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The Effect of Agricultural and Financial Sectors on Environmental Quality: Testing the Validity of the LCC Hypothesis in Türkiye

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ABSTRACT

The increasing destruction of nature after the Industrial Revolution has revealed that we need to be more sensitive to the environment. These adverse effects, mainly observed in the agriculture, forestry, and fishing sectors, have been the subject of limited studies in the literature. This study attempts to determine the impact of the agricultural and financial sectors on environmental quality in Türkiye. The first objective of this study is to test the hypothesis of load capacity curve (LCC) validity regarding the in Türkiye, focusing on the agricultural and financial sectors. The second is to calculate the level of GDP per capita, which is the turning point from environmental degradation to environmental quality. To this end, the study uses annual data from 1990 to 2021, indicating that the series has different levels of stationarity as a result of stationarity tests. It is evident that the Augmented Autoregressive Distributed Lag (A-ARDL) model is the best fitted as the dependent variable, the load capacity factor is *I(0).* The findings reveal that there is a cointegration relationship among the variables. Model results demonstrate that development in agricultural sectors increases environmental quality (EQ), whereas development in the financial sector causes environmental degradation (ED). Furthermore, the result proves that the hypothesis of LCC is valid for Türkiye, and it is detected that 20.720 USD is the amount of GDP per capita at which environmental degradation stops and environmental quality begins to increase. The findings show that policymakers should give more support and importance to the agricultural sectors to ensure increased environmental quality.

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Tarım ve Finans Sektörlerinin Çevresel Kalite Üzerine Etkileri: Türkiye'de LCC Hipotezinin Geçerliliğinin Test Edilmesi

ÖZET

Sanayi devrimi sonrasında artan doğa tahribatı, çevreye karşı daha duyarlı davranmamız gerektiğini ortaya koymuştur. Özellikle tarım-ormancılık-balıkçılık sektörlerinde gözlemlenen bu olumsuz etkiler, sınırlı sayıda akademik çalışmaya konu olmuştur. Bu çalışma, Türkiye'de tarımsal sektörler ile finans sektörünün, çevre kalitesi üzerindeki etkisini belirlemeye çalışmaktadır. Bu kapsamda, çalışmanın temel iki amacı bulunmaktadır. Bunlardan ilki; tarım ve finans sektörleri odağında, Türkiye'de yük kapasite eğrisine (LCC) ilişkin hipotezin geçerliliğini sınamaktır. İkinci amaç ise çevresel bozulmadan, çevresel kaliteye geçiş (dönüş) noktası olan kişi başı milli gelir düzeyini hesaplamaktır. Bu amaçla, 1990-2021 arası döneme ait yıllık verilerin kullanıldığı çalışmada, durağanlık testleri neticesinde serilerin farklı mertebelerden durağanlığa sahip oldukları görülmüştür. Bağımlı değişken olan yük kapasite faktörünün *I(0)* olması nedeniyle A-ARDL yöntemi tercih edilmiştir. Bulgular, değişkenler arasında eşbütünleşme ilişkinin varlığını göstermektedir. Model sonuçları, tarımsal sektörlerdeki gelişimin çevresel kaliteyi arttırdığını buna karşın finans sektöründeki gelişimin ise çevresel bozulmaya neden olduğunu

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yönündedir. Ayrıca Türkiye için LCC hipotezi geçerli olduğu tespit edilmiş olup çevresel bozulmanın durup, çevresel kalitedeki artışın başlayacağı kişi başı milli gelir düzeyi 20.720 ABD doları olarak hesaplanmıştır. Elde edilen bulgular, politika yapıcıların çevresel kalitedeki artışı sağlamak için tarımsal sektörlere daha fazla destek ve önem vermesi gerektiğini göstermiştir.

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INTRODUCTION

Throughout the Industrial Revolution, growing natural destruction and subsequent climate changes deeply affected the economic and social life of human beings. Decreased biodiversity due to ED (Pires et al., 2018; Habibullah et al., 2022; Jiang et al., 2024), rising air temperatures, forest fires, and drought have become critical subjects of academic studies. Global warming creates irreversible effects on natural ecosystems (Caglar et al., 2024) and profoundly affects agriculture (Alvarado et al., 2021; Li et al., 2023), forestry (Arshad et al., 2020; Ayad et al., 2024), and fishing industries (Ayad, 2023; Ayad & Lefilef, 2024), which are closely intertwined with nature. To this end, agriculture, forestry, and fishing industries stand out as areas both caused and affected by climate change and ED. Soil erosion, salinisation, desertification, and loss of organic matter are the elements that affect agricultural productivity and cause ED due to this situation. Agriculture's machinery and fertiliser production based on fossil fuels significantly lead to greenhouse gas emissions of greenhouse. This increase in emissions exacerbates climate change and poses a threat to the sustainability of agriculture. As greenhouse gas emissions increase, atmospheric temperatures increase (National Oceanic and Atmospheric Administration, 2023), leading to changing precipitation patterns, more frequent droughts, and rising sea levels. This poses significant risks to food security (Bandara & Cai, 2014), reduces crop productivity, increases forest fires, and threatens marine ecosystems. In addition, practices such as monoculture, intensive chemical use (Landrigan et al., 2018), and deforestation increase greenhouse gas emissions (Snyder et al., 2009), while also causing climate change through vulnerable agricultural systems (Nwokoro & Chima, 2017; Özkurt, 2024). Similarly, the forestry sector plays a significant role in combating climate change and ED, both as a carbon sink (Lindberg et al., 2023; Ayad et al., 2024) and can suffer severe damage as a result of wrong interventions (Cardil et al., 2020). In the fishing sector, ocean acidification, temperature increase, and habitat destruction negatively affect the life cycle of marine species (Hughes et al., 2005; Brander, 2008; Clark & Longo, 2019). In the face of these adverse effects, sustainable development policies (Göçoglu & Göksu, 2024) are of vital importance. Policies on the protection of natural resources, long-term planning, and environmental impacts can ensure both environmental and economic sustainability in these sectors. The expansion of climate and environmentally friendly practices in agriculture, the strengthening of reforestation and protection programs in forestry, and the practical implementation of fishing quotas and marine protected areas in fisheries are among the basic steps that can be taken in respect of the Sustainable Development Goals (SDGs). These actions will eventually halt ED, and the process of EQ is anticipated to start.

