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ORIGINAL RESEARCH PAPER

Examining the Effects of Sustainable Energy Policy and Socio-Economic Development on the Ecological Footprint with an Emphasis on Green Financing in Iran

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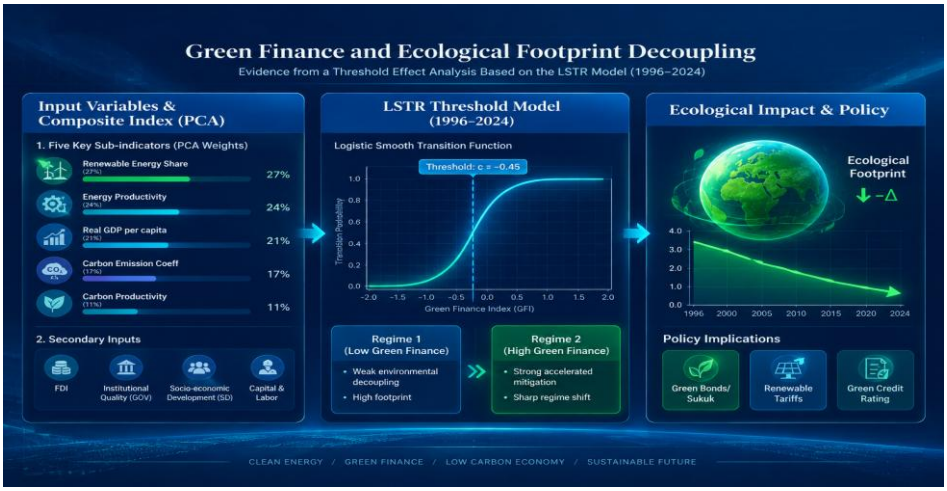
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A B S T R A C T

This study investigates the effects of sustainable energy policy and socio-economic development on the ecological footprint, with an emphasis on green financing in Iran. In this research, a composite green financing index was constructed using five sub-indicators: per capita real GDP, energy productivity, carbon productivity, carbon emission coefficient, and the share of renewable energy. The principal component analysis (PCA) method was employed to extract this index. After defining the indicators, the reliability and co-integration of variables were examined using the Phillips-Perron and Johansen-Juselius tests, which indicated that the variables are stationary at the first difference and that at least one co-integration vector exists among them, thereby allowing the estimation of long-term relationships.To analyze nonlinear and asymmetric effects, a Smooth Transition Autoregressive (STAR) regression model with the green financing index as the transition variable and a logistic function was applied. The results show that increases in the green financing index, foreign direct investment, sustainable energy policy, socio-economic development, capital and labor, and institutional quality each significantly reduce the ecological footprint. The nonlinear analysis indicated that once the green financing index exceeds a certain threshold, the ecological footprint responds sharply to changes in this index, revealing asymmetric effects between the two regimes.These findings suggest that policies based on green financing and sustainable development, in addition to enhancing economic and social productivity, play a significant role in mitigating environmental impacts.



1. Introduction

Sustainable energy policy has gained increasing importance in Iran as a key instrument for reducing negative environmental impacts and promoting social and economic development. Considering the limitations of fossil energy resources and the pressures caused by climate change, the use of renewable energy sources and the optimization of energy consumption have become essential components of national policies. These policies not only reduce greenhouse gas emissions but also facilitate industrial development, job creation, and the improvement of social welfare. Sustainable energy indicators including access to energy, energy efficiency, the share of renewable energy in the energy mix, and the level of pollution from energy production are important measures, and analyzing their effects on the ecological footprint can provide a comprehensive picture of the pressure of human activities on the environment

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[1].The ecological footprint, as a macro indicator for measuring human pressure on nature, reflects the amount of natural resources used and their regenerative capacity. In Iran, population growth, industrial development, and increased energy consumption have led to a rise in the ecological footprint and have placed significant pressure on ecosystems. Sustainable energy policy can positively contribute to reducing the ecological footprint by decreasing fossil fuel consumption, improving energy efficiency, and expanding renewable energy sources. At the same time, social and economic development accompanied by social justice and equitable access to energy resources can reduce the pressures caused by poverty and limited access to energy services, thereby decreasing unsustainable use of natural resources [2].Green financing plays a central role in implementing sustainable energy policies in Iran. Due to the limitations of government financial resources and the need for substantial investment in clean energy projects, green financial instruments such as green bonds, low-interest loans, and private-sector partnerships have become increasingly important. These instruments enable the development of large-scale projects such as solar and wind power plants, smart energy grids, and energy-efficiency projects in buildings and industries. In addition to providing financial resources, such investments increase the confidence of domestic and foreign investors and accelerate the development of sustainable energy, directly contributing to the reduction of the ecological footprint [3].Analysis of the effects of sustainable energy indicators and socio-economic development on the ecological footprint shows that increased energy efficiency, greater use of renewable resources, and reduced pollution significantly lower environmental pressure. In Iran, increasing the share of renewable energy in the energy mix particularly solar and wind energy has reduced dependence on fossil fuels and lowered carbon dioxide emissions. Furthermore, socio-economic development that includes improved education, better energy infrastructure, and the creation of green jobs can have even stronger positive effects on reducing the ecological footprint. In fact, integrating sustainable energy policies with socio-economic development initiatives provides a comprehensive approach to reducing environmental pressure and achieving sustainable development [4].Existing challenges in Iran include technological limitations, inadequate infrastructure, shortages of skilled human resources, and fluctuations in the energy market, all of which may restrict the implementation of sustainable energy policies. In addition, weaknesses in laws and incentive frameworks for green investment create barriers to the expansion of renewable energy. Overcoming these challenges requires the design of coordinated policies and the provision of financial and legal incentives to attract green investment. Such policies should include support for research and innovation, the provision of low-interest loans for clean energy projects, the issuance of green bonds, and the creation of domestic and regional markets for green technologies [5].The impact of socio-economic development indicators on the ecological footprint is also significant. Improved access to education and healthcare, job creation, and the reduction of inequalities can help decrease environmental pressures. For example, increasing public awareness about energy consumption and natural resource management can change consumption behavior and reduce unsustainable resource use. Moreover, investment in sustainable urban infrastructure such as clean public transportation and energy-efficient buildings reduces fossil fuel consumption and consequently lowers the ecological footprint [6].The role of green financing in Iran extends beyond simply providing financial resources for projects. It can contribute to the development of green markets, strengthen cooperation between government and the private sector, and enhance technological innovation. Green investment not only reduces pollutant emissions and improves energy efficiency but also creates employment opportunities in clean industries, promotes the production of advanced technologies, and increases the country's economic competitiveness. In addition, such investment can reduce economic risks associated with climate change and natural resource constraints, thereby contributing to economic and environmental sustainability [7].Empirical studies indicate that sustainable energy policies and socio-economic development particularly when supported by green financing can significantly reduce the ecological footprint in Iran. Lower fossil fuel consumption, improved energy efficiency, better access to clean energy, and enhanced socio-economic infrastructure all contribute to reducing ecological pressures and facilitating the achievement of sustainable development goals. In fact, combining these three factors as a comprehensive strategy creates convergence between economic, social, and environmental objectives and guides the country toward sustainable development [8]. From a policy-making perspective, successfully reducing the ecological footprint requires coordination among different institutions, the establishment of transparent legal frameworks, the provision of financial and social incentives, and increased public participation. Using sustainable energy and socio-economic development indicators as monitoring and evaluation tools can help both government and private sectors make evidence-based decisions. Additionally, the use of modern data-driven technologies and monitoring and reporting systems enables precise measurement of policy impacts on the ecological footprint and accelerates performance improvement [9].Ultimately, the analysis of the effects of sustainable energy policy indicators and socio-economic development emphasizing green financing in Iran demonstrates that an integrated and coordinated approach is essential for reducing environmental pressures and promoting sustainable development. Recognizing that clean energy and socio-economic development must be addressed simultaneously is key to reducing the ecological footprint and achieving long-term sustainable development. Green investment, as a facilitating tool in this process, enables the attraction of financial resources, technological advancement, and the development of human and industrial capacities, ensuring that energy and development policies generate positive outcomes for both the environment and society.

