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Investigating the effects of economic and human development on Iran's carbon footprint

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Abstract

Environmental pollution is nowadays one of the main challenges of the world. The global economic growth and the associated environmental degradation have put environmental protection at the forefront of attention. Regarding the aim of economic growth and its impact on environmental quality, the effect of various economic and human factors on environmental pollution and degradation is increasingly gaining importance in Iran. This study investigated the effects of economic growth, energy consumption, trade liberalization, urbanization, financial development, and human development on ecological footprint and environmental degradation in Iran over the period 1971-2015 using the Markov switching-error correction method (MS-ECM). Based on the results, the environmental Kuznets hypothesis was confirmed for the ecological carbon footprint with a reversed-U shape. Economic growth, urbanization, and energy use were found to have a positive and significant effect on environmental degradation, while financial development negatively influenced environmental degradation. Also, human development had a positive effect on the ecological carbon footprint. Finally, it is recommended to save energy, especially fossil fuels, by using clean energy, increase environmental awareness, and enforce strict environmental monitoring.

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Introduction

Economic growth is the main objective of economic development plans in any country, and driving the financial and capital resources towards productive economic activities is regarded as one of the ways to achieve this objective. To increae production and economic growth requires utilization of more natural resources and energy, especially fossil fuels, which results in environmental degradation (Tamazian et al., 2009; Masoudi et al., 2018). Presently, along with economic issues, policymakers are paying attention to environmental issues. However, many countries underestimate environmental issues in their early growth stages due to low awareness of environmental problems (Panayotou, 1993). Therefore, environmental degradation increases with higher incomes, while structural changes, increasing environmental awareness, and efforts to create and achieve superior technologies in higher stages of development result in marginal degradation of the environment, and the quality of the environment starts to improve after attaining a certain level of return on income (Nasrollahi and Ghaffari Golak, 2009). Although humans have long been aware of the importance of the environment in their life, it has drawn a lot of attention during the last decades of the twentieth century. The first large wave of public concern for environmental problems arose from industrialization in advanced economies. Environmental concerns and trade analyses emerged in the late 1970s and were considered major issues in international negotiations in the 1980s (Jayadevappa and Chhatre, 2000). In the 1990s, a relationship was found between various environmental pollution indicators and the economic growth. This relationship, which is inverse U-shaped, came to be known as the environmental Kuznets curve.

The environmental Kuznets curve proposed a relationship between income per capita and environmental degradation criteria as a reversed U-shaped relationship. In economic theory, the relationship between income per capita and environmental quality is expressed in terms of the environmental Kuznets curve (EKC). Based on this hypothesis, there is a U-inverse relationship between economic growth and environmental pollution so that as income increases, pollution starts to increase, then culminates, and finally decreases (Pajouyan and Tabrizian, 2010; Grossman and Kruger, 1995; McPherson and Nieswiadomy, 2005). Many studies have tried to validate this hypothesis (e.g., Managi and Jena 2008; Farhani et al., 2014; Jalil and Mahmud, 2009; Dinda and Coondoo, 2006; Al-Mulali, 2011). While some studies have supported the Kuznets hypothesis, others like Cox et al. (2012), Tsurumi and Managi, (2010), and Caviglia-Harris et al. (2009) have failed to do so. However, it might be that the inconsistency of the results is rooted in the empirical studies and the type of variables and econometric methods.

The consumption of natural and environmental resources has exceeded the biological capacity of the earth since the 1970s (WWF, 2014) so that human demands bring about pressure on the environment and the ecosystem, which can ultimately cause climate change, land degradation, pollution, the loss of biodiversity, poverty, and damage. By comparing the supply and demand of biological regions, it can be easily seen that the rate at which resources are consumed by societies is greater than their biological capacity. For this reason, many researchers have sought to examine and measure the factors affecting environmental degradation. There are many indicators for measuring environmental degradation and ecological footprint including air pollution, water pollution, deforestation, and greenhouse gas emissions like CO_2. Air pollution by fossil fuel combustion comprises one of the most dangerous pollutions. Pollutant emissions, such as CO, SOx, and NOx, cause acidic rain and health problems for humans and other organisms (Mohammadi et al., 2019; Aldy, 2005). This phenomenon is mostly investigated from regional and national points of view since greenhouse gas emissions cause climate change, which is a global issue.