The assessments and comments show us that the agricultural sector is both one of the causes of ED and the sector most affected by this degradation. The pressure on natural resources has increased due to a growing population that needs to meet its nutritional needs, and the concentration of agricultural production. The fact that these sectors operate primarily in rural areas and provide employment to many people makes them critical for the environment and economic growth (EGR). Nevertheless, while targeting short-term EGR, traditional production models cause ED and endanger long-term development goals. Thus, balancing EGR with ecological sustainability should be one of the main priorities of development policies. The current study examines the association between the agricultural sectors(agriculture-fishing-forestry) and ED on a different level in light of all these assessments. Centered on the LCC hypothesis, this paper demonstrates ecological sustainability, that is, the ability of the ecosystem to cope with ED by assessing both the demand and supply sides of nature, as put forward by Dogan and Pata (2022) and based on the EKC approach. If the LCF value is equal to or above "1", it indicates that environmental conditions are sustainable because nature's supply exceeds its demand. Otherwise, it suggests that ED continues. The U-shaped curve in Figure 1 below illustrates how ED starts as income rises. But after a while, ED hits its lowest point, and EQ starts to rise in tandem with the increase in income. The present study attempts to check the plausibility of LCC for the agricultural and financial sectors, and if it is valid, to calculate the national income per capita at which the turning point occurs. Consequently, the study variables are selected as LCF,

financial markets index (FMI), renewable energy consumption (RENW), GDP per capita, agriculture-forestry-fishing value added, and total natural resources rents. To reveal the study's originality, the literature review emphasises the EQ and focuses on the agriculture and finance sectors with the LCC hypothesis.

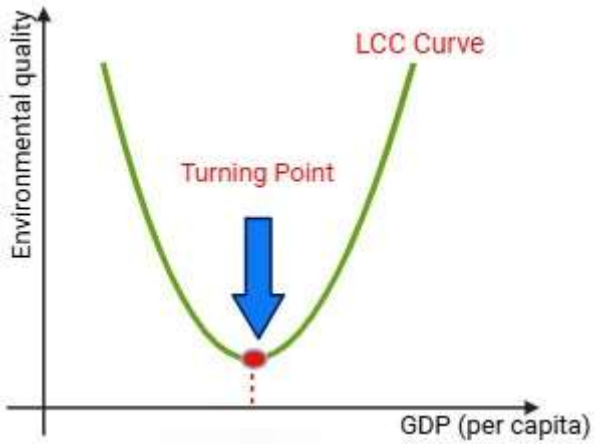

Figure 1. Load Capacity Curve (Doğan and Pata, 2022; Ayad, 2023).
Şekil 1: Yük Kapasite Eğrisi (Doğan and Pata, 2022; Ayad, 2023).

The remaining sections of the study attempt to identify the similarities and differences between the current study and previous studies in the literature. Following this, the materials and methods section is presented. Following this, a conclusion and a comprehensive discussion section are presented. The study concludes with a conclusion section that provides general assessments, policy recommendations for Türkiye, limitations, and suggestions for future research.

LITERATURE REVIEW

In recent years, the increasing demands of humankind on the environment have frequently become a subject of academic research. The linkage between ED and various variables has recently become one of the dominant topics in the literature. At this point, carbon dioxide emissions (CO_2) and Ecological Footprint (EF) are commonly encountered as ED indicators. LCF is the indicator that shows EQ. Many studies clearly show that ED occurs with increasing CO_2 emissions. While some studies (Charfeddine & Khediri, 2016; Bui, 2020; Jiang et. al., 2022; Wang et. al., 2022; Ahmad et. al., 2022) attribute this to financial development, studies such as Patel and Metha (2023) and Hussain et. al. (2022) show that the reason for this is economic indicators, and authors such as Mohamed et. al. (2024) and Lin et. al. (2023) demonstrate that energy use causes the increase in CO_2 emissions. Interestingly, studies focusing on the agricultural sector and CO_2 emissions show different results. Chandio et. al. (2020) demonstrates that energy usage in agriculture reduces CO_2 emissions, contradicting the findings of Ali et. al. (2023) and Chandio et. al. (2021). These authors contend that growing agricultural activities increase CO_2 emissions and cause ED. Another important indicator of ED is EF. This variable is one of the main subjects of many recent studies and has been used to show the effects of various variables on ED. In this regard, it discusses the compatibility between EF and economic indicators (Wang et al., 2022; Kazemzadeh et al., 2023; Özbek & Naimoğlu, 2025), financial development (Ahmed et al., 2021; Uzar & Eyüboğlu, 2024; Bergougui, 2024), and energy use (Mohamed et al., 2024; Azimi & Rahman, 2024; Georgescu & Kinnunen, 2024; Baigorri et al., 2025). The relations of EF and agricultural activities are also one of the current topics in the literature. While a significant part of these studies (Alvarado et. al., 2021; Gyamfi et. al., 2023; Li et. al., 2023; Shah et. al., 2023) conclude that agricultural activities increase EF, there are also studies (Mahmood et. al., 2019; Xu et. al., 2023; Raihan, 2023) in the opposite direction, that is, studies claiming that agricultural activities decrease EF. Last but not least, the studies on LCF, which is likewise employed as an indicator of EQ, are similarly categorised into three major topics. These are studies that examine the effect of financial development on LCF (Latif & Faridi, 2023; Okezie et. al., 2023; Ali et. al., 2024), LCF and EGR (Latif & Faridi, 2023; Du et. al., 2024; Altıntaş et. al., 2024), and finally LCF and energy consumption (Zhao et. al., 2023; Sun et. al., 2024; Pata & Pata, 2025). The mutual influence between agricultural activities and EQ is only covered in a limited number of studies. Salahuddin et al. (2020) explore the effect of EQ on sub-Saharan African countries' agricultural production. The findings show that a decreased EQ reduces agricultural production, confirming Olanipekun et al. (2019). Adekoya et. al. (2022) find that RENW, EGR, and resource rents, including agriculture, reduce EQ. Nwokoro and Chima (2017) examine the impact of ED on poverty

and agricultural production and show causality between the two variables. Zaman et. al. (2022) consider the interaction between agricultural production, female labour, RENW, and EQ. The study results indicate that using advanced machinery in agriculture increases EQ. This study was also partially supported by Oladele et. al. (2024) for Nigeria.