1.1. Literature Review

Sustainable energy policy has gained increasing importance in recent decades as the world faces challenges arising from climate change, population growth, and the growing demand for energy. These policies not only aim to reduce greenhouse gas emissions and protect the environment but also consider the social and economic development of societies. Sustainable energy includes the use of renewable resources such as solar, wind, biomass, and hydropower, along with optimizing energy consumption and improving energy efficiency. Such policies allow governments and organizations to align economic development with reduced environmental impacts while creating new employment opportunities and improving quality of life [10]. One of the key dimensions of sustainable energy policy is its direct relationship with socio-economic development. Access to sustainable and affordable energy improves living conditions, increases productivity in industry and agriculture, and reduces poverty. Sustainable energy enables disadvantaged communities to access essential services such as electricity, water, and transportation systems, thereby promoting social justice. Moreover, the development of green industries and clean technologies contributes to job creation and investment in innovative sectors, making national economies more resilient to global shocks. Investment in sustainable energy enhances countries' competitiveness and provides the foundation for long-term sustainable growth [11].Green financing plays a crucial role in implementing sustainable energy policies. This type of financing includes financial resources and instruments allocated to environmentally friendly projects and may involve green bonds, low-interest loans, joint investments, and international financial support. Green financing enables the implementation of large- and medium-scale projects such as solar and wind power plants and smart energy grids, while reducing economic risks associated with climate change and the instability of fossil fuel resources. In addition, investment in green energy attracts both domestic and foreign investors and stimulates economic activity [12]. Experiences from developed countries indicate that successful sustainable energy policies can only be effectively implemented when aligned with socio-economic development policies. For example, improving education and research in renewable energy and clean technologies creates the human and industrial capacity required for sustainable development. Furthermore, developing appropriate infrastructure for the production, distribution, and consumption of clean energy helps reduce energy losses and increase efficiency. In this context, governments can promote sustainable energy growth by offering financial and legal incentives, creating domestic and international markets for green products and services, and encouraging responsible consumption patterns [13]. From a social perspective, sustainable energy policy can have positive effects on public health and social welfare. Reducing air and water pollution, decreasing greenhouse gas emissions, and preventing environmental degradation improve citizens' quality of life and reduce pressure on healthcare systems. Equitable access to energy also helps reduce regional and social inequalities and supports balanced development in both urban and rural areas. Therefore, sustainable energy policy is not only an environmental issue but also a tool for social and economic development that can contribute to achieving sustainable development goals [14].Green financing, as a major pillar in this process, requires the design of innovative and efficient mechanisms. One effective approach is the issuance of green bonds by governments and corporations, which attracts investors to support environmentally friendly projects. Additionally, banks and financial institutions can provide green loans with lower interest rates to encourage investment in sustainable energy projects. Public–private partnerships can also reduce project risks and secure the necessary financial resources. Such financial mechanisms increase investor confidence, facilitate access to modern technologies, and accelerate the development of sustainable energy.However, there are significant challenges facing sustainable energy policy and socio-economic development. High initial costs, technological limitations, fluctuations in energy markets, and resistance from some traditional industries may slow the implementation of these policies. Furthermore, the lack of coherent legal frameworks and coordinated policies, shortages of skilled human resources, and limited public awareness can hinder long-term progress. To overcome these challenges, governments need to cooperate with international organizations, private institutions, and civil society to develop educational programs, financial support mechanisms, and legal incentives that can transform investment in sustainable energy and green financing into a reliable and sustainable trend [15].Sustainable energy policy and socio-economic development should be based on transparency, public participation, and careful analysis of economic and environmental impacts. Modern data-driven tools, energy monitoring systems, and social impact assessment programs can improve decision-making and reduce risks. In addition, international cooperation in technology transfer, joint investment, and knowledge exchange can create more opportunities for sustainable economic growth. Such an approach ensures that energy policies not only meet current needs but also promote environmentally compatible and socially just development for future generations [16]. In conclusion, the relationship between sustainable energy, socio-economic development, and green financing is reciprocal and complementary. Sustainable energy promotes economic growth and social welfare, while green investment provides the financial means to achieve these goals. Achieving sustainable development requires coordination of policies at national and regional levels and active participation from all stakeholders, including governments, investors, civil society, and citizens, in decision-making and project implementation processes. This approach not only reduces environmental impacts but also simultaneously enhances economic opportunities, employment, and social well-being.

1.2. Research Background

Amri Esrami [2] examined the convergence of green financing and sustainable tourism development. The study emphasizes that environmental degradation and rapid economic growth create unique challenges, and the tourism sector, due to its significant environmental impacts, requires strong financial mechanisms to reduce its ecological footprint. The findings indicate that the use of green financial instruments and environmental protection innovations reduces ecosystem degradation and strengthens sustainable development. Effective allocation of financial resources and appropriate regulatory frameworks play a key role in shaping sustainable tourism. Strategies such as green bonds and the integration of the circular economy can facilitate the implementation of ecosystem restoration projects and sustainable tourism practices. This study highlights the importance of synchronizing economic development with environmental protection in the tourism industry.

Akbari Dadamahleh [3] and Radfar investigated the impact of the green finance index on green growth and sustainable development. Their research shows that green financing, as an important tool supporting economic development, can significantly promote green transformation in the economy. Rapid urbanization and industrialization have increased resource consumption and environmental degradation, making the concept of green growth more prominent. Green financing, through investment in green projects, has the potential to reduce negative environmental and social impacts; however, it faces challenges such as lack of awareness, inconsistent definitions, policy coordination issues, and insufficient investor incentives. Control variables such as income level, population, and trade openness can also influence the impact of green finance on green growth and sustainable development. The findings reveal a bidirectional relationship between green finance and green growth, creating a reinforcing cycle that ultimately leads to sustainable development and a greener future.

