Research Article

Ecological Reflections of Turkey's Financial Development: An Evaluation on Foreign Direct Investment and Domestic Credit

Fatma DURAL[1]

[1] Asst. Prof., İstanbul Gedik University, fatma.dural@gedik.edu.tr, ORCID: 0000-0003-4039-0130

Abstract: Financial development, which is an important driver of economic growth, also has critical impacts on environmental sustainability. This study takes a holistic approach to examining the environmental consequences of financial development through the ecological footprint indicator, which represents the ecological capacity required for the continuity of an economy. The Global Footprint Network states the ecological footprint must be below 1.5 gha to protect biodiversity. However, in 2022, Turkey's per capita footprint was 2.58 gha. This shows its way of life isn't sustainable, so policymakers need action plans based on solid data. Within this framework, the main objective of this study is to empirically examine the causal relationship between domestic loans, which are an indicator of financial depth, and foreign direct investment, which represents financial openness, in order to provide a more comprehensive perspective on the environmental impacts of financial development. The Toda-Yamamoto causality analysis was applied in the study covering the period 1985-2022. According to the analysis results, a two-way causal relationship was found between the ecological footprint and direct foreign investment, while a one-way causal relationship was identified between domestic loans and the ecological footprint. These findings show that both the national financial system and international capital flows have a direct impact on Turkey's environmental performance. The study's results emphasize that if the capital accumulation provided through these channels is directed toward environmentally conscious investment areas, it can give the financial development process a dynamic momentum focused on sustainability.

Keywords: Sustainability, Ecological Footprint, Financial Development, Foreign Direct Investment, Toda Yamamoto
Jel Codes: Q56, Q57, E51, C32

Türkiye'nin Finansal Gelişiminin Ekolojik Yansımaları: Doğrudan Yabancı Yatırım ve Yurtiçi Kredi Üzerine Bir Değerlendirme

Öz: Ekonomik büyümenin önemli bir itici gücü olan finansal gelişme, aynı zamanda çevresel sürdürülebilirlik üzerinde de kritik etkilere sahiptir. Bu çalışma, finansal gelişimin çevresel sonuçlarını, bir ekonominin devamlılığı için gereken ekolojik kapasiteyi temsil eden ekolojik ayak izi göstergesi üzerinden bütüncül bir yaklaşımla ele almaktadır. Küresel Ayak İzi Ağı'na göre, biyolojik çeşitliliği korumak ve artan dünya nüfusunun ihtiyaçlarını karşılamak için ekolojik ayak izinin 1.5 kha'in altında olması gerekirken, Türkiye'nin 2022'deki kişi başına ekolojik ayak izi 2.58 kha olarak ölçülmüştür. Bu durum, ülkedeki yaşam faaliyetlerinin sürdürülebilir olmadığını ve politika yapıcılar için somut verilere dayalı eylem planlarına ihtiyaç duyulduğunu göstermektedir. Bu çerçevede çalışmanın temel amacı, finansal derinliğin bir göstergesi olan yurtiçi krediler ile finansal açıklığı temsil eden doğrudan yabancı yatırımlar (DYY) arasındaki nedensel ilişkiyi ampirik olarak inceleyerek, finansal gelişimin çevresel etkilerine dair daha kapsamlı bir bakış açısı sunmaktır. 1985-2022 dönemini kapsayan çalışmada Toda-Yamamoto nedensellik analizi uygulanmıştır. Yapılan analizler, ekolojik ayak izi ile doğrudan yabancı yatırımlar arasında iki yönlü bir nedensellik ilişkisi bulunduğunu ortaya koyarken, yurtiçi kredilerden ekolojik ayak izine doğru tek yönlü bir nedensellik saptamıştır. Bu bulgular hem ulusal finansal sistemin hem de uluslararası sermaye akışlarının Türkiye'nin çevresel performansı üzerinde doğrudan bir etkiye sahip olduğunu göstermektedir. Çalışma sonuçları, bu kanallar aracılığıyla sağlanan sermaye birikiminin çevreye duyarlı yatırım alanlarına yönlendirilmesi durumunda, finansal gelişme sürecine sürdürülebilirlik odaklı dinamik bir ivme kazandırılabileceğini vurgulamaktadır.

Anahtar Kelimeler: Sürdürülebilirlik, Ekolojik Ayak İzi, Finansal Gelişme, Doğrudan Yabancı Yatırımlar, Toda Yamamoto
Jel Kodları: Q56, Q57, E51, C32

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1. Introduction

Global carbon emissions are increasingly attracting the attention of policymakers and academics. This issue has been widely debated in the international arena and has been extensively studied in academia. As a result, authorities have implemented a wide range of policies and practices. In the last several years, the critical importance of not only reducing carbon emissions but also stabilizing the entire ecosystem has become evident. According to the 2022 Living Planet Report, the loss of biodiversity, pollution, species extinction, and climate change pose serious threats to both present and future generations. Global biodiversity decreased by 69% between 1970 and 2018 (World Wildlife Fund, 2022). Consequently, researchers have begun to approach the issue more holistically. They use the ecological footprint, a more comprehensive metric that includes several components such as carbon emissions, built-up land, grazing land, cropland, forests, and fishing grounds.

Wackernagel & Rees (1997) define the ecological footprint as a metric that "quantifies the total area of biologically productive land and water needed to provide the resources a population consumes and to absorb the waste it generates.” The concept of "ecological footprint" was developed and recognized in the literature in the early 1990s during Mathis Wackernagel's doctoral studies at the British Columbia University. A nation's ecological footprint is typically measured against its biocapacity—a measure of the regenerative capacity of its natural assets. This metric offers a holistic evaluation for understanding how sustainability is achieved.

The ecological footprint is calculated using six different land-use types (World Wildlife Fund, 2022). These include the “grazing land footprint”, which measures the area required for livestock grazing; the “forest product footprint”, which determines the forest area needed for timber, paper, and fuel; the “fishing grounds footprint”, which calculates the water area required to replenish marine life. The list also includes the “cropland footprint”, for agricultural land used to produce food, fiber, and animal feed; the “built-up land footprint”, which represents the productive land covered by infrastructure; and the “carbon footprint,” which simply tells how much forest area is needed to handle carbon emissions. As shown in Figure 1, the carbon footprint is the most dominant of these components.