As the literature review demonstrates, the number of studies on agriculture on CO_2 and EF, which are indicators of ED, and LCF, which shows EQ, is quite limited. This research, in contrast to previous studies, concentrates on the LCC to determine whether the credibility of the LCC hypothesis is valid or not in Türkiye and calculates the turning point if applicable. In this context, there are limited studies since the focus is on the agricultural activities (agriculture, fishery, forestry) and LCC. Ayad et. al. (2024) examine the nexus of deforestation and LCC in Brazil and detect that trade openness, energy use, and population growth stand out as factors causing deforestation. Pata and Pata (2024) investigate the impacts of RENW and the forest load capacity factor (LLCF) on CO_2 from a similar perspective. The results of the study using Indian data show that the EKC is valid. Gökmenoğlu et al. (2019) suggest that ED will decrease with a reduction in deforestation; Arshad et al. (2020) state that ED will increase with deforestation, and Parajuli et al. (2019) highlight the impact of forest areas on EQ through the absorption of carbon emissions. Ayad (2023) explores the interrelation between the fisheries sector and LCC, testing the LCC hypothesis specifically for G7 countries. The findings confirm the existence of LCC. Furthermore, the findings show that human capital and RENW positively impact the marine ecosystem. Ayad and Lefilef (2024) assess the LCC hypothesis for the fishing sector in China. The paper uses the Fourier Autoregressive Distributed Lags (FARDL) to explore the effects of EGR and FDI on marine ecosystems. Their results illustrate that the LCC hypothesis is valid for the fishing sector and support the study of Pata et. al. (2023).

Despite the lack of research specifically examining the nexus between LCC and agricultural productivity, the LCC hypothesis has been studied from several aspects and variables throughout the literature. Wang et al. (2024) examine the alignment between EGR, nuclear energy, RENW, and EQ through LCC and conclude that the LCC is valid for BRICS countries. Pata and Tanriover (2023) and Yang et al. (2023) confirm similar findings. Deng et. al. (2024) investigate the validity of the LCC hypothesis in leading emitter economies such as the US and China through clean energy and clean energy security. The findings confirm LCC's existence and show a U-shaped relationship between GDP and LCF. Fang et. al. (2024) seek the effect of political risk, natural resources, and biomass utilisation on LCC. The results corroborate the LCC hypothesis for Thailand. Using Nigerian data, Okezie et.al. (2023) check the effect of variables such as GDP, trade openness, and financial development on LCF. The findings provide a U-shaped interplay between GDP and LCF and affirm the LCC hypothesis. Pata et.al. (2025) investigate the impact of factors such as RENW, Fintech, and government effectiveness on LCF. The study shows a U-shaped association between GDP and LCF and confirms the LCC hypothesis. Apart from these, several studies explore the verification of the LCC hypothesis across various variables and groups of countries (Hakkak et al., 2023; Shahzad et al., 2023; Huang et al., 2023; Wu et al., 2023; Alola et al., 2023; Guloglu et al., 2023; Dai et al., 2023; Afshan & Yaqoob, 2023; Pata & Ertugrul, 2023; Pata et al., 2023; Fang et al., 2024). The findings consistently validate the conclusion that the hypothesis is valid. Eventually, studies examining the LCC hypothesis from various perspectives for Türkiye yield contradictory results. While studies such as Içen (2024), Çamkaya (2024), and Çağlar et al. (2024) argue that the LCC hypothesis is valid for Türkiye, Topal (2024) claims that it is not valid.

A general evaluation of the studies in the relevant literature reveals that CO_2 and EF are the most widely used indicators of ED, and their links with economic growth, financial development, energy use, and agricultural activity have been extensively investigated. While many studies indicate that increased economic and agricultural activity increases CO_2 and EF, conflicting findings are particularly striking regarding agricultural activity and energy use. Similarly, the few studies examining the relationships between LCF, which represents EQ, and economic growth, energy consumption, and financial development have taken a linear approach. Narayan and Narayan (2010), based on comparing short and long-term resilience of GDP, identified U-shaped or inverted-U-shaped relationships. However, the limited number of studies addressing the reciprocal effects between agricultural activity and LCF represents a significant gap in the literature. Even when the international literature is examined, no study has been found that calculates the turning point of the LCC, focusing on agricultural sectors. Based on this gap in the literature, the current study aims to determine whether Türkiye has reached its income level that will increase its EQ, considering both the demand and supply sides of EQ. More clearly, it aims to test the tenability of the LCC hypothesis and determine the minimum income level that will increase EQ, focusing on the agriculture, forestry, and fishing sectors and FD. The reason for selecting Türkiye as the sample for the study is not simply that there has not been a study conducted on this topic; there are many other reasons for this. Firstly, Türkiye ranks first globally in crop production for cherries, apricots, figs, and hazelnuts, and among the top ten globally for products such as barley, sunflowers, chickpeas, lentils, tomatoes, onions, apples, pistachios, walnuts, grapes, and olives, according to Republic of Türkiye Ministry of Agriculture and Forestry (2019). These figures highlight Türkiye's importance in agricultural production and present a sector that should be considered in environmental

assessments. Furthermore, examining the LCF variable, included in the model as an environmental quality indicator, reveals that Türkiye remains well below nature's capacity to absorb its resources. This situation, which could be irreversible without urgent action, necessitates urgent action. Finally, another reason for selecting Türkiye as the sample for the study was to determine whether Türkiye's recent investments in renewable energy have reached a level that would enhance environmental quality. In addition, testing the LCC hypothesis using a quadratic model using the A-ARDL method will be another original contribution to the literature regarding methodology. In conclusion, while the literature provides strong evidence that the LCC hypothesis is valid across many country groups and variables, the divergent findings, particularly regarding agricultural activities and energy use, indicate that these relationships should be examined in depth within the context of country, sector, and policy.