Bayat et al.[1] studied smart financing for sustainable urban infrastructure using advanced architectural technologies and green structures. Focusing on Iranian metropolitan areas facing challenges such as air pollution, water scarcity, large-scale waste production, and land subsidence, the study proposed a model integrating blockchain technology, tokenization of green assets through NFTs, Building Information Modeling (BIM), and the Internet of Things (IoT). Blockchain ensures transaction transparency and reduces management costs by up to 60%, while tokenization enables fractional citizen ownership of green infrastructure and creates a highly liquid secondary market. BIM reduces construction waste by up to 30%, and IoT enables real-time monitoring of project performance and environmental indicators. The integration of these technologies reduces the investment payback period to 6.5 years and nearly eliminates fraud risks. The proposed model strengthens public ownership by attracting small-scale citizen investments and ensures the financial sustainability of projects. Practical recommendations include launching a smart PPP platform based on Polygon, establishing national standards for green asset tokenization, and implementing pilot projects. This model provides a practical framework for achieving sustainable urban development in developing cities.

Yu et al. [10] investigated the impact of capital guidance policies on carbon neutrality pressure (CNP) and evaluated the effectiveness of market-based green finance policies compared with government fiscal policies. Using city-level data from China and a quasi-experimental multi-period difference-in-differences approach, the results show that government green fiscal policies are more effective in reducing carbon neutrality pressure than market-based green financing policies. The study also emphasizes that the selection of green policy instruments should consider regional differences. The positive effects of government green fiscal policies are stronger in non-resource-based cities and western regions. The analysis indicates that government green fiscal policies create significant technological and structural impacts by encouraging green technology adoption and optimizing industrial structures, whereas market-based green finance policies do not produce similar effects. The study provides a framework for rational prioritization of green financial and fiscal policies in achieving carbon neutrality goals.

Ullah et al. [12] examined the role of technological innovation, green financing, and economic factors in energy efficiency and sustainable development. Using data from various countries between 2003 and 2019, the study analyzed the effects of green financing, technological innovation, trade openness, infrastructure development, economic growth, and foreign direct investment on energy efficiency. The results show that green financing and technological innovation have significant relationships with energy efficiency and can enhance sustainable development by improving energy systems and reducing environmental impacts. The study also indicates that combining responsible financial policies with supportive infrastructure enables countries to develop sustainable and energy-efficient economies while minimizing environmental damage. The research highlights the importance of Sustainable Development Goals SDG 7 and SDG 14 and provides policymakers with a practical framework for reducing environmental risks and supporting present and future generations.

Zhou et al. [13] examined the synergistic relationship between artificial intelligence and green financing in promoting clean energy production and transitioning toward sustainable development. Using global data from 2019 to 2024 and advanced quantitative models such as time-varying quantile-on-quantile VAR and Bayesian time-series causality models, the study analyzed the effects of artificial intelligence on investment in clean energy and ESG-oriented companies under bullish, bearish, and normal market conditions. The findings show that artificial intelligence technologies and ESG strategies mutually reinforce clean production in stable markets, while market volatility creates vulnerability patterns. The results also indicate that green bonds and sustainable investments contribute to the development of renewable energy infrastructure and support SDG 7, while stronger ESG commitments reduce reliance on carbon offsetting and focus more on direct emission reductions aligned with SDG 13. By integrating sustainable transition theory, the Porter hypothesis, and the resource-based view, this research provides a comprehensive theoretical and empirical framework emphasizing the necessity of integrating artificial intelligence with targeted green financing policies to advance clean production and mitigate environmental risks.

Lin et al. [17] examined the role of green financing and a just energy transition in achieving environmental sustainability in the United States. Using time-series data from 1990 to 2022 and the load capacity factor (LF) as an indicator of environmental sustainability, the study analyzed the effects of just energy transition and green financing, while controlling for GDP, urbanization, and trade openness. Nonlinear methods such as quantile-on-quantile regression (QQR), wavelet quantile regression (WQR), and quantile-on-quantile Granger causality (QQGC) were used to identify dynamic and asymmetric relationships between variables. The findings indicate that just energy transition and green financing can enhance environmental sustainability in certain quantiles and help mitigate climate change and carbon emissions. In contrast, GDP and trade openness negatively affect environmental sustainability. Urbanization shows a positive relationship with environmental sustainability, highlighting the potential role of urban growth in supporting sustainable development. The results underscore the importance of integrating sustainable energy policies and green financial mechanisms into national and international development frameworks.

Zhao et al. [18] examined the impact of fintech innovation on green growth in China, considering the mediating role of green finance between 2011 and 2018. The results show that fintech and green finance significantly promote green economic growth. At the same time, the impact of fintech and green finance on green growth shows clear regional heterogeneity, with stronger effects in eastern China compared to central and western regions. Further analysis indicates that fintech innovation mainly promotes green economic growth through green credit and green investment. Therefore, fintech innovation can enhance green economic growth by improving the level of green financial development, offering valuable insights for many countries.

2. Method

2.1. Methodology

In the present study, the effects of the sustainable energy policy index and socio-economic development on the ecological footprint are examined, with emphasis on green financing in Iran. The regression model of the research is introduced as follows:The economics profession has generally been skeptical. The long run remains genuinely uncertain, and any responsible policy analysis must take seriously the possibility that the skeptics are wrong.

$$COE_t = \alpha_0 + \beta_1 Green\ financing_t + \beta_2 FDI_t + \beta_3 SD_t + \beta_4 L_t + \beta_5 NRS_t + \beta_6 RENE_t + \beta_7 GOV_t + \beta_8 CAP_t(\theta_1 Green\ financing_t + \theta_2 FDI_t + \theta_3 SD_t + \theta_4 URB_t + \theta_5 NRS_t + \theta_6 RENE_t + \theta_7 GOV_t + \theta_8 CAP_t) F(S_t, \gamma, c) + u_t$$

Where the transition function F is defined as follows:

$$F(\gamma, s_t, c) = (1 + GOV\{-\gamma(s_t - c)\})^{-1}, \qquad \gamma > 0$$

In this model, the variables are defined as follows:

(COE): Ecological Footprint.

The ecological footprint index is a tool for measuring the extent of human activity pressure on the Earth's renewable resources that calculates biological demand by converting consumption and waste generation patterns into the required land area, and by comparing it with nature's biocapacity, determines the gap between unsustainable consumption and the regenerative capacity of ecosystems to ultimately serve as an accurate tool for assessing the sustainability of development and natural resource management at a global level [19].

the ecological footprint is calculated as follows. The amounts of three greenhouse gases CO_2, CH_4, and N_2O are estimated from the product of the amount of energy consumed and the emission coefficients of each gas. The emission coefficients are considered as 1, 21, and 310 respectively per joule of energy consumed from each source.Given the different global warming potentials of CH_4 and N_2O, the total greenhouse gas emissions are converted into CO_2-equivalent values. Each kilogram of CH_4 and N_2O has a greenhouse effect equivalent to 21 and 310 kilograms of CO_2, respectively.After calculating the total Global Warming Potential (GWP), the GWP values are expressed in different units, including per unit area (kilograms of CO_2 equivalent per hectare), per unit weight (kilograms of CO_2 equivalent per ton), per unit of input energy (kilograms of CO_2 equivalent per gigajoule), and per unit of output energy (kilograms of CO_2 equivalent per gigajoule).

$$CO_{E\,it} = CO_2 + 21 * CH_4 + 310 * N_2O$$

After calculating Equation (2), it is substituted into the model as the ecological footprint index.