In the last few decades, a large part of the literature on environmental studies has emphasized the effect of economic growth on energy consumption (Atici, 2009; Baum, 2003; Begum et al., 2015; Behera and Dash, 2017; Bekhet et al., 2017). However, despite many previous studies, there is no consensus on the relationship between economic growth and environmental degradation. In other words, according to the Kuznets environmental hypothesis, the relationship between environmental degradation and economic growth is inverse U-shaped although this relationship has been reported to be U-shaped in some studies and N-shaped in others. This means that the extent of environmental degradation depends on the stage of economic growth. Therefore, there is no consensus on the actual relationship between GDP and environmental degradation, and the evidence as to the existence of the Kuznets environmental hypothesis is contradictory. In general, the outcome of the relationship between economic growth and environmental degradation depends on various factors, including the characteristics of the country in question, the type of pollutants, and the econometric techniques used (Charfeddine and Mrabet, 2017; Ahmed et al., 2021; Usman et al., 2020; Saudet al., 2020 and Destek and Sarkodie, 2019).

Hua et al. (2012) used the vector autoregression (VAR) model to study carbon footprint and economic activity and showed that economic growth caused CO_2 emissions. They used the CO_2 indicator as an ecological footprint because most of the economic growth depends on energy consumption, which mainly contributes to pollution. Charfeddine and Mrabet (2017) investigated the environmental Kuznets hypothesis for 15 MENA countries using the ecological footprint as an indicator of environmental degradation during the period 1977-2007. In the study of Charfeddine and Mrabet (2017), political, social, and economic indicators were used for all oil and non-oil countries. The results indicated that energy consumption caused environmental degradation, and economic growth confirmed the environmental Kuznets hypothesis. Boontome et al. (2017) investigated the causal relationship between CO_2 emission, economic growth, and non-renewable energy consumption using the cointegration method during 1971-2013 and indicated that rapid economic growth was followed by energy consumption and increasing CO_2 emission. A study by Charfeddine (2017) revealed that reducing air pollution was an effective factor in the health and life quality of citizens in Qatar. The effects of economic growth, energy use marketing, financial development, and urbanization on environmental pollution were studied by the Markov switching method using CO_2 as proxies of environmental degradation during 1970-2015. The results indicated that the U-shaped relationship was dependent on the regime, and this relationship was finally confirmed. In another research, the environmental Kuznets hypothesis was studied using ecological footprint and globalization indices in 146 countries during 1981-2009. The results indicated that globalization increased ecological footprint, but this has not been supported by all studies (Rudolpha and Figge, 2017). Appiah (2018) showed that Ghana's economy had experienced an increase in demand for energy, resulting in more greenhouse gas emissions. In this study, the causality test of Toda and Yamamoto (1995) and Granger (Johansson and Jossilius) correlations and causality between variables were measured using the data for 1960-2015. The results revealed that energy consumption and economic growth have had a positive effect on CO_2 emissions. Charfeddine et al. (2018) used the autoregressive distributed lag (ARDL) method to examine the relationship between energy consumption and economic growth in Qatar. They concluded that policymakers should pay more attention to energy consumption and environmental pollution in achieving economic growth. Balsalobre-Lorentea et al. (2018) examined the relationship between economic growth and CO_2 emissions in five EU states. During 1985-2016, in the form of the environmental Kuznets hypothesis, an N-shape relationship was found between economic growth and CO_2 emissions in these five European states. Wang et al. (2018) found a positive relationship between pollution variables and economic growth in all countries during 1980-2011.

