ISSN: 2147-5121 / E-ISSN: 2717-7610

İstanbul Nişantaşı Üniversitesi
Sosyal Bilimler Dergisi

Bilimsel Hakemli Dergi

Yıl: 2024 Cilt: 12 (Özel Sayı)

İSTANBUL NİŞANTAŞI UNIVERSITY

NUSBD

Yayın Aralığı: Yılda 2 Sayı - Başlangıç: 2013

İstanbul Nişantaşı University
Journal of Social Sciences

Scientific Refereed Journal

Year: 2024 Vol.: 12 (Special Issue)

ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

DOI: 10.52122/nisantasisbd.1543701

EXPLORING THE IMPACT OF FINANCIAL DEVELOPMENT, FINANCIAL INCLUSION AND RENEWABLE ENERGY ON SUSTAINABLE DEVELOPMENT: THE LEADING ROLE OF FINTECH IN TURKIYE*

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ABSTRACT

Financial systems can support sustainable development by promoting investments considering environmental and social impacts, developing green finance, and ensuring financial inclusion. Incorporating financial technology into financial services can also help increase sustainable investment and financial inclusion. Therefore, a study was conducted to investigate the effect of financial development and financial inclusion, FinTech, renewable energy, and economic growth on the ecological footprint of Turkiye from 2005 to 2023 using the ARDL method. The study also focused on the non-linear effect of financial development on ecological footprint and the moderating role of FinTech in the relationship between financial development and ecological footprint. The study revealed an inverted U-shaped relationship between financial development and ecological footprint in the long run. Additionally, in the long run, FinTech and economic growth increase environmental degradation, while financial inclusion and renewable energy decrease environmental degradation. In the short run, no significant relationship was found between financial development, renewable energy, and environmental degradation. On the other hand, FinTech and financial inclusion are found to decrease environmental degradation, while economic growth is found to increase environmental degradation. The results suggest that Turkiye needs to consider the targets of SDG7 (Affordable and Clean Energy), SDG8 (Decent Work and Economic Growth), and SDG17 (Partnerships for the Goals), as well as interactive policies, to achieve the targets of SDG13 (Climate Action).

Anahtar Kelimeler: Financial Development, Financial Inclusion, FinTech, Renewable Energy, Sustainable Development.

Jel Kodları: C33, F30, G00.

FİNANSAL GELİŞME, FİNANSAL KAPSAYICILIK VE YENİLENEBİLİR ENERJİNİN SÜRDÜRÜLEBİLİR KALKINMA ÜZERİNDEKİ ETKİSİNİN ARAŞTIRILMASI: TÜRKİYE'DE FINTEK'İN ÖNCÜ ROLÜ

ÖZ

Çevresel ve sosyal etkileri göz önünde bulunduran yatırımların teşvik edilmesi, yeşil finansmanın geliştirilmesi ve finansal kapsayıcılığın sağlanması gibi alanlar yoluyla finansal sistemlerin sürdürülebilir kalkınma hedeflerini desteklemesi sağlanabilmektedir. Bunun yanı sıra finansal teknolojinin finansal hizmetlere entegrasyonu, sürdürülebilir yatırımların ve finansal kapsayıcılığın artırılmasına yardımcı olabilir. Bu kapsamda mevcut çalışma 2005-2023 döneminde Türkiye için finansal gelişme ve finansal katılım, Fintek, yenilenebilir enerji ve ekonomik büyümenin ekolojik ayak izi üzerindeki etkilerini ARDL yöntemi ile araştırmayı hedeflemektedir. Ayrıca çalışma finansal gelişmenin ekolojik ayak izi üzerindeki doğrusal olmayan etkisine ve finansal gelişme ile ekolojik ayak izi ilişkisinde Fintek'in moderatör rolüne odaklanmaktadır. Çalışmadan elde edilen bulgulara göre uzun dönemde finansal gelişme ile ekolojik ayak izi arasında ters U şeklinde ilişki olduğu ortaya çıkarılmıştır. Ayrıca uzun dönemde FinTech ve ekonomik büyümenin çevresel bozulmayı artırdığı, finansal katılım ve yenilenebilir enerjinin çevresel bozulmayı azalttığı tespit edilmiştir. Kısa dönem de ise finansal gelişme ve yenilenebilir enerji ile çevresel bozulma arasında anlamlı ilişki tespit edilememiştir. Buna karşın Fintek ve finansal katılımın çevresel bozulmayı azalttığı, ekonomik büyümenin ise çevresel bozulmayı artırdığı ortaya çıkarılmıştır. Elde edilen bulgular Türkiye'de SKH13 (İklim Eylemi) hedeflerine ulaşmada SKH7 (Erişilebilir ve Temiz Enerji), SKH8 (İnsana Yakışır İş ve Ekonomik Büyüme) ve SKH17 (Hedefler için Ortaklıklar) hedeflerini dikkate alınması ve etkileşimli politikalara ihtiyaç duyulduğunu göstermektedir.

Anahtar Kelimeler: Finansal Gelişme, Finansal Katılım, Fintek, Yenilenebilir Enerji, Sürdürülebilir Kalkınma

Geliş Tarihi/Received: 04.09.2024 | **Kabul Tarihi/Accepted:** 12.12.2024 | **Yayım Tarihi/Printed Date:** 31.12.2024

Kaynak Gösterme: Topaloğlu E. E., Nur, T., and Ege. İ. (2024). "Exploring The Impact of Financial Development, Financial Inclusion and Renewable Energy on Sustainable Development: The Leading Role of Fintech in Turkiye", *İstanbul Nişantaşı Üniversitesi Sosyal Bilimler Dergisi*, 12 (Özel Sayı) 144-161.

* IERFM2024 Kongresinde sunulan bildirinin gözden geçirilmiş ve düzenlenmiş halidir.

INTRODUCTION

Countries are primarily motivated by economic growth, but this rapid growth in energy consumption can worsen current environmental conditions. Therefore, it is important to use resources in a way that does not further damage our planet, while maintaining sustainable economic growth (Çakmak & Acar, 2022). The UN Agenda 2030 and its 17 Sustainable Development Goals (SDGs), adopted in 2015, represent the most comprehensive global effort to achieve sustainable development. The SDGs aim to address ecological sustainability challenges alongside economic and social goals (Eisenmenger et al., 2020). To protect our planet and humanity's existence, it is crucial to take strong and rapid action to prevent climate change. COP-27 emphasized the importance of mitigation and adaptation policies, with global leaders agreeing on a specific mitigation plan. They also recognized that the use of non-renewable energy is the leading source of emissions (Qing, 2024). Financial development and financial inclusion are also recognized as important elements in achieving sustainable development goals. Financial systems can support sustainable development goals by promoting investments that take into account environmental and social impacts, developing green finance and ensuring financial inclusion. However, some argue that economic activity driven by the financial development of nations could potentially be central to the deteriorating state of the planet's ecosystems (Ashraf et al., 2022).