Green Financing:

Green financing refers to financial resources allocated to environmentally sustainable activities. To obtain the overall green financing index, the green financing indicators for different sectors are first calculated, including real GDP per capita, energy productivity, carbon productivity, carbon emission coefficient, and the share of renewable energy.To determine the weight of each sector, the cyclical component of the variables in each sector is regressed on the cyclical component of output growth. The resulting correlation coefficient is then used as the basis for calculating the weights of the different sectors in constructing the overall green financing index of the economy [20].

NRSOURCES:

Natural resource abundance is measured according to the referenced study as the sum of coal consumption, crude oil consumption, and natural gas consumption divided by the population.

$$RA_t = \frac{\alpha_1 * Coal + \alpha_2 * oil + \alpha_3 * Gas}{Population}$$

RENRGY: Sustainable Energy Policy Index

This index is measured using the share of clean energy (renewable energy) consumption in total energy consumption, based on data from the World Bank.

Institutional Quality (GOV): Average Institutional Quality Index

To measure institutional quality, five different groups or sub-indices are combined:

1. Size of government
2. Legal system and property rights
3. Accountability and transparency
4. Freedom of international trade
5. Regulation of credit, labor, and business

Each of these five areas includes several main components and sub-components that together form the overall index of institutional quality. The Fraser Institute assigns a score for each category and calculates the average of these five indices to obtain a comprehensive institutional quality index for each country. In this index, 0 represents the lowest institutional quality, while 5 represents the highest institutional quality.

URB:

Urban population growth rate.

CAP:

Gross fixed capital formation per capita in US dollars (expressed as a percentage growth rate).

SD_t: Socio Economic Development Index

For this variable, the country's sustainable development index is used. In different studies, various indicators are employed to represent the level of socio-economic development. In this study, the Sustainable Development Index provided by the World Bank is used, which offers comprehensive and up to date information on global development.

This index measures a country's achievements across several dimensions, including poverty, health, hunger, global warming, gender inequality, water scarcity, energy, and environmental degradation. The index ranges from 0 to 1, where higher values indicate countries with higher levels of sustainable development, while lower values indicate lower levels of sustainable development.

L: Labor force participation rate, expressed as a percentage of the total population.

To construct the green financing index, in the first stage Principal Component Analysis (PCA) is used to calculate the variables reflecting green financial activities. An important issue in aggregating indices is the use of an appropriate weighting method. Considering the research literature and the specific conditions of the Iranian economy, it appears that different sectors do not contribute equally to the creation of green financing in Iran's economy. Therefore, a weighting method for the variables is required.

In this approach, the cyclical component of each variable used in constructing the composite index is first regressed on the cyclical component of a reference variable (such as output growth), which the composite index aims to explain. The resulting correlation coefficient is then used, based on Equation (1), as the weighting criterion for constructing the composite green financing index.

$$W_k = \frac{r_k^2}{\sum_{k=1}^{n} r_k^2} \quad (1)$$

Accordingly, in this study, to obtain the overall green financing index, after calculating the green financing indicators in different sectors including real GDP per capita, energy productivity, carbon productivity, carbon emission coefficient, and the share of renewable energy the weight of each sector is determined. For this purpose, the cyclical component of the variables in each sector is regressed on the cyclical component of output growth. The resulting correlation coefficient, based on Equation (1), serves as the basis for calculating the different weights used in constructing the overall green financing index of the economy. Therefore, after calculating the green financing index, its effects on the ecological footprint will be examined using a threshold regression model.

The statistical population of this study consists of data related to the Iranian economy during the period 1996–2024, collected on an annual basis, which are used for estimating the research model.

3. Results and Discussion

3.1. Measurement of the Green Financing Index

The first step in estimating the model is to calculate the green financing index. As discussed earlier, this index consists of five sub-components: real GDP per capita, energy productivity, carbon productivity, carbon emission coefficient, and the share of renewable energy.

This method has wide applications in different fields of science. One of its important applications in economics is index construction. In this article, the green financing index is extracted using this approach.

In examining many economic phenomena, it is observed that various factors with different dimensions and in different fields affect the emergence of a given phenomenon. Including all these factors in econometric analysis not only creates technical problems such as multicollinearity, but also increases the complexity of the model and the possibility of statistical errors. Therefore, the use of techniques such as PCA is an effective way to reduce such errors and obtain more reliable results [21-24].

The analysis of multivariate data plays a fundamental role in data interpretation. Multivariate datasets contain many states or variables for each observation. If a dataset contains n variables, each variable may also have several dimensions. Since understanding and interpreting multidimensional space is often difficult, the PCA method reduces the dimensions of all observations based on a composite index and groups similar observations together.

This method is one of the most valuable applications of linear algebra and has been widely used in many analytical fields, ranging from neural networks to computer graphics, because it is a non-parametric method for extracting relevant information from complex datasets. In this method, variables existing in a correlated multidimensional space are summarized into a set of uncorrelated components, each of which is a linear combination of the original variables. These uncorrelated components are called principal components (PCs) and are obtained from the eigenvectors of the covariance matrix or the correlation matrix of the original variables.

In general, the main applications of PCA are:

- Reducing the number of variables, and
- Identifying the structural relationships among variables, which in fact amounts to grouping or classifying variables.

The main advantage of using this method in econometrics is the elimination of multicollinearity in models where a large number of explanatory variables are involved.

Scatter Plot No. 1 shows points on the two coordinate axes X1 and X2.

In this study, the following variables are used to construct the composite green financing index:

- Real GDP per capita
- Energy efficiency
- Carbon efficiency
- Carbon emission factor
- Share of renewable energies

To determine the general direction of the points, an ellipse is drawn so that the correlation between the variables can be identified.

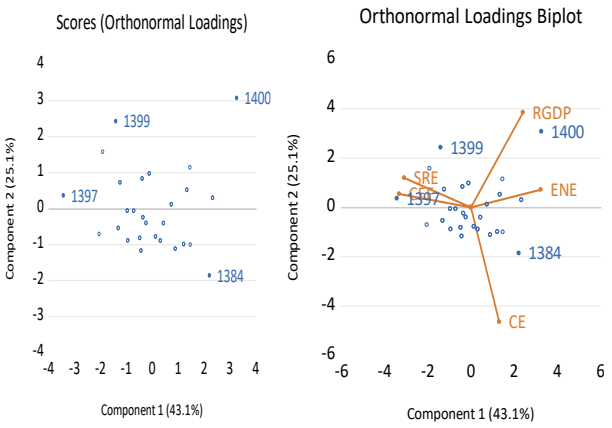


Figure 1. Transformation of Data into Principal Components

Source: Research Findings

The main direction of the dispersion of points is neither along X1 nor along X2, nor along the axes of other variables; rather, it lies between them and mostly along the major axis of the ellipse. This axis is called PC1, which represents the first principal component explaining the variability of X1, X2, and the other variables .The second component (PC2) lies along the minor axis of the ellipse, which is exactly perpendicular to PC1, and it explains the remaining variation in X1, X2, and the other variables . Therefore, PC1, PC2, and the other principal components form new axes for explaining X1, X2, and the other variables. Accordingly, it can be stated that X1, X2, and the other variables up to X5 are linear combinations of PC1, PC2, …, PC5, that is:

$$X_i = a_{i1}PC_1 + a_{i2}PC_2 + a_{i3}PC_3 + a_{i4}PC_4 + a_{i5}PC_5$$

The values of the principal components can also be obtained using the following equations.