Destek and Sarkodie (2019) examined the impact of national development and energy consumption on the ecological footprint of 11 industrialized countries using the data panel method. Their results supported the Kuznets environmental hypothesis regarding economic growth and ecological footprint. They also found energy had a positive effect on the ecological footprint in both categories of countries whereas the effect of the financial development on ecological footprint was positive in one group of countries but negative in the other group. Matustik and Koci (2020) showed that there was no consensus on a universal working definition of environmental footprints and methodological differences among footprint studies were often responsible for contradictory results. Saud et al. (2020) examined the role of financial development and globalization in the ecological footprint of selected European countries for the period 1990-2014. The estimation of the data panel model showed that financial development and globalization had increased environmental degradation over the studied period. Ahmed et al. (2021) investigated the relationship among ecological footprint, economic globalization, economic growth and financial development, population density control, and energy consumption in Japan as the third largest economy. Long-term empirical results showed that economic globalization and financial development increased the footprint in Japan. On the other hand, positive and negative changes in economic globalization reduced the footprint that also confirmed the Kuznets environmental hypothesis. In a study in Hong Kong and Macao, Dou et al. (2021) showed that the proportion of carbon footprints of Mainland China to global footprints had been tripled between 2000 and 2015. They showed that carbon emissions were different locally and globally so that pollution emissions were doubled locally and almost tripled globally. Also, the study showed the developed cities of China had started to pollute other cities by outsourcing economic activities, so policies would be necessary to reduce pollution.

The main reason for conducting the present study was that the environment is in an alarming status in Iran such that the average CO_2 is 5.087 while its global average is 4.49 (in metric tons per capita). Therefore, the study aimed to examine the impact of factors affecting ecological footprint concerning economic development and human development using the Markov Switching-Error Correction Model (MS-ECM). The study is important from two aspects. Firstly, it explores the impact of human development, in addition to economic development, on the carbon footprint of Iran. Secondly, the nonlinear MS-ECM is employed because it is advantageous over the linear models in the sense that it can measure the effect of factors on environmental degradation in different conditions and regimes. This method reduces fit error by allowing the fitting of variable coefficients in different regimes, thereby preventing the hiding of data break effects in variable coefficients. Also, it can reveal the coefficient of adjustment of short-term variations that helps in finding out the long-term trend, which is useful for policymaking.

Materials and Methods

Theoretically, several factors are responsible for the degradation of environmental quality including human activities, economic growth, energy consumption, trade and commerce liberalization, and financial development. The relationship between economic growth and environmental degradation in the form of the environmental Kuznets hypothesis has been studied in several research. The present study uses the new Markov switching approach to investigate the Kuznets environmental hypothesis for Iran. The main advantage of this method is that it allows the U-shaped behavior to be examined in the context of different regimes that have not been studied in Iran for Environmental Kuznets Curve (EKC).

Markov Switching-Error Correction Model

To test the EKC hypothesis, the Markov Switching-Error Correction Model (MS-ECM) was used because it can evaluate the effect of growth on pollution in different regimes. The general form of the MS-ECM is as follows (Charfeddine, 2017):

$$\Delta Y_t = \alpha ECM_{t-1,s_{t-1}} + \sum_{i=1}^{\gamma} \Gamma_j \Delta X_{t-i} + \sum_{j=1}^{s} \pi_j \Delta Y_{t-j} + u_t \quad (1)$$

$$ECM_{t-1,s_{t-1}} = (Y_{t-1} - \beta_{st-1} X_{t-1} - \mu_{st-1}) \quad (2)$$

α: The long-run adjustment

X_t: The vector of the independent variables

Y_t: Dependent variable

Δ: First-order difference

S and γ : The log of the independent and dependent variables in the short run

S_t: Dummy variable with values 0 and 1 in Markov's two regimes:

$$s_t \begin{Bmatrix} 1 \quad with\ probability\ p_{11} \\ 2 \quad with\ probability\ p_{22} \end{Bmatrix} \tag{3}$$

where $p_{11} = P[s_t = 1|s_{t-1} = 1]$,$p_{22} = P[s_t = 2|s_{t-1} = 2]$

$$\sum_{i=1}^{2} p_{ij} = 1 \quad for \quad j = 1{,}2. \tag{4}$$

Based on the explanations, intercept and slope coefficients can be measured based on the Markov-switching method:

$$\mu_{st} = \mu_1 + (\mu_2 - \mu_1)(s_t - 1) \tag{5}$$

$$\beta^{st} = ((\beta_1^1, \beta_1^2), (\beta_2^1, \beta_2^2), \dots, (\beta_k^1, \beta_k^2)) \tag{6}$$

where K represents the number of independent variables of the model and β represents the slope of independent variables in different regimes[1]. In this study, Gauss 15 and Matlab software were used to estimate the MS-ECM.

