Does Export Diversification Matter for Ecological Footprint in Uzbekistan? Empirical Evidence from ARDL Approach

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Abstract. The purpose of this paper is to conduct an empirical study of the impact of export diversification on the ecological footprint in Uzbekistan using the ARDL approach based on data from 1996-2020. The ARDL bound test for cointegration reveals the level relationship between the variables. Results of the Error Correction Model disclose that export diversification significantly mitigates the ecological footprint in Uzbekistan in the short and long run. The findings confirm the EKC hypothesis for Uzbekistan as an emerging economy. The relationship between ecological footprint and GDP per capita has an inverted U-shape. Renewable energy consumption and biocapacity are other significant factors negatively affecting ecological footprint in the long run. Export diversification towards eco-friendly products can be accompanied by a more sustainable use of natural resources and promote the adoption of green technologies and energy-efficient production methods that mitigate environmental degradation. The findings allow us to identify ways of achieving environmental sustainability in Uzbekistan.

Key words: Ecological footprint; Export diversification; Export product concentration index; Renewable energy consumption, Biocapacity.

1 Introduction

The modern world is experiencing a global environmental crisis manifested in climate change, loss of biodiversity, increased pollution, and waste. According to the World Bank, the global economy consumes over 100 billion tons of raw materials and generates about 90 billion tons of waste annually. Between 2000 and 2015, over half of all resources consumed in the 20th century were extracted. Moreover, global demand for primary resources has yet to peak and is expected to double by 2050. Because of substantial population growth and urbanization, annual waste will reach 3.88 billion tons, which is 73% higher compared to 2020 volumes. This will average amount to 1.09 kilograms of waste per capita per day. It should also be noted that material extraction, consumption, and utilization are responsible for

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two-thirds of global greenhouse gas emissions, 90% of biodiversity loss, and almost 70% of air quality-related deaths [1].

This is why the global community is not just stepping up, but racing against time to achieve the ambitious goal of zero CO2 emissions by 2050 under the Paris Agreement. This is a crucial step in mitigating the effects of climate change and ensuring a sustainable future for our planet.

Governments and businesses are scrutinizing opportunities for a more sustainable economy in many countries through equitable transition pathways. This challenge is highly relevant to Central Asian countries, as the region is currently facing widespread environmental disasters or threats of their occurrence. Many natural ecosystems are on the verge of crisis due to anthropogenic impacts, resulting in significant environmental degradation. The situation worsens because the environmental threat zones cover vast territories, including neighboring states [2]. In particular, the critical problems for Uzbekistan are growing water scarcity due, on the one hand, to population growth and increasing demands for food and energy and, on the other hand, to the reduction of snow and glaciers in the mountains as a result of climate change. Another serious issue is the drying up of the Aral Sea, caused by water withdrawal for irrigation and reduction of the Amudaria and Syrdaria flows that feed the body of water, accompanied by desertification, dust, and salt storms, and the spread of infectious and hazardous diseases. Uzbekistan’s population also suffers from air pollution caused by the growing number of cars, outdated fuel standards, use of coal and firewood for heating, and insufficient use of clean technologies. The following serious problems are soil erosion and degradation due to anthropogenic impacts: overgrazing, salinization of irrigated soils, pollution, and spoilage of land by industry [3].

These facts indicate a significant impact of human activity on the deterioration of the environment, including soil, air, and water. The ecological footprint indicator introduced by William Rees and Mathis Wackernagel [4, 5] shows the scale of negative human impact on the biosphere [6-9]. The ecological footprint is a measurement of human impact on the planet's ecosystems. It calculates the size of the surrounding area required to produce the environmental resources consumed by humans and absorb waste. This is considered 'the most widely used measure of environmental sustainability' [10]. Unfortunately, in many countries, the Ecological Footprint (EF) far exceeds the Earth's biocapacity, causing ecological scarcity and catastrophic consequences such as climate change, sea level rise, environmental degradation, and natural resource depletion [11-13].

Reducing the ecological footprint is a complex challenge, but it also presents a significant opportunity for positive change. By phasing out fossil fuel burning, increasing the share of renewable energy sources [14-16], improving the quality of human capital [17, 18], implementing the concept of smart cities [6, 19], and introducing zero-waste technologies [20], we can pave the way for a more sustainable future.

International trade is an important factor of economic development that affects the level of ecological footprint in the world [41, 42]. 'Export diversification' refers to the strategy of expanding a country's range of exported goods and services. Trade activities ambiguously affect the ecological footprint. The scientific literature contains many studies on the correlation between export diversification and environmental pollution, and this relation has a multidirectional character.