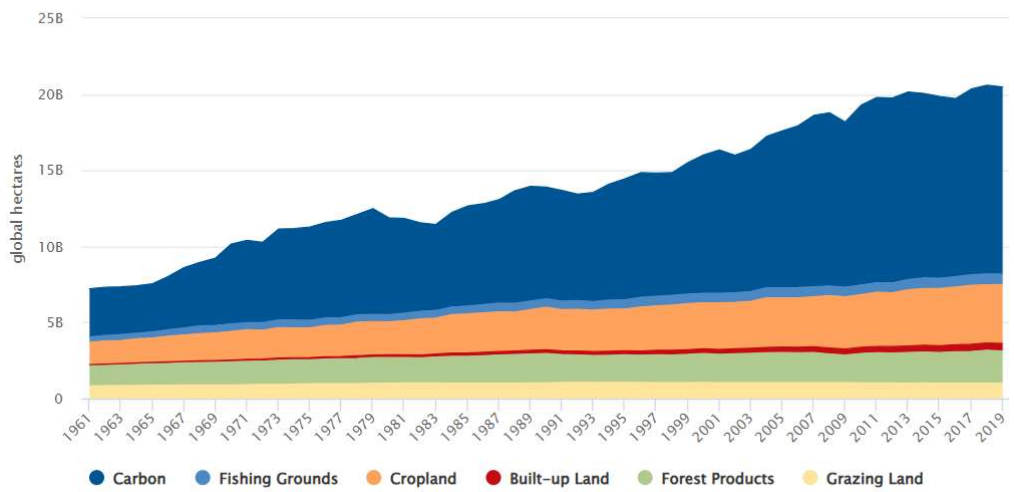

Figure 1. Global Ecological Footprint by Land Type
(Source: GFN, https://www.footprintnetwork.org/)

The pressure on natural resources needed for production and consumption can be expressed as an ecological footprint, while the supply of available productive space is referred to as biocapacity. In terms of demand, the ecological footprint illustrates the amount of farms, woods, pastures, and fishing grounds a nation requires to generate the resources consumed and assimilate the carbon it releases. In contrast, biocapacity indicates the productive capacity of natural resources within a given area (Global Footprint Network, n.d.).

These two metrics are measured in the unit "global hectare" (gha). Having a biocapacity higher than the ecological footprint is critical for sustainability. The ratio of these two terms to each other (EF/BC) is called Ecological Footprint Accounting. An EF/BC ratio greater than one indicates an ecological deficit, meaning a country is using more biocapacity than they control in their territory. Conversely, an ecological reserve occurs when the EF/BC ratio is less than one, indicating that a country has more biocapacity than its ecological footprint (World Wide Fund for Nature, 2006).

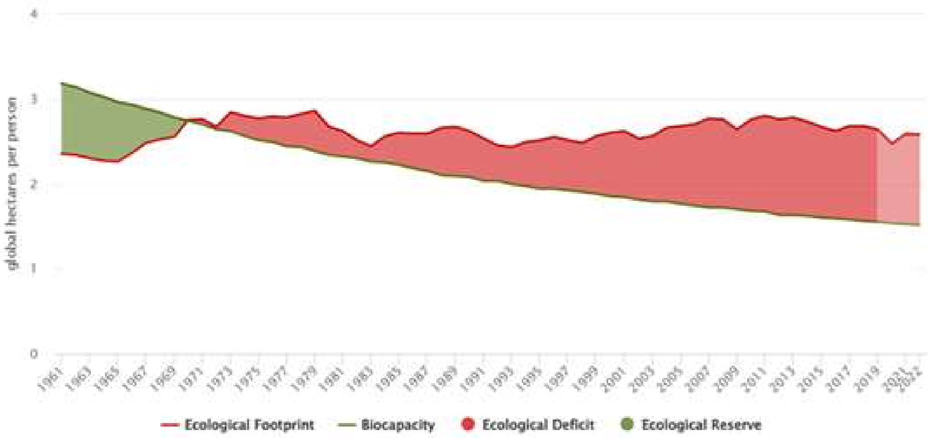

Figure 2. Global Ecological Footprint and Biocapacity Balance
(Source: Global Footprint Network (GFN), https://www.footprintnetwork.org/)

From 1961 to 2022, Figure 2 displays the global ecological footprint and biocapacity in global hectares (gha) per person. Each year, the Global Footprint Network measures the ecological footprint and biocapacity of countries around the world and publishes them in different categories. A country's ecological footprint per person is derived from its total ecological footprint divided by the population. The graph reveals that after 1970, the ecological footprint rapidly began to exceed the biological capacity, leading to a sustainability deficit. The red (top) line shows the total Ecological Footprint of 2.58 gha per capita in 2022. The green (bottom) line represents the global Biocapacity of 1.51 gha per capita in 2022. The difference of 1.07 gha presents that the ecological footprint exceeds the global biocapacity.

Global Footprint Network states that the ecological footprint ought to be much lower than the per capita limit of 1.5 gha in order to preserve biodiversity and to fulfill the demands of the expanding global population in terms of biological capacity.

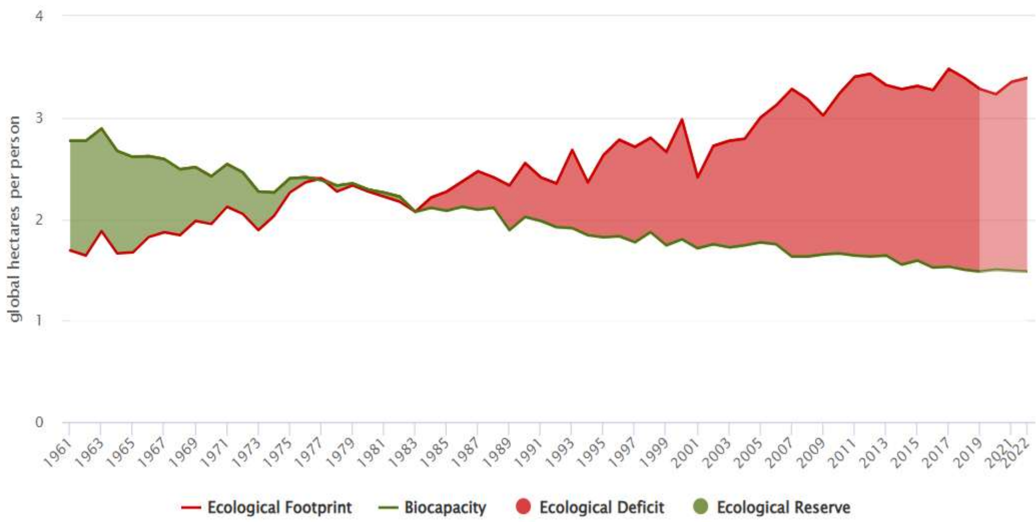

Figure 3. Turkey's Ecological Footprint and Biocapacity Balance
Source: GFN, https://www.footprintnetwork.org/

