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Research Article

An Investigating the Effect of Economic and Social Factors on Iran's Ecological Footprint Using the Markov Switching- Error Correction Model

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Abstract
Todays, environmental pollution is one of the main challenges of the world and global economic growth is causing environmental degradation. Therefore, considering the purpose of economic growth and its impact on ecological footprint, it is important to study the impact of economic and social factors on environmental pollution and its degradation in Iran, as well. This study investigated, the effects of the variable of economic growth, energy consumption, trade liberalization, financial development, human development and urbanization on environmental degradation over the period 1971-2015 in Iran using the Markov Switching – Error Correction model (MS-ECM). Based on the environmental Kuznets hypothesis was confirmed for the environmental degradation and its shape was found to be U-reversed. Economic growth, urbanization, energy use, financial development and urbanization were found to have a positive and significant effect on the environmental degradation, while the human development variable negatively influenced environmental degradation. Finally, practical recommendations are drawn from the results, for economic and environmental policies.
Keywords: Ecological footprint, Economic growth, environmental degradation, energy.

Introduction

Economic growth is the main objective of economic development plans in any country. Increasing production and economic growth requires using more natural resources and energy, especially fossil fuels, which results in environmental degradation (Tamazian et al., 2009). Presently, along with economic issues, the policy makers are paying attention to the environmental issues. The production process consumes natural resources and produces unpredictable outburst (environmental pollutants), as well. If the amount of these emission and contaminants is not controlled, the undesirable effects outweigh the benefits of the products. Accordingly, the costs of environmental damages cause irreparable losses and pose a serious risk to sustainable development (Ahmed et al., 2021).

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

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were considered major issues in international negotiations in the 1980s (Jayadevappa and Chhatre, 2000). In the 1990s, some evidence indicated a relationship between various environmental pollution indicators and the economic growth of the environmental Kuznets curve, relationship that came to known as the U-inverse of the environmental Kuznets curve. Environmental Kuznets' curve proposed a relationship between income per capita and environmental degradation criteria as a reversed U-relation. 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 increases, then culminates, and finally decreases (Ahmed et al. 2019; Pajouyan and Tabrizian, 2010; Grossman and Kruger, 1995). In addition, many studies tried to validate this hypothesis (e.g., Farhani et al. 2014; Hassan et al. 2019), While some studies supported, the Kuznets hypothesis, others like Cox et al. (2012), Tsurumi and Managi, (2010), did not confirm the environmental Kuznets hypothesis.

Many national and regional economies have witnessed economic improvements and transformation in the current century (Nathaniel and Khan, 2020). These improvements are accompanied by environmental pressure. According to the ecological footprint (Martines-Rocamora et al., 2016; Mancini et al, 2016; Rudolph and figge 2017), the consumption of natural and environmental resources has exceeded the biological capacity of the earth since the 1970s (WWF, 2014), so that human demands can bring about pressure on the environment and the ecosystem, which can ultimately causes climate change, land degradation, pollution and 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 including air pollution, water pollution, deforestation and greenhouse gas emissions like CO2, which can measure only a small fraction of degradation, while the ecological footprint is more comprehensive than any mentioned indicators (Molaei and Besharat, 2015). The ecological footprint index indicates the quality of using environment by human being, which compares the rate of resource consumption and waste generation by human with the rate of reproduction of resources and waste disposal by biosphere, which is defined by the amount of needed land to keep this cycle. The ecological footprint represents the amount of biological space needed to generate resources and eliminate waste generated by a population, organization, or activity, based on the management system and technology (charfeddine, 2017). Therefore, the ecological footprint is a way to link between natural resources and the demand of humans for the supply of goods and services. The ecological footprint represents the potential destruction of natural capital, which can be considered an indicator of the threat to the sustainability.

The research aimed to explore the impact of economic and social factors on the ecological footprint of Iran. This study is important for environmental consequences because it improves estimates of the relationship between economic and social factors and ecological footprint, which is crucial for environmental sustainability. If the relationship between these variables is not determined correctly, the results can be unreliable.The innovation of the research is that it has used the ecological footprint index as an indicator of environmental degradation and has simultaneously explored the effect of socio-economic factors on the ecological footprint of Iran using the Markov switching-vector error correction method that so far, no research has been conducted in this field.

