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Investigating the Impacts of Trade Openness and Energy Consumption on Environmental Quality in Azerbaijan: An Analysis under the Load Capacity Curve Hypothesis

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Abstract: Utilizing the load capacity curve (LCC) hypothesis within an autoregressive distributed lag (ARDL) model framework, this study investigates the implications of trade openness (TO), renewable energy consumption (REC), and non-REC on environmental quality in Azerbaijan for the period 1996-2022. The LCC hypothesis, which employs the load capacity factor (LCF) as an environmental quality indicator, facilitates a comprehensive evaluation of pollution across air, water, and soil domains. It was found that the LCC hypothesis does not hold for Azerbaijan. Specifically, fossil fuel consumption (FEC) was observed to exacerbate environmental degradation, whereas the influence of REC and TO on the LCF was not statistically significant. These findings suggest that Azerbaijan's strategy for using renewable energy does not effectively enhance environmental quality. Furthermore, the evidence indicates that economic expansion alone does not suffice to mitigate environmental challenges. To foster sustainable environmental improvement, it is recommended that the Azerbaijani government devises a more robust energy mix strategy that transcends the current reliance on renewable sources and adopts a holistic green growth model for the economy.

Keywords: Environmental quality; Load capacity factor; Load capacity curve hypothesis; Azerbaijan; Renewable energy; Non-renewable energy

1. Introduction

In the ever-changing world order, the nature of environmental problems is also undergoing significant transformation. Although global warming is the focus of policymakers, it is equally important to solve environmental problems in land and sea areas, thereby increasing the prosperity of societies. At this point, Rees (1992) developed the ecological footprint (EF) by considering the pollution of both land and marine areas. EF measures, in global hectares, the environmental impact of human consumption and production activities on land and water. EF is generally related to the consumption of societies, or, in other words, the demand for nature. However, EF does not include biocapacity, which symbolizes the capacity of nature to meet human consumption.

Researchers have realized over time that EF is not sufficient for a good assessment of environmental problems, and a more comprehensive environmental assessment tool is needed. Siche et al. (2010) emphasized that EF was not a better indicator to examine environment-related issues and that biocapacity also needed to be considered. In this context, Siche et al. (2010) proposed the LCF. Pata (2021) presented the first empirical analysis results for the LCF determinants. The LCF is a strong indicator of sustainable development, calculated as biocapacity/EF. A LCF value above 1 means that the environmental conditions are sustainable; otherwise, it means they are not sustainable. The value of 1 is defined as the sustainability threshold.

According to the Environmental Kuznets Curve (EKC) hypothesis, an inverted U-shaped relationship between environmental pollutants (e.g., EF) and economic expansion exists (Grossman & Krueger, 1991). Instead of focusing on pollution perspectives, LCF is an environmental quality indicator. Therefore, Pata & Kartal (2023) stated that there could be a U-shaped relationship between LCF and economic expansion and labeled this hypothesis as the LCC. The LCC hypothesis has attracted much attention from researchers in the environmental economics field over the past few years and its validity has been tested by many studies.

Recently, Pata et al. (2023b) found that LCC was invalid and EKC was valid in Germany. Similarly, Erdogan (2024) emphasized that LCC was invalid for African countries, whereas EKC was valid. On the contrary, Feng et al. (2024) proposed a U-shaped relationship between LCF and economic expansion in E7 countries. Pata & Kartal (2024) advocated for LCC in major oil-importing countries.

In the current literature, the testing results of the LCC hypothesis are different. In addition, no research has been conducted to analyze whether the LCC hypothesis is valid for Azerbaijan maybe because of the limited data available. However, there are 27 observations of the LCF series for Azerbaijan, which is suitable for applying the ARDL approach. Azerbaijan is an ecologically indebted country with a low LCF. Figure 1 illustrates Azerbaijan's LCF situation for the analysis period from 1996 to 2022.

