Examining the Effects of Green Financing on Sustainable Development in Iran

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Abstract

Green financing is a crucial approach in executing all economic activities, and it is essential to formulate and adopt strategies, comprehensive environmental policies within the framework of laws and development policies, green job creation, and green financing. Given the significance and impact of green financing on the country's sustainable growth and development, this study analyzes the relationships between the green financing index and sustainable development using the Smooth Threshold Autoregressive (STAR) model. To achieve this, the green financing index is first calculated, followed by an analysis of the relationship between the green financing index and the country's sustainable development. The results indicate that the threshold rate is 18%. Considering the differences in the coefficients obtained for the linear and nonlinear components of the model, the varying influence of sustainable growth on other variables is demonstrated. Furthermore, the findings reveal that before reaching the 18% threshold of sustainable development, the green financing index has a positive effect in the linear model. However, beyond this specified rate, its impact becomes negative and more substantial. The results of the diagnostic tests indicate that there is no serial autocorrelation or heteroskedasticity in the model, and the model has accurately captured all existing nonlinear behaviors, with the normality of the distribution being accepted.

Keywords: *Green Financing, Development, Sustainable Development.*

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1. Introduction

Tying the resolution of a domestic issue to an international challenge is a win-win strategy for the country, as it can showcase the nation's role in addressing shared global problems while simultaneously advancing national interests. Environmental issues, being global in nature and affecting all countries, require cross-national cooperation to minimize their adverse effects [1, 2].

Various studies have highlighted the seriousness of environmental problems, conducted by numerous scientists across different fields and over extended periods. A common conclusion from these studies is that excessive use of fossil fuels and, consequently, greenhouse gas emissions are primary factors driving various environmental crises [3]. Numerous scientific conferences and working groups have been organized to explore all aspects of these issues and propose solutions [4-8]. The outcome has been international cooperation agreements under the United Nations, such as the Paris Agreement, which is one of the most recent. A challenge faced by international agreements is encouraging countries to cooperate and fulfill their commitments. Joint projects, defining member capacities, and enabling the trading of emission quotas are strategies proposed to address this challenge [9].

Emissions trading has been one of the earliest tools used to control pollution levels and has evolved over different time periods [10]. In the literature, emissions trading refers to a market-based method for pollution control through economic incentives. In this system, emission rights (permits, quotas, or credits) are bought and sold to achieve a specific emission limit. Ongoing efforts by stakeholders include addressing shortcomings, encouraging greater collaboration in market development, establishing binding regulations, and creating a profitable environment [11].

One of the fundamental pillars and frameworks considered in European Union negotiations on climate change is climate finance. This type of financing aims to reduce emissions and enhance resilience against the adverse impacts of climate change, utilizing both public and private funding [12].

The concept of sustainable development emphasizes not only economic growth for the present and the current generation but also the rights of future generations and long-term development sustainability. It underscores the importance of a nation's natural and environmental resource capacity as well as the physical and social well-being of its citizens. Sustainable development ensures that the pace of technological progress, satisfaction with the increased supply of raw materials, and land resources do not degrade the quality of life or opportunities for future generations [13].

The literature highlights the multifaceted impacts of energy consumption, financial development, and green financing on environmental outcomes and sustainable development. Hafezi and Mamipour (2024) analyzed the dynamic effects of fossil fuel consumption on carbon dioxide emissions in Iran from 1955 to 2019 using the ARDL approach, revealing that diesel fuel consumption had the most destructive short-term and long-term impact on emissions [14]. Bahraminia et al. (2023) explored the threshold effects of financial development and good governance on carbon dioxide emissions in oil-exporting countries using panel smooth transition regression, noting a non-linear relationship where financial development initially increases emissions but turns negative past a certain threshold [9]. Nadimi and Dalvandi (2023) examined the interaction between innovation and financial development across 31 selected countries, finding that while unbridled innovation increases pollution, financial development mitigates its environmental impact [10]. Ghorbani Sheikhneshin and Haddad Zand (2023) conducted a comparative study on clean energy policies in the U.S. and China, emphasizing the role of clean energy in sustainable development, particularly China's strategic prioritization despite its late entry [15]. Mertzannis (2023) assessed green financing's effect on socio-environmental performance in 58 countries from 2013 to 2019, showing a small but statistically significant positive impact [16]. Zhou et al. (2020) explored green finance innovation's effect on green growth in China from 2011 to 2018, demonstrating significant regional heterogeneity and the role of green credit and investment [17]. Finally, Yang et al. (2021) used dynamic panel models to show that green financing comprehensively facilitates high-quality economic development in China, enhancing environmental sustainability and economic structure, though with limited impact on economic efficiency [18].