Therefore the study is effective from several aspects: Firstly, it explores the impact of social factors, in addition to economic factors, on the ecological footprint of Iran. Secondly, most studies have used CO_2 emission as a proxy of environmental degradation. But, the present research uses the ecological footprint index because it is all-inclusive and has global popularity as an index of environmental degradation. Thirdly, the nonlinear Markov Switching-Error Correction Model 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 to find out the long-term trend, which is useful for policymaking.

Present study has arranged in five sections. The research background of the study has reviewed in the second section, the research methodology is studied in the third section also the analysis of the experimental results is presented in section four. Finally, the results are presented and the policy proposals of the paper are discussed in the fifth section.

Research Background

Liobikien and Dagiliut (2016) stated that sustainable production and consumption policy are a key objective in the EU, and its members are pursuing sustainability policies at various levels. Data analysis showed that all European countries have reached the defined level of ecological footprint, even some of them have crossed the permissible limit. Therefore a commitment to reduce the environmental impact from consumption-based perspective should be more addressed covering values and lifestyles. 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 their study, political, social, and economic indicators were used for all oil and non-oil countries. The results showed that energy use worsens ecological footprint, whereas real GDP per capita exhibits an inverted U-shaped relationship with EF in oil-exporting countries and in the sample, the EKC hypothesis is validated. For the non-oil-exporting countries, the relationship between EF and economic growth is U-shaped. Moreover, their findings showed that socio-demographic variables such as urbanization, life expectancy at birth and fertility rate improve the environment in the long term. They also found that the improvement of political institutions in those countries has not been accompanied by a reduction of environmental stress.

A study by Charfeddine (2017) revealed that reducing air pollution is 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 EF and CO2 as proxies of environmental degradation during 1970-2015. The results indicated that the U-shaped relationship is dependent on the regime, and this relationship was finally confirmed. The findings showed also that when controlling for breaks the environment Kuznets curve hypothesis holds for the $CO2$ emissions and ecological carbon footprint pollutants and the U-shaped behavior holds for the total ecological footprint. Rudolpha and Figge (2017) analyzed the ecological consequences of globalization, by employing the ecological footprint as a proxy for human ecological demands and the KOF index of Globalization. They examined the phenomenon of the environmental Kuznets hypothesis using ecological footprint and globalization indices in 146 countries during 1981-2009. The results indicated that globalization has increased ecological footprint, but this has not been supported by all studies by analyzing extreme boundaries. Appiah (2018) showed the economy of Ghana continues to witness a rising demand for energy coupled with growth in gross domestic product that follows a wavy trajectory. Since there is a causal link between energy consumption and economic growth with its concomitant effect on CO_2 emissions, any energy conservation-oriented policy not derived from energy efficiency and technological progress may hurt the Ghanaian economy.

Charfeddine et al. (2018) in line with the priorities of the Qatar national vision 2030 and its principal pillars, used the ARDL method to examine the relationship between energy consumption and economic growth in Qatar during the period 1970–2014. They concluded that policymakers should pay more attention to energy consumption and environmental pollution in achieving economic growth. In another study in Kuwait, Salahuddina et al. (2018) examined electricity consumption and economic growth during the period of 1980-2013. They indicated using ARDL method and structural breaks that economic growth, electricity consumption, and FDI stimulate CO_2 emissions in both the short and long run. The VECM Granger causality analysis revealed that FDI, economic growth, and electricity consumption strongly Granger cause CO_2 emissions. Based on these findings, they recommended that Kuwait reduce emissions by expanding its existing carbon capture, utilization, and storage plants; capitalizing on its vast solar and wind energy and reducing high subsidies of the residential electricity scheme.

Ahmed et al. (2019) investigated the relationship between globalization and the ecological footprint for Malaysia from 1971 to 2014. The results of the Bayer and Hanck cointegration test and the ARDL bound test showed the existence of cointegration among variables. The findings disclosed that globalization is not a significant determinant of the ecological footprint, however, it significantly increases the ecological carbon footprint. Energy consumption and economic growth stimulated the ecological footprint and carbon footprint in Malaysia. Financial development and population density reduced the ecological footprint and carbon footprint.