According to Figure 3, the ecological reserve, which was 1.1 in the 1960s, decreased over the years, reaching 0 in 1982 and turning into an ecological deficit in the following years. It can be observed from the graph that the per capita biocapacity for 2022 is 1.5 gha, ecological footprint per capita is 3.4 gha and the ecological deficit has reached -1.9 gha. Therefore, Turkey's national ecological deficit is well above the global ecological deficit, which was measured as 1.07 in 2022. The rapid increase in national income and population in parallel with the ecological deficit is an indication of the intensity of unsustainable living activities in the country.

Clearly, the continuation of the unsustainable and increasing ecological overdraft indicates that the current biocapacity will become a greater risk for the Turkish economy. Therefore, it is of utmost importance to reduce environmental threats and ensure the sustainability of economic activities. This requires the swift determination of policies to improve environmental quality, as well as the development of environmental awareness in social and public terms. In order to create an action plan and emphasize the necessity for countries to take measures against the risk of ecological limit exceedance, this study, which is a situation analysis, is thought to be a guiding guide.

In the following sections, this study will proceed under the following headings, respectively: presentation of the conceptual framework, literature review, explanation of the data set and technique, presentation of the empirical findings, and evaluation of the final results.

2. Conceptual Framework

Environmental degradation and the over-consumption of natural resources represent a global threat that directly impacts the well-being of future generations.

In this vein, the ability of financial development to foster economic growth while simultaneously promoting environmental sustainability has been drawing increasing attention from both academics and policymakers. The Environmental Kuznets Curve (EKC) hypothesis provides a theoretical basis for understanding this complex interaction. It suggests that with economic development, environmental degradation first increases but then a downward trend begins after a specific income level is attained due to technological progress and the introduction of environmental regulations (Grossman & Krueger, 1995). The financial system perform two key roles in this process. In the early, upward phase of the EKC, it can inadvertently accelerate environmental degradation by funding polluting activities. Yet, as the system matures, it can shift toward a sustainability-oriented structure, helping the economy move more rapidly into the declining phase of the curve (Ionescu, 2021). This transition highlights the importance of the sustainable finance approach.

Sustainable finance, by integrating environmental, social, and governance (ESG) factors into investment and lending decisions, enables the financial system to internalize environmental costs and direct capital toward green initiatives. In doing so, it challenges the traditional notion that environmental protection hinders economic growth (Soundarrajan & Vivek, 2016). At the same time, by directing resources toward long-term, lower-risk, and innovative projects—such as renewable energy infrastructure and energy efficiency investments—it fosters new job opportunities, encourages technological advancement, and mitigates potential economic risks associated with climate change (Ionescu, 2021). Consequently, sustainable finance has assumed a key position in the new development paradigm often referred to as "green growth" or "low-carbon growth." To fully appreciate this transformation, however, it is essential first to understand the role of financial development in shaping economic growth.

The significant nexus of financial development and economic growth highlights the financial system as a central driver of development (King & Levine, 1993). Modern growth theories further emphasize that financial deepening accelerates capital accumulation by efficiently channeling savings into productive investments, enhances productivity, and thereby fosters economic growth (Levine, 1997). This process operates through two main channels, which are the focus of this study. Domestic credit allows local firms to expand production capacity, invest in new projects, and finance technological advancements, while Foreign Direct Investment (FDI) captures aspects of financial openness and international capital integration, representing the external channel of financial development. These channels do more than simply provide capital inflows—they also bring in new technologies, management expertise, and greater access to international markets (Blomström & Kokko, 1998; Alfaro et al., 2003; Abzari, Zarei & Esfahani, 2011).

These indicators also align with the World Bank's (2016) financial development framework. According to this framework, financial depth is one of the dimensions of financial development. Financial depth, which is critical in terms of work, refers to the size of funds in the financial system and the degree to which they are transferred to the real economy. In this context, domestic credits represent domestic capital flows as an indicator of financial depth, while FDI, although not included in the World Bank's direct classification, contributes to the depth of the financial system as an external capital flow and is considered an indicator of financial openness (Alfaro et al., 2004). The environmental impacts of these financial channels are of vital importance for developing economies such as Turkey, which are highly dependent on external capital flows.

At this point, the scale of global financing needs must also be taken into account. The World Investment Report 2023 (UNCTAD) highlights that developing economies will need to allocate approximately $2.4 trillion annually until 2030 to complete their energy transitions. Of this amount, around $1 trillion is expected to come from external sources. Given that renewable energy projects are generally larger in scale and more costly than fossil fuel investments, foreign direct investment plays a vital role as a financing source in supporting this transition.

In this study, domestic credits, which represent financial depth, and foreign direct investment, which reflects financial openness and international capital integration, are examined together within the broader framework of financial development. The environmental implications of financial development are evaluated in a comprehensive manner. Accordingly, the study seeks to investigate the causal impact of financial development on Turkey's ecological footprint, thereby contributing to the theoretical literature and providing actionable insights for policymakers.

3. Literature Review

In the literature, there is no conclusive evidence on how foreign direct investment and financial development metrics affect the ecological footprint.