Therefore, considering the importance and role of green financing in enhancing economic performance and sustainable development, this study first calculates the green financing index and then examines its effects on sustainable development.

2. Methodology

In this study, the Smooth Transition Autoregressive (STAR) model is used for estimation. The final model for examining the effects of green financing on sustainable development is specified as follows:

$SD\_i,t = \alpha 0 + \beta 1SD\_i,t + \beta 2W\_i,t + \beta 3TRADE\_i,t + \beta 4FDI\_i,t + \beta 5REENERGY\_i,t + \beta 6EG\_i,t + \beta 7EDU\_i,t + \beta 8CAP\_i,t + \beta 9COE\_i,t$ (11)

where:

SD: Sustainable development index.

W: Green financing index.

TRADE: Trade volume as a percentage of GDP.

FDI: Foreign direct investment (Central Bank of the Islamic Republic of Iran, 2023).

REENERGY: Share of energy consumption from renewable sources out of total final energy consumption (EC) (includes solar, wind, and hydro energy consumption) (Energy Balance Sheet, 2023).

EG: Economic growth of Iran (Central Bank of the Islamic Republic of Iran, 2023).

EDU: High school enrollment as a percentage of the total population (Statistical Center of Iran, 2023).

CAP: Physical capital stock (Central Bank of the Islamic Republic of Iran, 2023).

COE: Carbon emission index.

Using the derived model, we analyze the role and effects of green financing on sustainable development.

In this research, annual time series data for the years 1990–2022 are considered. All statistical data have been collected from the Central Bank of the Islamic Republic of Iran's website (Central Bank of the Islamic Republic of Iran, 2022), the Energy Balance Sheet (Deputy of Electricity and Energy Affairs, 2022), the Statistical Center of Iran (2023), and the World Bank website (2022). Data analysis has been conducted using EVIEWS software.

3. Findings

The statistical characteristics of the analyzed data are summarized in Table 1. According to Table 1, the carbon emission index has the highest mean, while the foreign direct investment variable has the lowest mean. Additionally, the median of the carbon emission index is the highest, while the median of the foreign direct investment variable is the lowest. Furthermore, the carbon emission index has the highest maximum value, and the minimum value belongs to the foreign direct investment variable. Among these variables, Iran's economic growth exhibits the highest standard deviation.

Table 1. Statistical Characteristics of the Data

Variable	Mean	Median	Maximum	Minimum	Standard Deviation
sdi	0.6645	0.6675	0.6840	0.6350	0.0153
trade	1.6304	1.6408	1.7359	1.4658	0.0671
reenergy	0.1932	0.2250	0.5300	0.0100	0.1621
fdi	-0.562	-0.269	0.4371	-0.4371	0.7672
eg	3.05836	0.7021	8.8150	-8.8150	3.4613
edu	6.5112	6.5292	6.6089	6.6089	0.0843
coe	8.3975	8.3483	9.5319	7.5319	0.2968
cap	1.4645	1.4705	1.5538	-1.5538	0.7114
w	3.7761	3.7874	3.8790	3.8790	0.0864

Before estimating the model, it is necessary to examine whether the research variables have unit roots. If some variables contain unit roots, the model estimation may suffer from spurious regression. Various tests are available to check for the presence of unit roots in panel data, and here the Augmented Dickey-Fuller (ADF) test is used at a 95% confidence interval. The null hypothesis of this test states that the variable in question does not have a unit root. The results of this test are presented in

Table 2. As shown in

Table 2, some variables are stationary at level, while others become stationary at the first difference. The general rule is that a linear combination of non-stationary variables remains non-stationary; however, cointegration is an exception to this rule. Cointegration indicates that non-stationary variables may have a real (non-spurious) relationship.