Hassan et al. (2019) discussed the impact of globalization and natural resources on economic growth from 1970 to 2014 in Pakistan. Based on an auto-regressive distributive lag model, they inferred that globalization promotes economic growth in Pakistan. Natural resources also contributed to economic growth, as the causality results suggested bi-directional causality between globalization and use of natural resources. Their study illustrated an inverted U-shaped linkage between environmental degradation and economic growth and a positive effect of natural resources on environmental degradation in the context of Pakistan. Policy implications were that countries should emphasize security, increase exports, encourage technological strength, and increase its intellectual management capacity. Destek and Sarkodie (2019) examined the role of energy and financial development on the ecological footprint in 11 newly industrialized countries using the augmented mean group estimator and heterogeneous panel causality method. The results of the estimator showed that there is an inverted U-shaped relationship between economic growth and ecological footprint. According to the causality test results, it is concluded that there is bi-directional causality between economic growth and ecological footprint. However, Rehman et al. (2019) found that globalization improves the environmental quality in high emission countries such as China, the United States (USA), and the United Kingdom (UK) and stimulates same in Brazil. He established that electricity consumption significantly encourages CO_2 emissions in China, the USA, Japan, and the UK, nonetheless, a reducing effect was observed for France.

Mohajeri et al. (2020) investigated the relationship between carbon dioxide emissions and economic growth with emphasis on the social welfare index of OPEC member countries. Thus, the data of OPEC member countries from 2000 to 2014 were analyzed using the data panel approach. The results showed that CO_2 emissions have a positive and significant relationship with the economic growth of OPEC member countries, which means that the higher the CO_2 emissions, the higher the nominal growth. Saud et al. (2020) investigated the role of financial development and globalization on the EF for selected one-belt-one-road initiative countries from 1990-2014. The pooled means group long-run panel estimation's results showed that the ecological footprint sparks off by 0.0211 percent global hectares in selected panel countries when there is a one percent rise in financial development. A one percent growth in globalization mitigated the ecological footprint by 0.0038 percent in the long-run, suggesting an inverse relationship. In addition, the pairwise Granger causality finding showed the feedback effects of both financial development and globalization on ecological footprint.

Hosseinidoust et al. (2020) studied the effect of GDP on CO2 emissions and using a time varying parameters vector auto regression method. The findings revealed the nonlinear impact of GDP on the greenhouse gas emission, so that until 2002 it had a positive effect on reducing greenhouse gas emission; whereas, from 2002 onwards it had a negative impact and led to escalating the greenhouse gas expansion. Besides, the positive shock of electricity consumption and GDP (without oil) on greenhouse gas emissions during the entire period was positive. Sun et al. (2020) showed the significant inter-country transfers of ecological footprint are embodied in foreign trade. The transfers of ecological footprints in foreign trade were dynamic and were influenced by environmental tax policies, whose future impacts have seldom been considered. They explored the effects of an energy tax, a common form of environmental tax, on these transfers. they combined a multi-sector dynamic computable general equilibrium model with ecological footprint assessment, and analyzed the changes in the actual and virtual land uses that comprise the ecological footprint under different tax intensities. For the actual land use component of the ecological footprint, the energy tax increased the export of ecological footprint but decreased its import in china.

Langnel and Amegavi (2020) examined the impact of trade liberalization and electricity consumption on the ecological footprint of Ghana. Using the ARDL method and data from the 1971-2016 period, they showed that trade liberalization, energy consumption and urbanization have increased the ecological footprint. On the other hand, economic growth reduce environmental quality, thus contributes to environmental degradation. Usman et al. (2020) verified the presence of cross-sectional dependency by utilizing second-generation tests for robust estimation. The results of augmented mean group estimation approach using 1990-2017 time data for 15 highest emitting countries showed that financial development, renewable energy and trade openness significantly contributed to overcome the environmental degradation, while economic growth and non-renewable energy utilization were more responsible for the environmental damages. Nathaniel and Khan (2020) concluded that economic growth, accompanied by rising energy demand in ASEAN countries have been unprecedented over these few years. On the other hand, the energy consumed in the ASEAN region was predominantly non-renewable, which could have implications for sustainable development. They examined explores the influence of renewable and non-renewable energy consumption, economic growth, and urbanization on a more reliable environmental indicator (ecological footprint) from 1990 to 2016, while controlling for trade. The findings revealed that economic growth, trade, and non-renewable energy contribute significantly to environmental degradation in ASEAN.