The findings of empirical research indicate that financial development metrics may have a beneficial or adverse impact on the ecological footprint. The biggest reason for the rapid increase in carbon emissions, which have the largest share in ecological footprint calculations, is the fossil fuel usage. Within this framework, the level of financial development can favorably decrease the ecological footprint by enabling the low-cost financing of expensive renewable energy investments. Therefore, it is expected that the ecological footprint will decrease by reducing the carbon emission footprint (Usman & Hammar, 2021; Caglar et al., 2021; Yao et al., 2021; Hafeez et al., 2019). However, an increase in credit could stimulate economic output and consumption, driving more industrialization and energy use, ultimately expanding the ecological footprint (Ashraf & Doytch, 2023; Kihombo et al., 2021; Yang et al., 2021). Table 1 presents some of the recent studies examining the interplay between financial development and ecological footprint.

Table 1. Recent Research on the Interaction of Financial Development with the Ecological Footprint

Author/Year	Scope/Period	Financial Variables	Method	Conclusion
Destek & Sarkodie (2019)	1977-2013 Newly industrialized countries	Private Sector Credits/GDP	Generalized Mean Group Estimator (MAG)	Financial development has been found to reduce the ecological footprint in China and Malaysia, while increasing it in Singapore.
Saud et al. (2020)	1990-2014 One Belt One Road countries	Airline Group Averages Estimator PMG	Domestic Credits/GDP	It was concluded that financial development increased the ecological footprint in 14 countries and decreased it in 30 countries.
Yang et al. (2021)	1990-2016 Brazil, India, Africa and China	Private Sector Credits/GDP	Error Correction Model, DSUR, FMOLS, Granger Causality	Financial development increases the ecological footprint in relevant countries.
Ahmed et al. (2021)	1971-2016 Japan	Private Sector Credits/GDP	Asymmetric and Symmetric ARDL	It has been concluded that financial development contributes to the expansion of ecological footprint in the relevant countries.
Ibrahim & Vo (2021)	1991-2014 27 Industrialized Countries	Financial Development Index	Panel Causality	It has been stated that financial development generally increases the ecological footprint, however, high innovation reduces this negative impact of financial development in some countries.
Caglar et al. (2021)	1980-2017 Top 10 countries with the highest environmental degradation	Private sector credits	Airline Group Averages Estimator PMG	In general, it was concluded that the financial sector has a positive impact on environmental quality.
Yao et al. (2021)	1995-2014 BRIC Countries and N-11 Countries	Private sector credits	Panel Cointegration GMM and panel causality	In times when corruption is under control, financial development reduces the ecological footprint by increasing energy efficiency.
Akınsola et al. (2022)	1984-2017 Brazil	Financial Development Index	ARDL, FMOLS, DOLS and CCR	It was discovered that Brazil's ecological footprint was lessened by its degree of financial development.
Idrees & Majeed (2022)	1972-2018 Pakistan	Domestic Credits/GDP	ARDL	It has been determined that the ecological footprint grows as a result of financial development.
Bakkal (2022)	1980-2018 USA and China	Financial Development Index	NARL	Reveals that rise in the ecological footprint is also a result of increased financial development.
Özkan & Coban (2022)	1980-2018 Türkiye	Financial Development Index	ARDL Simulation Model	It was concluded that the ecological footprint and financial development are positively correlated.
Long et al (2023)	2000-2019 E7 Countries	Domestic Credits/GDP, Banking sector indicators, foreign capital investments	Panel Cointegration within the STIRPAT Model	Considering all its dimensions, it has been explained that financial development increases the ecological footprint and the establishment of large financial institutions makes a positive contribution.
Dogan (2023)	1985-2000 Türkiye	Financial Development Index	ARDL bounds test and FMOLS estimator	It has been determined that there is a positive correlation between the ecological footprint and the rise in financial development.

Emerging nations need foreign direct investment from multinational companies to achieve their desired economic growth. This capital is essential for bringing in the latest technology, research, and development needed to drive production, improve productivity, and create new jobs (Wang & Blomström, 1992). The literature reveals that the impact of FDI on ecological footprint varies and there is no consensus on this issue yet. While some studies have concluded that FDI, which is seen as one of the dynamics of growth, increases the ecological footprint because it brings environmental degradation with it, some studies have found that FDI, which is essential for financing high-cost sustainable investments and transferring necessary technology, reduces the ecological footprint (Barış, 2024; Roy, 2024; Chowdhury et al., 2021; Udemba, 2021; Liu & Kim, 2018; Khan et al., 2019). In some other studies, it has been determined that the results are complicated according to the econometric method used and vary across countries (Arogundade et al., 2022; Solarin & Al-Mulali, 2018; Destek & Okumuş, 2019). In Table 2, some studies on FDI in recent years are given.

Table 2. Recent Research on the Interaction of Foreign Direct Investment with the Ecological Footprint

Author/Year	Scope	Variables	Method	Result
Solarin & Al-Mulali (2018)	(1982-2013) Developed and Developing Countries	CO2 emission, Carbon footprint, Ecological footprint, FDI, GDP, urbanization, energy consumption	Panel Cointegration (Westerlund Test and AMG and CCEMG estimators	When the panel analysis results are examined in general, it is seen that FDI does not have a significant effect, while in the country-based results, it is concluded that FDI increases environmental degradation in developing countries.
Liu & Kim (2018)	(1990-2016) BRI Countries (Belt-Road countries)	Ecological footprint, FDI and GDP	Panel VAR	The study stated that foreign direct investments have a considerable effect on ecological footprint and there is a reciprocal relationship between the two.
Zafar et al. (2019)	(1970-2015) USA	Ecological footprint, FDI, growth, human capital and energy consumption	ARDL	While Energy usage and economic growth are observed to be negatively correlated with the ecological footprint, FDI has been reported to lessen ecological footprint.
Khan et al. (2019)	(1990-2016) BRI Countries	GDP, energy consumption, financial development, foreign investment and footprint	Westerlund cointegration test, AMG and CCEMG estimators, Panel causality	The ecological footprint is said to be significantly impacted by financial development and foreign direct investment. Additionally, FDI and ecological footprint are found to be causally related in both directions.
Destek & Okumuş (2019)	(1982-2013) 10 Newly industrialized countries	Real GDP per capita, FDI, energy and footprint	Second generation panel data analysis (Westerlund Cointegration, CCEMG)	The study's findings demonstrated a U-shaped association between ecological footprint and foreign direct investment.
Doytch (2020)	(1984-2011) Developed and Developing Countries	Consumption, production, import, export footprint data	Dynamic Panel Data Analysis	It has been revealed that FDI contributes to the ecological footprint.
Udemba (2021)	(1980-2018) United Arab Emirates	Ecological footprint, FDI, GDP, energy and population	ARDL bounds test, VECM and Granger causality	FDI and ecological footprint were shown to be negatively correlated, and there was also a one-way influence from ecological footprint FDI.
Chowdhury et al. (2021)	(2001-2016) The 92 countries	Ecological footprint, FDI, growth, export, institutional quality	Panel Quantile Regression Model	The study found that regardless of the level of FDI, it shows a positive correlation with the ecological footprint.
Bakkal (2022)	(1980-2018) USA and China	Growth, ecological footprint, FDI, financial development index	ARDL bounds test, Toda Yamamoto and Fourier Toda Yamamoto Test	The ecological footprint is positively impacted by foreign direct investment, and this effect is more in the US than in China.
Arogundade et al. (2022)	(1990-2017) 31 African Countries	Ecological footprint, FDI, economic growth, urbanization	Driscoll-Kraay estimator and Spatial Durbin model.	The analysis yielded mixed results. In the first stage, it was determined that foreign direct investments reduced the ecological footprint to a certain level, then increased ecological degradation.

