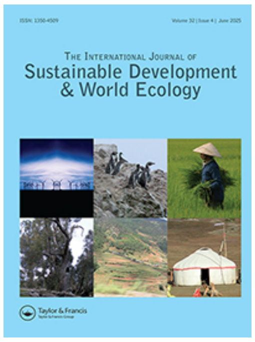

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Pathways to environmental sustainability: exploring the role of FinTech, natural resources and globalization in North Africa

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ABSTRACT

In recent years, financial technology (FinTech), natural resources, and globalization have gained prominence as key factors influencing environmental sustainability. However, there is a lack of research on their impact on the Load Capacity Factor (LCF) within the framework of the Load Capacity Curve (LCC) hypothesis, particularly in the North African region. Therefore, this study aims to investigate the heterogeneous effects of FinTech, natural resources, and globalization on LCF in North Africa from 1991 to 2022, marking the first comprehensive analysis of its kind in the region. This study employs the Augmented Mean Group (AMG) estimator and Hansen's threshold estimation to assess these relationships. The findings reveal that the LCC hypothesis is not valid in the region. Additionally, the study shows that the environmental benefits of FinTech become more pronounced at higher regimes, suggesting its potential to drive eco-friendly investments. Meanwhile, natural resource rents and globalization contribute to environmental degradation at lower thresholds but promote mitigation effects in the upper regime. Based on these findings, policymakers are encouraged to harness the positive effects of globalization and optimize resource utilization to improve environmental quality, ensuring a sustainable development trajectory for the region.

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Load capacity factor; threshold; globalization; load capacity curve hypothesis; North Africa

HIGHLIGHTS

- We assessed the impacts of Fintech, natural resources, and globalization on the Load Capacity Factor.
- We examined the North African region which is one of the lowest carbon emitters across the globe but vulnerable to climate impacts.
- We utilized an augmented mean group (AMG) and Hansen's threshold estimation The LCC hypothesis is not valid in the region. The study also found that FinTech, natural resource rents and globalization improve environmental quality at higher regimes.
- We suggest policy options to enhance environmental quality in the region.

1. Introduction

Climate change creates substantial hurdles to human progress and survival (Bilgili et al. 2024). The prevalent global patterns of unsustainable resource utilization make it challenging to attain intergenerational equity (Onifade 2022; Ahmad et al. 2024). In the last five decades, the global ecological footprint has increased by roughly 190% signifying a widening disparity between the ecosystem and humans. Strikingly, roughly 80% of the world population lives in nations with a significant ecological imbalance (Global Footprint Network 2022). Hence, humanity is considerably building up ecological debt, as countries across the world are using resources faster than they can be quickly restored by the Earth (Dimnwobi et al. 2021; Satrovic et al. 2024). Given this major global issue, the Sustainable Development Goals were established to address some of these concerns with SDG 13 underlining the pressing demand to tackle climate change and its effects (Dimnwobi et al. 2023)

The advancements in technology are commonly acknowledged to possess substantial potential in tackling ecological damages (Onuoha et al. 2023). Technological innovations have however been criticized specifically after the Industrial Revolution. The financial sector has witnessed considerable changes owing to advancements in technology with recent developments in Fintech transforming the dynamics of financial structures and markets (Dimnwobi et al. 2022). Fintech includes a variety of services and technologies like digital payments, crowdfunding platforms and algorithmic trading. Although Fintech development has majorly assisted in making financial services more convenient, efficient and accessible for users, it has become clear that these innovations may also influence the environment (Jia et al. 2024). From one angle, Fintech development can boost ecological quality by making it easier to fund initiatives that are beneficial to the ecosystem. Relatedly, Fintech

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solutions can enhance the effectiveness of the financial process, which entails using fewer resources like energy or paper. On the flip side, some Fintech applications are energy intensive and they can negatively influence the ecosystem. Moreover, the fast pace of Fintech development can generate electronic waste as outdated gadgets could be deployed increasing energy utilization (Lisha et al. 2022). This highlights that while Fintech provides some ecological benefits, it also creates substantial issues for sustainability and ecological health.