Ahmed et al., (2021) used both symmetric and asymmetric methods to examine the nexus between ecological footprint, economic globalization, economic growth, and financial development, controlling for population density and energy consumption in the third largest economy Japan. The findings revealed the long-run asymmetric and symmetric relationship of variables with the ecological footprint. The long-run empirical results of symmetric ARDL suggested that economic globalization and financial development increased footprint in Japan. On the flipside, the novel findings from the asymmetric ARDL indicated that positive and negative changes in economic globalization reduce footprint. The results showed economic liberalization has reduced the ecological footprint. Energy consumption and financial development have increased the ecological footprint as well as, and the Kuznets environmental hypothesis has been confirmed.

Regarding the environmental conditions, climate change, energy consumption and its impact on the economic sustainability, policymakers are pursuing the goals of improving the quality of the environment to strengthen the economic development process of the country. Therefore, the study aimed to examine the impact of effective factors on environmental degradation using ecological footprint index and Markov Switching - Error Correction Model (MS-ECM) in Iran.

Material and Methods

Coupled with the growing human consumption, this concern does not only increase the vulnerability of societies but also intensify the scarcity of ecological resources on earth. Theoretically, several factors are responsible for the degradation of environmental quality including human activities, economic growth, and energy consumption. The relationship between economic growth and environmental degradation in the form of the environmental Kuznets hypothesis has been studied in several studies.

There are many indicators for measuring environmental degradation including air pollution, water pollution and greenhouse gas emissions, each of these indicators only represent a small fraction of degradation, while the ecological footprint is more comprehensive than any one (Molaei and Besharat, 2015, charfeddine, 2017). The ecological footprint indicator was originally developed by Wackernagel and Rees (1996), Wackernagel et al. (2005) and Ahmed et al. (2021). To compare the level of environmental degradation and biosphere capacity, ecological footprint is a key concept which is expressed globally with the same unit (hectare). In this way, it is possible to compare the contamination between different studied areas globally. Ecological footprint represents a global pollution proxy which addresses several aspects of environmental degradation, including water, land, and air pollution.

The ecological footprint in primary form is calculated by equation (1):

$$EF_C = EF_P + EF_I - EF_E \qquad (1)$$

The components of the equation are: EF_c: The ecological footprint of consumption, EF_p: The ecological footprint of production, EFI-EFE: Ecological footprint of import and export

$$EF = \frac{P}{Y} \times YF \times EQF \times IYF \qquad (2)$$

P: The amount of production, Y: National average yield, YF: Yield factor, EQF: Equivalence factor

The present study uses the new Markov switching approach when examining the Kuznets environmental hypothesis for Iran. The main advantage of this method is that it allows U-shaped behavior to be investigated in the form of different regimes.

Markov Switching- Error Correction Model

The Markov Switching model was first introduced by Quandt (1972) and Goldfeld and Quandt (1973) and developed by Hamilton (1989). The Markov Switching model is nonlinear. The nonlinear models assume that the variable behaves differently in different conditions. This model employs probabilities to classify the time-series variables and/or the relations of the variables among two or more regimes and calculates the likelihood of transfer from one regime to another or staying in the existing regime. One advantage of the Markov Switching method over the other methods is distinguishing the endogeneity of the observations of a variable and distinguishing the endogeneity of the relations among the observations of variables. In this respect, the issues of dummy variables and structure failure are not relevant. It is also possible to predict the variations of the variables from one regime to another.