A well-developed financial sector, characterized by a strong banking system, efficient capital markets, and a well-regulated financial industry, plays a crucial role in a country's economic growth and the efficiency of its financial system (Baloch et al., 2019). However, the impact of financial development on the environment is a topic of debate in the literature. There are two views on this issue. The first view emphasizes the role of financial development in promoting energy efficiency and environmental quality. According to this view, financial development, which includes the availability of financial resources, the efficiency of financial intermediaries, and the depth and breadth of financial markets, can positively contribute to environmental sustainability and renewable energy by encouraging research and development efforts. On the other hand, the second view argues that financial development can lead to environmental degradation by increasing industrialization and conventional energy consumption (Majeed & Masher, 2019). Jahanger et al. (2022) noted that the financial systems of developing countries often lack proper formulation and implementation of financial policies, leading to the deterioration of environmental quality due to the monotonous fossil fuel dependence of these nations. Ahmed et al. (2021) argued that although many studies link rising income to environmental degradation, better environmental quality can be achieved at higher income levels through energy efficiency, environmental laws, and green technology. Therefore, the relationship between financial development and environmental sustainability varies depending on the development levels of countries and their environmental policies.

However, amidst severe environmental crises, technological advances and FinTech development have drastically changed the landscape of markets and institutions. FinTech refers to technology-enabled innovations and improvements in the financial sector that have enabled unique business models, processes, practices and corresponding significant impacts on the delivery of financial services (Xia & Liu, 2024) in the fourth industrial revolution. FinTech's enabling capabilities facilitate the flow of capital to environmentally conscious businesses and provide loans to firms and individuals that seek to reduce their environmental impact. However, transitioning to renewable energy requires intensive spending on infrastructure, R&D, and mass adoption of clean energy technology. FinTech platforms can encourage more people and businesses to adopt clean energy technology by providing financing for renewable energy projects. Renewable energy startups can now raise capital from a wider investor base using digital platforms, crowdfunding, and peer-to-peer financing (Saqip et al., 2023). On the other hand, the energy intensity of FinTech applications such as cryptocurrency mining raises concerns about their environmental impact. Moreover, the rapid expansion of FinTech may increase electronic waste and cause digital infrastructure and data centers to consume more energy (Ahmad et al., 2024).

Based on the above discussions, the current study aims to investigate the impact of financial development, financial inclusion, FinTech, renewable energy, and economic growth on ecological footprint in Turkiye during the period 2005-2023. Turkiye is a signatory to the Kyoto Protocol and the Paris Agreement, which it ratified in 2021 with the goal of achieving net zero emissions by 2050 and reducing global emissions by at least 50% by 2030 (Daştan & Eygü, 2023). Following the crises of 2000 and 2001, Turkiye implemented a comprehensive restructuring program to rehabilitate its financial system, resulting in significant efforts towards financial development (Gokmenoglu et al., 2020). Additionally, the FinTech Ecosystem Status Report (2023) shows that FinTech investments in Turkiye reached a record high in 2022, with 268 payment technology startups, 108 banking technology startups, and 100 blockchain and cryptoasset startups present in the country by the end of 2023 (https://www.cbfo.gov.tr).

Figure 1: Time Graphs of the Variables for Turkiye
Source: Constructed by the authors with data obtained from WB, GFN and IMF.

Taking all these into account, the study makes several contributions to the literature. Firstly, it reveals the non-linear impact of financial development on ecological footprint. While existing research suggests that financial development can affect environmental degradation negatively, positively, or in a non-linear fashion, depending on a country's level of development, this study reexamines the relationship between financial development and ecological footprint. Secondly, the study aims to uncover the impact of financial inclusion on ecological footprint. Financial inclusion, which contributes to financial development, has an uncertain impact on environmental degradation. Therefore, the study includes financial inclusion in the model for broader policy implications. Thirdly, unlike other studies, this study focuses on the direct impact of FinTech on ecological footprint and its moderating role in the relationship between financial development and ecological footprint. The study aims to provide innovative policy recommendations based on this analysis. Finally, the study aims to reveal the relationship between renewable energy and ecological footprint. Renewable energy is recognized as important for a sustainable environment, and this study offers new insights by interpreting the relationships in line with sustainable development goals. In addition, the study uses the ARDL method, which provides effective results in short-term analyses, taking into account the analysis period, can be used at different levels of stationarity, and takes into account endogeneity and autocorrelation and variance in the error terms. This method aims to analyze both short-run and long-run effects.

The paper is structured as follows. Section 2 reviews the existing literature and presents the hypotheses and research gap. In Section 3 we detail the dataset, empirical model and methodology. Section 4 discusses the findings and economic implications based on the results of the analysis. Finally, Section 5 presents the policy implications and conclusions of the study.

1. Literature Review and Hypothesis Development

This section presents theoretical discussions and hypotheses on the impact of financial development, financial inclusion, FinTech, economic growth and renewable energy consumption on ecological footprint. It also presents empirical findings from previous literature on these variables.

Although economic growth is often considered the primary goal of countries, the increase in energy demand and consumption is believed to have a negative impact on the environment. Energy use is not only a significant driver of GDP but also one of the leading causes of ecological degradation. As a result, the relationship between growth, energy, and environmental pollution is still a topic of debate in the literature (Balsalobre-Lorente et al., 2024a). Various studies have been conducted on the relationship between economic growth and environmental degradation, but the findings are not consistent. Some studies suggest that economic growth leads to an increase in the ecological footprint (e.g. Danish et al., 2019; Ahmad et al., 2020; Nathaniel, 2021; Chu et al., 2023). On the other hand, the impact of economic growth on environmental degradation is analyzed through the Environmental Kuznets Curve (EKC) hypothesis. According to this hypothesis, in the initial stages of economic growth, the increase in economic activities may harm the environment. However, as the economy progresses, an inflection point between growth and the environment occurs in the second stage, and a return to the previous level of environmental quality can be achieved (Balsalobre-Lorente et al., 2024b).The EKC relationship between economic growth and ecological footprint has been supported by many studies (e.g. Can & Gozgor, 2017; Yilanci & Pata, 2020; Acevedo- Ramos et al., 2023; Balsalobre- Lorente et al., 2024b).

A well-developed financial sector plays a critical role in a country's economic growth and increases the economic efficiency of the financial system. However, financial development can also have negative effects on the environment. It can lead to environmental pollution by consuming natural resources in various ways and increasing energy demand (Balosh et al., 2019). Nevertheless, various studies have shown that financial development can also reduce environmental pollution (e.g. Pata & Yilanci, 2020; Omoke et al., 2020; Jahanger et al. 2022; Acar et al. 2023). There are two views on how financial development affects the environment. On the one hand, it can reduce environmental degradation by facilitating investment in clean technologies and developing more environmentally friendly projects through research and development (R&D). On the other hand, by providing credit facilities to purchase machinery, equipment, and automobiles, financial development can help investors expand their business horizons and build new machinery and plants, which increases the concentration of carbon emissions in the environment and worsens environmental quality (Majeed & Mazhar, 2019).