Natural resources are essential in catalyzing societal evolution and economic advancement across the globe (Nwani et al. 2024). However, their excessive use and unsustainable consumption especially of fossil fuels contribute substantially to ecological decay (Okere et al. 2024). On the other hand, the revenue obtained from natural resources could be invested strategically in research and development of sustainable energy initiatives hence enhancing ecological performance. This strategy aside from tackling critical ecological issues also promotes ecological balance by channeling resource assets towards sustainable energy initiatives. Aside from these aforementioned variables, globalization which drives economic growth and integration across frontiers is another variable that can influence environmental quality. In one regard, globalization can assist in decreasing emissions by encouraging the uptake of stricter ecological regulations through enhanced interconnectedness and cross-territorial economic operations. This can boost sustainability as economies conform with global environmental regulations. In contrast, globalization can also impede ecological sustainability by accelerating growth in both production and consumption habits resulting in increased extraction and ecological decay (Ibrahim et al. 2024). Additionally, it can unintentionally make nations reduce their ecological standards as they strive to induce foreign investments.

We selected North Africa as the main focus of this study because of these justifications. First, the strategic location of the region (which links Africa, the Middle East and Europe) is essential in facilitating cultural exchange and global trade. North Africa is widely recognized for its rich economic, cultural and historical tapestry with different civilizations, economies and landscapes presenting a mosaic of development (Idroes et al. 2024). The region is faced with substantial ecological challenges especially rising carbon emissions fuelled by economic engagements (Shouwu et al. 2024). As per the World Bank (2023), emissions per capita have risen considerably in the region. For instance, Algeria's emission level increased to 3.71 metric tons per capita in 2020 from 2.46 in 1990. Similarly, Egypt and Morroco increased from 1.53 and 0.87, respectively, in 1990 to 1.96 and 1.81 in 2020. Despite this rise, the region is one of the lowest carbon emitters across the globe but is vulnerable to climate impacts. Relatedly, the Notre Dame Global Adaptation Initiative (ND-GAIN) Index positions most economies in the region in the lower half of their worldwide ranking highlighting that the region is among the least equipped to handle the issue of climate change and is very susceptible to its impacts. This blend of increasing emission levels and high susceptibility to climate issues underlines the criticality of examining the predictors of environmental quality in North Africa using both comprehensive ecological measure and variables that are yet to gather adequate attention in the region. This study can provide both abatement measures to reduce the rise in environmental decay and an adaptation framework to boost adaptability against the effects of climate change. Second, the North African Fintech sector is expanding rapidly driven primarily by the region's financial inclusivity and a digital-savvy, youthful demographics. The region's Fintech sector is majorly driven by Egypt which currently accounts for roughly 6.5% of Africa's Fintech start-ups (BDO 2024). Beyond the African region, Egypt is also responsible for 14% of the Arab world's Fintech firms with Morocco and Tunisia accounting for 13% and 9% respectively of the Fintech firms in the Arab region (Statista, 2023). This rapid expansion of Fintech in North Africa aside from creating avenues for diversifying the economy and enhancing financial services across the region also presents environmental challenges. Third, North Africa is endowed with natural resources with substantial accessibility. The region produces roughly 40% of Africa's gas and crude oil (Shouwu et al. 2024). This unclean fuel widely produced and utilized in this region is responsible for over 80% of greenhouse gas (GHG) emissions in these economies (Charfeddine and Mrabet 2017). The substantial dependence on fossil fuels aside from substantially contributing to global climate change also undermines the region's efforts to attain sustainable development. The profusion of fossil fuel has over time influenced the energy and economic strategies of this region. This attention on fossil fuels has mostly constrained funding for sustainable energy options, undermining the region's cleaner energy transitions. Fourth, globalization in the region has been progressing rapidly, with the KOF Globalization Index showing that Morocco (69), Egypt (66), and Tunisia (66) surpassed the global average of 61 in 2021. This growth highlights the relevance of the pollution halo hypothesis in the region, as trade and foreign investment continue to increase owing to the effect of globalization. However, while globalization has its positive side, the accompanying economic operations can contribute to ecological decay. Hence, assessing the effect of globalization on environmental sustainability in North African economies is critical to establishing well-designed strategies to balance economic expansion with ecological quality in the region.