$$PC_1 = W_1X_1 + W_2X_2 + W_3X_3 + W_4X_4 + W_5X_5$$

$$PC_2 = W_6X_1 + W_7X_2 + W_8X_3 + W_9X_4 + W_{10}X_5$$

$$PC_5 = W_{20}X_1 + W_{21}X_2 + W_{22}X_3 + W_{23}X_4 + W_{24}X_5$$

Where W_i represents the regression coefficient of the principal components on the variables.Principal components can be calculated using the original dataset. If the original data are not available, they can also be computed using the covariance matrix or the correlation matrix. Generally, when variables in a dataset have different measurement units or different variances, the correlation matrix is preferred.When the correlation matrix is used, it means that standardized variables are applied, where each variable has a mean of zero and a standard deviation of one.

3.2. Characteristics of Principal Components

The first extracted principal component accounts for the largest amount of dispersion in the entire dataset. This means that the first component is correlated with at least some of the variables. The second extracted component has two important characteristics. First, it accounts for the largest variance of the dataset that has not been explained by the first component. In other words, the second component is correlated with some of the observed variables that do not have a high correlation with the first component. The second characteristic is that the second component is not correlated with the first component; that is, the correlation between the two components is zero. The other components extracted in this method also possess these two characteristics.

3.3. Estimating the Number of Principal Components

The number of components extracted in each model is equal to the number of variables being analyzed. However, it is possible to select only a specific number of these components. Usually, the first two or three components explain a considerable portion of the data dispersion. Therefore, selecting the first two or three components is sufficient for further analysis. However, in some cases it is necessary to consider additional criteria to determine the required number of components. These criteria are as follows:

First Criterion (Scree Test): Plotting the eigenvalues against the corresponding principal components produces the scree plot. In this plot, the change in the importance of eigenvalues for each principal component is shown. Figure 4 2 illustrates a hypothetical scree plot. As can be observed, the eigenvalue of the first vector (the variance explained by the first vector) is about 1.2, the eigenvalue of the second vector is about 0.9, and the eigenvalue of the third vector is less than 0.9. This indicates that initially the decline in importance is rapid, and then the rate of decline slows down. The breakpoint shows the maximum number of principal components that should be considered. One PC fewer than the number indicated by the breakpoint may also be appropriate. Based on this, in Figure 4 2 the first component or the first three components can be selected.

Second Criterion (Eigenvalue): Components with eigenvalues greater than one are retained, while the remaining components are disregarded.

Third Criterion (Variance): Components that explain a larger percentage of the total variance are sufficient for further analysis. Usually, the first component explains the greatest amount of variance.

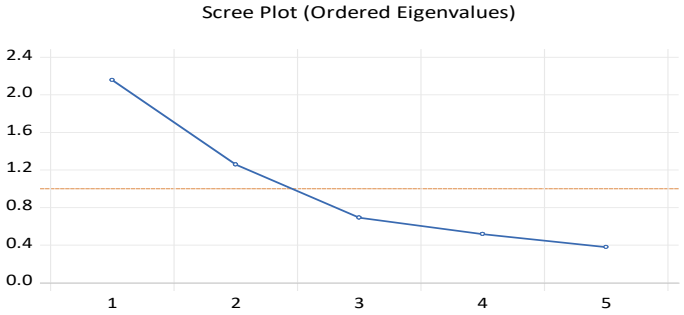


Figure 2. Eigenvalues of the Principal Components

Source: Research Findings

How to Calculate the Principal Components

To extract the Green Financing Index, five variables are used [24]:

1. Real GDP per capita
2. Energy productivity
3. Carbon productivity
4. Carbon emission coefficient
5. Share of renewable energy.

Table 1. Correlation Matrix of Green Financing Indicators

	RGDP	ENE	CE	CEF	SRE
RGDP	1.000000				
ENE	0.442958	1.000000			
CE	-0.238077	0.194274	1.000000		
CEF	-0.277098	-0.433110	-0.200485	1.000000	
SRE	-0.240710	-0.319965	-0.257410	0.487120	1.000000

Source: Research Findings

Table (1) shows that there is a relatively high correlation among the above-mentioned indicators. Therefore, by reducing the dimensionality of the variables, the Green Financing Index is extracted using the PCA method. Table (2) shows that the eigenvalue of the first principal component is greater than one, and approximately 43 percent of the dispersion (variance) of the dataset is explained by this component. Therefore, this component is selected as the best representation for constructing the index.

Table 2. Results of Estimating the Composite Green Financing Index Using the PCA Method

Eigenvalues: (Sum = 5, Average = 1)					
Number	**Value**	**Difference**	**Proportion**	**Cumulative Value**	**Cumulative Proportion**
1	2.156439	0.899970	0.4313	2.156439	0.4313
2	1.256470	0.564386	0.2513	3.412909	0.6826
3	0.692084	0.175020	0.1384	4.104993	0.8210
4	0.517064	0.139120	0.1034	4.622057	0.9244
5	0.377943	-	0.0756	5.000000	1.0000
Eigenvectors (loadings):					
Variable	**PC 1**	**PC 2**	**PC 3**	**PC 4**	**PC 5**
RGDP	0.387918	0.618616	0.112783	0.319848	0.593136
ENE	0.521743	0.115009	0.633411	-0.043667	-0.558069
CE	0.211096	-0.748055	0.378247	0.211935	0.455923
CEF	-0.534374	0.087095	0.294306	0.759848	-0.207059
SRE	-0.497179	0.192133	0.596979	-0.522976	0.293274

Source: Research Fandings

The relationship between the observed variables and the principal components can be expressed using factor loadings as follows:

RGDP= 0.38 PC1 + 0.61 PC2 + 0.11 PC3 + 0.31 PC4 + 0.59 PC5

ENE= 0.52 PC1 + 0.11 PC2 + 0.63 PC3 - 0.04 PC4 - 0.55 PC5

CE= 0.21 PC1 - 0.74 PC2 + 0.37 PC3 + 0.21 PC4 + 0.45 PC5

CEF= -0.53 PC1 + 0.08 PC2 + 0.29 PC3 + 0.75 PC4 - 0.20 PC5

SRE= -0.49 PC1 + 0.19 PC2 + 0.59 PC3 -0.52 PC4 + 0.29 PC5

An estimate of the principal components using the Factor Score can also be expressed as follows:

PC1= 0.38 RGDP +0.52 ENE + 0.21 CE -0.53 CEF -0.49 SRE

Thus, it can be stated that the linear combination of the first principal component (PC1) for the Green Financing Index is as shown above. Finally, the weights of each of the sub-indices in the composite Green Financing Index are presented in the following table.