In various studies conducted on the relationship between financial development and ecological footprint, researchers have found differing results. Ahmed et al. (2021) found that financial development increased the ecological footprint in Poland between 1990-2013, while Khimbo et al. (2021) found the same in West Asia and Middle East countries between 1990-2017. Jahanger et al. (2022) also found an increase in ecological footprint in 73 developing countries between 1990-2016. These authors generally believe that financial development can lead to more consumption, increased use of natural resources and ecological problems. However, Pata and Yılancı (2020) found that financial development decreased the ecological footprint in Japan between 1980-2015, Omoke et al. (2020) found the same in Nigeria between 1971-2014, and Acar et al. (2023) in Azerbaijan between 1990-2017. These authors suggest that advanced financial systems can encourage the use of innovative technologies by investing in research and development for green and low-carbon projects. From a different perspective, Khan et al. (2022) and Balsalobre-Lorente et al. (2023) found an inverted U-shaped relationship between financial development and ecological footprint in APEC countries, indicating a diminishing scale effect of financial development and the increasing technological and compositional effects of financial development that transform the economy. Based on the above discussion, researchers have formulated various hypotheses for Turkiye regarding the relationship between financial development and ecological footprint.

H_1: There is an inverted U-shaped relationship between financial development and ecological footprint.
H_2: Economic growth increases the ecological footprint.

Another factor considered to be related to ecological footprint in the study is financial inclusion. Similar to financial development, financial inclusion can affect environmental degradation positively or negatively. In other words, increased financialization leads to economic expansion and pollution by attracting more foreign investment, or a developed financial sector reduces pollution by financing clean technology development and deployment (Saqip et al., 2023). Previous empirical studies provide evidence supporting both cases. Accordingly, Hussain et al. (2021) (2004-2017 in OECD countries, Ali et al. (2022) (1990-2016 in Economic Community of West African States, Anu et al. (2023) (2000-2018) in developing countries found that financial inclusion increases ecological footprint. On the other hand, Zaidi et al. (2021) found that financial inclusion decreased the ecological footprint in OECD countries in the period 2004-2017, and Liu et al. (2022) found that financial inclusion decreased the ecological footprint in five Asian emerging economies in the period 1995-2019. Based on the above discussion, we formulate the following hypothesis for Turkiye.

H_3: Financial inclusion reduces ecological footprint.

On the other hand, the study also focuses on the impact of FinTech on ecological footprint. With the FinTech sector, traditional financial services are becoming more effective and efficient through innovative technologies. However, there is an ongoing debate on the impact of financial technologies on environmental quality. One view is that financial technologies can minimize unnecessary human activities and ensure the efficient use of natural resources, while the other view is that financial technologies contribute to environmental pollution by causing large amounts of energy consumption (Saqip et al., 2023). When empirical findings are analyzed, Udeagha & Ngepah (2023) found that FinTech positively affected environmental quality in BRICS countries in the period 2000-2018, and Shu et al. (2024) found that FinTech positively affected environmental quality in China in the period 2010-2022. Similarly, Xia & Liu (2024) found that FinTech reduced ecological footprint in G7 countries in the period 2000-2020, Ahmad et al. (2024) found that FinTech reduced ecological footprint in 25 EU countries in the period 1990-2020. Based on the above discussion, we formulate the following hypotheses.

H_4: FinTech reduces its ecological footprint.
H_5: FinTech has a moderating role in the relationship between financial development and ecological footprint.

Finally, the study focuses on the relationship between renewable energy and ecological footprint. Renewable energy sources are seen as an important factor for sustainable development. They also play an important role in combating climate change and conserving natural resources by bringing environmental and social benefits. Empirical findings generally support the view that the adoption of policies towards the use of renewable energies will ensure environmental sustainability. Accordingly, Destek & Sinha (2020) found that renewable energy reduces ecological footprint in 24 OECD Countries in the period 1980-2014, Huang et al. (2022) in E7 and G7 countries in the period 1995-2018, Adebayo et al. (2023) in MINT countries in the period 1990-2018, Kongkuah (2024) in Belt-Road countries, Qing et al. (2024) in South Asian countries in the period 1990-2020. Based on the above discussion, we formulate the following hypothesis.

H_6: Renewable energy consumption reduces the ecological footprint.

An analysis of previous empirical studies focusing on the relationship between financial development, financial inclusion, economic growth, FinTech and renewable energy and environmental degradation reveals that the findings differ depending on the level of development of countries, the period and the methodology. Therefore, the effects of these variables on environmental quality remain uncertain. To the best of our knowledge, this study investigates the impact of the relevant variables on ecological footprint for Turkiye for the first time. It also focuses on the non-linear effect of financial development. On the other hand, by revealing the moderating role of FinTech in the relationship between financial development and ecological footprint, the study aims to reveal the uncertain relationships and provide valuable policy recommendations. Finally, by linking the findings to the SDGs, the study aims to put forward innovative policy objectives.

2. Methodology

The current study aims to investigate the effects of financial development, financial inclusion, FinTech, economic growth, and renewable energy sources on ecological footprint. The data used in this analysis were obtained from the Global Footprint Network (GFN), the World Bank (WB), and the International Monetary Fund (IMF). The study employs data from the period of 2005-2023, focusing on Turkiye. To measure FinTech and financial inclusion, the study created an index using principal component analysis (PCA). The FinTech index incorporates three indicators: mobile cellular subscriptions (per 100 people), fixed broadband subscriptions (per 100 people), and the percentage of individuals using the internet. The financial inclusion index, on the other hand, uses the indicators of automated teller machines (per 100,000 adults) and commercial bank branches (per 100,000 adults). Table 1 provides detailed information about the variables and data sources used in the study.