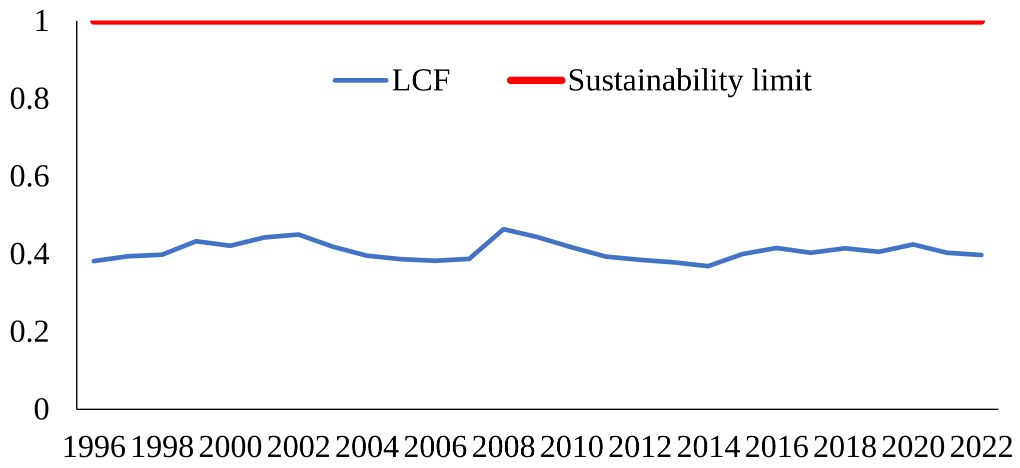

Figure 1. LCF status of Azerbaijan
Source: GFN (2024).

As shown in Figure 1, Azerbaijan's LCF is below the critical threshold throughout the years. Azerbaijan obtained a LCF value of 0.38 in 1996 and 0.39 in 2022. The LCF statistics show that there has been no improvement in environmental quality over the years in Azerbaijan, and even 2.5 times more than the natural resources of Azerbaijani society have been consumed. Against this background, the study examines the validity of the LCC hypothesis in Azerbaijan and the impact of REC, FEC and TO on the LCF.

Many studies have analyzed Azerbaijan's environmental problems. For instance, Mikayilov et al. (2018) emphasized the invalidity of EKC for Azerbaijan if carbon dioxide (CO_2) emissions were taken into account. Mikayilov et al. (2019) found that foreign trade and energy consumption boosted the EF. Gurbanov (2021) stated that natural gas consumption reduced CO_2 emissions. Hasanov et al. (2023) emphasized that renewable energy development reduced CO_2 emissions. However, the main focus of current studies is CO_2 emissions and Azerbaijan's EF. As a result, there is a research gap because no study has uncovered the determinants of LCF in Azerbaijan.

Therefore, this study aims to contribute to the existing knowledge by empirically testing the validity of the LCC hypothesis for Azerbaijan for the first time. By considering a set of explanatory variables, i.e., income, TO, REC, and FEC, the LCF was used as the environmental quality proxy, which is consistent with the evolving literature. Then, the ARDL method was applied using annual data from 1996 to 2022, aiming to find out the impact of the aforementioned variables on the environmental quality of Azerbaijan. It was found out that the LCC hypothesis was not valid for the Azerbaijan case, the impact of FEC was significant, and that of REC and TO was insignificant. The study makes contributions in two aspects. First, this study is leading by examining the LCF determinants in Azerbaijan. Second, the study is pioneering by empirically testing the validity of the LCC hypothesis for Azerbaijan. Thus, fresh insights can be provided for Azerbaijan.

Section 2 briefly depicts the methods. Section 3 presents and discusses the empirical results, and Section 4 provides the conclusions.

2. Methods

2.1 Data and Variables

This study analyzes the validity of the LCC hypothesis using data from 1996 to 2022 for Azerbaijan. Data was compiled from three different sources and incorporated into the analysis using logarithmic transformations. This study uses the data concerning gross domestic product (GDP), TO, REC, FEC, and LCF. Further information on the variables is summarized in Table 1.

Table 1. Definition of the variables

Variable	Measurement (Unit)	Data Source
LCF*	Biocapacity/EF (index)	GFN (2024)
GDP	Per capita (constant 2015 USD)	The World Bank (2024)
TO	Proportion of trade in GDP (%)	The World Bank (2024)
REC	Per capita (kWh)	Ritchie et al. (2024)
FEC		

Notes: * denotes the dependent variable.

Selected based on the current literature, the aforementioned variables were used to find out the change in environmental quality. Hence, in line with the present studies, this study considers LCF as the dependent variable to proxy the environmental quality (Feng et al., 2024), and uses GDP (Pata & Kartal, 2023), TO and REC (Pata et al., 2023a), and FEC (Kartal et al., 2024). These are critical factors in the aspect of environmental quality advancement. Therefore, a unique estimation model was created by considering all of them in a single equation.