The following equation is used:

$$ED = f(RGDP, E, OP, FD, HDI, UR) \tag{7}$$

In other words,

$$LED_t = \mu_{st} + \beta_1 LRGDP_t + \beta_2 LRGDP_t^2 + \beta_3 LE_t + \beta_4 LOP_t + \beta_5 LFD_t + \beta_6 LHDI_t + \beta_7 UR_t + \epsilon_t \tag{8}$$

in which ED is an indicator of ecological footprint and environmental degradation (CO_2 pollution in metric tons per capita), RGDP refers to the real gross domestic product (GDP) per capita variable, GDP^2 is real GDP per capita squared, E indicates energy consumption, OP is the openness of trade liberalization indicator, FD is financial development (ratio of government credit to private sector production gross domestic product), HDI refers to human development index, and UR represents urbanization variable. All variables were used logarithmically. In this way, the relationship between ecological footprint and economic growth was estimated. The annual dataset for 1971-2015 was sought for data availability. Regarding time series data, it is necessary to examine the stationary variables. In this study, structural root break tests were used with and without a structural break. Then, using the Markov-switching method, a long-term relationship between variables was investigated. The advantage of using the Markov-switching method is that it avoids hiding the effects of regime change on the coefficients of the model variables. Finally, the Granger causality test was used to investigate the causality relationship between the variables. The long-term series of residual series are called ECT_{1t} (Charfeddine, 2017).

$$ECT_{1t} = (LCO_{2t} - \hat{\beta}_1 LRGDP_t - \hat{\beta}_2 (LRGDP)_t^2 - \hat{\beta}_3 LE_t - \hat{\beta}_4 LOP_t - \hat{\beta}_5 LFD_t - \hat{\beta}_6 LHDI_t - \hat{\beta}_7 LUR_t - \mu_{st}) \tag{9}$$

Then, we estimated the short-term relationship using Equation 9:

$$\begin{pmatrix} \Delta LCO_{2t} \\ \Delta LRGDP_t \\ \Delta LE_t \\ \Delta LOP_t \\ \Delta LFD_t \\ \Delta LHDI_t \\ \Delta LUR_t \end{pmatrix} = \begin{pmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \\ \omega_4 \\ \omega_5 \\ \omega_6 \\ \omega_7 \end{pmatrix} + \sum_{j=1}^{k} \begin{pmatrix} d_{1,1,j} & \dots d_{1,7,j} \\ & . \\ & . \\ & . \\ d_{7,1,j} & \dots d_{7,7,j} \end{pmatrix} \begin{pmatrix} \Delta LCO_{2t-1} \\ \Delta LRGDP_{t-1} \\ \Delta LE_{t-1} \\ \Delta LOP_{t-1} \\ \Delta LFD_{t-1} \\ \Delta LHDI_{t-1} \\ \Delta LUR_{t-1} \end{pmatrix} + \begin{pmatrix} \pi_1 \\ \pi_2 \\ \pi_3 \\ \pi_4 \\ \pi_5 \\ \pi_6 \\ \pi_7 \end{pmatrix} ECT_{2t-1} + \begin{pmatrix} \vartheta_{1,t} \\ \vartheta_{2,t} \\ \vartheta_{3,t} \\ \vartheta_{4,t} \\ \vartheta_{5,t} \\ \vartheta_{6,t} \\ \vartheta_{7,t} \end{pmatrix} \tag{10}$$

Therefore, the long-term and short-term relationships between variables were fitted, and their coefficients and their significance were discussed.

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[1]Since it was impossible to simultaneously change the slope of the independent variables and the intercept in the Oxmetric software, the Gauss 15 and Matlab software packages were used. In the present study, to determine the number of model regimes, we used the significance level of the models fitted with the number different and the significance of the transfer matrix coefficients (Charfeddine, 2017). Due to the limitations of the available data, after fitting different models, the model with two regimes and the change in the coefficient of production variable simultaneously with the change in intercept from the highest level of significance were selected compared to other fitted models.

Results and Discussion

Unit root testing of variables was performed. The results of Table 1 indicate that none of the variables are stationary. However, all variables have become stationary with first-order differencing.

Table 1. Unit root and stationary test without structural break.