Table 2. Unit Root Test Results

Variable	t-Statistic	p-Value	Condition	Result
sdi	-2.7170	0.2373	With trend and intercept	Non-stationary
w	-1.2036	0.8916	With trend and intercept	Non-stationary
reenergy	-4.8555	0.0035	With trend and intercept	Stationary
coe	-4.0062	0.0194	With trend and intercept	Stationary
eg	-5.3611	0.0009	With trend and intercept	Stationary
edu	-4.5687	0.0065	With trend and intercept	Stationary
cap	-3.0237	0.1427	With trend and intercept	Non-stationary
fdi	-5.6461	0.0005	With trend and intercept	Stationary

The cointegration test results are provided in Table 3. According to Table 3, since the ADF test statistic is less than the critical values, the null hypothesis of the presence of a unit root in the residuals is rejected, indicating a long-term equilibrium relationship between the dependent and explanatory variables.

Table 3. Cointegration Test Results

Variable	t-Statistic	p-Value
resid01	-8.763527	0.000

First, the sustainable growth variable is considered the dependent variable. The first step in estimating the Smooth Transition Autoregressive model is determining the optimal lag for the model variables. Based on the Schwarz and Hannan-Quinn criteria, the optimal lag was determined to be zero. The next step involves testing for the existence of a nonlinear relationship among the variables, with the results presented in Table 4.

Table 4. Nonlinearity Test Results

Variable	F-Statistic p-Value	F4 p-Value	F3 p-Value	F2 p-Value	Suggested Model
SDIt-1	1.3093	1.3226	1.4406	2.6312	Linear
SDIt-2	1.4711	2.108	2.217	1.0648	Linear
SDIt-3	1.7665	1.372	0.610	0.227	Linear
SDIt-4	1.97031	2.230	3.6685	1.138	LSTR1

The exponential and logistic weighting functions for the sustainable development index variable are shown in Figure 1.

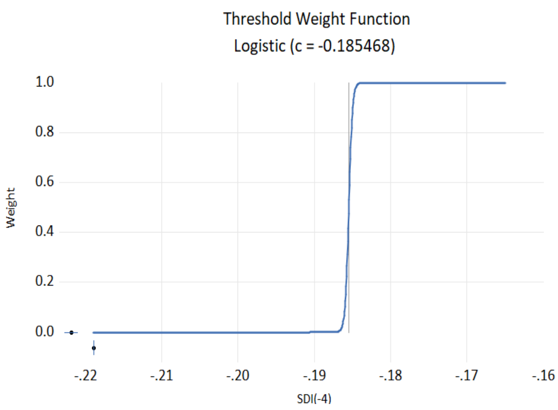

Figure 1. Exponential and Logistic Weighting Functions for the Sustainable Development Index Variable

The model for the dependent variable sustainable growth is now estimated, with the results shown in Table 5 for the linear part of the model.

Table 5. Estimation Results of the Model with SDI as the Dependent Variable (Linear Part)

Variable	Coefficient	Standard Error	t-Statistic	p-Value
w	2.144	0.6432	33.33	0.0000
re_energy	0.0002	7.1625	3.882	0.0037
fdi_in	-0.234	0.0045	-51.92	0.0000
eg	-0.0009	5.833	-16.93	0.0000
edu	0.817	0.0084	96.63	0.0000
co_e	0.372	0.0006	595.88	0.0000
cap	-0.251	0.008	-29.61	0.0000
trade	-1.1836	0.324	-36.48	0.0000
c	-14.645	0.2620	-55.88	0.0000

Table 6. Estimation Results of the Model with SDI as the Dependent Variable (Nonlinear Part)