Table 1: Variables Definition and Data Sources

	Variables	Acronym	Definition	Sources
Dependent	Ecological footprint	EF: log of EF	Ecological Footprint (gha per person)	GFN
Independent	Financial development	FDI	Financial development Index (Broad-based index of financial depth, access, and efficiency)	IMF
Independent	Financial technology index constructed by principal component analysis based on three components: Mobile cellular subscriptions Fixed broadband subscriptions Individuals using the Internet	FINTEC	Per 100 people Per 100 people % of population	WB
Independent	Financial inclusion index	FI	Automated teller machines (ATMs) per 100000 adults Commercial bank branches (per 100,000 adults)	WB
Control	Gross Domestic Product	GDP	GDP per capita growth (annual %)	WB
Control	Renewable energy consumption	RNW: log of RNW	% of total final energy consumption	WB

For the purpose of the study, the basic econometric function of the research is as in Equation (1-2).

$$EF_{it} = f_1(FDI_{it}, FDI_{it}^2, FINTEC_{it}, FININC_{it}, RNW_{it}, GDP_{it}) \quad (1)$$

$$EF_{it} = f_2(FD_{it}, FD_{it}^2, FINTEC_{it}, FININC_{it}, RNW_{it}, GDP_{it}, FD_{it} \times FINTEC_{it}) \quad (2)$$

EF represents ecological footprint, FDI represents financial development, FINTEC represents financial technology, FININC represents financial inclusion, RNW represents renewable energy consumption and GDP represents economic growth. To investigate the non-linear relationship between financial development and ecological footprint, the square of financial development

(FDI^2) is included in the model. Moreover, this study focuses on the moderating role of financial technologies in the relationship between financial development and ecological footprint. Therefore, we extend the model by adding an interaction variable as in Equation 2.

In line with this objective, the stationarity of the series is first analyzed using ADF test developed by Dickey and Fuller (1981). Equation 3 is the "none" model, Equation 4 is the "intercept" model and Equation 5 is the "intercept and trend" model.

$$\Delta y_t = \delta y_{t-1} + \sum_{i=2}^{p} \beta i \Delta y_{t-i+1} + \varepsilon_t \qquad \varepsilon_t \sim WN(0, \sigma^2) \qquad (3)$$

$$\Delta y_t = \mu + \delta y_{t-1} + \sum_{i=2}^{p} \beta i \Delta y_{t-i+1} + \varepsilon_t \qquad \varepsilon_t \sim WN(0, \sigma^2) \qquad (4)$$

$$\Delta y_t = \mu + \delta y_{t-1} + \delta_2 + \sum_{i=2}^{p} \beta i \Delta y_{t-i+1} + \varepsilon_t \qquad \varepsilon_t \sim WN(0, \sigma^2) \qquad (5)$$

In the equation, y_t is the value of the time series at time t, Δy_t is the first difference of the time series, t is a time trend expressing the time curve, δ is the coefficients of the lag values of the first differences, ε_t is the error term of the model. After the unit root test, the ARDL bounds test approach developed by Pesaran et al. (2001) is applied to determine both the long-run and short-run relationship and cointegration relationship. The error correction model for the ARDL model is as in Equation 6.

$$\Delta LnEF_t = \beta_0 + \sum_{i=1}^{m} \beta_{1i}\Delta LnEF_{t-i} + \sum_{i=0}^{n} \beta_{2i}\Delta LnFDI_{t-i} + \sum_{i=0}^{n} \beta_{3i}\Delta LnFDI\hat{}2_{t-i} + \sum_{i=0}^{n} \beta_{4i}\Delta LnFINTEC_{t-i} + \sum_{i=0}^{n} \beta_{5i}\Delta LnFININC_{t-i} + \sum_{i=0}^{n} \beta_{6i}\Delta LnRNW_{t-i} + \sum_{i=0}^{n} \beta_{7i}\Delta LnGDP_{t-i} + \beta_8 LnEF_{t-1} + \beta_9 FDI_{t-1} + \beta_{10} LnFDI\hat{}2_{t-1} + \beta_{11} LnFININC_{t-1} + \beta_{12} LnRNW_{t-1} + \beta_{13} LnGDP_{t-1} + \varepsilon_t \qquad (6)$$

In the model, the difference operator is denoted by "Δ", the slope coefficient is denoted by "β_0", the short-run dynamic relationship coefficients are denoted by "β_1- β_7" and the long-run dynamic relationship coefficients are denoted by "$\beta_8 - \beta_{13}$". In order to apply the error correction model, firstly, AIC (Akaike Information Criterion) is used to determine the lag length. After determining the lag length, the F statistic is used to examine whether there is cointegration. The hypotheses for the F statistic test are as in equation 7.

H_0: $\beta_5 = \beta_6 = \beta_7 = \beta_8 = 0$

H_1: $\beta_5 \neq \beta_6 \neq \beta_7 \neq \beta_8 \neq 0$ (7)

The models for coefficient estimation after cointegration are as in Equation 8 for the long run and Equation 9 for the short run.

$$\Delta LnEF_t = \alpha_0 + \sum_{i=1}^{m} \alpha_{1i}\Delta LnEF_{t-i} + \sum_{i=0}^{n} \alpha_{2i}\Delta FDI_{t-i} + \sum_{i=0}^{n} \alpha_{3i}\Delta LnFDI\hat{}2_{t-i} + \sum_{i=0}^{n} \alpha_{4i}\Delta LnFINTEC_{t-i} + \sum_{i=0}^{n} \alpha_{4i}\Delta LnFININC_{t-i} + \sum_{i=0}^{n} \alpha_{4i}\Delta LnRNW_{t-i} + \sum_{i=0}^{n} \alpha_{4i}\Delta LnGDP_{t-i} + \varepsilon_t \qquad (8)$$

$$\Delta LnEF_t = \delta_0 + \sum_{i=1}^{m} \delta_{1i}\Delta LnEF_{t-i} + \sum_{i=0}^{n} \delta_{2i}\Delta FDI_{t-i} + \sum_{i=0}^{n} \delta_{3i}\Delta LnFDI\hat{}2_{t-i} + \sum_{i=0}^{n} \delta_{4i}\Delta LnFINTEC_{t-i} + \sum_{i=0}^{n} \delta_{4i}\Delta LnFININC_{t-i} + \sum_{i=0}^{n} \delta_{4i}\Delta LnRNW_{t-i} + \sum_{i=0}^{n} \delta_{4i}\Delta LnGDP_{t-i} + \delta_{5i} ECM_{t-1} + \varepsilon_t \qquad (9)$$

The estimation results are tested for reliability and robustness using Breusch-Pagan-Godfrey Heteroskedasticity, Breusch-Godfrey Serial Correlation LM, Jargue-Bera normal distribution and Ramsey's Reset tests. In addition, both CUSUM and CUSUMQ tests developed by Brown et al. (1975) are applied to determine whether the estimated long-run coefficients are stable.

Within the scope of the above models and theoretical explanations, we assume an inverted U-shaped relationship between financial development and ecological footprint for the Turkiye sample. We also expect financial technology, financial inclusion and renewable energy to decrease the ecological footprint, while economic growth is expected to increase it. We assume that the interaction variable will have a decreasing effect on the ecological footprint. We aim to emphasize policies related to SDG7, SDG8 and SDG17 in achieving SDG13 in Turkiye. In this context, the theoretical framework is presented in Figure 2.