Li et al. (2023)	(1988-2021) China	Ecological footprint, economic growth, FDI, renewable energy consumption, R&D expenditures	Cointegration analysis and Moment quantile regression	It is found that economic growth plays a significant role in the deterioration of environmental quality in China, while renewable energy, R&D and FDI reduce the ecological footprint.
Özcan (2024)	(1997-2020) 131 countries	Foreign direct investment, GDP, urbanization, energy, industrialization	Quantile regression	It has been stated that foreign direct investment, urbanization and GDP positively affect ecological footprints.
Roy (2024)	(1990-2016) India	Ecological footprint, FDI, growth, trade openness, natural resources, energy	ARDL	The study results reveal that foreign direct investment, renewable energy and growth worsen the ecological footprint.
Eweade et al. (2024)	(1975-2020) Mexico	Ecological footprint, FDI, fossil fuel, consumption, growth and globalization	ARDL, NARDL,	Based on findings, while the ARDL model indicates that FDI reduces the ecological footprint, the NARDL model reveals that positive developments in FDI and globalization negatively affect the environment.
Barış (2024)	(1990-2021) The 19 Countries with the Highest FDI	FDI, Ecological footprint, Economic growth, renewable energy consumption	Panel ARDL, PMG	The ecological footprint has been found to be positively impacted by foreign direct investments.
Han (2024)	(1980-2020) Turkiye	FDI, economic growth, population growth, urbanization rate, renewable energy consumption and globalization	Toda-Yamamato Causality Test	It was determined that a reciprocal relationship exists between ecological footprint and FDI.

4. Data Set and Methodology

4.1. Data

The study uses annual data on ecological footprint, domestic credits and foreign direct investment. Domestic credits represent financial development in terms of financial depth as it indicates the volume of credit extended by banks to the private sector and thus the size and potential of accessible funds in the financial system. Foreign direct investment, on the other hand, is used since it contributes to financial development through capital accumulation as an important source of external financing. Foreign direct investments are in US dollars and represent net inflows. Financial data are obtained from the IMF's IFS database. Ecological footprint data, published annually in global hectares per capita and source is GFN database. This study's sample period extends from 1985, when ecological footprint data was first published, to 2022, which marked the latest update available during this research. The data were analyzed in natural logarithmic form.

In the international literature, the influence of financial development on the ecological footprint is generally examined in terms of the amount of credit provided by financial institutions or the financial development index. In Turkey-specific studies, the financial development index is predominantly used. This study creates a difference by adopting a credit-focused approach, which is common in the international literature but relatively neglected in the Turkish literature. Furthermore, the analysis includes not only credits but also foreign direct investment, which contributes to the depth of the financial system through foreign capital inflows. Thus, by considering domestic credits and FDI together, the depth dimension of financial development is highlighted, and a more comprehensive perspective is offered.

This choice is based on selecting the two key indicators that most directly reflect the environmental outcomes of financial development, rather than attempting to control all external factors that could influence the ecological footprint simultaneously. Furthermore, considering that countries may have different economic and structural dynamics, the study focuses solely on Turkey and evaluates these two variables, which have not been analyzed together in the literature, under the concept of financial development. This approach provides a more specific analysis of the ecological impacts of Turkey's financial development. Table 3 contains details of the data used in the analysis.

Table 3. Summary information about the data set

Variables	Definition	Period
EF	Ecological Footprints (global hectares per capita)	
CR	Domestic Credits (% GDP)	1985-2022
FDI	Foreign Capital Investments (net inflows, USD)	

Figure 4 shows the ratio of domestic credits to GDP. This ratio increased particularly rapidly between 2003 and 2020, reaching its highest value of approximately 71% in 2020.

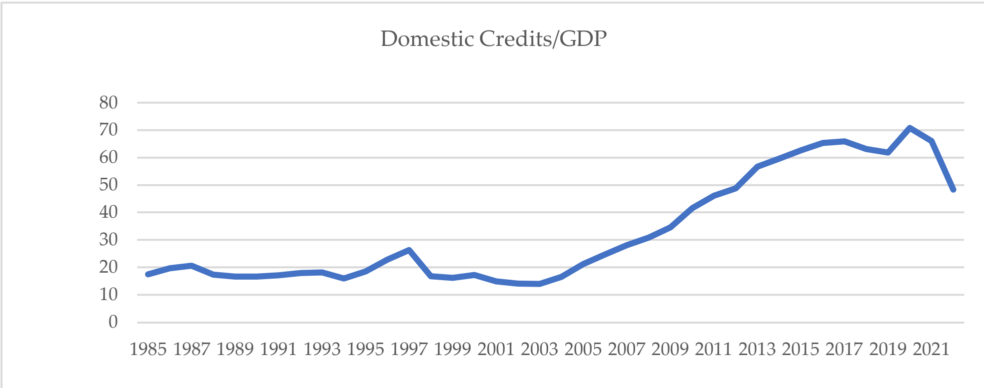

Figure 4. Domestic Credits (% of GDP)