Table 3. Relative Importance of Variables in the Composite Green Financing Index

Relative Importance	Variable Name
21	Real GDP per capita
24	Energy productivity
11	Carbon productivity
17	Carbon emission coefficient
27	Share of renewable energy
100	Total

Source: Research Fandings

Table (3) shows the relative importance of the components of the overall index based on the selected variables using the rotational element regression method. According to the obtained weights, the share of renewable energy has the greatest impact on the composite Green Financing Index. After that, energy productivity and real GDP per capita have the next highest effects. The Green Financing Index is calculated as the weighted sum of the five variables using the weights obtained in Table (4). Finally, using the **"**Make Principal Component Analysis**"** command, the composite index related to green financing is extracted and then used in estimating the final research model. Subsequently, the stationarity of the variables in the regression model is examined. In this study, the commonly used Phillips–Perron unit root test is employed. Considering the theoretical foundations of stationarity tests, the null hypothesis (H_0) in these tests assumes that the variable is non-stationary. Based on the test results, it can be stated that all variables in the model are stationary at the first difference, i.e., I(1).

Table 4. Results of the PP Test on the Level of the Model Variables

Statistic pp				
Variables	**Test**	**Statistic**	**Probability**	**Variable Status**
COE	Phillips-Perron test statistic	-0.545210	0.4740	-
D(COE)	Phillips-Perron test statistic	-8.896707	0.0000	I(1)
Green financing	Phillips-Perron test statistic	-0.347221	0.5531	-
D(Green financing)	Phillips-Perron test statistic	-6.548390	0.0000	I(1)
FDI	Phillips-Perron test statistic	-0.343461	0.5545	-
D(FDI)	Phillips-Perron test statistic	-8.294790	0.0000	I(1)
SD	Phillips-Perron test statistic	-1.338930	0.1641	-
D(SD)	Phillips-Perron test statistic	-7.363514	0.0000	I(1)
L	Phillips-Perron test statistic	-3.131054	0.1143	-
D(L)	Phillips-Perron test statistic	-7.137129	0.0000	I(1)
NRS	Phillips-Perron test statistic	-0.342985	0.5547	-
D(NRS)	Phillips-Perron test statistic	-68.59957	0.0000	I(1)
RENE	Phillips-Perron test statistic	-1.231441	0.1963	-
D(RENE)	Phillips-Perron test statistic	-4.708142	0.0000	I(1)
GOV	Phillips-Perron test statistic	0.014475	0.6810	-
D(GOV)	Phillips-Perron test statistic	-8.873245	0.0000	I(1)
CAP	Phillips-Perron test statistic	-1.263973	0.1861	-
D(CAP)	Phillips-Perron test statistic	-15.21728	0.0000	I(1)

Source: Research Fandings

3.4. Cointegration Test Results

Since the variables in the model have the same order of integration I(1), the cointegration test is used to determine whether a long-run equilibrium relationship exists among the model variables. For this purpose, the Johansen–Juselius method is employed. To conduct this test, the number of cointegration

vectors must first be determined. In examining the results of the cointegration test, it is necessary to select an appropriate model regarding the presence or absence of a time trend and intercept in the cointegration vector. In this regard, five models are considered: the first model, without intercept and without time trend; the second model, with a restricted intercept and without time trend; the third model, with an unrestricted intercept and without time trend; the fourth model, with an unrestricted intercept and a restricted time trend; and the fifth model, with an unrestricted intercept and an unrestricted time trend. These five models are estimated for the variables from the most restricted (the first model) to the least restricted (the fifth model). Then, the null hypothesis of no cointegration vector is tested against the alternative hypothesis of the existence of one cointegration vector, followed by testing the hypothesis of at most one cointegration vector against the existence of two cointegration vectors. This testing procedure continues until n−1 cointegration vectors are examined (where n represents the number of variables). The summary of the results of the Trace test (λTrace) and the Maximum Eigenvalue test (λMax) regarding the number of cointegration vectors based on the five mentioned models is presented in Table 5. As observed, the null hypothesis of no cointegration vector against the existence of one cointegration vector among the variables in the model is rejected. Therefore, at least one cointegration vector exists among the variables under study.

Table 5. Summary of the Results for the Number of Cointegration Vectors

Model	Trace Test	Maximum Eigenvalue Test
Model 1	4	3
Model 2	6	5
Model 3	6	2
Model 4	3	5
Model 5	4	6

3.5. Smooth Transition Autoregressive (STAR) Model

Given the limitations of linear models, many studies have suggested the use of various types of nonlinear models to specify nonlinear behavior in time series. In this study, in order to model the nonlinear behavior and examine the effects of the Sustainable Energy Policy Index and socio-economic development on the ecological footprint with an emphasis on green financing in Iran, the STAR model is employed.

Unlike TAR models, which use an indicator function to control the regime-switching process, STAR models use exponential and logistic functions for this purpose. These models are very suitable for analyzing asymmetric cycles of variables, and many studies have shown that they effectively capture regime-switching mechanisms when examining nonlinear dynamics of variables.

In fact, the STAR model uses a transition variable and the value of the slope parameter to model the nonlinear relationship between variables in a continuous manner. The Teräsvirta smooth transition regression model can be generally specified as follows.

$$y_t = \pi' z_t + \theta' z_t + F(s_t, \gamma, c) + u_t$$

Where z_t is a vector containing the exogenous variables of the model; π is the vector of linear parameters; θ is the vector of nonlinear parameters of the model; and utu_tut is the error term, which is assumed to be independently and identically distributed with zero mean and constant variance. The transition function can also be specified in logistic or exponential form according to the following relations.

Where z_t is a vector containing the exogenous variables of the model; π is the vector of linear parameters; θ is the vector of nonlinear parameters of the model; and utu_tut is the error term, which is assumed to be independently and identically distributed with zero mean and constant variance. The transition function can also be specified in logistic or exponential form according to the following relations.

$$F(s_t, \gamma, c) = \left[\frac{1}{1+\exp(-\gamma(s_t - c))} - \frac{1}{2}\right]$$

$$F(s_t, \gamma, c) = \left[1 - \exp\left(-\gamma(s_t - c)\right)^2\right]$$

Equation (2) represents the logistic transition function, while Equation (3) expresses the exponential transition function. In these functions, s_t denotes the transition variable; γ represents the slope parameter; and ccc indicates the threshold value or the point at which regime switching occurs. If the slope parameter γ, which reflects the speed of transition from one regime to another, approaches infinity, the STAR model turns into a Threshold Autoregressive (TAR) model. In this case, if the transition variable is greater than the threshold value (c<st), the transition function becomes equal to one (F=1). On the other hand, if (c>st), the value of the transition function becomes zero (F=0). Furthermore, if the value of the slope parameter approaches zero, the STAR model becomes a linear model**.**

The estimation process of the STAR model proceeds as follows: in the first step, the dynamic structure of the model or the optimal number of lags is determined. Then, the existence of a nonlinear relationship among the variables under study is tested, and based on this, the transition variable and the number of regime changes are selected. In the second step, using the Newton–Raphson algorithm and the Maximum Likelihood method, the selected STAR model is estimated. Finally, diagnostic tests are conducted to ensure that the obtained results are reliable

3.6. Linearity Test, Selection of the Transition Variable, and Model Type:

To estimate the Smooth Transition Regression model, all variables included in the model were tested using the Phillips–Perron stationarity test in order to select the transition variable. The results indicate that all variables in the study are stationary at level (I(0)). Furthermore, all variables in the model were tested as potential candidates for the transition variable.