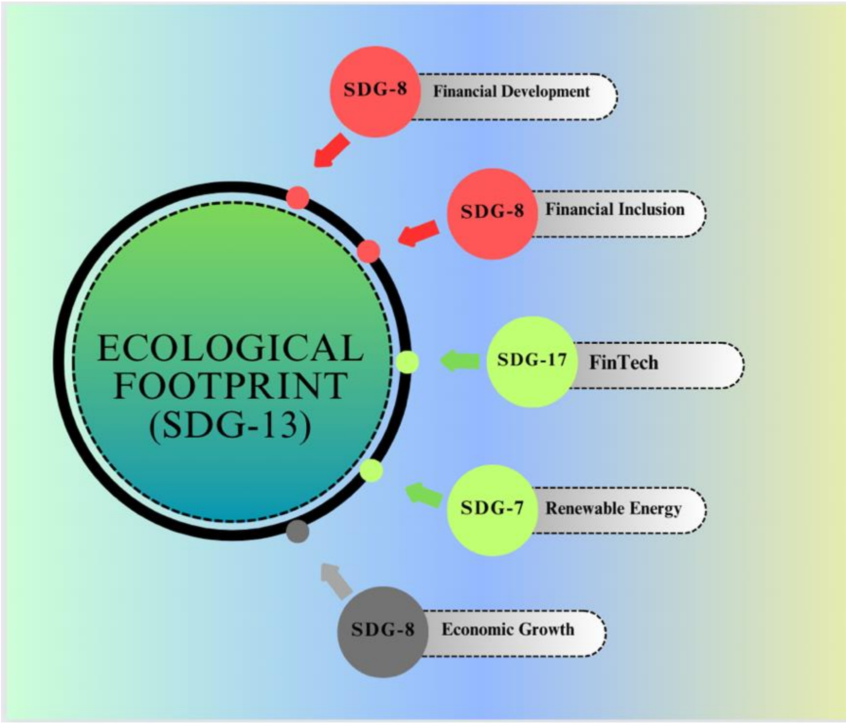


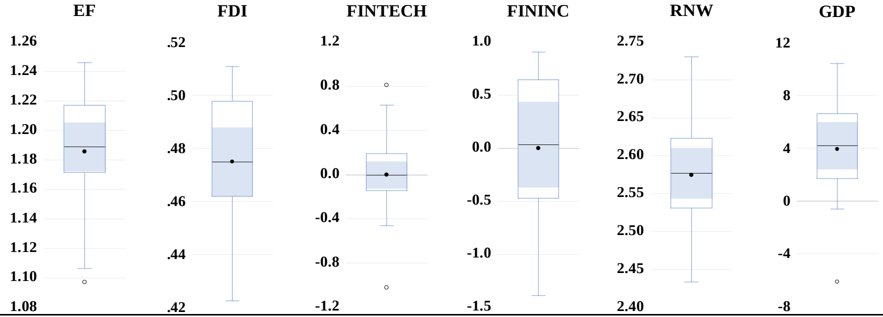
Figure 2: Theoretical Framework

3. Empirical Results

The study aims to investigate the impact of financial development, financial inclusion, FinTech, renewable energy and economic growth on ecological footprint. Among the analyses carried out in line with the objective of the study, first descriptive statistics are presented in Table 2.

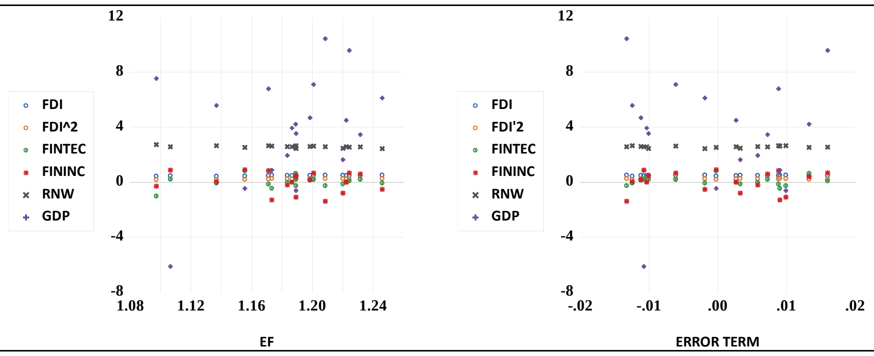
Table 2: Descriptive Statistics

Boxplots



	EF	FDI	FINTECH	FININC	RNW	GDP
Mean	1.185745	0.474995	7.44E-16	2.27E-15	2.574577	3.931070
Median	1.189141	0.474995	-0.000819	0.036313	2.577229	4.209876
Maximum	1.245956	0.510864	0.812083	0.906551	2.730464	10.42940
Minimum	1.097154	0.422537	-1.021281	-1.389959	2.433613	-6.127857
Std. Dev.	0.039780	0.025989	0.386412	0.736772	0.074964	3.900072
Skewness	-0.785896	-0.681073	-0.382356	-0.555146	-0.140795	-0.646996
Kurtosis	3.069843	2.499241	4.585754	2.147268	2.847290	3.632812
Jarque-Bera	1.959701	1.667410	2.453692	1.551587	0.081235	1.642603
Probability	0.375367	0.434437	0.293216	0.460338	0.960196	0.439859
Observations	19	19	19	19	19	19

Scatters



Based on the descriptive information statistics, it can be observed that GDP has the highest mean value (3.931070), while FININC has the lowest mean value of 2.27E-15. The highest and lowest median values are associated with GDP (4.209876) and FINTEC (-0.000819) respectively. GDP is the most volatile, while FDI is the least volatile. All variables have negatively skewed distributions. The null hypothesis of normal distribution cannot be rejected for all variables based on J-B values. Therefore, Pearson correlation analysis is used to investigate multicollinearity and endogeneity problems. The correlation test results are presented in Table 2.

Table 3: Correlation Matrix

	EF	E.T.	FDI	FINTECH	FININC	RNW	GDP
EF	1.000000						
E.T.	0.442602	1.000000					
FDI	0.624535	1.32E-12	1.000000				
FINTECH	0.232117	7.44E-15	-0.101488	1.000000			
FININC	-0.178868	-6.02E-15	-0.506560	0.616768	1.000000		
RNW	-0.578208	3.54E-12	-0.392834	-0.540495	-0.076519	1.000000	
GDP	0.354619	-3.49E-14	-0.045704	-0.283468	-0.090880	0.116607	1.000000

Based on the correlation analysis, it was found that EF has a positive correlation with FDI, FINTEC, and GDP, while FININC and RNW have a negative correlation. The strongest correlation is between FDI and EF, with a value of 0.6245. Therefore, there is no issue of multicollinearity between the explanatory variables. The correlation between the error term of the model estimated through OLS and the explanatory variables shows that there is no endogeneity problem in the model. To check the stationarity of the variables, the ADF test was conducted, and the results are presented in Table 4.