MATERIALS and METHODS

The study addresses this topic using a quadratic model. The LCC hypothesis originates from the EKC hypothesis, which is opposed to the EKC hypothesis but offers a broader perspective because it reflects the demand for and supply of nature. Therefore, the LCC hypothesis is based on the premise that the GDP variable will decrease environmental quality to a certain level and then increase it after a certain threshold value/turning point. In light of these explanations, this empirical study aims to test the existence of the LCC hypothesis in Türkiye, with emphasis on the agricultural (Agriculture-Forestry-Fishing) sectors and the financial sector. In contrast to prior studies, it also concentrates on the turning point in income level (GDP per capita): how ED turns into EQ. Undoubtedly, the factors expected to impact environmental quality are not limited to these. In addition, we will attempt to uncover the environmental impact of Türkiye's recent increase in renewable energy investments. The study uses annual data from 1990 to 2021 and takes the natural logarithm of all variables to eliminate scale differences in the variables (Pata & Samour, 2022). Disruptions in domestic and international financial markets post-1990 caused economic shrinkage in the Türkiye economy (Bülbül & Akgül, 2018). Therefore, it was decided to begin the analysis in 1990. On the other hand, the reason for limiting the scope of the study to 2021 is that, unlike other variables, the Financial Markets Access Index and Total natural resources rents (% of GDP) data expire in 2021. This issue constitutes one of the most important limitations of the study. Table 1 below illustrates the definitions, abbreviations, and data sources of the variables that are used in the study.

Table 1. Definition of variables
Çizelge 1. Değişkenlerin tanımı

Symbol	*Description*	*Source*
lcf	Load capacity factor (Biocapacity x Ecological footprint-1)	Global Footprint Network
fmi	Financial Markets Access Index	International Monetary Fund
renw	Renewable energy annual consumption (TWh equivalent)	Our World in Data
gdp	GDP per capita (constant 2015 US$)	World Bank
aff	Agriculture-forestry-fishing value added (constant 2015 US$)	World Bank
natres	Total natural resources rents (% of GDP)	World Bank

A total of six different variables are utilised in the study. Among them, *LCF* is the dependent variable, and the other five variables (*fmi, renw, gdp, aff, natres*) are independent. The impact of AFF, FMI, RENW, and GDP on EQ emerges through multidimensional and interrelated dynamics. While agricultural activities may harm the environment, they also hold the potential to enhance environmental quality through sustainable practices. Financial development can yield positive environmental outcomes when it supports eco-friendly investments; however, in the absence of adequate environmental regulations, it may exacerbate ED. RENW use stands out as a key factor that directly improves EQ by reducing dependence on fossil fuels. Although economic growth may exert environmental pressure in the short term, within the framework of the Environmental Kuznets Curve (EKC) hypothesis, it may lead to environmental improvements in the long run through investments in green technologies. The joint analysis of these four variables provides an original contribution to the literature, as such a comprehensive approach has been rarely addressed in previous studies. The study differs from other studies because the *FMI* and *AFF* variables are used for the first time in a study of this scope. In essence, the dependent variable, *LCF*, is basically calculated by dividing the biocapacity by the ecological footprint. The agricultural sector is represented by three distinct subgroups: namely, agriculture, forestry, and fishing. Since one of the study's main objectives is to determine the income level that will provide EQ, another important independent variable is GDP. Currently unable to reap the full benefits of RENW sources, Türkiye is investing more and more in this field yearly. Therefore, total natural resources rent (*natres*) is considered as another independent variable in terms of showing the rate of natural resource use together with *RENW*. Using all these variables, equation 1 below is constructed,

and an attempt is made to determine the nexus between the variables.

$$lnlcf_{it} = \alpha_0 + \alpha_1 lngdp_{it} + \alpha_2 lngp^2_{it} + \alpha_3 lnaff_{it} + \alpha_4 lnfmi_{it} + \alpha_5 lnnatres_{it} + \alpha_6 lnrenw_{it} + \varepsilon_i \quad (1)$$

The detection of a cointegration relationship between dependent and independent variables can be achieved using various methods widely employed in the literature. Some of these include the tests developed by Engle and Granger (1987), Johansen and Juselius (1990), and Phillips and Ouliaris (1990). However, the most critical assumption of these tests is that all variables must be stationary at first difference, i.e., they must satisfy the I(1) condition. Therefore, if the series exhibits stationarity at different levels, the application of these models becomes invalid, and it is not possible to detect a cointegration relationship among the variables. In response to this limitation, the ARDL (Auto-Regressive Distributed Lag) model, developed by Pesaran and Shin (2001), has been introduced into the literature to test both short-run and long-run relationships among variables with mixed orders of integration. Also known as the Bounds Testing approach, this method has become more widely used in the literature compared to previous cointegration tests and tends to produce more robust results. In the ARDL approach, the use of an unrestricted error correction model (ECM) allows for a more comprehensive statistical analysis and more reliable results, particularly in small sample sizes, when compared to the tests of Engle and Granger (1987) and Johansen and Juselius (1990). Thus, the study employs the ARDL method rather than the Fourier approach, primarily because ARDL demonstrates greater suitability for small samples, accommodates series with different orders of integration, and captures both short- and long-run dynamics concurrently. These characteristics enhance the flexibility of the model. By selecting an appropriate lag structure, the method mitigates issues of autocorrelation and endogeneity. Furthermore, the extensive use of ARDL in studies on Turkish data enhances comparability and provides a clear methodological advantage.

This method provides efficient estimates when the dependent variable is *I(1)* and the independent variables are *I(0)* or *I(1)*. If the dependent variable is *I(0),* the A-ARDL procedure also captures the same efficiency. However, there should be no variable *I(2)* among the variables. The A-ARDL model proposed by Sam et al. (2019), created within the study's scope, is presented in Equation 2 below.

$$\begin{aligned}\Delta LCF_i = \alpha_0 &+ \sum_{i=1}^{a} \alpha_{1i}\, \Delta LCF_{t-i} + \sum_{i=1}^{b} \alpha_{2j}\, \Delta lnFMI_{t-i} + \sum_{i=1}^{c} \alpha_{3k}\, \Delta lnRENW_{t-i} + \sum_{i=1}^{d} \alpha_{4l}\, \Delta lGDP_{t-i} + \sum_{i=1}^{e} \alpha_{5m}\, \Delta lnAFF_{t-i} \\ &+ \sum_{i=1}^{f} \alpha_{6n}\, \Delta lnNATRES_{t-i} + \sum_{i=1}^{g} \alpha_{7O}\, \Delta lnGDP^2{}_{t-i} + {}_{\alpha_8} LCF_{t-1} + \alpha_9 lnFMI_{t-1} + \alpha_{10} lnRENW_{t-1} \\ &+ \alpha_{11}\, lnGDP_{t-1} + \alpha_{12}\, lnAFF_{t-1} + \alpha_{13}\, lnNATRES_{t-1} + \alpha_{14}\, lnGDP^2{}_{t-1} \\ &+ \varepsilon_t \end{aligned} \quad (2)$$

In Equation 2, "Δ" denotes the difference operator, "ε" represents the error term, "a…e" indicates the lag lengths, "α_0" represents the constant term, "α_1… α_5" shows the short-term coefficients, and "α_6…α_{10}" illustrates the long-term coefficients.