Consequently, this study appraised these research questions (1) Is the LCC hypothesis valid for the North African region? (2) What is the effect of Fintech, natural resources and globalization on the region's ecological quality? (3) Does Fintech, natural resources and globalization have a threshold effect on environmental sustainability in the North African region? This study makes several additions to the extant literature. First, it represents the pioneer efforts that appraise the effect of Fintech, natural resources, and globalization on environmental sustainability in the North African region in a single framework. Second, prior studies have majorly employed carbon emissions and ecological footprint as surrogates for ecological performance. Carbon emissions are widely regarded as a significant share of greenhouse gas emissions. However, some environmental scholars have criticized this metric of environmental quality as a simplistic, limited indicator that cannot capture the entire complexity of ecological quality. The ecological footprint sidesteps this shortcoming by incorporating six distinct pollution elements, offering a multifaceted evaluation of human's impact on the environment through resource utilization patterns. However, this metric has also been criticized for concentrating on resource demand without considering environmental supply capacity. We addressed this lacuna by utilizing the Load Capacity Factor (LCF) which blends both demand and supply facets of the ecosystem providing a more comprehensive measure of ecological quality. This technique is in sync with the SDGs which underscores the criticality of ensuring ecological stability and as such policymakers in this region can obtain holistic insights on ecological health, potentially resulting in more efficient and tailored policy interventions. Third, the North African region has shown a strong commitment towards reducing environmental pollution and achieving numerous SDGs thereby making the establishment of effective policies essential. Formulating robust strategies necessitates the assessment of recent theories with our study documenting the load capacity curve (LCC) hypothesis in North Africa. The LCC ideology argues a short-term adverse influence of income expansion on LCF followed by long-run favourable influence as economies develop is still emerging in the literature and research attention on this hypothesis has not been directed to the region. The assessment of this hypothesis in this context will assist decision-makers in crafting effective initiatives for sustainable development that balance economic growth with ecological protection. Fourth, utilizing a threshold regression model, we establish the optimal levels of globalization, Fintech development and resource utilization that maintain low environmental pollution while promoting a healthier environment. This analysis showcased the critical thresholds that can be utilized to bolster ecological health without endangering economic advancements. Fifth, diverging from existing studies, this study utilized the latest data that shows the current realities in the region. Hence, this study will assist in crafting policy roadmaps that will assist the region in attaining a sustainable environment. Lastly, this study employed advanced econometric techniques to obtain robust outcomes that show the present economic landscape, improving on the weaknesses of earlier studies. Notably, the study adopted the Augmented Mean Group (AMG) methodology and Hansen's (1999) threshold regression which is capable of dealing with complex data structures. The former tackles heterogeneity and cross-sectional dependence in panel data while the latter uncovers non-linear connections and regime changes and together these techniques provide robust outcomes that supply decision-makers with a more holistic toolkit for policy decisions. Aside from this section, the study has four other sections. The second segment contains related literature. Section 3 documents the methodology. Section 4 presents the findings while Section 5 provides the policy options.

2. Literature review

We have segmented past studies into four subsections, covering the connection between Finetch and the environment, natural resources and the environment, globalization and the environment and the empirical gaps.