Table 4: Results of ADF Unit Root Tests

	Intercept		Intercept and Trend	
Variables	t-stat	p-value	t-stat	p-value
EF	-1.712	0.406	-1.621	0.737
ΔEF	-4.072	0.008	-4.670	0.011
FDI	-2.278	0.188	-1.619	0.743
ΔFDI	-3.711	0.014	-4.966	0.006
FINTECH	-1.632	0.444	-1.492	0.785
ΔFINTECH	-6.017	0.000	-5.650	0.001
FININC	-1.202	0.649	-1.939	0.592
ΔFININC	-3.141	0.042	-6.732	0.000
RNW	-1.949	0.303	-1.815	0.646
ΔRNW	-6.023	0.000	-5.858	0.001
GDP	-2.592	0.115	-2.500	0.323
ΔGDP	-5.072	0.001	-4.109	0.026
CV(Intercept) 1% (-3.857), 5% (-3.040), 10% (-2.660)				
CV(Intercept and Trend) 1% (-4.571), 5% (-3.690), 10% (-3.286)				

The ADF unit root test assumes the null hypothesis that the series has no unit root. The results indicate that all variables are non-stationary at the I(0) level when using constant and constant with trend, but become I(1) stationary when differenced at first order. This suggests that there are no unit root problems with any of the variables. The model is estimated using ARDL and the findings are presented in Table 5.

Table 5: Findings of ARDL Aproach Short and Long Terms

(Dependent variable:EF)	Model 1		Model 2	
Regressor	Coeff.	p-value	Coeff.	p-value
FDI	6.94895***	0.001	7.05534***	0.000
FDI^2	-7.56198***	0.002	-7.55815***	0.000
FINTECH	0.03724**	0.048	0.58077***	0.009
FI	-0.03485***	0.008	-0.02188**	0.037
RNW	-0.17595***	0.007	-0.20127**	0.010
GDP	0.01395***	0.005	0.01638***	0.000
FDI*FINTECH	-	-	-1.22066**	0.014
ΔFDI	-7.52526	0.191	0.37227	0.912
ΔFDI^2	8.98609	0.159	1.02692	0.782
ΔFINTECH	-0.04267**	0.046	-	-
ΔFI	-0.02630**	0.043	-0.01359	0.105
ΔRNW	0.00051	0.990	-0.00510	0.870
ΔGDP	0.01009***	0.000	0.01150***	0.000
ΔFDI*FINTECH	-	-	-1.97805***	0.000
ECT	-1.40073***	0.001	-1.43383***	0.000
Adj. R^2	0.7283		0.8258	
F statistic	2.777		4.309	
F-stat CV	I(0)	(I1)	I(0)	(I1)
10%	1.75	2.87	1.7	2.83
5%	2.04	3.24	1.97	3.18
2.5%	2.32	3.59	2.22	3.49
1%	2.66	4.05	2.54	3.91
Diognastic Tests	t-stat	p-value	t-stat	p-value
Jarque-Bera	1.496	0.473	1.114	0.572
Ramsey-Reset	2.853	0.202	8.843	0.101
BPG	0.532	0.825	1.409	0.437
BG-LM	0.493	0.652	8.546	0.104
E.T. Correlograms	0.375	0.540	1.593	0.207

Model 1 is constructed to examine the impact of explanatory variables on ecological footprint and Model 2 is constructed to investigate the moderating role of FinTech in the relationship between financial development and ecological footprint. The models were estimated with ARDL, and long and short-run elasticity coefficients were calculated. The F statistic value revealed a long-run cointegration relationship between the relevant variables and ecological footprint in both models. The short-run error correction model results showed that deviations that occur in the short run are balanced in the long run, with a statistically significant error correction coefficient between 0 and -1. In both models, financial development and its square were positively and negatively related to ecological footprint in the long run, respectively, indicating an inverted U-shaped relationship between financial development and ecological footprint in Turkiye. This finding is consistent with previous studies conducted by Khan et al. (2022) and Balsalobre-Lorente et al. (2023). This can be explained by the decreasing effect of financial development on scale, and the increasing effect of financial development on technology and composition, transforming the economy.

On the other hand, FinTech increases the ecological footprint in the long run and decreases it in the short run. This finding differs from the studies by Udeagha & Ngepah (2023), Shu et al. (2024) and Xia & Liu (2024) who find that FinTech improves environmental quality in the long run. It is known that the FinTech sector in Turkiye is developing rapidly. Although it provides positive contributions to environmental quality in the short term, it contributes to environmental pollution in the long term. This can be explained by the fact that the rapid development of FinTech increases electronic waste and causes more energy consumption. Therefore, it can be said that FinTech applications in Turkiye do not yet provide renewable energy incentives by increasing financial inclusion. In addition to the direct impact of FinTech on ecological footprint, this study focuses on the moderating role of FinTech in the relationship between financial development and ecological footprint. The interaction variable in Model 2 has a negative effect on ecological footprint in both the long and short run. Therefore, it can be said that FinTech instruments can provide a balance between financial development and environmental sustainability. However, considering the direct impact of FinTech, it is clear that it is not yet a sufficient policy instrument on its own in achieving sustainable development for Turkiye.

In both models, there is a negative relationship between financial inclusion and ecological footprint in the long and short run. This finding is similar to the studies by Zaidi et al. (2021) and Liu et al. (2022). Ali et al. (2022) stated that financial inclusion can significantly affect environmental quality and can be used as a means of adaptation to environmental degradation. They also emphasized that a financial system developed to combat global warming would promote a green economy. Our findings support this view. This suggests that increasing financial inclusion in Turkiye may reduce environmental pollution by financing clean technology development and deployment. Similarly, renewable energy sources are found to reduce the ecological footprint in the long run. This finding is in line with studies by Huang et al. (2022), Adebayo et al. (2023) and Qing et al. (2024). This indicates that renewable energy sources improve environmental quality and support sustainable development. Finally, economic growth is found to increase the ecological footprint in the long and short run. This finding is in line with the studies by Ahmad et al. (2020), Nathaniel, (2021) and Chu et al. (2023). When countries focus on economic growth, they face ecological problems due to high levels of energy and natural resource use. Therefore, it is important for policymakers to consider environmental and social factors (see fig. 4.).