As apparent in Figure 2, after the short-term and long-term coefficients are obtained and interpreted, the model is examined for autocorrelation and heteroscedasticity problems with the help of diagnostic tests. Furthermore, the functional form structure of the model is tested, and it is assessed whether the error terms of the model exhibit a normal distribution. Lastly, the model's stability and the coefficients' reliability are revealed with CUSUM graphs.

Figure 2 below displays the analyses and procedures followed throughout the methodology phase.

RESULTS and DISCUSSION

Following the construction of equation 1, descriptive statistics are obtained. Table 2, presented below, shows the variables' basic descriptive statistics and distribution characteristics. There are 32 observations since the series that makes up the yearly data set spans 1990–2021. Table 2 lists each series' mean, median, maximum, and minimum values. Additionally, Table 2 contains the series' skewness, kurtosis, standard error values, and the Jarque-Bera statistics to test normal distribution. The fact that the mean and median values of the variables are relatively close to each other indicates their symmetric distribution. The *FMI* variable is negatively skewed, whereas the *NATRES* and *RENW* variables appear to have an asymmetric distribution due to their positive skew statistics. These variables also deviate from the normal distribution in terms of kurtosis values. Therefore, the *LCF, GDP, and AFF* variables show a normal distribution in addition to all of these inferences. However, the other variables do not when the Jarque-Bera test statistic's probability value is considered. Since one of the study's objectives is to calculate the GDP per capita, which will allow for EQ, the present value of this variable also becomes

important. Currently, the minimum GDP per capita for 1990-2021 is $7721, and the maximum is $13449.This variable, which averages $8136, will be used for comparisons in interpreting the results and the policy determination phase. Thus, it will be able to show the increase in national income that will start the EQ process.

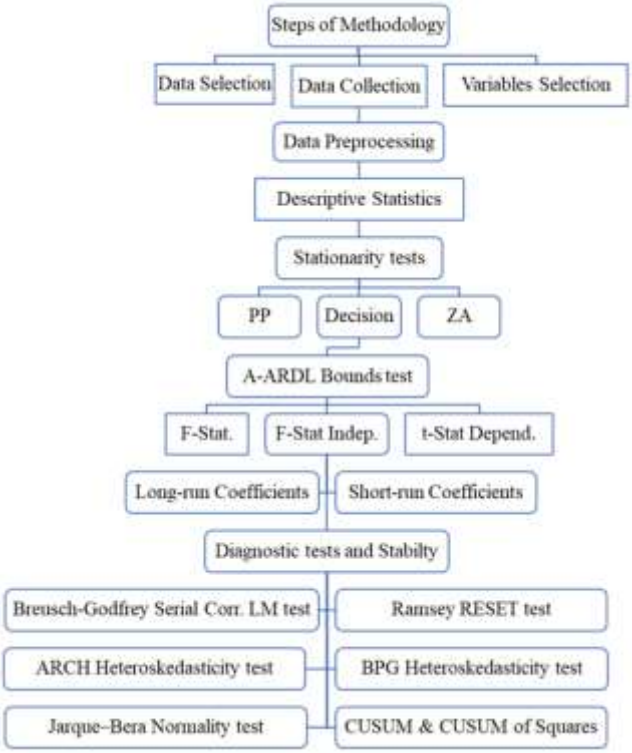

Figure 2. Methodology flowchart
Şekil 2. Metod akış şeması

Table 2. Summary statistics
Çizelge 2. Özet istatistikler

	lcf	*gdp*	*aff*	*fmi*	*natres*	*renw*
Mean	0.586840	8136.213	4.66E+10	0.318719	0.437638	143.3485
Median	0.577213	7721.121	4.36E+10	0.327000	0.382317	112.5093
Max.	0.821025	13449.93	6.76E+10	0.408000	1.155990	337.3349
Min.	0.440642	5101.207	3.50E+10	0.173000	0.143922	63.3832
Std. Dev.	0.119758	2564.862	1.02E+10	0.057242	0.235469	76.9521
Skew.	0.466843	0.537100	0.633815	-0.811372	1.465084	1.2639
Kurto.	2.029372	1.944423	2.057322	3.187602	4.895792	3.5327
JB	2.418516	3.024197	3.327372	3.557987	16.23988	8.8980
Prob.	0.298419	0.220447	0.189439	0.168808	0.000298	0.0117
Obs.	32	32	32	32	32	32

Unit root tests are the first step in selecting the appropriate model in time series analysis. Unit root tests determine whether the series is stationary at the level or not. Hence, the primary purpose is to determine whether the series contains a unit root. Ignoring this will cause interconnections to appear as if they do not exist or result in an existing linkage not being revealed. The Philips-Perron (PP) unit root test is applied to all variables in this context. As a result of visual examination of the data, since the variables used in the study had a constant and trend structure, evaluations were made based on the C&T model results. Based on the Philips-Perron (PP) unit root test results in Table 3 below, it is clear that all variables except *lnfmi* and *lnlcf* are not stationary at the level. For the test specification with constant and trend, the variables *lnfmi* and *lnlcf* are *I(0).* The remaining variables become stationary when the first differences are taken.

Table 3. PP unit root test results
Çizelge 3. PP birim kök testi

At Level		lnlcf	lngdp	lngdp^2	lnaff	lnfmi	lnnatres	lnrenw
	t-Stat.	-3.8980	-2.4827	-2.2483	-2.9776	-5.2947***	-2.5550	-0.4919
C & T	*Prob.*	*0.0239***	*0.3338*	*0.4485*	*0.1537*	*0.0008*	*0.3018*	*0.9787*
At First Difference		Δ(lnlcf)	Δ(lngdp)	Δ(lngdp^2)	Δ(lnaff)	Δ(lnfmi)	Δ(lnnatres)	Δ(lnrenw)
	t-Stat.		-7.4834***	-7.4516***	-21.3417***	-5.3722***	-6.0344***	-4.2802**
C & T	*Prob.*		*0.0000*	*0.0000*	*0.0000*	*0.0007*	*0.0001*	*0.0101*
Decision		**I(0)**	**I(1)**	**I(1)**	**I(1)**	**I(0)**	**I(1)**	**I(1)**

"(**) %5"; (***) %1 indicates the significance level.