Positive relation: Khan et al. [21] show that export diversification increases CO2 emissions in the Regional Comprehensive Economic Partnership (RCEP) countries. This indicates that export diversification efforts in these countries lead to an increase in emissions, possibly due to the nature of the diversified industries and their energy needs. Another study also found a positive link between export diversification and CO2 emissions. The article [22] emphasizes that in G-7 countries, export diversification tends to increase carbon emissions. However, when combined with eco-innovation, negative environmental impacts can be mitigated, which indicates the importance of technological advances in managing the ecological footprint of diversified exports.

Mixed relationship: Lui et al. [23] found that although export diversification initially increases CO2 emissions, it can contribute to a decrease over time as countries move along the 'Environmental Kuznets Curve (EKC) '. The EKC is a theoretical framework that suggests that environmental degradation first increases with economic growth, but then decreases after a certain level of income is reached. This implies that diversification's effect on emissions depends on the stage of economic development.

Negative relationship: Mania [24] and Ali et al. [25] support the EKC hypothesis, indicating that export diversification can contribute to reducing CO2 emissions in the long run. Diversification leads to a shift to less polluting industries and more efficient production processes, ultimately reducing the overall carbon footprint.

Conditional relationship: Lee and Ho [26] shows that the impact of export diversification on pollution depends on the stringency of existing environmental regulations. In countries with strict regulations, diversification can decrease energy intensity and increase the use of renewable energy, which in turn reduces emissions. In contrast, in countries with lax regulations, diversification may lead to increased emissions [43].

Thus, the connection between export diversification and pollution is complex and depends on region and context. In some cases, diversification increases emissions, while in others, it may contribute to reducing them, especially in the presence of strong environmental regulations and technological innovation.

This study is very relevant to the Central Asian region, especially to Uzbekistan. The country is actively developing trade relations and increasing exports while simultaneously in the zone of environmental threats. This study investigates the impact of export diversification on the ecological footprint in Uzbekistan. The paper analyses data from 1996-2020 using the Autoregressive Distributed-Lag (ARDL) model. Results reveal that export diversification significantly mitigates the ecological footprint in Uzbekistan in the short and long run. In addition, the EKC hypothesis was confirmed in the case of Uzbekistan. Before the turning point, GDP per capita growth increases the ecological footprint per person. After the turning point, an increase in GDP per capita decreases the ecological footprint per person. Another essential factor in reducing the ecological footprint in Uzbekistan in the long run is renewable energy consumption.

Considering the above, this research contributes to the current literature on export diversification in two ways. First, to the best of our knowledge, this is the first study that analyses the relationship between export diversification and environment in the context of Uzbekistan. Second, we used the ecological footprint per person as a dependent variable as this is a more comprehensive indicator of environmental degradation. Finally, we employed the ARDL approach to investigate the long-run and short-run relationships between the chosen variables.

The structure of the next parts of this study is as follows: Section 2 outlines the paper's methodology, presents the data set, explains the key variables, and provides the model specification. Section 3 presents and summarizes the results obtained. Section 4 interprets and explains the significance of the study's empirical findings in light of existing theories and facts. Section 5 contains conclusions and some policy recommendations.

2 Materials and Methods

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2.1 Data and model construction

To investigate the impact of export diversification on the ecological footprint in Uzbekistan, we use the ecological footprint of consumption per person as a dependent variable and the export product concentration index as a key independent variable.

The ecological footprint, a key concept in our study, represents the amount of productive land and water needed to sustain the resources consumed and waste produced by an individual, population, or activity. This measurement, typically expressed in hectares, takes into account global trade, including land and sea resources from various regions. Equally important is the concept of biocapacity, which refers to biologically productive land and ocean capacity to support various human needs and environmental functions, measured in global hectares.

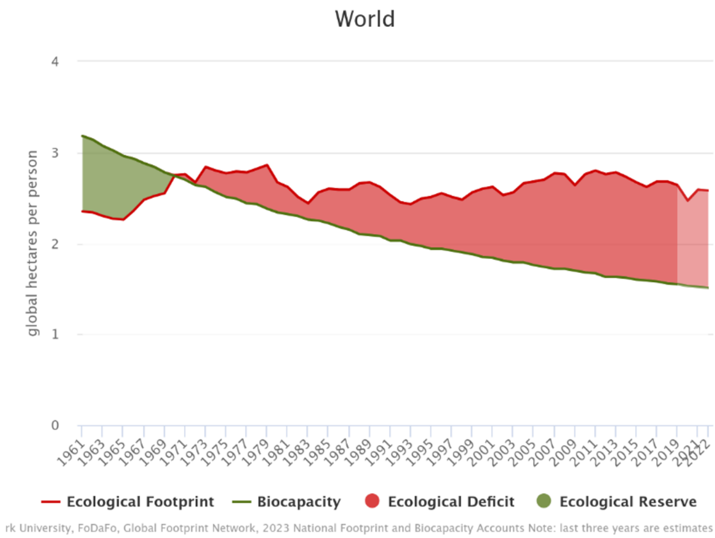

Fig. 1. Ecological footprint and biocapacity from 1961 to 2022 (last 3 years are estimates) [27].