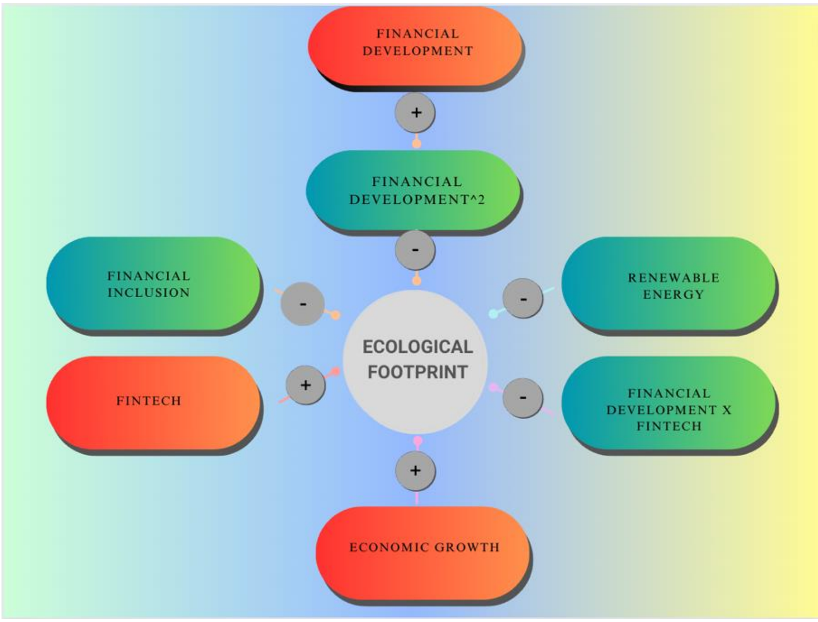


Figure 3: Graphical Summary of Results

According to the results of the diagnostic tests performed for the models, it is observed that the model is normally distributed and there are no autocorrelation and variance problems. In addition, according to the Ramsey reset test, there is no specification error in the model (Table 5). CUSUM-CUSUM of Square plots are shown in Figure 4 to determine whether there is stability among the estimated parameters. When Figure 4 is analyzed, the red (critical bounds) and blue (statistical values) bounds in the graphs indicate whether the model coefficients are stable or not. Therefore, since the statistical values are between the critical limits according to both CUSUM and CUSUMQ values, it can be said that the coefficients calculated in the ARDL model are stable.

Figure 4: CUSUM and CUSUMQ Graphs

CONCLUSION AND POLICY RECOMMENDATIONS

The purpose of this study is to examine the impact of financial development and financial inclusion, FinTech, renewable energy, and economic growth on ecological footprint in Turkiye from 2005 to 2023. The study also aims to demonstrate the non-linear effect of financial development on ecological footprint and the moderating role of FinTech in the relationship between financial development and ecological footprint. The study employs the ARDL method to calculate long-run and short-run coefficients between the variables to obtain reliable results. The findings of the study suggest that there is an inverted U-shaped relationship between financial development and ecological footprint in the long run. This indicates the decreasing scale effect of financial development and the increasing technological and compositional effects of financial development that transform the economy. The study also shows that while FinTech increases the ecological footprint in the long run, it decreases it in the short run, and plays a moderating role in the relationship between financial development and ecological footprint. Additionally, financial inclusion and renewable energy sources reduce the ecological footprint, while economic growth increases it. The findings are in line with those of Zaidi et al. (2021), Khan et al. (2022), Liu et al. (2022), Huang et al. (2022), Adebayo et al. (2023), Chu et al. (2023), and Qing et al. (2024).

The study offers some policy recommendations within the scope of the findings. 1) Financial development in Turkiye is a determinant of ecological footprint. Therefore, sustainable development goals can be supported by encouraging investments that take into account environmental and social factors and ensuring financial inclusion. 2) Financial technologies reduce ecological footprint in the short run and play a moderating role in the relationship between financial development and ecological footprint. Therefore, there is a need for policies to limit the high energy use of financial technologies in the long term in Turkiye and for financial technologies to encourage investment in green projects and renewable energy sources by increasing financial inclusion. It is important to consider SDG 17 targets in achieving SDG 13 targets. 3) The use of renewable energy sources in Turkiye contributes to reducing its ecological footprint. Therefore, increasing renewable energy consumption is critical for reducing environmental pollution and achieving SDG7 targets. Preventing unnecessary consumption of energy resources and promoting renewable energy in production and consumption activities are important steps towards a sustainable environment in Turkiye. 4) Economic growth increases Turkiye's ecological footprint. Therefore, strict laws and restrictions are needed to prevent further consumption of energy and natural resources. Turkiye can control environmental degradation through policies that interact with SDG13 and SDG8 targets, i.e. by linking economic growth policies and green policies.

The study examines some of the factors thought to influence environmental degradation. However, it has some limitations. First, the period of the study has limitations. The study can be repeated by updating the data in future studies. Second, it focuses on ecological footprint as an indicator of environmental pollution. Different environmental pollution indicators can also be included in the study. Third, social factors such as human development and population density can be added to the explanatory variables. Thus, broad policy implications can be made with different sustainable development goals.

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EXTENDED ABSTRACT

GENİŞLETİLMİŞ ÖZET

FİNANSAL GELİŞME, FİNANSAL KAPSAYICILIK VE YENİLENEBİLİR ENERJİNİN SÜRDÜRÜLEBİLİR KALKINMA ÜZERİNDEKİ ETKİSİNİN ARAŞTIRILMASI: TÜRKİYE'DE FINTEK'İN ÖNCÜ ROLÜ

Giriş ve Çalışmanın Amacı:

Çevresel ve sosyal etkileri göz önünde bulunduran yatırımların desteklenmesi, yeşil finansmanın teşvik edilmesi ve finansal kapsayıcılığın artırılması gibi adımlarla, finansal sistemlerin sürdürülebilir kalkınma hedeflerini desteklemesi sağlanabilir. Ayrıca, finansal teknolojinin (Fintek) finansal hizmetlere entegrasyonu, sürdürülebilir yatırımların ve finansal katılımın artırılmasına katkı sağlayabilir. Bunun yanında, yenilenebilir enerji kaynakları, sürdürülebilir kalkınma hedeflerine ulaşmada kritik bir unsur olarak değerlendirilmektedir. Bu bağlamda, bu çalışma, 2005-2023 döneminde Türkiye için finansal gelişme, finansal katılım, Fintek, yenilenebilir enerji ve ekonomik büyümenin ekolojik ayak izi üzerindeki etkilerini incelemektedir. Bu çerçevede çalışma ilk olarak finansal gelişmenin ekolojik ayak izi üzerindeki doğrusal olmayan etkisine odaklanmaktadır. Mevcut literatürde, finansal gelişmenin çevresel bozulmayı farklı düzeylerde etkilediğine dair çeşitli kanıtlar bulunmaktadır. Bu nedenle bu belirsiz ilişkilerin yeniden keşfedilmesi politika çıkarımları açısından önemlidir. Diğer yandan çalışma diğerlerinden farklı olarak, Fintek'in ekolojik ayak izi üzerindeki doğrudan etkisine ve finansal gelişme ile ekolojik ayak izi ilişkisi üzerindeki moderatör rolüne odaklanmaktadır. Bu yaklaşımla yenilikçi politika önerilerinin geliştirilmesi ve bulguların sürdürülebilir kalkınma hedefleri doğrultusunda tartışılması amaçlanmaktadır.