A second unit root test that accounts for structural breaks is employed to verify the robustness of our inference, and the results are presented in Table 4. As per the ZA unit root test findings, the dependent variable *lnlcf* and the independent variable *lnfmi* are both *I(0).* Similar to the PP unit root test, no variable is *I(2)*, and the variables are stationary at different levels. In addition, in parallel with the PP unit root test, the dependent variable is determined as *I(0)* in the ZA unit root test. Consequently, it has been decided that the A-ARDL method will be the best-fitted model for the methodology.

Table 4. ZA unit root test results
Çizelge 4. ZA birim kök testi sonuçları

Variables	At Level			Decision
	Lag	Break point	Test stat.	
lnlcf	0	2007	-5.4331***	I(0)
lngdp	0	1999	-4.0086	I(1)
lngdp2	0	1999	-4.0201	I(1)
lnaff	1	2001	-4.5832	I(1)
lnfmi	2	1999	-5.9014***	I(0)
lnnatres	0	2006	-3.3458	I(1)
lnrenw	0	2008	-2.7979	I(1)

"(**) %5"; (***) %1 indicates the significance level. Model C (With constant and trend)

Determining the variables' stationarity levels accurately yields crucial information for selecting the best-fitted model. To achieve this target, together with traditional unit root tests, the Zivot and Andrews (2002) (ZA) unit root test is used, which also considers the structural breaks experienced in the literature. The results show that under the presence of structural breaks, the *lnlcf* and the *lnrenw* are stationary at the level. In contrast, all the remaining variables are stationary at the first difference. Thus, the A-ARDL procedure can be applied (De and Tamang, 2023; Göksu & Balkı, 2023) since the dependent variable is *I(0)* and *I(0)* or *I(1)* for the independent variables.

A bounds test is applied to determine cointegration interactions among variables, and the results are presented in Table 5. Accordingly, the *F-stat* test value, which considers the lagged values of all variables, is calculated as 7.570. Since this test value is greater than the extreme critical value of 6.21 calculated by Narayan (2005), there is a cointegration relationship among the variables at the 1% statistical significance level. The statistical value of the *t-statistic depends.* test, which only focuses on the lagged value of the dependent variable, is determined as -6.559. Since this test value is smaller than the extreme critical value (-4.66) calculated by Pesaran et al. (2001), there is a cointegration interplay across the variables at the 1% statistical significance level. When considering only the lagged values of the independent variables, the *F-Stat Indep.* test provides a statistical value of 8.134. At the 1% statistical significance level, there is a cointegration connection between the variables since this test result is higher than the extreme critical value (6.16), as determined by Sam et al. (2019).

Table 5. A-ARDL cointegration test result
Çizelge 5. A-ARDL Eşbütünleşme testi sonuçları

$f(lnlcf \mid lngdp, lngdp^2, lnaff, lnfmi, lnnatres, lnrenw)$	Optimum Lags	F-Stat	F-Stat Indep.	t-Stat Depend.
	(2, 2, 2, 0, 1, 2, 1)	5.741**	5.694**	-5.179***
Critical values (upper bound)	10%	5%	1%	
$F_{Stat.}$	3.80	4.50	6.21	Narayan (2005)
$F_{Stat\ Indep}$	3.62	4.37	6.16	Sam et al. (2019)
$t_{Stat\ Depend.}$	-4.04	-4.38	-4.99	Pesaran et al. (2001)

Max lag=2 case III, (**) %5"; (***) %1 indicates the significance level.

Table 6 below presents the short-term and long-term coefficient estimation results after determining the cointegration compatibility. All independent variables are significant at different statistical significance levels. In the long term, Agriculture, forestry, and fishing value added *(lnaff)* positively affect the load capacity factor (*lcf*). A 1% increase in *lnaff* increases the *LCF* by approximately 0.21%. This result empirically confirms that the agriculture, forestry, and fishing sectors contribute to improving EQ. These results are broadly consistent with the findings of Pata and Pata (2024), Gökmenoğlu et al. (2019), Ayad (2023), Lefilef (2024) and Pata et al. (2023).

In the long run, 1% increase in GDP leads to approximately a 7.42% decrease in LCF, while the squared GDP term indicates that a 1% rise results in a 0.37% increase, confirming the LCC hypothesis. Agricultural, forestry, and fishery activities have a positive effect, as a 1% increase in this sector raises the LCF by about 0.29%. Financial development exerts a mitigating influence, with a 1% rise reducing the LCF by nearly 0.15%. Natural resource use also demonstrates a beneficial role, where a 1% increase lowers the LCF by around 0.04%. Although renewable energy consumption shows a negative effect, a 1% increase corresponds to only a 0.06% reduction, which remains statistically insignificant. Overall, these findings highlight the validity of the LCC hypothesis while emphasising the positive roles of financial development and efficient natural resource use. To this end, *lnfmi*, *lnnatres* and *lnrenw* have a negative impact on the LCF. The most dominant negative impact on EQ belongs to the FMI. This result shows that the development of financial markets reduces EQ. Economic growth generally implies increased production, consumption, and energy demand. This, in turn, leads to greater consumption of natural resources, increased waste generation, and higher greenhouse gas emissions. The development of financial markets can accelerate investment flows and stimulate the expansion of environmentally intensive sectors such as industry, construction, and transportation. Investments driven by profit maximisation often externalise environmental costs, thereby overlooking their ecological impacts. Moreover, if financial incentives support environmentally harmful projects, such as those involving fossil fuels, this may directly contribute to the deterioration of EQ. The long-term impacts of the study's findings on EQ may be attributed not only to the proposed scenarios. They may also result from a range of additional contributing factors. Surprisingly, *RENW* has adverse effects on EQ, but this effect is statistically insignificant. This result is consistent with the study of Al-Mulali et. al. (2015) and Chen et. al. (2019). However, considering that the share of RENW in total energy consumption remains very low, we interpret that RENW sources are not sufficiently developed in Türkiye. The insignificance of the short-term coefficient of the RENW substantiates this interpretation and assessment. The possible reason for these results may vary. Solar panels or wind turbines may have been installed in areas that threaten natural habitats. The destruction of forests, agricultural lands, or wetlands for this purpose can lead to biodiversity loss and ecosystem degradation

Table 6. A-ARDL short-run long-run result
Çizelge 6. A-ARDL kısa dönem-uzun dönem sonuçları