In 2022, the Global Footprint Network reported that the global ecological footprint was 2.6 hectares per person, while the planet's biocapacity was 1.5 hectares per person (Fig. 1). This indicates that humanity required the equivalent of 1.7 Earths to meet its needs that year. An ecological deficit occurs when a country's ecological footprint surpasses its biocapacity, whereas an ecological reserve exists when the biocapacity exceeds the footprint.

When a region or country is in the grip of an ecological deficit, it either imports biocapacity through trade, depletes local ecological resources, or emits waste into global commons like the atmosphere. However, unlike individual countries, trade cannot fully offset the global ecological deficit, leading to an ecological overshoot. This stark reality underscores the environmental impact of nations. Countries with a footprint smaller than their biocapacity have an ecological reserve and are often termed environmental creditors, while countries with a larger footprint are environmental debtors.

Currently, most countries and the global population face ecological deficits, with over 85% of the world's population living in such conditions. Ecological Footprint Analysis is a crucial tool for evaluating the sustainability of resource use and environmental impact on a national scale and can inform strategies for sustainable development. To tackle these pressing issues, each of us must contribute to reducing our ecological footprint, enhancing resource use efficiency, and adopting more sustainable practices in sectors such as energy, transportation, agriculture, and industry.

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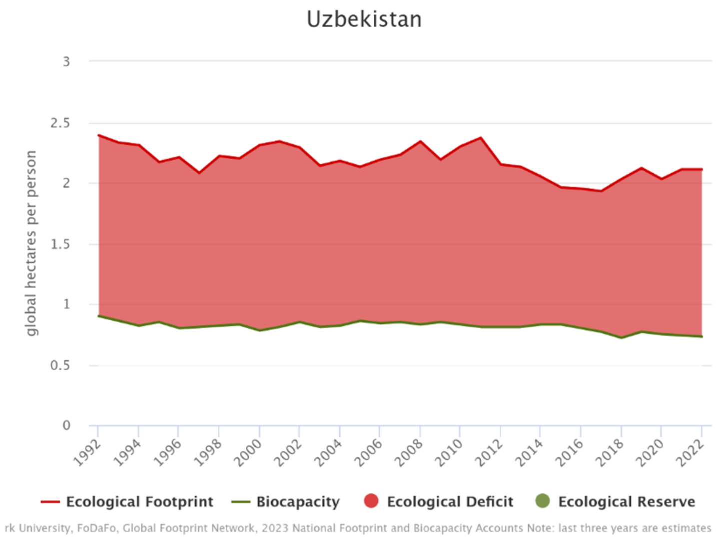

Fig. 2. Ecological footprint and biocapacity from 1961 to 2022 (last 3 years are estimates) for Uzbekistan [27].

In 2022, Uzbekistan had an ecological footprint of 2.1 global hectares (gha) per person and a biocapacity of 0.7 gha per person. This results in an environmental deficit of -1.4 gha per person, indicating that the country consumes resources beyond its ecological capacity, thus negatively affecting environmental sustainability (Fig. 2). Consequently, Uzbekistan is classified as a biocapacity debtor with a deficit of -180%.

This environmental deficit, while a significant challenge, also presents an opportunity for Uzbekistan to make a positive change. By reducing its ecological footprint through improved energy efficiency, adoption of renewable energy sources, reduction of air pollution, and implementation of other environmental initiatives, Uzbekistan can significantly enhance its environmental sustainability.

Export diversification can negatively affect the ecological footprint. The shift to producing and exporting less resource-consuming innovative and sophisticated products can reduce environmental degradation [25]. We employ the export product concentration index as a measurement of export diversification. The Export Product Concentration Index is a normalized Herfindahl-Hirschmann index of the product concentration of the country's merchandise exports. The following formula calculates this indicator:

$$H_j = \frac{\sqrt{\sum_{i=1}^{N}\left(\frac{x_{ij}}{X_j}\right)^2} - \sqrt{\frac{1}{N}}}{1-\sqrt{\frac{1}{N}}} \; ; \; X_j = \sum_{i=1}^{N} x_{ij} \quad (1)$$

where, *Hj* is the export product concentration index for country *j*, *Xi,j* is the value of exports of product *i* by country *j*, *Xj* is the total value of exports of country *j*, and *N* is the number of products exported at the three-digit level of the SITC Revision 3. The index ranges from zero to one, with a larger value indicating a higher concentration of merchandise exports structure. The index value close to zero denotes the high level of export diversification, i.e., the county's exports are homogeneously distributed among all products.