Variables	Level				*First difference*			
	MZ_{α}^{GLS}	MZ_{t}^{GLS}	MSB^{GLS}	MP_{t}^{GLS}	MZ_{α}^{GLS}	MZ_{t}^{GLS}	MSB^{GLS}	MP_{t}^{GLS}
CO2	0.59578	0.34569	0.58024	26.0875	-30.3188	-3.89264	0.12839	0.81077
GDP	-4.05679	-1.42348	0.35089	6.04008	-14.3084	-2.67413	0.18689	1.71462
E	1.38204	1.50858	1.09156	87.7538	-20.7561	-3.20408	0.15437	1.24137
OP	0.32795	0.14335	0.43713	17.0611	-19.9819	-3.16063	0.15817	1.22688
FD	-0.18967	-0.08842	0.46619	16.9261	-20.7453	-3.21288	0.15487	1.20830
UR	0.54919	0.38255	0.69658	34.2570	-18.5807	-3.04778	0.16403	1.31940
HDI	0.44984	0.34895	0.77571	40.0290	-20.9361	-3.23539	0.15454	1.17039

The critical values are -8.10, -1.98, 0.233, and 3.17 for the $MZ\alpha$, $MSBGLS, MZt$, and MPT GLStests, respectively.
The null hypothesis of Ng-Perron tests is non-stationary.
The null hypothesis is rejected if the statistic is lower than critical values.
The italic and underlined statistics show that the series is stationary in levels.

According to previous experience, in time series data, it is better to perform the unit root tests with a structural break. Thus, as shown in Table 2, stationary variables are reported using Dickey-Fuller with and without a structural break.

Table 2. The results of Ng and Perron's (1996) unit root tests with and without breaks

		Critical value 5%	Without breaks	Critical value 5%		Critical value 5%	With breaks	Critical value 5%	Breaks date(Level)	Breaks date
	Level		First difference		Level		First difference			
CO2	-0.210	-2.929	-5.245	-2.9331	-2.428	-4.443	-5.133	-4.443	1997	1986
GDP	-1.540	-1.948	-3.449	-1.948	-2.411	-4.443	-5.925	-4.443	2006	1991
E	-2.123	-2.933	-8.339	-2.933	-3.593	-4.443	-8.479	-4.443	1989	1997
OP	-0.629	-2.931	-5.109	-2.933	-2.377	-4.443	-5.469	-4.443	1991	1988
FD	-0.345	-2.931	-5.694	-2.933	-3.846	-4.443	-6.244	-4.443	2005	1997
UR	-2.319	-2.935	-6.983	-2.931	-7.714	-4.443	-2.696	-4.443	1992	1997
HDI	-0.593	-2.931	-6.755	-2.931	-4.290	-4.443	-9.175	-4.443	1986	2010

the Persian Gulf War, and global economic crises have affected energy consumption, economic growth, and CO_2 pollution in the region.

As shown in Table 2, the variables are stationary with a break and without a structural break on the non-stationary and become stationary only with a first-order difference operation.

After checking the stationarity of the model variables, the likelihood ratio (LR) test was used to ensure the nonlinear model versus the linear model. In the likelihood ratio test, the hypothesis of zero linearity of the model is tested against the hypothesis of the existence of a nonlinear Markov-switching model. Therefore, the model was first estimated linearly and then nonlinearly, and using Equation $LR = 2(LL_{ms} - LL_{linear})$ and its significance level, the null hypothesis that the model is linear was tested. Given that the statistic of this test was 85.717 and the related probability was 0.000, the hypothesis of zero linearity of the research model was rejected and the existence of a nonlinear Markov-switching model was confirmed (Table 3). Therefore the linear or nonlinear determination likelihood ratio test was performed, and the results show that the model is nonlinear. The results of the long-run relationship between all variables are reported in Table 3 when only the intercept and the coefficient of income slope (GDP per capita) are switched in regimes 1 and 2.

Below, the structural break was introduced in the unit root test in which the break years are as follows: the years of data break are mainly related to oil shocks, and

$$LCo2_t = -9.254 + 3.542LRGDP_t - 0.304LRGDP_t^2 + 0.188LE_t + 0.040LOP_t - 0.050LFD_t + 0.156LHDI_t + 0.144\text{LU}R_t + \hat{\epsilon}_t \quad (11)$$

If $S_t = 1$ and

$$LCo2_t = -3.332 + 2.705LRGDP_t - 0.304LRGDP_t^2 + 0.188LE_t + 0.040LOP_t - 0.050LFD_t + 0.156LHDI_t + 0.144\text{LU}R_t + \hat{\epsilon}_t$$