Panel (A) Long run	Coefficient	Std. Error	t-Statistic	Prob.
lngdp	-7.422***	2.365	-3.138	0.008
$lngdp^2$	0.373**	0.132	2.820	0.015
lnaff	0.285*	0.156	1.821	0.092
lnfmi	-0.145**	0.055	-2.625	0.021
lnnatres	-0.044***	0.012	-3.701	0.003
lnrenw	-0.056	0.038	-1.461	0.168
Turning point (GDP*)	Logarithmic value		Monetary value	
	9.939		**US$ 20.720**	
Panel (B) Short run	Coefficient	Std. Error	t-Statistic	Prob.
C	47.081***	6.144	7.663	0.000
$\Delta(lnlcf)_{t-1}$	0.676***	0.149	4.537	0.001
$\Delta(lngdp)$	-11.915***	2.852	-4.178	0.001
$\Delta(lngdp)_{t-1}$	15.110***	3.787	3.990	0.002
$\Delta(lngdp^2)$	0.623***	0.160	3.903	0.002
$\Delta(lngdp^2)_{t-1}$	-0.791	0.210	-3.768	0.002
$\Delta(lnfmi)$	-0.075	0.049	-1.515	0.154
$\Delta(lnnatres)$	-0.020	0.014	-1.451	0.171
$\Delta(lnrenw)$	-0.048	0.033	-1.454	0.170
$\Delta(lnrenw)_{t-1}$	-0.067**	0.027	-2.468	0.028
ECT_{t-1}	-1.624***	0.212	-7.664	0.000

The robustness of the LCC hypothesis for Türkiye is one of the fundamental research topics of this paper. The quadratic model developed by equation 2 is attempted to be identified.

$$gdp^* = e^{-(\frac{\alpha_2}{2x\alpha_3})} = 20.720\$ \quad (3)$$

Equation 3 states that US$ 20.720 per capita national income marks the transition from ED to EQ. Given that the maximum value of the GDP per capita in Table 2 is US$ 13.450. It is clear that the income level does not reach the level that will increase EQ. However, the LCC curve is valid for Türkiye because the long-term coefficient of income (*lngdp*) is negative, while the long-term coefficient of income squared ($lngdp^2$) is positive and statistically significant at the 1% significance level. These findings also align with the studies conducted by İçen (2024), Çamkaya (2024), and Çağlar et al. (2024) that established the verification of the LCC hypothesis for Türkiye, as well as the studies implemented by authors like Hakkak et al. (2023), Shahzad et al. (2023), Huang et al. (2023), Wu et al. (2023), Alola et al. (2023), Guloglu et al. (2023), Dai et al. (2023), Afshan and Yaqoob (2023), Wang et al. (2024), Fang et al. (2024), and Pata et al. (2025) for various countries. Figure 3 below shows this finding and the turning point on a graph. The validity of the LCC hypothesis for Türkiye may also be linked to different dynamics. For example, while Türkiye has long relied on construction and industry for growth, we have recently witnessed an increase in the share of the service sector, a less carbon-intensive sector. This transformation suggests that the burden on environmental capacity is decreasing in line with the nature of economic growth. Similarly, significant legal regulations regarding environmental protection and waste management, implemented in recent years in line with the SDGs, may have increased societal and institutional awareness of environmental issues. Therefore, the validity of the LCC curve for Türkiye is also supported by the transformation of Türkiye's economic structure, diversification of energy resources, environmental regulations, and international commitments such as the SDGs.

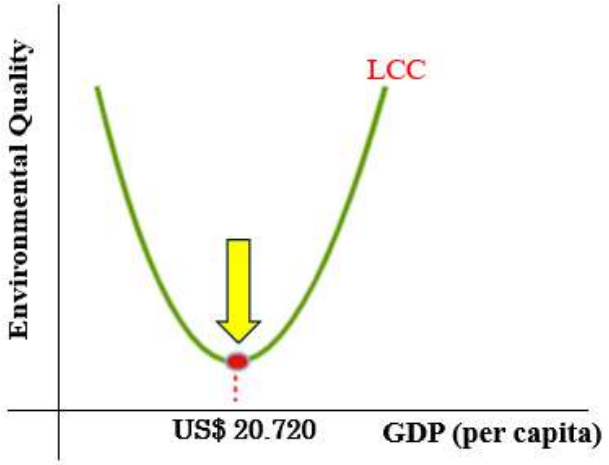

Figure 3. Turning Point for LCC of Türkiye (Own elaboration)
Şekil 3. Türkiye'nin LCC için Dönüm Noktası (Yazar tarafından oluşturulmuştur)

In the short run, all variables except the FMI and RENW are statistically significant. The error correction term (ECT) coefficient is statistically significant and negative. This result reinforces the existence of a long-term equilibrium alignment. However, as mentioned by Narayan and Smyth (2006), the absolute coefficient value greater than one indicates an unbalanced convergence. This indicates an over-adjustment, which may signal oscillations around equilibrium.

Table 7. Diagnostic test results
Çizelge 7. Tanısal test sonuçları

Test Type	Test value	Probability
χ^2_{SC}	2.715	0.257
$\chi^2_{NORM(J\text{-}B)}$	0.261	0.878
$\chi^2_{HET(BPG)}$	14.920	0.531
$\chi^2_{HET(ARCH)}$	0.050	0.823
χ^2_{FF}	2.309	0.155

"(**) %5"; (***) %1 indicates the significance level.

Table 7 above presents the diagnostic test results of the established model. Since the probability values of the diagnostic tests are greater than 0.1, there is no autocorrelation and heteroscedasticity problem. Moreover, the

functional form structure of the model is appropriate, and the error terms are normally distributed. Subsequently, the CUSUM graphs are provided below in Figure 4.