In our study, we meticulously select four control variables that are widely recognized in the literature as essential factors affecting the ecological footprint. For instance, GDP per capita, a proxy for economic growth, is considered a fundamental factor in environmental degradation. We go a step further by including the quadratic term of GDP per capita to check the presence of an inverted U-shaped relationship between economic growth and ecological footprint in Uzbekistan, in line with the Environmental Kuznets Curve (EKC) hypothesis. We also consider the impact of increased energy consumption from renewable sources, which has been shown to mitigate the ecological footprint [28, 29]. Lastly, we acknowledge the role of biocapacity in increasing the ecological footprint, causing more environmental degradation [30].

We constructed the following model to investigate the relationship between the ecological footprint and export diversification:

$$LnEFP_t = \alpha_0 + \alpha_1 LnGDPpc_t + \alpha_2 (LnGDPpc)_t^2 + \alpha_3 LnEPCI_t + \alpha_4 LnREC_t + \alpha_5 LnREC_t + \alpha_6 LnBC_t + \varepsilon_t \quad (2)$$

In this equation, $LnEFP$ denotes the ecological footprint per person, $LnGDPpc$ indicates GDP per capita (constant 2015 US dollar), $LnGDPpc^2$ is the quadratic term of GDP per capita to verify the EKC hypothesis. $LnEPCI$ represents the export product concentration index, $LnREC$ is the renewable energy consumption, $LnBC$ indicates the biocapacity, and ε_t refers to the error term.

The ecological footprint and biocapacity per person data are derived from the Global Footprint Network website. The data on the export product concentration index is obtained from the UNCTAD statistics database. The GDP per capita and renewable energy consumption data are collected from the World Development Indicators (WDI) database. Our study utilizes yearly data on Uzbekistan from 1996 to 2020. We transformed all variables into natural logarithms to obtain reliable estimates. Table 1 represents information about variables used in the analysis and their data sources.

Table 1. Variables and data sources.

Variable used	Descriptions	Data source
Ecological footprint per person (lnEFP)	It is measured in global hectares per person	Global Footprint Network
GDP per capita (LnGDPpc)	GDP per capita (constant 2015 US dollar)	World Development Indicators
Quadratic term of GDP per capita ($LnGDPpc^2$)	Quadratic term of GDP per capita (constant 2015 US dollar)	World Development Indicators
Export product concentration index (LnEPCI)	Ranges from 0 to 1. The value closer to 1 indicates the more concentrated structure of exports	UNCTADstat
Renewable energy consumption (LnREC)	Renewable energy consumption as a percentage of total final energy consumption	World Development Indicators
Biocapacity per person (LnBC)	It is measured in global hectares per person	Global Footprint Network

2.2 Econometric methodology

We used the Autoregressive Distributed-Lag (ARDL) model to investigate the impact of export diversification on the ecological footprint in Uzbekistan. This model contains the lagged values of the dependent variable and the current and lag values of explanatory variables that can be both endogenous and exogenous. ARDL model can be specified if the model has a combination of variables with I(0) and I(1) order of integration or if all variables are stationary at first difference. The ARDL model is sufficient for small data samples and allows for obtaining unbiased long-run estimates [31].

First, we applied Augmented Dickey-Fuller (ADF), Kwiatkowski-Phillips-Schmidt-Shin (KPSS), and Zivot and Andrews (ZA) unit root tests to examine the unit root properties of our variables. The null hypothesis of the ADF test is the non-stationarity of the variable. The null hypothesis is rejected if the MacKinon approximate p-values are below 0.1, 0.05, and 0.01. The KPSS test is based on the null hypotheses of trend stationary. The null hypotheses cannot be rejected if the Lagrange multiplier (LM) statistic is below the critical values. The ZA unit root test not only determines the order of integration but also reports information about potential structural breaks. The decision on trend stationarity is made by comparing the minimum t-statistic with the critical values. If the t-statistic is beyond the critical values, we can conclude that the trend is stationary.

Second, we employed the ARDL bound test for cointegration to define the presence of cointegration between the variables. This methodology is more convenient for our analysis as we have a small sample size. The ARDL approach provides robust estimates in small sample sizes and can be used if the variables have different orders of integration (I(0) or I(1), but not I(2)) [13]. The ARDL bound test method is free from autocorrelation, and the endogeneity issue can be eliminated by appropriately selecting the lag order. The ARDL bound test's null hypothesis is the absence of a level relationship. We can reject the null hypothesis and detect the cointegration if the F-statistic is higher than the upper critical bound (UCB).