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

$$\Delta Y_t = \alpha ECM_{t-1,s_{t-1}} + \sum_{i=1}^{\gamma} \Gamma_j \Delta X_{t-i} + \sum_{j=1}^{s} \pi_j \Delta Y_{t-j} + u_t \tag{3}$$

$$ECM_{t-1,s_{t-1}} = (Y_{t-1} - \beta_{st-1} X_{t-1} - \mu_{st-1}) \tag{4}$$

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 short-run

$$s_t \begin{Bmatrix} 1 & with\ probability\ p_{11} \\ 2 & with\ probability\ p_{22} \end{Bmatrix} \tag{5}$$

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

$$\text{Where } p_{11} = P[s_t = 1|s_{t-1} = 1],\quad p_{22} = P[s_t = 2|s_{t-1} = 2] \tag{6}$$

$$\sum_{i=1}^{2} p_{ij} = 1 \quad for \quad j = 1,2. \tag{7}$$

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

$$\mu_{st} = \mu_1 + (\mu_2 - \mu_1)(s_t - 1) \tag{8}$$

$$\beta^{st} = ((\beta_1^1, \beta_1^2), (\beta_2^1, \beta_2^2), \dots, (\beta_k^1, \beta_k^2)) \tag{9}$$

Where K represents the number of independent variables of the model and β is represents the slope of independent variables in different regimes. In this study, Gauss 15 and Matlab software were used to estimate the MS-ECM and to determine the number of model regimes, used the significance level of the models fitted with the number different and the significance of the transfer matrix coefficients.

The following equation is used:

$$EF = f(RGDP, E, OP, FD, HDI, UR) \tag{10}$$

In other words,

$$LEF_t = \mu_{st} + \beta_1 LRGDP_t + \beta_2 LRGDP_t^2 + \beta_3 LE_t + \beta_4 LOP_t + \beta_5 LFD_t + \beta_6 LHDI_t + \beta_7 UR_t + \epsilon_t \tag{11}$$

Where, EF is ecological footprint, RGDP refers to the real GDP (Gross Domestic Product) per capita variable, GDP^2 is real GDP per capita squared, E indicates energy consumption, OP is openness of trade indicator, FD is financial development (ratio of government credit to private sector production gross domestic product), HDI refers human development index and UR represents urbanization variable. All variables were used logarithmically. The study employs a time series analysis to examine the relationship between economic and social factors and ecological footprint in Iran. The annual dataset from 1971 - 2015 is subject to data availability. The entire dataset was collected from the World Bank's development indicators (WDI) except for the

Ecological Footprint which was collected from the National Footprint Accounts (NFAs) of the Global Footprint Network. Regarding time series data, it is necessary to examine the stationary variables. In this study, a structural root break tests were used with and without 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 avoiding 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.

$$ECT_{1t} = (LEF_t - \beta_1 LRGDP_t - \beta_2 (LRGDP)_t^2 - \beta_3 LE_t - \beta_4 LOP_t - \beta_5 LFD_t - \beta_6 LHDI_t - \beta_7 LUR_t - \mu_{st}). \tag{12}$$

Then, we estimated the short-term relationship using the equation (12).

$$\begin{pmatrix} \Delta LEF_t \\ \Delta LRGDP_t \\ \Delta LE_t \\ \Delta LOP_t \\ \Delta LFD_t \\ \Delta LHDI_t \\ \Delta LUR_t \end{pmatrix} = \begin{pmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \\ \theta_4 \\ \theta_5 \\ \theta_6 \\ \theta_7 \end{pmatrix} + \sum_{j=1}^{k} \begin{pmatrix} c_{1,1,j} & \dots c_{1,7,j} \\ & \cdot \\ & \cdot \\ & \cdot \\ & \cdot \\ c_{7,1,j} & \dots c_{7,7,j} \end{pmatrix} \begin{pmatrix} \Delta LEF_{t-1} \\ \Delta LRGDP_{t-1} \\ \Delta LE_{t-1} \\ \Delta LOP_{t-1} \\ \Delta LFD_{t-1} \\ \Delta LHDI_{t-1} \\ \Delta LUR_{t-1} \end{pmatrix} + \begin{pmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \lambda_4 \\ \lambda_5 \\ \lambda_6 \\ \lambda_7 \end{pmatrix} ECT_{1t-1} + \begin{pmatrix} u_{1,t} \\ u_{2,t} \\ u_{3,t} \\ u_{4,t} \\ u_{5,t} \\ u_{6,t} \\ u_{7,t} \end{pmatrix} \tag{13}$$

Therefore, (12) and (13) the long-run and short-term relationship between variables were fitted and their coefficients and their significance were discussed.