Figure 2 shows the progression of the logarithmic variables.

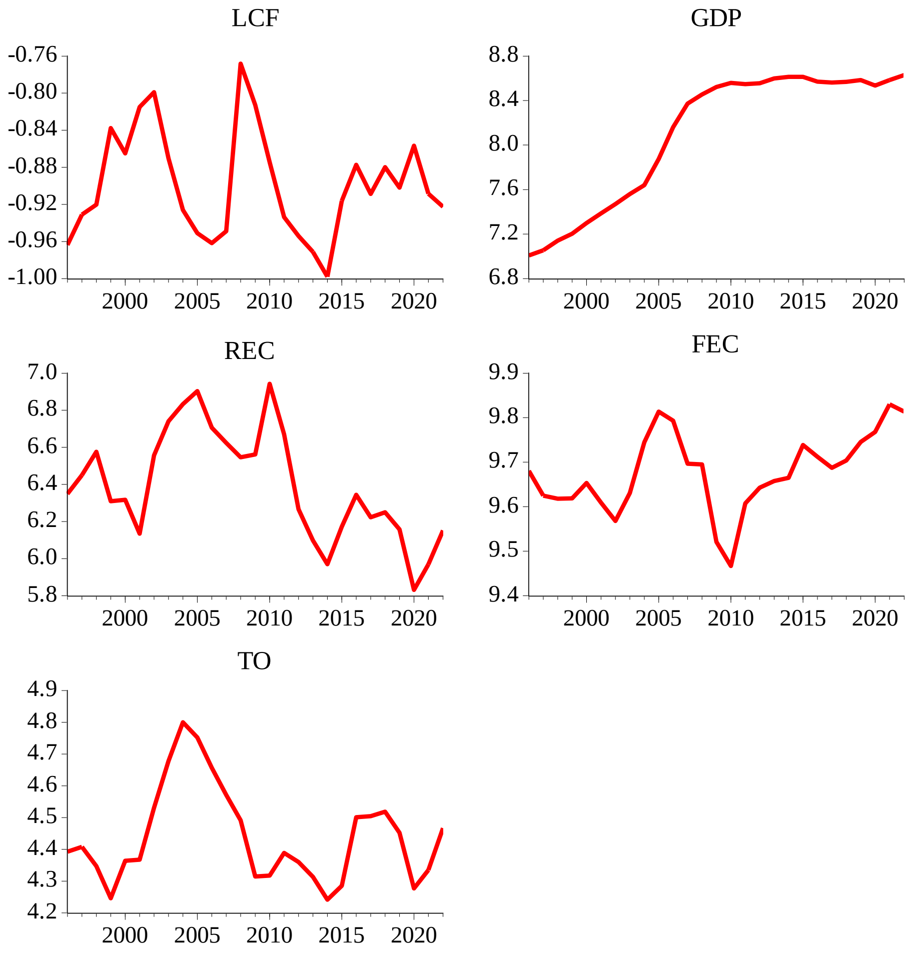

Figure 2. Time courses of the logarithmic variables

2.2 Theoretical Approach

The study analyzes the validity of the LCC hypothesis using Eq. (1):

$$lnLCF_t=\delta_0+\delta_1 lnGDP_t+\delta_2 lnGDP_t^2+\delta_3 lnTO_t+\delta_4 lnREC_t+\delta_5 lnFEC_t+z_t \quad (1)$$

where, δ_1 must be negative and δ_2 positive for LCC to be valid. δ_3 may vary depending on the country's development level. δ_4 is expected to be negative (Adebayo & Kartal, 2023; Kartal et al., 2023). However, if the country uses renewable resources inefficiently, δ_4 may be statistically insignificant (Pata, 2018). Since fossil fuels are carbon-intensive, it is expected that the coefficient of δ_5 is positive (Kartal & Pata, 2023; Ulussever et al., 2023). Hence, the study empirically tests the LCC hypothesis for the Azerbaijan case, which focuses on environmental quality by taking into consideration the supply (biocapacity) side of nature rather than focusing on degradation or pollution only.

2.3 Empirical Approach

The empirical flowchart of the study is shown in Figure 3.