Third, after identifying cointegration, we estimated the unrestricted Error Correction Model (ECM) to explore the short-run and long-run effects of the explanatory variables on the ecological footprint in Uzbekistan. The ECM equation of the ARDL is as follows:

$$\Delta LnEFP_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i}\, \Delta LnEFP_{t-i} + \sum_{i=1}^{q} \alpha_{2i}\, \Delta LnGDPpc_{t-i} + \sum_{i=1}^{q} \alpha_{3i}\, \Delta LnGDPpc_{t-i}^2 + \sum_{i=1}^{q} \alpha_{4i}\, \Delta LnEPCI_{t-i} + \sum_{i=1}^{q} \alpha_{5i}\, \Delta LnREC_{t-i} + \sum_{i=1}^{q} \alpha_{6i}\, \Delta LnBC_{t-i} + \beta_1 LnEFP_{t-i} + \beta_2 LnGDPpc_{t-i} + \beta_3 \Delta LnGDPpc_{t-i}^2 + \beta_4 LnEPCI_{t-i} + \beta_5 LnREC_{t-i} + \beta_6 LnBC_{t-i} + \varepsilon_t \quad (3)$$

where p is the lag length of the dependent variable, q is the lag length of the regressors, $\alpha_1, \alpha_2, \alpha_3, \alpha_{4,} \alpha_5, \alpha_6$ are the short-run coefficients of the variables, and $\beta_1, \beta_2, \beta_3, \beta_{4,} \beta_5, \beta_6$ represent the long-run parameters of the equation. Δ is used for the first difference operator.

Fourth, we applied various diagnostics tests to check for serial correlation, heteroscedasticity, and normality of residuals. We also performed the cumulative sum of squares (CUSUMsq) test to check for the stability of model parameters.

3 Results

Table 2 summarizes the descriptive statistics of the variables employed in the analysis from 1996 to 2020. The variables are in natural logarithm form. LnEFP per capita ranges from 0.665 to 0.869, with a mean of 0.771. LnGDPpc ranges from 7.039 to 8.153 because GDP per capita has significantly increased in Uzbekistan over the period analyzed. The mean of the export product concentration index (lnEPCI) constitutes -1.157. The minimum value of -1.447 indicates a low level of export concentration, and the maximum level of -0.618 implies a high level of export concentration. LnREC ranges from -0.329 to 0.56 with a mean of 0.208 because Uzbekistan's government implements various programs to increase renewable energy consumption. The mean of biocapacity (LnBC) constitutes -0.229.

Table 2. Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
LnEFP	28	0.771	0.053	0.665	0.869
LnGDPpc	28	7.571	0.382	7.039	8.153

Variable	Obs	Mean	Std. Dev.	Min	Max
LnGDPpc²	28	57.456	5.785	49.549	66.47
LnEPCI	28	-1.157	0.224	-1.447	-0.618
LnREC	26	0.208	0.267	-0.329	0.56
LnBC	28	-0.229	0.055	-0.357	-0.105

Table 3 displays the results of unit root tests. The ADF test's results indicate that the variables are non-stationary at levels as the probability values are higher than 0.10 and the test statistic is lower than the Dickey-Fuller critical values. Obtaining the first differences of the variables made them stationary because the relevant probability values were lower than 0.10. The results of the KPSS test confirm the non-stationarity of variables at levels, as the values of LM statistics are above the critical value at a 1% significance level. However, variables become stationary at first difference because LM statistics are below critical values at different significance levels.

Table 3. Unit root tests.

Variables	Augmented Dickey Fuller (ADF)				KPSS	
	AT level		First Difference		AT level	First Difference
	t-stat.	Prob.	t-stat.	Prob.	LM statistics	LM statistics
LnEFP	-1.387	0.5885	-3.439	0.0012	0.265	0.0495
LnGDPpc	-1.539	0.8154	-2.000	0.0290	0.328	0.208
LnGDPpc²	-1.751	0.7278	-2.048	0.0263	0.346	0.206
LnEPCI	-2.402	0.3785	-4.458	0.0001	0.456	0.0346
LnREC	-2.414	0.1380	-3.773	0.0006	0.198	0.042
LnBC	-1.970	0.3000	-6.557	0.0000	0.133	0.0448
Critical values of the KPSS test are 0.119 (10%), 0.146 (5%), and 0.216 (1%) *** significance at 1% level ** significance at 5% level						

In addition to ADF and KPSS unit root tests, we employed the Zivot and Andrews (1992) [32] unit root test to define the potential structural breaks. Table 4 demonstrates the results of the ZA unit root test. According to its results, the variables are stationary at first difference because the t-values are lower than critical values at different significance levels. The logarithm of ecological footprint had a structural break in 2016. The 2016-2020 Environment Monitoring Program, approved in the Republic of Uzbekistan, has brought about significant positive changes. Through targeted environmental protection measures, the total mass of emissions of pollutants into the atmosphere decreased by 1.5 times. The quality of irrigated lands in the areas of Namangan, Fergana, Bukhara, Khorezm, Kashkadarya, Surkhandarya, Andijan and Syrdarya regions increased from 0.9 to 4.7 points. These improvements have not only enhanced our environment but also our quality of life. Environmental monitoring has played a key role in this, contributing to the overall decrease in the ecological footprint in the republic.