2.1. Fintech and the environment

In a bid to comprehend the environmental effects of Fintech, several studies have appraised the influence of Fintech on the ecosystem with these studies documenting diverse outcomes. We have grouped these studies into two strands. The first strand finds that Fintech promotes ecological performance. For instance, Ma et al. (2024) combine both emerging (BRICST) and advanced (G7) nations and conclude that Fintech protects the environment. In BRICS economies, Kai et al. (2024) and Liao et al. (2024) document the enhancing influence of Fintech on the environment by substantially reducing carbon emissions. This also does not differ from the conclusions of Firdousi et al. (2023) in 26 emerging nations, Li et al. (2024) in leading manufacturing economies and Vu et al. (2024) in 42 economies demonstrating that Fintech development is essential for environmental preservation. Xu et al. (2024) also find that in leading tourist locations, environmental protection responds positively to Fintech development. This shows that Fintech is pro-environment as it reduces carbon emissions. Jia et al. (2024), Feng et al. (2024) and Uddin et al. (2024) also report that carbon emissions can be mitigated in G20 nations through the utilization of Fintech. This underscores that Fintech is essential for environmental protection. Andlib et al. (2024) affirm that Fintech development is essential in curtailing carbon emissions in the United Kingdom. This also relates to the conclusions in China (Li et al. 2024; Liu et al. 2024; Shu et al. 2024) highlighting that Fintech boosts ecological balance by reducing carbon emissions. The foregoing studies utilized carbon emissions as a measure of ecological health. Other studies have utilized ecological footprint (EF) to achieve the same purpose. For instance, Xia and Liu (2024) document that Fintech improves the advanced (G7) economy's environment by substantially reducing its EF. Ahmad et al. (2024) disclose that the ecological footprint is reduced by Fintech development in EU nations. Differing from the foregoing that have predominately utilized carbon emissions and EF, the utilization of LCF which is considered a holistic ecosystem measure has not garnered considerable research attention. In this regard, Saqib and Shahzad (2024) employ the ecological load capacity factor and report that Fintech is vital in protecting the ecological health of resource-rich nations by improving the ecological load capacity factor.

In contrast to the above strands, some studies argue that Fintech is not beneficial to ecological performance. In other words, they find that Fintech impedes ecological balance. Lisha et al. (2022) highlight that Fintech undermines ecological quality by increasing carbon emissions in BRICS. Fintech development has also been found to hinder Vietnam and China's environmental stewardship (Liu et al. 2024) using carbon emission as a surrogate for ecological balance. This also aligns with the observation of Ali et al. (2024) in 17 economies of diverse regions documenting that Fintech worsens ecological balance.

2.2. Natural resources and environment

The opinions of scholars on the environmental effects of natural resources are divided. In one aspect, some studies confirm that natural resources promote ecological balance using diverse surrogates of ecological quality. For instance, Adebayo et al. (2023) and Jahanger et al. (2022) report that resource utilization enhances ecological performance in BRICS and emerging nations respectively. This also relates to the conclusion of Saud et al. (2022) in MENA and Tufail et al. (2021) in advanced nations. One common factor with the above studies is that they employ carbon emissions as a proxy for the environment. Other studies utilized other measures and still obtained the same conclusions. Among these studies are Zafar et al. (2019) in the USA, Razzaq et al. (2022) in European nations and Liu et al. (2022) in developed economies revealing that resource utilization reduces EF and, in the process, fosters environmental health in these economies. For studies on natural resources and LCF, Akadiri et al. (2022) find in India that natural resources protect the ecosystem. This also corresponds to the conclusions in the OECD context (Guloglu et al. 2023) and 17 nations (Sun et al. 2024)

In contrast, some studies highlight that ecological vitality is undermined by natural resources. For instance, Alhassan and Kwakwa (2023), Sun et al. (2020), Caglar et al. (2022) and Onifade et al. (2023) disclose that natural resources are linked with increased carbon emissions in Ghana, 88 economies, BRICS and MENA respectively. For EF studies, Awosusi et al. (2022) show that natural resources trigger ecological decay. This also aligns with the outcomes obtained by Xu et al. (2022) in emerging nations as well as in G20 nations (Qing et al. 2023) also showing that natural resources detrimentally affect the ecosystem. Regarding LCF studies, Erdogan (2023) notes that Africa's ecosystem is destroyed by resource utilization. The same observations are made in resource-rich nations (Ni et al. 2022), in emerging nations (Zhao et al. 2023) as well as in BRICS (Yang et al. 2023; Ya et al. 2024) and China (Usman et al. 2024).