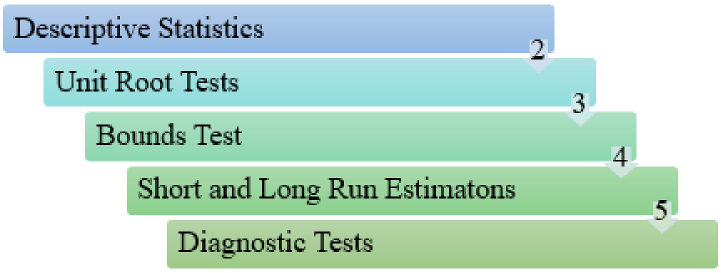

Figure 3. Empirical flowchart

An analytical strategy based on the ARDL method was used as an empirical approach. To this end, the descriptive statistics were first examined. Analysis of the stochastic properties of the series was conducted by applying the unit root tests, specifically the Augmented Dickey-Fuller (ADF) test proposed by Dickey & Fuller (1981), and the Zivot-Andrews (ZA) test (Zivot & Andrews, 2012). Then the ARDL method was used to explore cointegration among the variables and to perform estimations encompassing both short- and long-term dynamics. Additionally, diagnostic checks were conducted to ensure that the model estimations were valid and robust.

The number of observations for the variables is limited to 27 and autoregressive relationships exist between dependent and independent variables. Therefore, it is appropriate to use an econometric method that is consistent with the properties of the data set. The ARDL method is employed to facilitate the simultaneous estimation of short- and long-run coefficients. In addition, this approach solves the endogeneity problem and allows cointegration analysis of I(0) and I(1) integrated series in different degrees. In the first stage of ARDL, the cointegration analysis was done with a bounds test. Once the variables were cointegrated, coefficient estimates and elasticity calculations were performed. In the final stage, diagnostic tests were used to analyze whether the results obtained were reliable or not. Accordingly, the ARDL method was applied.

This study does not provide unnecessary explanations of the ARDL method, as it is not solely an econometric approach development article. Instead, further information can be gathered from the original studies of Pesaran et al. (2001).

3. Empirical Results

Annex 1 shows the descriptive statistics examined. The variables of lnFEC and lnGDP have the highest mean and median values. lnFEC has the highest maximum value, while lnLCF has the lowest minimum value. GDP volatility is the highest variable. This indicates that the Azerbaijani economy is following a fluctuating course. The Jarque-Bera statistic has a skewness approximately equal to 0, a kurtosis approaching 2, and probability values exceeding 0.10, indicating that the series has a normal distribution.

Furthermore, both the ADF and Phillips-Perron (PP) tests were used in this study. Table 2 shows the results.

Table 2. Unit root results

Variable	ADF		ZA	
	I(0)	I(1)	I(0)	I(1)
LCF	-2.911	-4.675*	-4.184 [2018]	-5.013 [2015]**
GDP	-2.525	-1.795	-5.675 [2005]*	—
TO	-2.649	-3.103**	-3.589 [2009]	-4.989 [2005]**
REC	-2.054	-3.795*	-3.061 [2012]	-5.066 [2018]**
FEC	-2.547	-3.980*	-6.803 [2009]*	—

Notes: * and ** indicate 1% and 5% significance levels.

According to the results of the ADF and ZA tests, GDP and FEC are stationary, while LCF, TO, and REC contain unit roots. In other words, LCF I(1) is the dependent variable. Since the other series are mixed with I(0) and I(1), it is appropriate to apply the ARDL approach.

The bounds test was conducted in the third step and the results are presented in Table 3.

Table 3. Bounds test results

	k=5	Critical Values	
F-statistics	4.578**	I(0)	I(1)
	1%	3.41	4.68
	5%	2.62	3.79

Notes: * and ** denote 1% and 5% significance levels.

The F-statistic is 5% greater than the critical values of I(1). Hence, LCF, GDP, TO, REC, and FEC are cointegrated. The coefficients were predicted using the ARDL approach after the cointegration relationship was determined. Table 4 presents the results.

Table 4. ARDL estimation results

Panel	Variable	Coefficient	Std. Error	t-Statistic	Prob.
Panel A: short run	D(lnGDP)	3.92**	1.82	2.16	0.0474
	lnD($lnGDP^2$)	-0.29	0.12	-2.57	0.0215
	lnD(lnREC)	0.01	0.06	0.23	0.8199
	lnD(lnFEC)	0.17	0.14	1.20	0.2504
	lnD(lnFEC(-1))	0.47	0.15	1.16	0.2065
	lnD(lnTO)	-0.17	0.11	-1.48	0.1593
	Constant	-25.41	4.37	-5.82	0.0000
	ECT	-0.87	0.15	-5.82	0.0000
Panel B: long run	lnGDP	6.12**	2.30	2.66	0.0179
	$lnGDP^2$	-0.39	0.15	-2.68	0.0170
	lnREC	0.06	0.08	0.77	0.4535
	lnFEC	-0.56	0.31	-1.82	0.0890
	lnTO	-0.27	0.18	-1.52	0.1490

Notes: *, **, and *** denote 1%, 5%, and 10% significance levels.