As the results of unit root tests reveal that the variables under study are integrated of I(1), we can apply the ARDL model for our analysis.

Table 4. Zivot and Anrews unit root test.

Variables	t-value	Structural break
LnEFP	-7.847	2016
LnGDPpc	-4.950	2008
LnGDPpc²	-4.940	2008
LnEPCI	-5.279	2001

Variables	t-value	Structural break
LnREC	-7.547	2016
LnBC	-6.890	2006
Critical values are -4.93 (1%), -4.42 (5%), -4.11 (10%)		

We employed the ARDL bound test for cointegration to define the cointegration between the variables. We determined the optimum lag length using the Schwarz-Bayesian criterion (SBC) before applying the cointegration test. Table 5 presents the results of the bound cointegration test, and Table 6 reports the critical values for this test. We reject the null hypothesis of no cointegration because the value of the F-statistic (12.732) is larger than the UCB of Pesaran (2001) [33] at a 1% significance level. The variables are cointegrated, and we can estimate ECM to derive the long-run and short-run elasticity coefficients.

Table 5. ARDL bound test for cointegration.

Estimated model	F-statistics	Lag order	Cointegration
(LnEFP, LnGDPpc, $LnGDPpc^2$, LnEPCI, LnREC, LnBC)	12.732***	[1,1,1,1,0,1]	There is cointegration
Optimum lag length 1 under the Schwarz-Bayesian criterion (SBC) is used *** significance at 1% level			

Table 6. Critical values for the ARDL bound test.

Critical values	I(0)	I(1)
1% significance	3.41	4.68
5% significance	2.62	3.79
10% significance	2.26	3.35

Table 7 presents the results of ECM. The long-run results of estimation testify to the EKC hypothesis in the case of Uzbekistan. The relationship between the ecological footprint and GDP per capita is inverted U-shaped. The coefficient of LnGDPpc is positive and statistically significant at a 1% level, while the coefficient of $LnGDPpc^2$ is negative and statistically significant at a 1% level. Before the turning point, an increase in GDP per capita upsurges the ecological footprint per person. After the turning point, a rise in GDP per capita reduces the ecological footprint per person. Our result is consistent with the findings of [34] for emerging economies.

Table 7. Results of the Error correction model.

Variables	Coefficients	t-statistics	Prob.
Long run results			
LnGDPpc	9.8785***	4.61	0.000
$LnGDPpc^2$	-0.6601***	-4.70	0.000
LnEPCI	0.1853***	3.70	0.002
LnREC	-0.0747***	-3.11	0.008
LnBC	-0.7154***	-3.95	0.001
Short run results			
LnGDPpc	-14.4999**	-2.33	0.035
$LnGDPpc^2$	0.9543**	2.32	0.036
LnEPCI	0.2078**	2.79	0.014
LnBC	0.4383**	2.95	0.011
Constant	-41.5631**	-2.93	0.011
*** significance at 1% level ** significance at 5% level * significance at 10% level			

The coefficient of the export product concentration index (LnEPCI) is positive and statistically significant at a 1% level. As a higher value of the export product concentration index means a lower level of export diversification, we can explain this result as follows: export diversification reduces the ecological footprint per person. This finding is similar to that of [25] for India from 1965 to 2017. Export diversification can contribute to the reduction of ecological footprint by developing the production of environmentally friendly products and technologies. Export diversification can be accompanied by more sustainable use of natural resources and facilitate the adoption of green technologies and energy-efficient production methods mitigating environmental degradation.

The coefficient of renewable energy consumption (LnREC) is negatively statistically significant at a 1% level, suggesting that the transition to renewables reduces Uzbekistan's ecological footprint. This result is in line with the outcomes of [28, 29, 35-38]. Uzbekistan, with its vast potential for renewable resources, is poised to play an essential role in mitigating environmental degradation. This was underscored at the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) COP26 in Glasgow, UK, where Uzbekistan announced its ambitious climate goal - to reduce specific greenhouse gas emissions per unit of GDP by 35% by 2030 compared to 2010 levels.

The government's strategies for the transition of the Republic of Uzbekistan to a green economy for the period 2019–2030 are centered around the importance of renewable energy sources. These strategies aim at increasing the energy efficiency of primary sectors of the economy, diversifying energy consumption, adapting and mitigating the effects of climate change, and using financial and non-financial mechanisms to support the "green'' economy. The consistent introduction of renewable energy sources will play a pivotal role in reducing our environmental footprint.

Finally, the coefficient of biocapacity (LnBC) is also negatively statistically significant at a 1% level, implying that increased biocapacity reduces ecological footprint. An increase in biocapacity signifies an improvement in ecosystem stability [39].