If $S_t = 2$

the transition matrix between the two regimes is:

$$\hat{P} = \begin{pmatrix} \hat{p}_{11} & \hat{p}_{12} \\ \hat{p}_{21} & \hat{p}_{22} \end{pmatrix} = \begin{pmatrix} 0.93 & 0.07 \\ 0.09 & 0.91 \end{pmatrix} \quad (12)$$

In the transfer matrix for CO_2, the probability of stability is 0.93 in regime 1 and is 0.91 in regime 2, and the probability of transition from regime 1 to regime 2 and reverse is 0.07 and 0.09, respectively. Also, the high level of significance of the probability of stability of regimes 1 and 2 indicates that each regimen is stable for a sufficient period of time, which confirms the reliability of the results obtained from the model.

Using the Markov-switching method, the LR indicator shows that the Markov-switching model is better than linear form by changing intercept and slope per capita income. These results are confirmed by the estimated value of the transition probability p_{11} and p_{22} and their statistical significance level. In other words, the results indicate that the link between environmental degradation and real incomes in breaks is hidden. These results are confirmed by the high estimates of p_{11} andp_{22}.

The first and second regimens for contamination and CO_2 emission last for 14 years and 3 months and 11 years and 1 month, respectively. These results indicate that the behavior of actual production per capita and CO_2 per capita could be hidden in coherent vector breaks. The results of estimating the standard EKC equation using the Markov-switching method show that the LR indicator of the Markov-switching model outperforms the linear form by changing the intercept and slope of per capita income.

Table 3. Estimation of the long-term relationship with Markov shifts

		Co_2	
		Linear	Markov Switching
Independent variables	Parameter	Coefficient	Coefficient
Intercept	μ_1	-2.437	-9.254***
	μ_2	-	-3.332**
LRGDP	β_1	0.549**	3.542*** 2.705**
$LRGDP^2$	β_2	-0.062 **	-0.304**
LE	β_3	0.345***	0.188***
LOP	β_4	0.091	0.040**
FD	β_5	-0.133*	-0.050***
LHDI	β_6	0.257**	0.156***
LUR	β_7	-0.989	0.144*
Probability Transition	P11	-	0.93***
	P22	-	0.91***
Log-Likelihood	LL	65.171	108.029
LR-test	LR		85.717***
Regime 1	$1/(1-P_{11})$		14 years and 3 months
Regime 2	$1/(1-P_{22})$		11 years and 1 month

* Indicate significance at the 10%
** Indicate significance at the 5%
*** Indicate significance at the 1%

The results of the estimated long-run relationship indicate that the actual GDP coefficients $(3.542, 2.705)$ are significantly positive for CO_2 in both regimes. The coefficients of GDP^2 were negative and significant at the 5% level. These results confirmed the environmental Kuznets curve (U reverse) in Iran for CO_2. This EKC hypothesis for the CO_2 emissions pollutant confirms the results of Jammazi and Aloui (2015), Charfeddine (2017), and Charfeddine and Mrabet (2017).

Further, the results indicated that energy consumption had a positive and significant effect on environmental degradation and carbon footprint (CO_2). In other words, a 1% increase in energy consumption will increase CO_2 emission by 0.188%, meaning that air pollution is aggravated, so energy is not an environmentally-friendly resource in Iran. The results are consistent with those reported by Omri et al. (2015), Charfeddine and Mrabet (2017), Charfeddine (2017), Hamit-Haggar (2012), and Jalil and Feridun (2011). The main source of emissions is fossil fuels as they are currently one of the main sources of energy production in Iran's economy. In other words, the adoption of less polluting technologies or the import of commodities whose production would increase domestic pollution will reduce pollution and environmental degradation. This is related to the significant share of oil and gas in Iranian manufacturing industries. These results are supported by Omri et al. (2015), Charfeddine and Khediri (2016), Hamit-haggar (2012), and Ang (2008).

The coefficient associated with trade openness is positive and significant ($P < 0.05$). This result can be explained by the importance of the share of gas and oil exports in total GDP, which results in greater environmental degradation by the production and consumption processes. The result of this study is in accordance with the studies of Langnel and Amegavi (2020), Ahmed et al. (2021), and Charfeddine (2017).