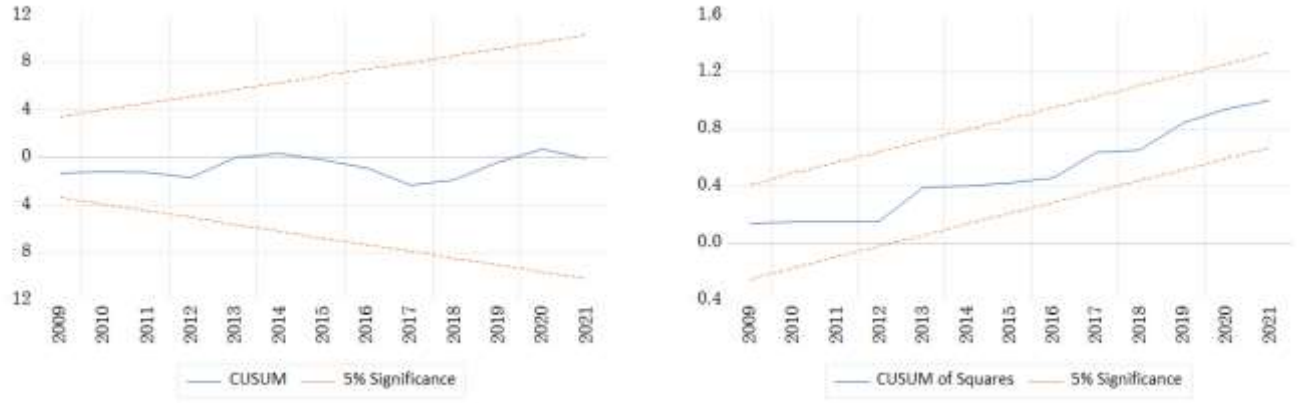

Figure 4. CUSUM graphics
Şekil 4. CUSUM grafikleri

QUSUM graphs display that the established model is stable and that the estimated coefficients are reliable. These tests also demonstrate that the model has exhibited consistent behaviour over time, thereby increasing confidence in the findings. Moreover, the QUSUM graphs suggest that there is no statistically significant structural break in the model parameters or in the variance of the residuals over time. Overall evaluation of the results reveals a cointegration linkage. Additionally, it is evident that the established model is significant and that the findings are generally consistent with a limited number of previous studies. The 2024 GDP per capita value of $15.463 is considered close to the turning point GDP per capita value. This means ED will persist until the GDP per capita reaches $20.720. Beyond this point, the trend will shift from ED to improved EQ.

CONCLUSION

The demands of human consumption on the environment have grown steadily since the Industrial Revolution. This increase has caused natural destruction due to the neglect of the supply side. This collapse has unavoidably impacted seas, forests, and agricultural areas, as natural devastation encompasses all aspects of the ecosystem. Low yields in agriculture, reduction in arable lands, decrease in diversity in agricultural production, deforestation, forest fires, conversion of forest areas into residential areas, decrease in sea biodiversity, increase in seawater temperatures, and declines in fishing activities are the results of all these factors. In this context, academic studies have increased in recent years, and these destructive factors on the environment have been tried to be revealed. Nevertheless, a significant part of these studies focuses only on the demand side, ignoring the supply side of the environmental balance. In order to address this deficiency, the LCF, which is obtained by dividing the biocapacity by the ecological footprint, has recently come to the fore as an important indicator of EQ. Few studies have focused on the agricultural sector using the *LCF*, which is frequently used to show how the environment impacts different variables. Consequently, studying the nexus between the *LCF* and the agricultural sectors is a relatively unexplored field in the literature. The current study stands out from the literature in that it is the first to investigate the justification of the LCC hypothesis by considering both the supply and demand sides of the environmental balance over agriculture, forestry, and fisheries in Türkiye. In addition, the most original aspect of this paper is that, for the first time in a study, the turning point of GDP per capita that will pass from ED to EQ is calculated with the added value of agricultural sectors and the emphasis on the financial sector. More clearly, it tests the validity of the LCC hypothesis by focusing on the agriculture, forestry, and fishing sectors and financial markets (Financial Markets Index) and determining the minimum income level that will increase EQ.

The findings demonstrate a long-term positive interconnection between the *lnlcf* and the *lnaff*. Also, their linear combinations converge to the equilibrium point. Furthermore, the short-term error correction term's statistically significant and negative coefficient provides empirical evidence for a long-term equilibrium association for these variables. This result empirically illustrates that agricultural sectors contribute to the EQ process. Nonetheless, *lnfmi, lnnatres* and *lnrenw* negatively affect the *lnlcf* in the long run and cause ED. This result reveals the negative impact of developments in financial markets on the environment. Although using natural resources also causes ED, surprisingly, the negative impact of *RENW* on the environment in Türkiye is primarily due to limited resource usage. The insignificance of the short-term coefficient of *RENW* affirms this interpretation because all variables except the *FMI* and *RENW* are statistically significant in the short term. As an overall assessment, the LCC

hypothesis is valid for Türkiye. Based on this theory, a U-shaped alignment exists between GDP per capita and EQ. This situation shows that as income increases, ED will increase at first, and after reaching the turning point, EQ will increase with income. The bottom point for Türkiye is determined to be $20.720 due to the turning point calculation, one of the study's original sections. The goal is not too far away, as seen by the $15.463 GDP per capita attained by the end of 2024. Therefore, if the *EGR* targets are achieved, Türkiye will enter a period in which EQ will increase in the next few years. This requires developing policies that support EGR, ensure ecological sustainability, and holistically address agricultural and environmental policies. Furthermore, the finance sector would prioritise green transformation in its initiatives and pay attention to the environment as it develops. In light of this, it is recommended that policymakers encourage sustainable, innovative, and environmentally conscious practices in fishing, forestry, and agriculture. Agricultural insurance and credit systems should be restructured in favour of farmers who adopt environmentally friendly practices. Ecological farming techniques can be promoted more widely. Providing grants and technical support for drip and pressurised irrigation systems represents another policy recommendation. Furthermore, supporting the use of solar and biomass energy systems in the agricultural sector, as well as the conversion of agricultural machinery to electric motors, can be considered important steps toward improving EQ.

This study has some limitations. The first of these is that it is limited to 32 observations covering the period 1990-2021. The expiration of the *Infmi* and *Innatres* variables in 2021 limited the ability to conduct analyses with more up-to-date data. Second, more comprehensive studies are needed regarding country samples for the generalizability of the findings. Finally, this paper used the LCF as an indicator of EQ as the dependent variable. For future studies, it may be recommended that the findings obtained from the ecological footprint and CO_2, which are ED indicators, contribute to the generalizability of the findings in addition to the LCF on larger country samples. Furthermore, a more thorough approach may be taken to the coherence between natural resources and RENW in the agricultural, fishery, and forest sectors. The financial sector and the impact of emerging global uncertainties on ED, focusing on agriculture, are among the most recommended topics for researchers.

Author's Contributions

Single author

Statement of Conflict of Interest

The study has a single author.

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