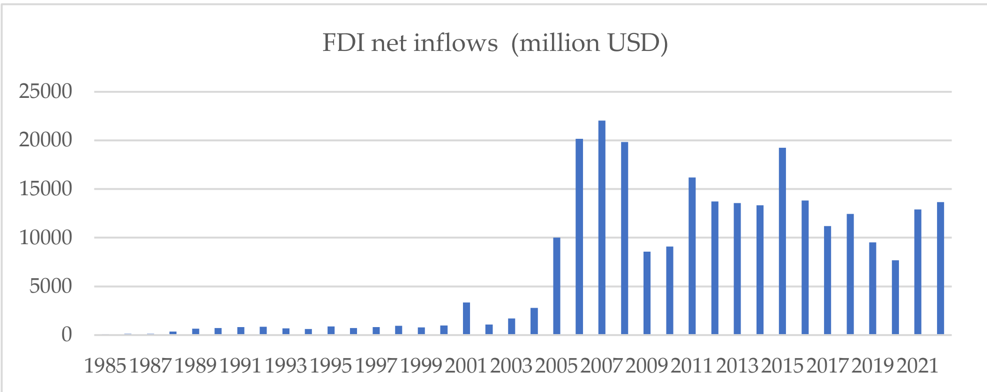

Figure 5. Foreign Direct Investments

According to Figure 5, net FDI inflows in Turkey amounted to $10 bn in 2005 and $20 bn in 2006. Before the global crisis, inflows peaked at $22 bn in 2007. After declining to $8.6 bn in 2009 due to the global crisis, inflows reached $16.2 bn in 2011. In the following period, inflows, which were around $12-13 bn annually, increased to $19.2 bn with a new upward trend in 2015, but showed a sharp decline in 2016 and remained at 11-12 bn dollars in the following periods. Foreign direct capital inflows, which then started to increase again, amounted to $12.90 bn in 2021 and $13.67 bn in 2022.

4.2. Methodology

This research employs the Toda-Yamamoto (1995) causality test to reveal the relationship between Turkey's ecological footprint, domestic credits, and FDI. This specific method was chosen to deal with the constraints of the traditional Granger causality test, which often requires strict assumptions about the stationarity and cointegration properties of the series.

The Toda-Yamamoto test provides a robust and reliable alternative since it makes possible the exploration of causality irrespective of the series' order of integration or the presence of a long-term relationship between them. This approach is particularly advantageous as it avoids the potential pre-test biases and erroneous results that can arise from traditional tests, especially when series have different degrees of stationarity or when the nature of their long-term relationship is unclear.

The core of the method involves applying the Wald test on a Vector Autoregression (VAR) model estimated at the level. his allows for the robust testing of coefficient restrictions without taking into account the time series' stationarity characteristics. To apply the test, the optimum lag length (k) and maximum degree of integration (dmax) are first determined for the VAR model. Afterward, the VAR (k+dmax) model is estimated by summing the selected lags and integration degrees. This ensures that the causality can be examined independently of the series' stationarity properties (Toda & Yamamoto, 1995).

$$Y_t = a_0 + \sum_{i=1}^{k+d_{max}} a_{1i} Y_{t-i} + \sum_{i=1}^{k+d_{max}} a_{2i} X_{t-i} + u_t \quad (1)$$

$$X_t = \beta_0 + \sum_{i=1}^{k+d_{max}} \beta_{1i} X_{t-i} + \sum_{i=1}^{k+d_{max}} \beta_{2i} Y_{t-i} + v_t \quad (2)$$

The VAR (k+dmax) model estimated by the Toda-Yamamoto method is shown in equations (1) and (2). The hypotheses of the Toda-Yamamoto causality test are as follows (Şahin & Durmuş, 2018): H_0: X does not Granger cause of Y. H_1: X does granger cause of Y. The null hypothesis' rejection suggests that X is Y's Granger cause.

The models of this research are presented in equations (3) and (4).

$$EF_t = a_0 + \sum_{i=1}^{k+d_{max}} a_{1i} EF_{t-i} + \sum_{i=1}^{k+d_{max}} a_{2i} FD_{t-i} + u_t \quad (3)$$

$$FD_t = \beta_0 + \sum_{i=1}^{k+d_{max}} \beta_{1i} FD_{t-i} + \sum_{i=1}^{k+d_{max}} \beta_{2i} EF_{t-i} + v_t \quad (4)$$

The hypotheses of this study are as follows:

Hypotheses of equation (3):
H_0: Financial Development (FD) variable is not ecological footprint's Granger cause.
H_1: Financial Development variable is ecological footprint's Granger cause.

Hypotheses of equation (4):
H_0: Ecological Footprint is not Financial Development's Granger cause.
H_1: Ecological Footprint is Financial Development's Granger cause.

5. Empirical Findings

In order to conduct the Toda-Yamamoto's test of causality within the framework of the VAR model, it is first required to ascertain the optimum lag length and the maximum degree of integration. For this purpose, as an initial step Augmented Dickey-Fuller and Phillips-Perron Stationarity tests were performed (Dickey & Fuller, 1979; Phillips & Perron, 1988).

Table 4. Unit Root Test Results

			ADF			PP		
			EF	FDI	CR	EF	FDI	CR
At Level	Constant	t-Statistic	-1.2083	-1.8489	-0.9332	-1.5473	-1.8826	-0.7476
		Prob	***0.6602***	***0.3519***	***0.7659***	***0.4989***	***0.3365***	***0,8219***
	With Constant & Trend	t-Statistic	-4.8840***	-2.0937	-2.0957	-5.0153***	-2.1437	-1.6857
		Prob	***0.0018***	***0.5322***	***0.5307***	***0.0013***	***0.5055***	***0.7375***
	Without Constant & Trend	t-Statistic	1.4187	1.5105	1.0641	1.4655	1.6046	0.9362
		Prob	***0.9585***	***0.9653***	***0.9219***	***0.9621***	***0.9712***	***0.9037***
At First Difference	Constant	t-Statistic	-10.6528***	-5.9210***	-4.0265***	-12.3510***	-5.9276***	-3.9548***
		Prob	***0.0000***	***0.0000***	***0.0035***	***0.0000***	***0.0000***	***0.0043***
	With Constant & Trend	t-Statistic	-10.5308***	-6,0120***	-3.9355**	-13.0680***	-6.1561***	-3.8560**
		Prob	***0.0000***	***0.0001***	***0.0206***	***0.0000***	***0.0001***	***0.0247***
	Without Constant & Trend	t-Statistic	-10.3122***	-5.6163**	-4.0481***	-11.0775***	-5.6168***	-4.1021***
		Prob	**0.0000**	**0.0000**	***0.0002***	**0.0000**	**0.0000**	***0.0002***

According to the AIC information criterion used in the ADF and PP test results, the symbols *, **, *** indicate stationarity at 10%, 5% and 1% significance, respectively.