2.3. Globalization and the environment

The influence of globalization on ecological sustainability has gathered research attention in the literature; however, the outcomes of these studies are varied. On one hand, some studies argue that globalization is primarily responsible for the ecological decline since it drives the migration of high-polluting industries from advanced economies (with stringent environmental regulations) to emerging economies with weak ecological laws. For example, Shahbaz et al. (2015) and Sethi et al. (2020) disclose in India that globalization undermines environmental sustainability efforts by increasing carbon emissions. Khan et al. (2019) report that globalization does not promote ecological quality in Pakistan. Wang et al. (2019) conclude that globalization encourages ecological decline by expanding carbon emissions in OECD nations. This same outcome is recorded by Shahbaz et al. (2018) in 25 developed nations, Sun et al. (2022) in the ten most polluted nations and Sadiq et al. (2023) in economies dependent on nuclear energy. Some other studies (Sadiq et al. 2022; Kartal and Pata 2023; Ibrahim et al. 2024; Sharif et al. 2024) take a different approach (using other ecological measures) to arrive at the same conclusions. For instance, Sadiq et al. (2022) and Gyamfi et al. (2023) affirm that globalization instigates pollution decay by expanding EF in top-polluted nations and emerging nations respectively. Figge et al. (2017) document that globalization stresses the ecosystem of diverse economies by increasing the EF. For LCF studies, Sharif et al. (2024) document that globalization triggers ecological damage in top-emitting nations by reducing LCF. Kartal and Pata (2023) and Ibrahim et al. (2024) find that globalization degrades China and the USA's ecosystem, respectively, by reducing LCF thereby undermining sustainability efforts.

Other studies argue that globalization reduces ecological decline by enhancing ecological awareness, removing trade barriers, encouraging sustainable energy importation and expanding technological progress. Ahmad et al. (2023) reveal that India's environment responds positively to globalization underlining that globalization is favourable to ecological quality in India. Similarly, Wang et al. (2023) report that globalization boosts ecological integrity by reducing carbon emissions in China. Wang et al. (2024) conclude that globalization reduces emission levels in major emitting economies which also aligns with the discovery of Idroes et al. (2024) and Feng et al. (2024) in North Africa and resource-endowed nations respectively. Concentrating on EF studies, Ahmed et al. (2021) and Bilgili et al. (2020) reveal that economic globalization reduces Japan's and Turkey's EF, respectively, thereby promoting ecological quality. Eweade et al. (2023) made a similar discovery in the United Kingdom. Onwe et al. (2023) report that globalization lowers EF in G7 nations indicating that globalization spurs ecological balance. Pata et al. (2024) find that globalization boosts the environment by decreasing EF in BRICS nations. Focusing on LCF studies, Zhang et al. (2024) observe from resource-rich nations that financial globalization expands LCF thereby enhancing environmental performance. This also concurs with the observation of Ali et al. (2024) using LCF in nuclear-dependent nations.

Some other studies document that the influence of globalization on ecological performance could be dependent on the nation's economic developmental level. In this context, Leal et al. (2021) appraise the environmental effect of globalization in 58 nations (split across 32 advanced and 26 emerging nations) showing that globalization in emerging economies expands carbon emissions while the opposite effect is discovered in developed nations. Le and Le (2023) focus on 128 nations across diverse income groups and find that globalization improves the ecological quality of high- and middle-income economies while exacerbating ecological damage in low-income economies.

Lastly, some studies highlight insignificant connections between both variables. Put differently, some studies discovered the link between both variables is not significant. For instance, Ahmed et al. (2019) conclude that globalization is insignificantly correlated with the EF in Malaysia, while Xu et al. (2018) also affirm an insignificant connection between Saudi Arabia's globalization and carbon emissions.