Variable	Coefficient	Standard Error	t-Statistic	p-Value
w	-2.0910	0.0912	-22.92	0.0000
reenergy	-0.0003	0.0001	-1.9295	0.0875
fdi	0.2343	0.0076	30.733	0.0000
eg	0.0013	0.0003	3.6690	0.0052
edu	0.7164	0.0589	12.149	0.0000
coe	-0.395	0.0151	-26.2215	0.0000
cap	0.23800	0.0834	2.8537	0.0190
trade	1.1902	0.0364	32.6835	0.0000
c	13.813	0.3996	34.573	0.0000
slope	4241.920	3832.693	1.1067	0.2971
threshold	-0.1854	0.0003	-612.6800	0.0000
R^2	0.9700			
F-Statistic	15.039			0.0001

Thus, the linear and nonlinear parts of the model are represented as follows:

Linear Model:

SDI = 2.14W - 0.23FDI - 0.0009EG - 0.49CAP + 0.0002REENERGY + 0.81EDU + 0.37COE - 0.25CAP - 1.15TRADE (12)

Nonlinear Model:

SDI = 13.81 - 2.09W + 0.234FDI + 0.001EG - 0.39COE + 0.23CAP + 0.71EDU + 1.19TRADE (13)

The calculated threshold rate is -18%. The differences in the coefficients between the linear and nonlinear parts of the model highlight the varying impact of sustainable growth on other variables. For instance, before reaching the 18% threshold of sustainable development, the green financing index has a positive effect in the linear model. However, beyond this threshold, its effect becomes negative and more significant.

Foreign direct investment has a negative impact on sustainable development before reaching the threshold but turns positive afterward. This change occurs because foreign investment needs to be at a sufficient level to have a positive influence on key macroeconomic factors like economic growth. Economic growth has a slightly negative impact before the threshold (though with a very small coefficient) but becomes positive after surpassing the threshold. This behavior indicates that economic growth distribution is

Physical capital investment has a negative impact before reaching the threshold and a positive impact after reaching the -18% threshold. Investment is a dynamic variable that reveals its true effects over time. Once other variables contributing to sustainable development—such as improving the business environment and environmental factors—are controlled and optimized, investment can positively influence sustainable development in Iran.

Moreover, before reaching the threshold, the environmental and human factors necessary to maximize the use of physical capital stock are absent. As physical capital increases beyond the threshold, sustainable development improves. In the second regime (after the threshold), green financing has a negative effect on sustainable development. This outcome is due to the fact that, apart from production and renewable energy, other factors related to green financing may decrease well-being and quality of life.

uneven, benefiting the wealthiest deciles of the population and, consequently, decreasing sustainable development rather than enhancing it.

The human capital variable is significant and positively impacts sustainable development at a 90% confidence level before the threshold. This finding implies that sustainable development requires adequate investment in human capital. The minimal coefficient of renewable energy indicates a lack of long-term investment in clean energy sources, which is consistent with the investment data for renewable energy in Iran.

Specifically, environmental pollution has a more substantial negative impact than the positive contributions of economic growth and renewable energy after the threshold. This indicates that with increased energy intensity and air pollution, the benefits of economic growth and renewable energy are neutralized, leading to a negative effect of green financing on the sustainable development index. Similarly, carbon emissions reduce the sustainable development index by contributing to global warming, disrupting environmental equilibrium, and increasing mortality and illness rates.

Physical capital investment has a negative impact before the threshold but becomes positive afterward, highlighting the dynamic nature of investment and its ability to foster sustainable development when certain conditions, such as an improved business environment, are met.

Table 7 presents the results of the post-estimation diagnostic tests.

Table 7. Diagnostic Test Results

Test Statistic	Probability Value	Test Type
0.102	Test of No Error Autocorrelation	
0.805	Heteroskedasticity Test	
0.3006	Remaining Nonlinearity Test	
0.306	JARQUE-BERA	

As shown in the table above, the test statistics for serial autocorrelation and heteroskedasticity are greater than 0.05, indicating the absence of serial autocorrelation and heteroskedasticity in the model. Additionally, the test for nonlinearity in the residuals shows that the model successfully captures all existing nonlinear behaviors. Finally, the test for the normality of the distribution in the model is also accepted.

