaller than the lower critical value, the null hypothesis cannot be refuted; and if it is between the upper and lower critical values, the result is uncertain. In the second step, if the presence of cointegration is supported (the null hypothesis is refuted), the long-term $ARDL(P,q_1,q_2,\ldots,q_4)$ model is given as below:

$$CO2_t = \beta_0 + \sum_{i=1}^{P} \lambda_1 c_{t-i} + \sum_{i=1}^{q_1} \lambda_2 FD_{t-i} + \sum_{i=1}^{q_2} \lambda_3 ENC_{t-i} + \sum_{i=1}^{q_3} \lambda_4 GDP_{t-i} + \sum_{i=1}^{q_4} \lambda_5 POP_{t-i} + U_t \qquad (7)$$

where:

LFD = the logarithm of financial development in the agricultural sector;

$LCO2$ = the logarithm of $CO2$;

$LPOP$ = the logarithm of the population;

$LGDP$ = the logarithm of GDP in the agricultural sector; and

$LENC$ = the logarithm of energy consumption in the agricultural section.

In this model, the ranks are selected by SBC. The last step of estimating an ARDL model is to examine the short-term relationship between variables and to calculate the rate of adjustment of short-term unbalances in each period to reach the long-term balance. To this end, ECM is defined as below:

$$\Delta CO2_t = \beta_0 + \sum_{i=1}^{P} \delta_i c_{t-i} + \sum_{i=1}^{q_1} \phi_i FD_{t-i} + \sum_{i=1}^{q_2} \omega_i ENC_{t-i} + \sum_{i=1}^{q_3} \eta_i GDP_{t-i} + \sum_{i=1}^{q_4} \mu_i POP_{t-i} + \alpha ECM_{t-1} + U_t \qquad (8)$$

in which μ_i, η_i, ω_i, ϕ, and δ_i denote the short-term dynamic coefficient of model convergence to long-term, and α is the rate of adjustment. To ensure the stability of the estimated coefficient of the model over time, the tests of the cumulative sum of residues (CUSUM) and the cumulative sum of the square of residues (CUSUMSQ) are employed (Ali et al., 2018).

According to what was mentioned, this paper employs the autoregressive distributed lag method. The data and statistical information are derived for the period from 1991 to 2023 from statistical sources, such as the Central Bank of IRI (the Islamic Republic of Iran).

RESULTS AND DISCUSSIONS

Before examining the long-term relationship, the stationarity of the variables was analyzed. The results indicated that all variables, except for population, became stationary after first differencing. The t-test was used to study the long-term relationships between the variables. From this analysis, a dynamic equation was evaluated, leading to an equation in which the dependent variable with a one-period lag is presented in Table 2. Based on the values reported in Table 1, the optimal lag lengths chosen for the variables in this study are 1, 1, 2, 2, and 0.

Table 2

Dynamic Results of the Dependent Variable (LCO2).

Variable	Coefficients	Standard error	t-statistic
LCO2(-1)	0.71	0.02	-10.35
LFD	-0.02	0.006	2.58
LFD(-1)	-0.05	0.007	-2.19
LENC	0.30	0.01	16.13
LENC(-1)	-0.44	0.02	-9.74
LENC(-2)	-0.08	0.01	-4.13
LGDP	0.30	0.02	3.66
LGDP(-1)	-0.07	0.02	4.22
LGDP(-2)	0.13	0.03	-11.54
GPOP	1.92	0.16	2.95
C	-21.82	1.90	4.15

After confirming the presence of a long-term relationship between the variables, the long-term relationship was analyzed, with the results shown in Table 3. The findings reveal that financial development has a significant negative relationship with CO2 emissions. Specifically, a 1 percent increase in financial development in the agricultural sector leads to a 0.27 percent reduction in CO2 emissions in the long run. Conversely, the relationship between energy consumption and CO2 emissions is positive, with a 1 percent rise in energy consumption in the agricultural sector leading to an 80 percent increase in CO2 emissions in the long term. Additionally, increases in both GDP and population in the agricultural sector contribute to higher CO2 emissions.