Financial development has a negative and significant impact on CO_2. That is, a 1% increase in financial development as a share of GDP will reduce CO_2 emission by 0.050%, which reflects that Iranian policymakers can further reduce air pollution and environmental degradation by increasing financial development. Furthermore, increasing energy consumption, especially fossil fuels, leads to an increase in CO_2 emissions and accordingly more pollution. Financial development combined with environmental monitoring can increase economic growth by reducing investment risk, facilitating capital equipping, and increasing innovation. On the other hand, it can reduce the negative effects of economic growth on environmental quality by creating sufficient incentives to control pollution. With the advent of financial intermediaries and the introduction of new financing and development tools, financial development addresses goals such as risk reduction, increasing capital efficiency through optimal resource allocation, and saving mobility and ultimately pursues the goal of long-term economic growth for the economy. Nonetheless, along with the impact of economic development on economic growth, there will also be effects on the environment. Financial development can indicate the ability to attract capital, which improves research and development and positively influences economic growth and environmental improvement so that increasing financial development can lead to the use of new environmentally friendly technologies. If financial development leads to an increase in industrial activities, it will lead to the emission of environmental pollutants, especially CO_2. Also, if financial development is not environmentally supervised, the activities of private companies aimed at making more profit will increase energy consumption and pollution, but if financial development is accompanied by improved research and development and sustainable development, it will reduce pollution.

Meanwhile, financial development can encourage producers to implement environmental projects such as production process improvement by providing low-cost finance. Then, they can reduce energy consumption by improving their production process and making an investment in newer technologies. Therefore, financial development can reduce emissions and pollutants directly by reducing energy consumption. Financial development allows a country to attract more foreign direct investment and liberalization and achieve a higher level of technology, which in turn leads to economic growth and environmental quality. The achievement of environmental-friendly technologies in developing countries, including Iran, is the result of financial development policies. Technology affects environmental pollution in two ways. With the improvement of technology and the use of new technologies, production functions will have less need for environmental goods and less pollution will be emitted during production. Also, the improvement of technology makes the industries act more efficiently and at a lower cost to eliminate pollution, which is the result of reducing pollution. However, the increase in industrial activities resulting from financial development is a factor involved in increasing industrial pollution and environmental degradation, and higher economic growth will lead to more production and consumption to meet human needs, which will lead to more pollution and environmental degradation. These results are consistent with Charfeddine (2017), Frankel and Romer (1999), Asgharpour et al. (2013), Behboudi et al. (2014), Hori et al. (2013), Shahbaz (2013), and Shahbaz et al. (2013) but inconsistent with Omri et al. (2015), Charfeddine and Khediri (2015), Tamazian and Rao (2010), and Wang and Jin (2007).

In this study, the results show that human development leads to increased CO_2 emissions. In other words, with human development (improvement of health indicators, life expectancy, and knowledge), the amount of environmental pollution such as CO_2 emissions increases, which is related to the fact that it enables people to put more focus on economic growth goals and increase production. Our results also demonstrated that weak environmental laws and inadequate environmental pollution monitoring have also increased over ths studied period.

The results for the variable of urbanization show that the estimated coefficient associated with this variable for the ecological footprint is positive and significant. Increased urbanization increases demand for goods and services, population density, and transportation, thereby leading to increased environmental pollution. This result supports some empirical studies that have found a positive relationship between environment degradation (CO_2) and the urbanization level, e.g., Farhani et al. (2014) and Charfeddine (2017).

Table 4. Estimation of the short-term relationship (MS-ECM)

Variables	ΔCO2
	Coeff.
DCO2(-1))	0.968***
DGDP(-1)	1.194***
DE(-1)	0.456**
DOP(-1)	-0.350**
DFD(-1)	-0.361*
DHDI(-1)	0.183
DUR(-1))	0.479
ECT(-1)	-0.526***
C	1.388*

* Indicate significance at the 10%
** Indicate significance at the 5%
*** Indicate significance at the 1%

The results of estimating the short-term relationship are reported in Table 4. The ECT coefficient (-0.526) is negative and significant, and as such have a long-term equilibrium. In addition, ECT is a moderation rate, which indicates the rate of long-term adjustment for CO_2 and shows that fluctuation is adjusted each year for CO_2.