4. Discussion and Conclusion

This study examined the effects of green financing on the country's sustainable development. To do this, the green financing index for Iran was calculated. Using empirical studies, variables such as per capita real GDP, energy efficiency, carbon efficiency, carbon emission coefficient, and the share of renewable energy were utilized to compute the green financing index across various sectors. To determine the weight of each sector, the cyclical component of each variable in each sector was regressed on the cyclical component of GDP growth, and the resulting correlation coefficient served as the basis for calculating the weights in the overall green financing index.

Subsequently, the impact of the green financing index on the country's sustainable development was assessed using the Smooth Transition Autoregressive (STAR) model. After introducing the model, the research variables were presented, followed by the statistical characteristics of each variable. Unit root and cointegration tests were conducted before estimating the model, followed by post-estimation tests such as autocorrelation and heteroskedasticity tests.

The results of the stationarity tests indicated that the variables were either stationary at level I(0) or at the first difference I(1). The cointegration test results confirmed the rejection of the unit root hypothesis in the residuals, indicating a long-term equilibrium relationship between the dependent and explanatory variables.

Initially, sustainable growth was considered the dependent variable. The first step in estimating the Smooth Transition Autoregressive model was to determine the optimal lag for the variables using the Schwarz and Hannan-Quinn criteria, which identified zero as the optimal lag. The next step involved testing for the presence of a nonlinear relationship among the variables, revealing a threshold rate of -18%. The differences in coefficients between the linear and nonlinear parts of the model highlight the varying impact of sustainable growth on other variables.

For example, before reaching the 18% sustainable development threshold, the green financing index has a positive effect in the linear model, but beyond this rate, the impact becomes negative and more pronounced. Foreign direct investment has a negative effect before the threshold but becomes positive afterward, as sufficient foreign investment is needed to have a positive influence on key macroeconomic factors like economic growth. Economic growth initially has a negative effect (albeit with a very small coefficient) but turns positive after surpassing the threshold, indicating the unequal distribution of economic growth, which benefits the wealthiest segments of society, reducing rather than enhancing sustainable development.

Human capital has a significant positive effect at a 90% confidence level before the threshold, indicating that sustainable development depends on adequate human capital investment. The small coefficient for renewable energy reflects a lack of long-term investment in clean energy sources, consistent with renewable energy investment data in Iran.

Physical capital investment negatively impacts sustainable development before reaching the threshold but positively impacts it afterward. Investment is a dynamic variable whose true effects manifest over time. Once environmental and business factors are optimized, investment can positively influence sustainable development in Iran. Before reaching the threshold, environmental and human conditions for maximizing physical capital were insufficient, but after the threshold, increasing physical capital enhances sustainable development.

In the second regime, or after the threshold, green financing negatively impacts sustainable development. Aside from production and renewable energy, other factors associated with green financing reduce well-being and quality of life. After reaching the threshold and with economic growth, environmental pollution has a more pronounced negative effect compared to the benefits of economic growth and renewable energy. In other words, increased energy intensity and air pollution nullify the positive effects of economic growth and renewable energy, resulting in a negative impact of green financing on the sustainable development index. Carbon emissions, by increasing pollution and global warming, reduce the sustainable development index and contribute to higher mortality and illness rates.

Physical capital investment shifts from a negative impact before the threshold to a positive impact afterward, highlighting the dynamic nature of investment and its potential to support sustainable development when conditions improve.

In OECD countries, trade development has led to technological advancements, the use of cleaner technologies, and stricter environmental standards, reducing emissions and pollution. Conversely, in OPEC countries, trade expansion, heavily reliant on oil resources, has increased pollution. Thus, trade structure reform is needed in two main areas: first, the importation of capital and intermediate goods should promote the transfer of clean technologies; second, economic diversification through export-driven industrial development reduces reliance on oil and compels the economy to adopt environmental standards. Furthermore, the government can improve environmental conditions by facilitating the attraction of Clean Development Mechanism projects and reducing tariffs on eco-friendly production machinery and equipment.

Authors' Contributions

Authors equally contributed to this article.

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Declaration of Interest

The authors report no conflict of interest.

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Ethical Considerations

All procedures performed in this study were under the ethical standards.

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