Table 3
Results of the Long-Term Evaluation.

Variables	Coefficients	Standard error
LFD	-0.27	0.05
LENC	0.80	0.15
LGDP	1.28	0.16
LPOP	6.86	1.07
C	-77.89	12.07

To evaluate the extent of short-term imbalances adjusting towards the long-term equilibrium of CO2 emissions, the vector error correction model (VECM) was applied. The error correction coefficient was found to be 0.28, meaning that 28 percent of the short-term deviations from the long-term CO2 emission levels are corrected in each period, bringing the system closer to the long-term equilibrium. The details of these results are provided in Table 4.

Table 4
Results of the Short-Term Evaluation.

Variables	Coefficients	Standard error
Dlfd	-0.02	0.006
dLENC	0.30	0.016
dLENC1	0.08	0.017
dLGDP	0.30	0.02
dLGDP1	0.13	0.03
dLPoP	1.92	0.16
dLC	-21.82	1.90
ECM(-1)	-0.28	0.02

The findings indicate that financial development reduces CO_2 emissions in both the short and long run, emphasizing the importance of financial sector reforms in mitigating environmental pollution. Financial development should be strategically linked to R&D investment and the adoption of green technologies, especially in the agricultural sector, which can contribute significantly to reducing greenhouse gas emissions in Iran.

In the short run, financial development can lead to an immediate reduction of emissions, showing that financial corrections and efficient allocation of resources impact environmental outcomes. The direct relationship between energy consumption and CO_2 emissions suggests that energy-intensive economic activities continue to be a major source of environmental degradation.

In the long run, financial development, GDP growth, and energy consumption all influence CO_2 emissions, but financial development has a mitigating effect. This demonstrates the potential of financial reforms and policies to drive environmentally sustainable growth if appropriately managed.

The policy implication is clear: financial reforms should prioritize energy efficiency and environmentally friendly technologies. Attracting foreign investment and promoting R&D in low-carbon technologies, along with offering financial incentives for green projects, are key strategies to align economic growth with environmental sustainability in Iran.

CONCLUSION

The findings of this paper emphasize the crucial role of financial development in reducing energy consumption and CO_2 emissions in both the short and long run. Key points and suggestions include:

Financial Development and Energy Consumption: The results indicate that financial development effectively decreases energy use, which is a primary driver of CO_2 emissions. This highlights the need for policies that integrate financial incentives with energy efficiency measures.

Population Growth Impact: Population growth is identified as a significant factor increasing CO_2 emissions, necessitating strategic planning to manage resource consumption sustainably.

Government Initiatives: The ongoing government plan to replace fuel with electrical energy can lead to economic benefits and should be further supported by financial mechanisms that encourage investment in renewable energy sources.

Technology Transfer: Financial development is linked to improving the bio-environment by attracting foreign and domestic investment and facilitating the transfer of low-carbon technologies.

Long-Term Strategies: Strategies must prioritize energy source replacement, strict pollution regulations, and education on achieving efficiency. Addressing the adverse effects of agricultural and industrial growth on environmental quality is vital.

Recommendations:Comprehensive Pollution Plan: Develop a nationwide plan to assess and manage pollution levels effectively.

Carbon Emission Source Identification: Establish a systematic approach to identify major sources of CO_2 emissions and monitor their impact on environmental variables annually.

Support Policies for Industries: Create supportive policies for factories and large production facilities that incentivize sustainable practices and investments in green technologies.

These suggestions aim to foster a sustainable environment while supporting economic growth, ultimately leading to a reduction in CO_2 emissions and improving overall environmental quality in Iran.

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CONFLICT OF INTERESTS

There are no conflicts of interest in this article.

AUTHORS' CONTRIBUTIONS

In this article, A.S.Sh was responsible for writing, analyzing, and all discussions.

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