Result and Discussion

In this step, unit root testing of variables was performed. The results of Table 1, indicate that none of the variables are stationary. But, all variables have become stationary with a once the difference.

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}
EF	0.3893	0.2671	0.6861	32.415	-32.349	-4.0202	0.1242	0.7621
GDP	-4.0567	-1.4234	0.3508	6.0400	-14.308	-2.6741	0.1868	1.7146
E	1.3820	1.5085	1.0915	87.753	-20.756	-3.2040	0.1543	1.2413
OP	0.3279	0.1433	0.4371	17.061	-19.981	-3.1606	0.1581	1.2268
FD	-0.1896	-0.0884	0.4661	16.926	-20.745	-3.2128	0.1548	1.2083
UR	0.5491	0.3825	0.6965	34.257	-18.580	-3.0477	0.1640	1.3194
HDI	0.4498	0.3489	0.7757	40.029	-20.936	-3.2353	0.1545	1.1703

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's tests is the non-stationary.
The null hypothesis is rejected if the statistic is lower than critical values.
The statistics in italic and in underline show that the series are stationary in levels.

The results of Table 1 show that all variables are non-stationary, and all of them become stationary with one-time differentiation function. However, according to some researchers, 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 (1995) unit root tests with and without breaks

Without breaks			With breaks			
Variable	Level	First difference	Level	First difference	Breaks date (Level)	Breaks date
EF	0.044	-5.639	-2.557	-5.796	1989	1989
GDP	-1.540	-3.449	-2.411	-5.925	2006	1991
E	-2.123	-8.339	-3.593	-8.479	1989	1997
OP	-0.629	-5.109	-2.377	-5.469	1991	1988
FD	-0.345	-5.694	-3.846	-6.244	2005	1997
UR	-2.319	-6.983	-7.714	-2.696	1992	1997
HDI	-0.593	-6.755	-4.290	-9.175	1986	2010

The critical values 5% are -2.931 and -4.443 in Ng and Perron's unit root tests without and with breaks respectively.

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, the Persian Gulf War, global economic crises and domestic economic shocks that have affected energy consumption, economic growth, and ecological footprint. As shown in Table 2, the variables are non-stationary with a break and without a structural and become stationary only with first order difference.

The linear or nonlinear determination likelihood ratio test has been 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.

$$LEF_t = 6.502 + 1.263LRGDP_t - 0.253LRGDP_t^2 + 0.282\ LE_t + 0.096\ LOP_t + 0.157LFD_t - 0.147LHDI_t + 0.188\text{LU}R_t + \hat{\epsilon}_t \quad (14)$$

If $S_t = 1$

And

$$LEF_t = 8.023 + 1.177LRGDP_t - 0.253LRGDP_t^2 + 0.282\ LE_t + 0.096\ LOP_t + 0.157LFD_t - 0.147LHDI_t + 0.188\text{LU}R_t + \hat{\epsilon}_t \quad (15)$$

If $S_t = 2$

The transition matrix between the two regimes is:

$$p = \begin{pmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{pmatrix} = \begin{pmatrix} 0.92 & 0.08 \\ 0.06 & 0.94 \end{pmatrix} \quad (16)$$

In the transfer matrix for EF, the probability of stability is 0.92 in regime 1 and is 0.94 in regime 2, and the probability of transition from regime 1 to regime 2 and reverse is 0.08 and 0.06, 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 models.

The results of estimating the standard EKC equation (linear without rotation of Markov switching) indicate that the behavior of second class between environmental degradation and income per capita is not significant and therefore the relationship is not confirmed. However, 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} and p_{22}. In other words, the first regime lasts for 12 year and 6 months of EF (environmental degradation) and the second regime takes 16 year and 7 months the first and second regimens for contamination.