2.4. Empirical gaps and our contributions

The literature discussions in the foregoing sections show that the connection between Fintech, natural resources, globalization and environmental quality has been assessed in several regions and nations (though with diverse outcomes) but the issue has not been empirically analyzed in the North African region. The inability to arrive at a consensus by prior studies demands further research, especially in regions that have been overlooked in the literature. Moreover, previous studies have predominately proxied environmental quality using either carbon emission or ecological footprint covering only the demand segment of the ecosystem, this study differs from these studies by using the ecological load capacity factor which comprehensively captures the environmental dynamics by looking at both the demand and supply side (Ezenekwe et al. 2023; Awosusi et al. 2024; Samour et al. 2024). It is also pertinent to note that this study is the first attempt to study the effect of Fintech and LCF in North Africa. Another important aspect that previous studies ignored is establishing the threshold level of Fintech, natural resources and globalization before its effect improves or undermines environmental quality. To implement effective strategies for guaranteeing the efficient utilization of Fintech, globalization and natural resources, it is essential to unearth the exact point of its favourable or adverse impacts. The foregoing shows that in a bid for the North African region to achieve SDG 13, this study is essential. Lastly, economies across the globe have been substantially impacted by the recent pandemic and Russia-Ukraine crisis and existing studies have neglected these recent shifts. As a result, their outcomes have been unable to showcase prevailing economic and environmental situations. These changing economic and ecological conditions underline the pressing demand for new studies using data that documents these recent events and their implications. It is only such studies that can craft impactful strategies that relate to contemporary economic situations and ecological requirements.

3. Methodology

3.1. Theoretical model

The foundation of this study is based on the Load Capacity Curve (LCC) hypothesis, which illustrates the relationship between a country's affluence and its load capacity factor. The LCC[1] hypothesis suggests a U-shaped relationship where economic affluence initially leads to environmental degradation, but after surpassing a certain income threshold, further economic growth results in environmental improvements (Pata and Kartal 2023). This hypothesis indicates that the immediate adverse effects of increased affluence are eventually followed by long-term beneficial impacts. Empirically, the STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and

Technology) framework as sub-set of LCC hypothesis, developed by Dietz and Rosa (1994), is widely used to assess the environmental impact of human activities. The STIRPAT equation, which analyzes the drivers of environmental impact, is expressed as follows:

$$I_t = \varphi P_t^{\alpha} A_t^{\beta} T_t^{\delta} \quad (1)$$

This Equation (1) represents a functional relationship where I_t depends on three factors: $P_t, A_t, andT_t$, each raised to a power and scaled by α, β, δ, and they are the elasticity parameters (indicating the percentage change in I_t resulting from a 1% change in $P_t, A_t, andT_t$ respectively). Accordingly, Equation (1) can be modified to facilitate the empirical narrative of this analysis:

$$\begin{aligned} lnELC_{i,t} = \theta_0 + \theta_1 lnP_{i,t} + \theta_2 lnGDP_{it} + \theta_3 lnGDPsq_{it} \\ + \theta_4 lnNR_{i,t} + \theta_5 lnGLO_{i,t} + \theta_6 lnFinTech_{i,t} \\ + \varepsilon_{i,t} \end{aligned} \quad (2)$$

Dependent Variable: $lnELC_{i,t}$ = Log of ecological load capacity (ELC) for country/region *i* at time *t*. This represents the natural logarithm of ecological load capacity, making the equation log-linear.

Independent Variables: $lnP_{i,t}$ = Log of population, which measures Population, total. $lnGDP_{it}$= Log of gross domestic product (GDP), capturing the relationship between economic activity and ecological load capacity. $lnGDPsq_{it}$ = Log of squared GDP, allowing for a nonlinear relationship between GDP and ecological load capacity (e.g. an U-shape, as predicted by the Load Capacity Curve (LCC) hypothesis). $lnNR_{i,t}$ = Log of natural resources (NR), representing the availability of ecological load capacity (ELC) in country *i*. $lnGLO_{i,t}$= Log of globalization (GLO), capturing how trade and economic openness impact ecological load capacity. $lnFinTech_{i,t}$ = Log of financial technology (FinTech), which may influence ecological load capacity through digital transactions.