Conclusion

The most important impact of human activities on the climate mainly comes from increasing greenhouse gas (GHG) emissions, while carbon dioxide (CO_2) is the most common GHG in the world. Pollution and environmental degradation, including CO_2 emissions, are considered a serious threat to the future. Thus, understanding the factors affecting carbon emissions can help develop wise pollution control policies. In this study, the long-term relationships between carbon footprint and economic and human development were investigated using the data for the period 1971-2015 in Iran. The CO_2 variable was used as an indicator of carbon footprint and environmental degradation. Numerous scholars have explored the causes of environmental degradation using CO_2 emissions as a proxy of environmental degradation.

After performing a unit root test with a structural break for environmental degradation variable, real GDP, energy consumption, human development, urbanization, trade liberalization, and financial development, using Markov-switching, the long-term and short-term relationship between variables, and their impact on carbon footprint were measured. The nonlinear Markov-switching method has the advantage that it can measure the effects of different factors on environmental degradation in different regimes and it also reduces the error.

The positive coefficient of GDP variable shows that an increase in production and economic growth has increased CO_2 emissions in Iran. The negative GDP^2 coefficient also shows that after achieving a certain level of production and income, it is possible to help reduce environmental problems through innovation and structural changes in the economy. Therefore, the existence of the environmental Kuznets hypothesis over the studied period in Iran is confirmed. Although the inverse U-shaped relationship between economic growth and carbon footprint is different in different Markov regimes, the existence of the environmental Kuznets hypothesis is supported in both studied regimes.

Therefore, the difference between the two regimes shows that the economic structure of the country has an important role in degrading the environment and spreading pollution.

The positive effect of energy consumption variable on carbon footprint in Iran shows that increasing energy consumption in the country has increased the emission of CO_2 pollution, so it seems necessary to use renewable energy, increase the use of energy-saving technology, pay attention to energy efficiency with development, adopt appropriate technologies, invest in green energy, reduce the share of fossil fuels, and increase the share of clean energy such as solar energy.

The variable of financial development has had a negative and significant effect on the carbon footprint in Iran. This variable can have a positive or negative effect on the carbon footprint. Financial development through the development of businesses increases energy production and consumption. Low-interest financial development will also increase people's purchasing power and destroy the environment. Financial development can also prevent environmental degradation by investing in environmentally-friendly technologies and supporting research and development in environmental projects and the consumption of green energy and clean energy.

Financial development can increase pollution and environmental degradation by increasing industrial activity. In other words, although financial development can increase economic growth, insufficient oversight in the allocation of funds will have devastating environmental effects. Therefore, it is necessary to define conditions in the allocation of credits, such as forcing producers to adopt environmental standards.With the increase in urbanization, the process of economic development has moved towards industrialization, and for this reason, pollution has also increased by increasing urbanization, industrialization, and population density. As a result, environmental degradation has been aggravated while no attention has been paid to productivity and resource efficiency.

The positive effect of the liberalization of the economy on pollution emissions and carbon footprint in Iran is due to the high share of oil and petroleum products in exports and trade. In other words, with the increase in trade and exports, the demand for oil and gas products has increased and more production has been associated with more pollution. Trade liberalization is an economic stimulus due to its beneficial effect on productivity and adoption and use of better technology, but recent trade dynamics and investment growth aimed at further production have degraded the environment. In Iran, the growth of production and trade has been accompanied by energy consumption and has led to the destruction of the environment.

The Human Development Index had a positive effect on the carbon footprint in the study period. This result shows that to increase knowledge and awareness and improve health indicators through excessive focus on increasing production and economic growth, as well as weak environmental laws and lack of proper supervision, have caused environmental degradation. Therefore, it is necessary to promote society's environmental knowledge and express the necessity of environmental protection as observing environmental considerations not only increases the level of health and life expectancy of society but it can also be effective in growth and development by improving the health status.

The results of this study showed that structural failure can obscure the real relationship between the variables, so to reduce the estimation error, the Markov-switching method will be useful. Therefore, considering the positive impact of variables of production, urbanization, human development, and energy consumption on CO_2 emissions and environmental degradation, it is suggested to consider the efficiency of production units, energy saving, use of energy-reducing technologies, replacement of fossil energy with clean energy, urban population density, and serious environmental monitoring along with the efforts on increasing production.

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