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

		EF	
		linear	Markov
Independent variables	Parameter	Coefficient	Coefficient
Intercept	μ_1	-6.332 **	6.502**
	μ_2	-	8.023***
LRGDP	β_1	1.266	1.263***
		-	1.177***
LRGDP2	β_2	-0.055**	-0.253***
LE	β_3	0.194***	0.282***
LOP	β_4	-0.108	0.096
FD	β_5	0.177*	0.157***
LHDI	β_6	-0.298 **	-0.147***
LUR	β_7	1.347*	0.188**
Probability Transition	P11	-	0.92
Log-Likelihood	P22	-	0.94
	LL	44.976	117.823
LR-test	LR		45.694***
Regime 1	$1/(1-P_{11})$	-	12 year and 6 months
Regime 2	$1/(1-P_{22})$	-	16 year and 7 months

* 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 real GDP coefficients (1.262, 1.177) are significantly positive for ecological footprint contamination in both regimes. The coefficients of GDP^2 for environmental degradation (-0.253) was negative and significant at the 5% level. These results confirmed the environmental Kuznets curve (U reverse) in Iran for ecological footprint. This evidence as to the EKC confirms the results of Charfeddine (2017), Destek and Sarkodie (2019), Ahmed et al. (2021).

Further, the results indicated that energy consumption has a positive and significant effect on environmental degradation and ecological footprint. In other words, one percent increase in energy consumption will increase 0.282 the ecological footprint. The main source of emissions is fossil fuels is currently regarded as one of the main sources of energy production in the economic systems of Iran, due to the main oil and gas contribution in the country's manufacturing industries. This results may be attributed to vintage and obsolesce energy technologies that influence economic productivity. The results are Omri et al. (2015), charfeddine and Mrabet (2017) and Destek and Sarkodie (2019), confirmed these results.

The financial development is effective on environmental degradation. That is, 1% increase in financial development as a share of GDP will increase the 0.157 % of ecological footprint. The industrial activity driven by financial development is considered as a factor in increasing industrial pollution on environmental degradation and higher economic growth creates more production and consumption to meet human needs which in turn causes pollution and environmental degradation. The results show that the financial sector may be stimulated budget for environmentally friendly industry, technologies and green environmental projects in some countries, but increased financial growth in Iran has damaged the environment. According to the positive and significant coefficient of this variable on the ecological footprint, financial development in recent decades has not led to the acquisition of pollution reduction technologies and economic development has been without considering environmental considerations, these results are in agreement with those of Ahmed et al.(2021), Saud (2020) and Destek and Sarkodie (2019).

Human development coefficient (-0.147) is supposed to reduce environmental pollution. However, in this study, the results indicated that human development leads to reduce environmental degradation. In other words, in order to increase human development in achieving the desired level of welfare, some policies should be made for environmental degradation. Human development increases the level of knowledge and awareness of people in society and environmental damage is reduced. Along with human development, human health and the environment become valuable, and as a result, human development has reduced environmental degradation.

The results for the variable of urbanization show that the estimated coefficient (0.188) associated with this variable for the ecological footprint pollutant is positive and significant at 5% level. Increased urbanization has increased demand for goods and services, increases population density, and increases transportation, thus leading to increased environmental pollution.This result supports some empirical studies that have found a positive relationship between environment degradation and the urbanization level, e.g. Charfeddine (2017).

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

Variables	ΔEF Coeff.
DEF(-2))	0.526**
DGDP(-1)	1.354
DE(-1)	0.700***
DOP(-1)	0.285**
DFD(-1)	0.278***
DHDI(-1)	0.297
DUR(-1))	1.347
ECT(-1)	-0.596***
C	-0.005

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

The results of estimating the short-run relationship are reported in Table (4). Since the ECT coefficient (-0.596) is negative and significant for ecological footprint, based on theoretical foundation, this coefficient should be negative and significant in order to have a long-term equilibrium. In addition, ETC is the moderation rate, which indicates the rate of long-term adjustment for EF and indicates that fluctuation is adjusted each year for EF.

Improving the quality of the environment is the main goal of the country and policymakers. Applying effective policies and strategies is essential for recognizing the factors affecting environmental degradation properly. The reverse U relationship between GDP per capita and EF confirm the relationship between economic growth and environmental degradation. Therefore, it is necessary to pay attention to energy consumption and environmental quality, along with growth and economic policies.