According to the short-run results, the coefficients of all variables are significant at a 5% significance level. All significant variables except GDP per capita positively affect Uzbekistan's ecological footprint in the short run. The outcomes of the short-run analysis do not support the EKC hypothesis in Uzbekistan. LnGDPpc reduces the ecological footprint while $LnGDPpc^2$ upsurges it, and the coefficients are -14.5 and 0.95, respectively. A 1% increase in the export product concentration index (LnEPCI) is associated with a 0.2% rise in ecological footprint. This result is consistent with our long-run findings, meaning that export diversification mitigated the environmental degradation in Uzbekistan. Biocapacity (LnBC) has a significant positive impact on the ecological footprint in the short-run, which is the reverse of its long-run effect. Other things equal, a 1% increase in biocapacity is associated with a 0.44% upsurge in ecological footprint. The coefficient of ECT is negative (-1.15) and significant at a 1% level, which indicates a strong cointegration relationship between variables.

Table 8. Results of the diagnostics tests.

DW statistics	2.0856
R^2	0.8665
Adjusted R^2	0.7711
chi^2 Breusch-Godfrey LM test	0.107 [0.7436]
chi^2 White's test	31.65 [0.6308]
Jarque-Bera normality test	0.4196

Table 8 reports the results of the diagnostic tests. The outcomes of the Durbin-Watson and Breusch-Godfrey LM tests imply that our model is free from serial correlation. White's test result testifies that the model does not have a heteroscedasticity problem. The outcome of the Jarque-Bera normality test indicates that the errors are normally distributed.

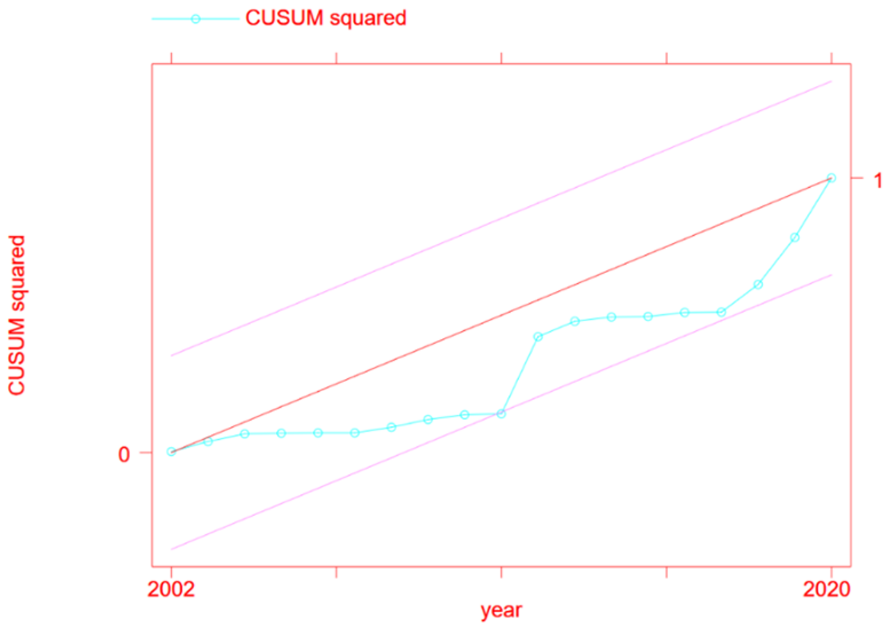

Fig. 3. Plot of cumulative sum of squares of recursive residuals.

Fig. 3 illustrates the results of the CUSUMsq method. The plotted lines of the cumulated sum of squares are within the 5% critical bound. The test results indicate the stability of our model parameters.

4 Discussion

Ecological Footprint Analysis is an essential tool for assessing the sustainability of resource consumption and the environment at the national level. It can also serve as a basis for developing sustainable development strategies.

According to research results, there is a direct relationship between the value of GDP per capita and the ecological footprint since both indicators determine the production of all consumed resources. To determine the ecological footprint, arable land, pastureland, fishing grounds, forestland, carbon footprint, and built-up land are considered, i.e., ecological footprint determines human consumption [40, 44].

The primary driver of greenhouse gas (GHG) emissions in Uzbekistan is the electricity and heat generation sector. This sector's excessive consumption and use of natural resources directly contribute to GHG emissions, leading to climate change. Consequently, the ecological balance is disrupted, and the sustainability of economic growth is jeopardized.

It is important to stress that Uzbekistan, according to international estimates, is uniquely vulnerable to the consequences of climate change in the Central Asian region. At present, the total greenhouse gas emissions of the Republic of Uzbekistan stand at approximately 206.96 million tons of CO_2-equivalent, accounting for a total share of 0.39%. In terms of emissions, the country ranks 43rd globally, 4th among the CIS countries, and 2nd in the Central Asia region.