In the short run, the lnLCF and lnGDP have an inverted U-shaped relationship. The remaining variables do not have an important impact on lnLCF. In the long run, the relationship between lnLCF and lnGDP implies that the LCC hypothesis is not valid. This result is in line with that of Mikayilov et al. (2018), which define the invalidity of the EKC for Azerbaijan, because the invalidity of the LCC suggests that economic expansion is not an ultimate tool to solve environmental problems. Moreover, neither lnTO nor lnREC have a statistically significant long-term impact on the LCF. REC does not enhance ecological quality, maybe because Azerbaijan is not able to use renewable resources effectively and sufficiently. This finding is consistent with the results of Pata (2018) for Turkey. A 1% increase in lnFEC reduces lnLCF by 0.55%. The FEC in Azerbaijan has a negative impact on environmental quality.

The results of the diagnostic tests, which can be found in Annexes 2 and 3, show that the ARDL model is free from problems, such as autocorrelation, heteroscedasticity, non-normal distribution, or model specification error. In addition, the coefficients of the ARDL model are stable.

4. Conclusion

LCF is a relatively new environmental indicator and its determinants have been analyzed for different countries. Azerbaijan has not yet undergone similar research, creating a research gap. Against this background, this study uses the ARDL approach to analyze the LCF determinants for Azerbaijan under the LCC hypothesis. This study, with its unique theoretical properties, is the leading research on the case of Azerbaijan in examining the determinants of the LCF and empirically testing the validity of the LCC hypothesis. In accordance with the results of the empirical analysis, the LCC hypothesis is not valid for Azerbaijan; FEC accelerates environmental degradation; and REC and TO have no significant impact on LCF. These findings provide important clues for the environmental development of Azerbaijan. Various policies are discussed based on the robust results obtained, which makes this study important from a practical point of view.

According to the data and results of the empirical investigation, Azerbaijan's current environmental situation is not sustainable. The LCF value consistently falls below the sustainability threshold, indicating the need for proactive measures to enhance environmental conditions. The invalidity of the LCC hypothesis shows that rising income is not sufficiently used for environmental purposes, with environmental destruction increased by economic expansion. Furthermore, the environmental ineffectiveness of the REC implies an inefficient use of renewable resources. Considering these empirical findings, it is suggested that the Azerbaijani government should reorient its economic growth strategy by focusing on green growth and taking into account sustainable development goals, thereby preventing the damage caused by fossil fuels. Additionally, the government should reduce its reliance on fossil fuels by investing in technologies that enhance energy efficiency, thereby reducing energy intensity. It is highly critical to focus on accelerating the energy transition in the green direction. Furthermore, environmental development should be supported by investing the increasing per capita income in environmental awareness programs across the whole society. If the LCF value of about 0.40 persists in Azerbaijan due to the hysteresis impact, it may not be possible to improve environmental conditions in the future. Therefore, LCF-increasing energy and economy-related measures should be taken effectively.

Although this study represents the inaugural exploration into the validity of LCC for Azerbaijan, there are also some research limitations. First, this research focuses on a single country. Therefore, new research could be a panel data analysis with a group of Turkish countries (e.g., Kazakhstan, Kyrgyzstan, and Uzbekistan) in the coming years. Second, the study does not account for structural breaks in ARDL estimation, a limitation primarily attributable to the paucity of available observations. Hence, future studies could retest the validity of the LCC for Azerbaijan with more data and structural breaks. Lastly, this study neglects technological development due to data unavailability. If sufficient data on environmental patents, energy-related R&D investments, and technological investments are available for Azerbaijan at the time series level, detailed information and a roadmap on the environmental situation of Azerbaijan could be provided by examining the technology-LCF relationship for Azerbaijan. By addressing these points, the existing knowledge can be expanded and the validity of LCC for the Turkish world can be further discussed.

Author Contributions

The authors have contributed equally to this work. All authors read and approved the final manuscript.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

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