Conclusion and recommendations

Human consumption has exceeded nature's biological production potential in many regions leading to serious degradation of ecosystems. Ecological footprints, which represent the area of productive land or water required to provide a given level of ecological services and absorb pollutants for a specific population and consumption situation, provide an effective tool to measure the impacts of human consumption on nature. The approach has been widely used to calculate national ecological assets, evaluate the appropriation of land, and measure the demands humans place on the ecological environment's regenerative capacity in a region or a country.

In this study, the long-term relationship between environmental degradation and economic and social factors were investigated using the data for the period 1971- 2015 in Iran. Numerous scholars have explored the causes of environmental degradation using CO2 emissions to proxy environmental degradation. However, CO2 emissions only reveal partial information on environmental degradation. Recently, scholars have shifted their focus, and the use of ecological footprint as an indicator of environmental problems is growing because of its comprehensiveness, so the ecological footprint variable was used as an indicator of environmental degradation in the present study.

After performing a unit root test with a structural break for environmental degradation variable, real GDP, energy consumption, human development, trade liberalization, and financial development, using Markov switching, the long-term and short-term relationship between variables, and their impact on environmental degradation 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 reduce the error.

The coefficient of GDP is positive, which indicates that economic growth drives human demands and ecological problems in Iran. The negative coefficient of GDP^2 suggests that after achieving a certain level of income, the environmental problems in Iran can be reduced with better environmental regulations, innovation, and structural changes in the economy. Therefore, the results of the study showed that the relationship between economic growth and ecological footprint is an inversed-U shape, and the relationship varies in different regimes, supporting the environmental Kuznets hypothesis. Further, the economic structure in Iran plays an important role in the rate of environmental degradation.

The positive coefficient of energy variables due to the environment shows that high energy consumption in Iran has led to increased environmental degradation. Thus, it is necessary to address and modify energy policies such as using renewable energies and allocating subsidies on goods. Since the ecological footprint can measure the potential destruction of natural capital (not real destruction), it can be regarded as an indicator of the threat of sustainability. Therefore, promoting energy conservation and energy efficiency by developing better technologies would be a viable strategy for Iran. More investment in green energy will generally be one preferred option to reduce environmental degradation. The share of fossil fuels and oil in the country's production processes should also be reduced and the share of clean energy such as biomass, wind, and solar energy should be increased.

The variable of financial development has had a positive and significant effect on Iran's ecological footprint. However, this impact is plausible because the financial sector affects the ecological footprint through several channels. First, the financial sector advances money to businesses, which enables them to establish new ventures as well as to expand existing projects, which in turn increases land usage, energy consumption, and waste generation. Second, the financial sector provides credit to individuals with a low-interest rate, which substantially increases the purchasing power of the general public. People can buy more goods, which leads to environmental degradation. Third, the financial sector supports infrastructure projects, such as seaports, buildings, railway tracks, and roads, which require water, land, and other resources. Financial development can reduce environmental degradation by investing in environmentally friendly technologies. Thus, the financial sector also needs to invest in green energy products and support research and development in modern technology to improve the environment.

The Human Development Index has had a negative impact on environmental degradation. In other words, increasing awareness of the importance of the environment leads people to demand a cleaner environment, enforce environmental laws, policies, and regulations, and in turn reduce environmental pollution. Based on the results, urbanization has had a positive effect on the ecological footprint in Iran. With the increase in urbanization and the growth of urban job opportunities, population density has increased and the rate of depletion of natural resources has been aggravated, and as a result, the ecological footprint has increased.

The results showed that structural failure can hide the real correlation between variables, so to avoid estimation error, the Markov switching method will be useful. Finally, it is suggested that environmental quality improvement policies should be included in sustainable development paths. Environmental policies should also target increasing public awareness about the consequences of human activities for the environment. However, energy consumption can be reduced by improving its efficiency in production units, diversifying its economy, encouraging the private sector in using low-consumption technology to reduce the ecological footprint with low-interest loans and strict regulatory policies.

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