Error Term: $\varepsilon_{i,t}$= Error term capturing unobserved factors affecting ecological load capacity. Coefficients: θ_0= Intercept, representing the baseline level of load capacity factor when all independent variables are zero. θ_1,$\theta_2, \theta_3, \theta_4, \theta_5, \theta_6$ = regression coefficients, indicating the elasticity (percentage change in energy consumption resulting from a 1% change in each independent variable). To account for the Load Capacity Curve (LCC) can be valid if θ_3 <0 and θ_3 >0. θ_1- θ_6 indicates coefficients of NR, GLO, and FinTech, respectively.

3.2. Techniques

3.2.1. Augmented mean group estimate (AMG)

Panel data with cross-sectional dependence and heterogeneity can be effectively analyzed using the Augmented Mean Group (AMG) estimator, developed by Eberhardt and Teal (2010). This method estimates individual parameters by incorporating cross-sectional averages into the model and then aggregates these results to obtain long-run coefficients. The AMG estimator is particularly valuable for investigating long-term correlations in diverse datasets, providing robust and precise estimations. The first stage is given as thus:

$$Y_{it} = \rho_i + \alpha_i \Delta X_{it} + \tau_i \delta_t + \sum_{t-1}^{T} \phi_t D_t + \varepsilon_{it} \quad (3)$$

Y_{it}= The response variable for unit *i* at time *t*, representing the outcome of interest. ρ_i= Unit-specific intercept, capturing unobserved individual heterogeneity. $\alpha_i \Delta X_{it} + \tau_i$= The impact of changes in explanatory variable X on Y, $\tau_i \delta_t$= Time-specific effects, where: $\sum_{t-1}^{T} \phi_t D_t$ = A summation term representing additional time-variant factors.

The second group is the group-specific regression and represented as thus:

$$AMG = \frac{1}{N} \sum_{i=1}^{N} \widehat{\alpha}_i \quad (4)$$

Where, AMG (Augmented Mean Group Estimator): This represents the overall estimated coefficient for the entire dataset, obtained by averaging the individual coefficients $\hat{\alpha}_i$ across all units. N (Number of Cross-Sectional Units): The total number of countries in the dataset. $\hat{\alpha}_i$ (Unit-Specific Coefficients): Each individual unit *i* has its own estimated coefficient $\hat{\alpha}_i$ reflecting heterogeneous effects across groups. $\sum_{i=1}^{N} \widehat{\alpha}_i$ (Summation Term):

3.2.2. Hansen (1999) threshold

The core objective of this study is to explore the dynamic and nonlinear effects of FinTech, natural resource rents, and globalization on environmental sustainability. This analysis is vital as nations transition to carbon-saving energies, aiming to live within their ecological means and support their populations sustainably. Indeed, FinTech adoption is beneficial, but can sometimes drive unsustainable consumer behavior (Yang and Zhang 2022). Mismanaged natural resource rents can lead to over-exploitation, increasing the ecological footprint and degrading biocapacity (Zambrano-Monserrate and Ormeño-Candelario 2023). Globalization, without adequate environmental safeguards, can exacerbate environmental degradation through increased resource consumption and pollution (Muoneke et al. 2022). This imbalance can cause the ecological footprint to exceed the regenerative capacity of biocapacity, thus lowering the Ecological Load Capacity Factor (Al Doghan and Chong 2023). However, the move to maintain a balance for environmental quality could negatively impact the economic performance of industrializing nations, creating a significant trade-off. To address this, it is crucial to identify thresholds for FinTech, natural resource rents, and globalization that balance economic growth with environmental sustainability. To achieve this, we employ Hansen (1999) threshold regression[2] to pinpoint the levels where these factors can simultaneously support robust environmental quality. This approach offers a pathway to ensuring a sustainable future.