Although Uzbekistan does not significantly contribute to GHG emissions, global climate change significantly damages the republic regarding economic development and the social sphere. The country's temperature rise rate is higher than the global average. Every ten years, air temperature rises by an average of 0.270°C. Uzbekistan ranks 72 out of 191 countries in terms of vulnerability to climate change.

Global changes and sensitivity to ongoing transformations in the country's natural resource complex determine the need for a consistent climate policy. Since 2017, Uzbekistan has actively participated in global climate and environmental policy, joining several international initiatives, such as the Bonn Challenge, NACAG, the Global Methane Pledge, the Declaration of the Global Green Growth Institute (GGGI), and the UN.

The 'Strategy for the transition of the Republic of Uzbekistan to a green economy for the period 2019–2030' stands as a beacon of our forward-thinking approach. It was the first legislative document of its kind, developed and approved in support of the implementation of the obligations of the Paris Agreement. This Strategy paves the way for policy and action in the field of climate change and green development, aiming to achieve economic growth with minimal emissions.

One of the priority areas of this strategy is the large-scale introduction of renewable energy sources (solar, wind, biogas technologies, and small and micro-hydroelectric power stations). Uzbekistan has an average of 330 sunny days a year, and its renewable energy potential is almost 51 billion tons of oil equivalent. Existing equipment and technologies in the world make it possible to use 179 million tons of oil equivalent, more than three times the country's current annual volume of fossil fuel production.

Despite its immense potential, as of 2022, the share of electricity produced from renewable sources in Uzbekistan was a modest 7.74%. This figure is largely due to the significant contributions of hydroelectric power plants and thermal power plants, which generated 36.5 billion kWh and 28.7 billion kWh, respectively, accounting for 9% and 7% of total production. In comparison, renewable energy sources, including solar and wind power, provided a relatively small 50 million kWh and 17 million kWh. This data underscores the current low penetration of renewable energy in Uzbekistan's energy mix, presenting a significant opportunity for growth and investment in this sector.

Five solar and one wind station have been built in Uzbekistan to generate energy from renewable sources, and the total capacity is almost 3,000 megawatt. As part of investment projects for the construction of new solar and wind power plants with a capacity of more than one megawatt, it is planned to introduce a mandatory electric energy storage system with a capacity of at least 25 percent of the installed capacity of these stations.

According to the Ministry of Energy of the Republic of Uzbekistan, the total volume of energy generated through renewable energy sources will increase from 2.5 megawatt in 2021 to 11.8 megawatt in 2030, including solar and wind energy, which will account for 5 megawatt and 3 megawatt by 2030, respectively.

Over the past three decades of independence and reform, Uzbekistan has significantly improved environmental quality. Ongoing national environmental sustainability plans and targets are becoming central to the transition to a low-carbon and green economy.

Much remains to be done to ensure a green future for Uzbekistan, whose priorities include efficient use of energy and resources, energy industry reforms to reduce fuel consumption and emissions, updates to climate and industry regulations, optimization of the use of natural resources, and investment in landscape restoration.

Export diversification can also contribute to Uzbekistan's green transition. Structural changes that lead to the production and export of eco-friendly products will benefit the environment. Transitioning from mineral exports to high-value-added products reduces the overexploitation of natural resources and mitigates environmental degradation. Export diversification facilitates technology transfer between countries, leading to the adoption of more environmentally friendly and energy-efficient production methods that reduce negative environmental impacts.

5 Conclusion

This study investigates the relationship between export diversification and ecological footprint in Uzbekistan by analysing data from 1996-2020 and employing the ARDL approach. The long-run estimates of the ARDL model reveal a positive relationship between the export product concentration index and the ecological footprint, which implies that export diversification mitigates environmental degradation. The relationship between GDP per capita and ecological footprint per person supports the EKC hypothesis for Uzbekistan. Renewable energy consumption and biocapacity reduce the ecological footprint in the long run.

Several recommendations can be made based on our research. Firstly, the government of Uzbekistan should implement strategies fostering export diversification. Diversification of production and export structure should be accompanied by measures stimulating the adoption of green technologies, energy-efficient production methods, and sustainable agricultural practices. This policy will lead to the production and export of eco-friendly products and improve the environment. Secondly, Uzbekistan’s government should continue implementing its green transition policies to ensure sustainable development. Uzbekistan can significantly enhance its environmental sustainability by reducing its ecological footprint through improved energy efficiency, increasing consumption of renewable energy sources, reducing air pollution, and implementing other environmental initiatives.

This study has some limitations. A more extended study period in future research could lead to more accurate conclusions on the determinants of ecological footprint in Uzbekistan. Other factors influencing the environment could be incorporated as control variables in the model and studied. Other estimation methods, like DOLS and FMOLS, could be employed to verify the long-run results of the ARDL method.

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