Kavramsal/kuramsal çerçeve: Finansal gelişme, finansal katılım, ekonomik büyüme, Fintek ve yenilenebilir enerji ile çevresel bozulma arasındaki ilişkiye odaklanan önceki ampirik araştırmalar incelendiğinde (Danish vd., 2019; Ahmad vd., 2020; Jahanger vd., 2022; Acar vd.,. 2023; Shu vd., 2024; Qing vd., 2024) bulguların ülkelerin gelişmişlik düzeyine, çalışılan döneme ve kullanılan yöntemlere bağlı olarak farklılık gösterdiği dikkat çekmektedir. Bu durum, ilgili değişkenlerin çevre kalitesi üzerindeki etkilerine dair belirsizliğin devam ettiğini ortaya koymaktadır. Bu bağlamda, mevcut çalışma, bildiğimiz kadarıyla, bu değişkenlerin ekolojik ayak izi üzerindeki etkilerini Türkiye özelinde birlikte ele alan ilk araştırma olma özelliğini taşımaktadır. Bunun yanı sıra, çalışma, finansal gelişme ve ekolojik ayak izi arasındaki ilişkiye Fintek'in moderatör rolünü dahil ederek bu ilişkiye dair belirsizlikleri gidermeyi ve anlamlı politika önerileri geliştirmeyi amaçlamaktadır. Son olarak, elde edilen bulguların Sürdürülebilir Kalkınma Hedefleri (SKH) ile ilişkilendirilmesi yoluyla yenilikçi ve uygulanabilir politika hedefleri sunmayı hedeflemektedir.

Yöntem ve Bulgular: Çalışmada ARDL yöntemi ile uzun ile kısa dönem esneklik katsayıları tahminlenmiştir. Bulgular, uzun dönemde finansal gelişme ile ekolojik ayak izi arasında pozitif bir ilişki bulunurken, finansal gelişmenin karesi ile negatif bir ilişki olduğunu göstermektedir. Bu durum, Türkiye'de finansal gelişme ile ekolojik ayak izi arasında ters U şeklinde bir ilişki olduğunu doğrulamaktadır. Ayrıca, Fintek'in uzun dönemde ekolojik ayak izini artırdığı, ancak kısa dönemde azalttığı görülmüştür. Türkiye'de Fintek sektörünün hızla gelişmekte olduğu bilinmektedir. Kısa dönemde çevresel kaliteye olumlu katkılar sağlarken, uzun dönemde elektronik atıkların artışı ve enerji tüketiminin yükselmesi nedeniyle çevre üzerinde olumsuz etkiler yaratmaktadır. Bununla birlikte, Fintek'in finansal gelişme ve ekolojik ayak izi arasındaki ilişkide moderatör bir rol oynadığı tespit edilmiştir. Fintek araçlarının, finansal gelişme ile çevresel sürdürülebilirlik arasında bir denge sağlama potansiyeline sahip olduğu söylenebilir. Bulgular ayrıca, Türkiye'de artan finansal katılımın, temiz teknolojilerin geliştirilmesi ve yaygınlaştırılmasını finanse ederek çevresel bozulmayı azaltabileceğini göstermektedir. Benzer şekilde, yenilenebilir enerji kaynaklarının uzun dönemde ekolojik ayak izini azalttığı belirlenmiştir. Bu durum, yenilenebilir enerji kaynaklarının çevresel kaliteyi artırdığı ve sürdürülebilir kalkınmayı desteklediğini göstermektedir. Son olarak, ekonomik büyümenin hem uzun hem de kısa dönemde ekolojik ayak izini artırdığı ortaya konmuştur. Ekonomik büyümeye odaklanıldığında, yüksek enerji ve doğal kaynak kullanımı nedeniyle ülkelerin ekolojik sorunlarla karşı karşıya kaldığı gözlemlenmektedir.

Sonuç ve Öneriler: Çalışmada elde edilen bulgulara göre Türkiye'de finansal gelişme, ekolojik ayak izinin önemli bir belirleyicisi olarak öne çıkmaktadır. Bu doğrultuda, çevresel ve sosyal faktörleri dikkate alan yatırımların teşvik edilmesi ve finansal katılımın artırılması, sürdürülebilir kalkınma hedeflerine ulaşılmasını destekleyebilir. Fintek, kısa dönemde ekolojik ayak izini azaltırken, finansal gelişme ile ekolojik ayak izi arasındaki ilişkide moderatör bir rol üstlenmektedir. Ancak, uzun vadede enerji tüketimini sınırlayan politikalar ile Fintek'in yeşil projeler ve yenilenebilir enerji yatırımlarını teşvik edici rolünü güçlendiren düzenlemeler büyük önem taşımaktadır. Bunun yanı sıra, yenilenebilir enerji tüketiminin artırılması, ekolojik ayak izini azaltarak çevresel kirliliğin önlenmesine katkıda bulunabilir ve SKH7 hedeflerine ulaşılmasını destekleyebilir. Ekonomik büyüme ise ekolojik ayak izini artırıcı bir etkiye sahiptir; dolayısıyla, enerji ve doğal kaynak tüketimini sınırlandıracak sıkı yasa ve düzenlemelerin hayata geçirilmesi gereklidir. Ekonomik büyüme politikaları ile yeşil politikaların entegre edilmesi, çevresel bozulmayı kontrol altına alabilir. Çalışmanın sınırlılıkları arasında, belirli bir döneme odaklanılması ve çevre kirliliği göstergesi olarak yalnızca ekolojik ayak izinin kullanılması yer almaktadır. Gelecekteki çalışmalar, daha güncel verilerle tekrarlanabilir, farklı çevresel göstergeler ve insani gelişim ile nüfus yoğunluğu gibi sosyal faktörler eklenerek genişletilebilir. Bu tür yaklaşımlar, daha kapsamlı politika çıkarımlarına olanak sağlayacaktır.

KATKI ORANI BEYANI VE ÇIKAR ÇATIŞMASI BİLDİRİMİ

Sorumlu Yazar *Responsible/Corresponding Author*	Emre Esat TOPALOĞLU
Makalenin Başlığı *Title of Manuscript*	EXPLORING THE IMPACT OF FINANCIAL DEVELOPMENT, FINANCIAL INCLUSION AND RENEWABLE ENERGY ON SUSTAINABLE DEVELOPMENT: THE LEADING ROLE OF FINTECH IN TURKIYE
Tarih *Date*	22/12/2024
Makalenin türü (Araştırma makalesi, Derleme vb.) Manuscript Type (Research Article, Review etc.)	Research Article

Yazarların Listesi / *List of Authors*

Sıra *No*	**Adı-Soyadı** *Name - Surname*	**Katkı Oranı** *Author Contributions*	**Çıkar Çatışması** *Conflicts of Interest*	**Destek ve Teşekkür (Varsa)** *Support and Acknowledgment*
1	Emre Esat TOPALOĞLU	%35	The authors declare no competing interests.	-
2	Tuğba NUR	%35	The authors declare no competing interests.	-
3	İlhan EGE	%30	The authors declare no competing interests.	-