Table 4 displays the results of the unit root test. The FDI series' unit root tests don't offer enough proof to disprove the fundamental premise that "the series has a unit root" at the 5% level of significance. This demonstrates that the FDI series is not stationary at level. Nevertheless, the series becomes stationary and integrated of order 1 after obtaining the first difference. The ADF and PP tests performed for the stationarity analysis of the EF series invalidate the hypothesis of "the series has a unit root" at a significance level of 5% in the constant and trend model. This indicates that the EF series in this model is stationary at the level. However, since the same result cannot be obtained in other models the EF series is generally not stationary at the level. When the first difference of the EF series is taken, the unit root hypothesis is rejected at a 5% level of significance in all models and the series becomes stationary. This finding reveals that the EF series is also integrated of the first degree (I(1)). The ADF and PP tests show that the CR variable is stationary of the first degree in all models. Consequently, the highest degree of integration is found to be 1 since all series are I(1).

Then, the appropriate lag length between the variables was determined through the VAR Model. According to Table 5, all information criteria indicate that the first lag is the most appropriate lag length. Accordingly, the appropriate lag length (k) is set as 1.

Table 5. Optimal Lag Lengths According to Information Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-19.78974	NA	0.000738	1.302271	1.435586	1.348291
1	61.82871	144.5812*	1.17e-05*	-2.847355*	-2.314092*	-2.663273*
2	68.26563	10.29908	1.37e-05	-2.700893	-1.767684	-2.378749
3	73.07118	6.865072	1.80e-05	-2.461210	-1.128055	-2.001005

* It refers to the optimal lag found according to the relevant information criterion.

In the next step, the distribution of the inverse roots of the AR characteristic polynomial was analyzed. Figure 6 shows that AR characteristic polynomial are located inside the circle and furthermore the modulus values in Table 6 are less than 1, which supports the stationarity of the series. These findings prove the stationarity and stability of the VAR model.

Table 6. Modulus Values

Root	Modulus
0.899309 - 0.099256i	0.904769
0.899309 + 0.099256i	0.904769
-0.425839	0.425839
0.094126 - 0.380940i	0.392397
0.094126 + 0.380940i	0.392397
0.357484	0.357484

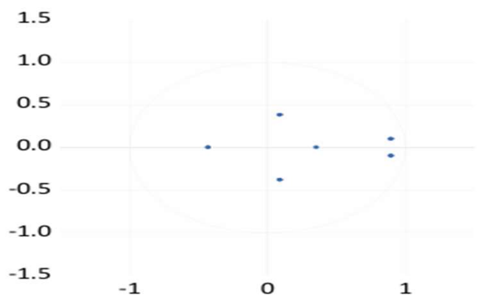

Figure 6. Inverse Roots of AR

In addition, prior to the Toda-Yamamoto causality test, in order to confirm the reliability of the estimates to be obtained, validity of the assumption that the error terms don't relate to one another and whether the variance of the error terms changed over time were analyzed with various diagnostic tests.

Table 7. Lagrange Multiplier (LM) Autocorrelation Test

Number of Days	LM Statistic	Prob. Value
1	10.04662	0.3467
2	10.07983	0.3441
3	14.20735	0.1151

Based on the findings of the LM autocorrelation test in Table 7, the hypothesis of no autocorrelation among the error terms of the 1-lag model is accepted at 5% significance level. Therefore, it is determined that the error terms do not exhibit a statistically significant autocorrelation problem.

Table 8. Heteroscedasticity Test

$\chi 2$	Degrees of freedom	Prob Value
72.72477	72	0.4539

Likewise, as seen in Table 8; the hypothesis that there is no heteroscedasticity among the error terms was accepted at a significance level of 5%, and it was determined that there was no heteroscedasticity problem according to the 1 lag model.

After the reliability of the model was confirmed, the causal connections between the variables were analyzed using the Toda-Yamamoto (1995) causality test. For this purpose, after the VAR Model, the SUR model was used to make the estimate.

After this stage, the causality test was carried out. For this test, the VAR model is established as VAR (dmax+k). Since the dmax value was found to be 1 and the most suitable lag length (k) value was found to be 1 within the scope of the analysis, the VAR(2) model was established. This model was re-estimated by selecting the Seemingly Unrelated Regression (SUR) method and the Wald test was applied for the solution of the

2-lag Toda Yamamoto equation. Since the probability value in the Wald test was not calculated according to the k degree of freedom table value, the real probability value must be found. For this purpose, the chi-square value in the Wald test was taken and the probability value was calculated according to the k=1 degree of freedom situation and the table was rearranged. The Wald Test results are given in Table 9.

Table 9. Toda-Yamamoto Causality Test

Causality Direction	χ2 Stat.	Prob.	Result
FDI ⟹ EF	6.790954	0,009162***	Result shows that FDI has a statistically significant causal effect on EF.
EF ⟹ FDI	10.48971	0,0012***	The analysis presents that the EF has a causal effect on foreign direct investments.
CR ⟹ EF	4.596795	0.032032**	Results indicate significant causal relationships from credits to ecological footprint.
EF ⟹ CR	0.647265	0.421092	The analysis shows that the EF doesn't have a statistically significant causal effect on credit.

Note: (*), (**) and (***) denote 10%, 5% and 1% significance levels, respectively.