Among the tested variables, the variable that rejects the null hypothesis of linearity with the highest probability is selected as the transition variable. It should be noted that the proposed STAR model, based on the selected transition variable, is chosen as the optimal model for estimating the effects of the Sustainable Energy Policy Index and socio-economic development on the ecological footprint, with emphasis on green financing in Iran.

The results presented in Table 7 show that the transition variable in the estimated model is the Green Financing Index. The null hypothesis of model linearity is rejected, and the first-order Logistic Smooth Transition Regression (LSTR) model is confirmed. Therefore, the main focus of the study is on the nonlinear part of the results.

Table 7. Linearity Test, Selection of the Transition Variable, and Type of Model

Variable	GS (t)
F1 Statistic	0.8958
F2 Statistic	0.7745
F3 Statistic	0.5425
F4 Statistic	0.3896
Proposed Model	1LSTR

Source: Research Findings

3.7. Estimation Results of the Model

In the next stage, using a first order LSTR (LSTR1) model in which the transition variable is the Green Financing Index, the function analyzing the effects of the Sustainable Energy Policy Index and socio economic development on the ecological footprint, with emphasis on green financing in Iran, is modeled.For this purpose, initial values for the threshold parameter of the transition variable (C) and the slope parameter (γ) were first selected. Then, using these initial values and applying the Newton–Raphson algorithm, the model parameters were estimated through the Maximum Likelihood method. The results are reported in Table (2).According to the estimation results, in the nonlinear part of the model, the coefficient of the Green Financing variable is statistically significant and has a negative effect on the ecological footprint. The coefficient of foreign direct investment (FDI) also has a negative and significant effect on the ecological footprint, indicating the inflow of foreign investment into Iran and its allocation to industries that do not harm the environment; on the contrary, such investments help prevent environmental damage. A clear example of this can be seen in the transfer of modern technologiesaimed at improving environmental quality in Iran.The coefficient of the Sustainable Energy Policy variable is negative, and its probability value is less than 0.05, indicating a negative and statistically significant effect on the ecological footprint in Iran. The effects of capital and labor on the ecological footprint are also negative and statistically significant. Furthermore, institutional quality has a negative and significant impact on the ecological footprint in Iran. Finally, as expected, the coefficient of the socio economic development index is negative and statistically significant at the 5% significance level.

Table 8. Estimation of the Model Using the LSTR Model

Variable	Coefficient	Std. Error	t-statistic	Prob.
Estimation of the Linear Part		-	-	-
CONSTANT	0.329059	0.136048	2.418698	0.0234
URB	0.158886	0.075984	2.091051	0.0419
FDI	0.582868	0.239013	2.438644	0.0149
SD	0.096233	0.026454	3.637702	0.0003
L	0.496421	0.175702	2.825358	0.0069
NRS	0.212527	0.090308	2.353357	0.0356
RENE	-0.393667	0.142781	-2.757139	0.0201
GOV	0.626607	0.230948	2.782475	0.0200
CAP	0.097980	0.028983	3.380603	0.0008
Estimation of the Nonlinear Part				
CONSTANT	0.433451	0.159418	2.718959	0.0218
URB	0.110132	0.055542	1.982849	0.0491
FDI	0.016009	0.007091	2.335214	0.0355
SD	0.089278	0.027937	3.195642	0.0015
L	0.197885	0.085146	2.324058	0.0201
NRS	0.022717	0.010298	2.205968	0.0274
RENE	-0.053752	0.022425	-2.396934	0.0165
GOV	0.012901	0.004822	2.675502	0.0077
CAP	0.235516	0.085117	2.762255	0.0053
Threshold Value (θ)	-0.459343	0.083521	-0.549973	0.0000
Slope Parameter (γ)	0.735776	0.215697	3.411155	0.0007
Adjusted R 2	0.88	-	-	-

Source: Research Findings

The comparison of coefficients across the two different regimes is conducted based on the transition variable and its values. The value of the transition variable determines the transition function and, consequently, the prevailing regime. In fact, whether the transition variable is below or above the threshold level can generate two distinct regimes in the estimated function.In the above estimation, the transition variable is the Green Financing Index, and the estimated threshold value for this variable is −0.45. Based on the deviation of green financing from this threshold value, the model follows two different extreme regimes.By comparing the model coefficients across the two regimes, it is observed that once green financing surpasses the threshold (−0.45), the ecological footprint's response to changes in this variable increases substantially. In other words, as green financing expands beyond the threshold level, the ecological footprint improves (i.e., decreases), indicating a stronger environmental improvement effect in the higher regime state.

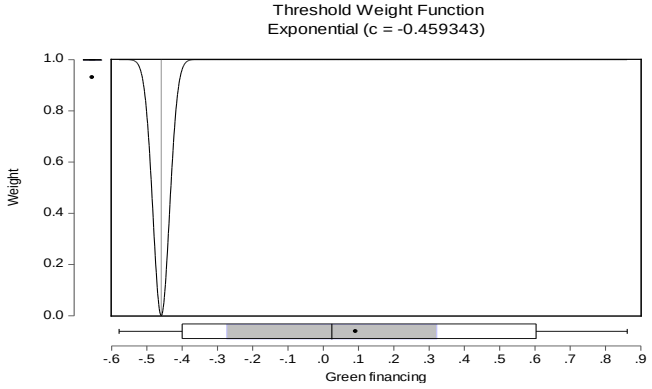


Figure 1. Relationship Between the Transition Function and the Green Financing Index Variable

Source: Research Findings

3.8. Diagnostic Tests

According to the estimation results, there is no evidence of autocorrelation or heteroskedasticity in the estimated LSTR1 model. The test for the absence of remaining nonlinearity also indicates that the LSTR1 model has successfully captured all the nonlinear behaviors present in the model.

Test	F-value	P-value
ARCH LM-test	0.9748	0.6525
No remaining nonlinearity test	1.4525	0.4785
Parameters constancy test	1.5414	0.3968

Source: Research Findings

The results of the parameter stability test across different regimes also indicate that the null hypothesis assuming stability of the coefficients and parameters of the model in the two regimes is rejected. This means the coefficients of explanatory variables differ significantly between the two regimes, confirming the presence of asymmetric effects on the dependent variable, namely the ecological footprin. Therefore, based on the estimated model results and the conducted diagnostic tests, it appears that the first-order LSTR model (LSTR1) is a suitable model for analyzing the effects of the Sustainable Energy Policy Index and socio-economic development on the ecological footprint, with an emphasis on green financing in Iran. Consequently, the reliability of the results obtained from estimating this model can be confidently trusted.