While evaluating the results of the Toda-Yamamoto Causality Test in Table 9, a comparison was made by calculating the probability value according to the case with k degrees of freedom. As shown in Table 6, the basic hypothesis that "FDI is not the Granger cause of ecological footprint" is rejected at 1% significance level. Similarly, the null hypothesis of "Ecological footprint is not the Granger cause of FDI" in the second model is not accepted at the 1% significance level. These findings show that there is a mutual causality connection between the variables. When the table is examined, the hypothesis of "Credits are not the Granger cause of the ecological footprint" at the 5% significance level, it is rejected, while the hypothesis of "Ecological footprint is not the Granger cause of credits" is not rejected at the 5% significance level. This indicates the existence of a unilateral causality relationship from credits to ecological footprint.

6. Conclusion

This study examines the causal relationship between credits provided to the private sector, which is an indicator of the depth of financial development, and foreign direct investment, which represents international capital flows, on the ecological footprint. This study takes a holistic approach to the environmental impacts of financial development through two different channels: financial depth and financial openness. In the analysis, domestic credits were used for the financial depth dimension, while foreign direct investment was used for the financial openness and international capital integration dimension.

As a preliminary preparation for the Toda-Yamamoto causality test based on the VAR model, the most appropriate number of lags and the highest degree of integration in the series were first determined. According to the findings VAR(2) model is constructed and estimated with the Seemingly Unrelated Regression (SUR) method. Then, the Toda Yamamoto equation was solved with the Wald test. As a result of the analysis, while there is evidence of bidirectional causality between ecological footprint and foreign direct investments, there is one-way causality from credits to ecological footprint.

Additionally, to evaluate how reliable the forecasts are, modulus values was examined and autocorrelation and variance tests were performed. Since the model was found to be stable, the results were found to be reliable.

Unidirectional Causality Between EF and CR: The unidirectional causality in the analysis can be linked to the scale effect in the EKC hypothesis, which is frequently discussed in the literature for developing countries (Grossman & Krueger, 1995). According to this theory, growth in production and consumption activities tends to increase the ecological footprint by increasing resource use. Our findings indicate that an increase in credits affects economic activity by encouraging investment and consumption, thereby influencing the ecological footprint.

On the other hand, our findings do not provide evidence that a change in the ecological footprint (e.g., an improvement or deterioration in environmental conditions) affects credit supply. The expansion of the ecological footprint is not the primary factor determining the amount of credit. Financial decisions are generally more sensitive to variables such as macroeconomic stability, interest rates, sector profitability, and risk perception. Therefore, the one-way causal relationship from credit to the ecological footprint is an expected result and clearly highlights the guiding role of the financial system in environmental outcomes. This finding is consistent with similar studies (Han, 2024; Khan et al., 2019; Liu & Kim, 2018; Olowu et al., 2018; Yağiş, 2023).

Bidirectional Causality Between EF and FDI: The findings reveal a two-way causal relationship between FDI and ecological footprint. Similar findings have been reported in the international literature (Nuta et al., 2024; Udemba, 2020; Khan et al., 2019). However, there are differences between countries: For example, while Udemba (2020) found a two-way causality in his study on Turkey, Nuta (2024) reported a one-way causality (FDI → ecological footprint) in Turkey; a two-way relationship was found in Latvia, Poland, and the Czech Republic.

The bidirectional causality found in this study for Turkey can be explained by the simultaneous operation of two different mechanisms. On the one hand, FDI increases resource consumption caused by economic growth through the scale effect (Antweiler, Copeland & Taylor, 2001), reduces the ecological footprint through improvements in production technologies via the technical/composition effect (Eskeland & Harrison, 2003), and creates a pollution haven effect by taking advantage of differences in environmental regulations On the other hand, the ecological footprint shapes FDI inflows by influencing investors' perceptions and sector preferences (Cole & Elliott, 2005).

The composition of FDI coming to Turkey also supports this relationship. According to data from the Turkish Investment Office, of the total $262 billion in FDI that came to Turkey between 2003 and 2023, the largest share was taken by finance (30.7%) and manufacturing (24.2%). This situation shows that investments are coming to the country from both "dirty" industries (manufacturing) and "clean" sectors (such as finance, information technology, and services). Thus, the two-way causality reveals that FDI flows in Turkey attract investors with low environmental costs and influence investors who consider environmental performance. This complex dynamic shows that FDI interacts with ecological outcomes through multiple mechanisms rather than a single channel.

As this study shows, the first step toward shifting the relationship in favor of the ecological footprint is for the authorities to create environmentally friendly policies. The absence of a strong and comprehensive legal framework in Turkey hinders the implementation of principles aimed at achieving sustainability goals (Demir & Güzel, 2024). Therefore, it is critical that the state establish policies to align access to finance with green transformation goals.

First, mechanisms that encourage green finance can be established. In this context, it would be beneficial to increase the number and variety of products such as green bonds, green financial leasing, and green loans, and to expand their scope to reach a broader base (Flammer, 2021). In addition, banking regulations that make environmental and social risk assessment mandatory in lending processes may be implemented (International Finance Corporation [IFC], 2012). Indeed, it is known that only a few banks in Turkey apply systems that assess environmental and social risks in the projects they finance (Banking Regulation and Supervision Agency [BDDK], 2024). These environmental impact assessment reports in the lending process can be disseminated more rapidly. In addition, it is necessary to establish stronger ties with sustainability-conscious international investors, attract them to green projects in Turkey, and integrate sustainability into investment decisions. This can be achieved through amendments to existing laws and regulations that support green financing instruments.

In short, Turkey needs to combine its investment appeal with sustainability principles. In line with the findings of our study, this approach is expected to pave the way for the transfer of carbon-reducing technology and environmentally friendly renewable energy investments, which are likely to have a positive effect on the ecological footprint. Even though this study offers important insights into the link between financial development and the ecological footprint, there is still much to explore. Future research could broaden the picture by adding other measures of financial openness, such as portfolio flows or trade-based indicators. It may also benefit from using methods that capture non-linear or time-varying dynamics, or by comparing different groups of countries. Taking these steps would not only strengthen the reliability of the results but also help build a deeper and more comprehensive understanding of how finance and the environment interact.

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