4. Conclusions

The present study was conducted with the aim of empirically analyzing the effects of the sustainable energy policy index, socio-economic development, and macroeconomic factors on the ecological footprint, with a focus and emphasis on the moderating role of green finance in Iran's economy. The escalating environmental challenges of recent decades, depletion of base resources, climate change, and the rapid increase in the ecological footprint have made revising the energy policymaking structure and the financing

methods of production projects an inevitable necessity. In the first step, given the lack of a comprehensive and integrated index for directly measuring green finance, as well as to prevent issues such as multicollinearity and variance inflation, the Principal Component Analysis technique was used to construct this composite variable. The results extracted from this analysis showed that the first component, relying on an eigenvalue greater than one, was able to cover more than forty-three percent of the total dispersion and variance of the constituent variables. In this structure, the variables of the share of renewable energy with a weight close to twenty-seven percent, energy efficiency with twenty-four percent, and gross domestic product per capita with twenty-one percent accounted for the main drivers and relative weights in shaping green financing flows in the country; a matter that indicates the inseparable connection of green financial resources with technological modernization, increasing energy conversion efficiency, and upgrading the share of renewable sources in the country's consumption basket.

Subsequently, considering the volatile behavior of macroeconomic variables in Iran's oil-based economy, the stationarity of the variables was assessed using the Phillips–Perron test, and the results indicated the cointegration and stationarity of all variables at first difference. Also, the results of the Johansen–Juselius cointegration test proved the existence of a stable cointegrating vector among the variables in the long run. Given the inherent limitations of classical regressions in portraying discontinuities, regime switches, and asymmetric shocks, the behavior of the model was estimated within the framework of the Logistic Smooth Transition Autoregressive model. The results of the linearity hypothesis tests showed that the relationship between sustainable energy policies, macroeconomic dimensions, and the ecological footprint index is completely non-linear and regime-based, and the single-transition logistic model with the transition variable of the green finance index has the highest statistical and empirical conformity. The estimation of the threshold limit of negative forty-five hundredths along with a significant slope parameter proved that the reaction of the dependent variable to the explanatory variables has the characteristic of a smooth structural break, and the economy experiences different adjustment mechanisms by being placed at levels higher or lower than the green finance threshold.

The findings from the regime estimation indicate that the establishment and expansion of green finance exert a significant effect on reducing ecological pressures and curbing the environmental footprint. When the economy is in the regime below the threshold limit, the effect of green financial instruments on environmental quality is pale and the effect of traditional production activities on intensifying the ecological footprint is more significant; but by passing the monetary system and capital market from the threshold level and the expansion of environmentally friendly financing tools, the behavior of the economic system undergoes a change and the intensity of ecological degradation is curbed. In the meantime, the sustainable energy policy index has always had a negative and inhibitory effect on the ecological footprint, which is strengthened after crossing the green finance threshold. On the ogtther hand, the inflow of foreign direct investment along with social development and improvement of institutional quality can fulfill their deterrent mission against the decline of ecological indices only when green financial infrastructures direct resources toward low-carbon intensity industries and efficient technologies.

In the analysis of the effects of socio-economic development and production factors including labor force and capital formation, data showed that economic growth based on physical accumulation and sole reliance on inputs without considering sustainability standards puts direct pressure on ecosystems in the first regime; however, in light of access to green credits and facilities, the investment process shifts away from polluting industries toward projects with higher energy efficiency and reduces the intensity of ecological degradation. This empirical outcome shows that the phenomenon of environmental degradation in Iran is not unidimensional, but rather a function of institutional coordination, the credit allocation system, and the structure of the country's energy basket, and achieving sustainability will be impossible without the intertwining of the financial system with environmental requirements.

Based on this empirical evidence, the orientation of the country's financial system requires fundamental rearrangement toward supporting low-carbon projects. The Central Bank and the Securities and Exchange Organization must realize the critical threshold of green finance in the country by designing incentive packages such as green bonds, sustainability sukuk, sustainability disclosure requirements, and prioritization in credit allocation and preferential rates to industries supporting low-consumption technologies. In addition, reforming pricing and non-pricing policies in the energy sector, reducing unjust fossil fuel subsidies, and directing the resulting resources toward the development of solar and wind farms will play a complementary and vital role in synergy with green finance so that the economy, along with achieving growth rates, can distance itself from the ecological footprint and smooth the path of long-term sustainability.The fundamental innovation of this research is manifested in creating a comprehensive and multidimensional approach to examine the link between sustainable energy policies, socio-economic development, and the ecological footprint in the structure of Iran's economy, which, unlike previous studies, has not merely sufficed with unidimensional pollution criteria such as carbon dioxide emissions and has considered total biocapacity; also, for the first time by utilizing the Principal Component Analysis method, an indigenous and composite index of green finance based on five key variables including gross domestic product per capita, energy efficiency, carbon productivity, emission factor, and the share of renewable energies was extracted to overcome the dilemmas of multicollinearity and statistical dispersion. Another prominent methodological innovation of this study is surpassing the limiting linear assumptions and employing the single-transition Logistic Smooth Transition Autoregressive model, which models the asymmetric behavior and non-linear dynamics of variables with the transition variable of the green finance index; thus, the present research has been able to identify a specific threshold value for the effectiveness of green financial tools and explain the different adjustment mechanisms of the ecological footprint in two separate structural regimes, which provides policymakers with an unprecedented empirical basis for designing optimal environmental policies.

4.1. Suggestions

The Central Bank and the Securities and Exchange Organization must issue modern financial instruments including green bonds and sustainability sukuk with tax exemptions and government guarantees in the capital market by drafting comprehensive sustainability guidelines; also, the allocation of preferential credit lines and discounts on the legal reserve requirement rate for banks that allocate a major share of their facilities to low-carbon projects is essential so that the volume of credits allocated to clean sectors crosses the empirical threshold limit estimated in this study and the credit allocation system is directed toward the development of sustainable infrastructure in a targeted manner.

The Ministry of Energy and the Plan and Budget Organization need to operationalize the comprehensive framework of sustainable energy policies through designing long-term guaranteed renewable electricity purchase contracts and launching the Clean Technology Support Fund; in this regard, redistributing a portion of hidden fossil energy subsidies as direct financial incentives for solar and wind farm investors can reduce the comparative advantage of using traditional energies and, by strengthening the share of renewable energies in the country's consumption basket, halt the rapid growth trend of the ecological footprint in the long run.

The Department of Environment, in cooperation with the Ministry of Industry, Mine and Trade, must align environmental impact assessment standards with acceptance and credit rating indicators in the banking system; accordingly, the creation of an integrated green credit rating system in order to evaluate carbon efficiency, pollutant emission intensity, and energy efficiency levels of companies applying for facilities is essential so that companies with high ecological footprints are subject to heavier financing costs and enterprises leading in environmental innovations enjoy financing priority.

The Organization for Investment, Economic and Technical Assistance of Iran must draft special incentive packages to attract foreign direct investment in sectors compatible with the circular economy and advanced pollution-reducing technologies; establishing green special economic zones.

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Author Contributions

All authors contributed equally to the conception, preparation, and writing of this manuscript.

Conflict of Interest

The authors, while observing publication ethics in the referencing, declare the absence of interest of conflict.

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