$$Y_{it} = \beta_1 X_{it} I|q_{it} \leq \gamma| + \beta_2 X_{it} I|q_{it} > \gamma| + \mu_{it} \tag{5}$$

Dependent Variable: Y_{it}= The outcome of interest for unit iii at time t (e.g. environmental quality, emissions level). Independent Variables: X_{it} = The explanatory variable influencing Y_{it}. β_1 and β_2= Coefficients measuring the effect of X_{it} before and after the threshold level $\gamma.q_{it}$= The threshold variable, determining which regime applies. γ = The threshold value, where the relationship between X_{it} and Y_{it} changes. Indicator Functions: $I|q_{it} \leq \gamma|$ = Equals 1 if $q_{it}$is less than or equal to γ (first regime) and 0 otherwise. $I|q_{it} \leq \gamma|$ = Equals 1 if $q_{it}$is greater than γ (second regime) and 0 otherwise. Error Term: μ_{it}= The stochastic error, capturing unobserved influences.

3.3. Sample selection

The dataset includes five North African countries (Algeria, Egypt, Libya, Morocco and Tunisia) selected based on available annual data from 1991 to 2022. Appendix Table A1 is the summary statistics. The study uses the Ecological Load Capacity (ELC) concept as the ratio of biocapacity to ecological footprint. A higher ELC (ELC >1) indicates sustainable natural resource use, either through increased biocapacity or reduced consumption footprint, while a lower ELC (ELC <1) suggests unsustainable resource exploitation. The study explores the relevance of FinTech, natural resource rents (% of GDP), and the Globalization index, along with real per capita GDP and total population, in North Africa.

Table A1, Panel A (see Appendix) presents descriptive statistics. Higher GLO and FinTech indicator values suggest that globalization might have enforced stricter environmental regulations, reducing pollution levels. The rise of FinTech has significantly altered the financial and business sectors, channelling more resources into low-carbon, eco-friendly activities. Figures 1 and 2 shows graphical plots of the study variables' distribution. The correlation coefficient matrix in Table A1, Panel B, reveals that the ELC variable has a strong negative correlation with all explanatory variables.

4. Regression result

4.1. Preliminary result

Appendix A provides a summary of the preliminary tests. All the selected variables display significant dispersion from their mean values indicating substantial variability and volatility. Table A2 (See Appendix) reveals that coefficient of skewness indicates that most variables exhibit positive skewness. The kurtosis values suggest that the distributions generally have lighter tails and a flatter peak compared to a normal distribution, characterizing them as platykurtic. Due to space constraints, these values are not reported here but will be provided upon request. Table A3 (See Appendix) indicates that the assumption of no cross-sectional dependence (CD) is rejected based on Pesaran's (2004) test, confirming CD in the data series. The same table shows Pesaran and Yamagata's (2008) test results, which reject the homogeneity of slope coefficients, indicating heterogeneity. Table A4 (See Appendix) confirms no multicollinearity issues based on the Variance Inflation Factor test. Cross-sectionally augmented unit root tests were performed, employing various CD-adjusted panel unit root procedures. The results indicate that the variables are integrated in mixed orders (See Table 1), suggesting their suitability for cointegration analysis. We further apply the Cointegration tests (See Table 2), and based on model specifications in Equation (2), we reject the null hypothesis of no cointegration among the variables, confirming a long-run relationship in all fitted models. The parameter estimates, computed using AMG estimators, account for both homogeneity and heterogeneity in slope coefficients, ensuring robust and reliable estimates for policy decisions and at the same time address the first objective of this study.

4.2. Results and analysis

The AMG estimates in Table 3 indicate that population growth, natural resource rent, and globalization significantly negatively impact ELC in North African countries, reducing it by 0.532%, 0.0238%, and 0.537%, respectively, in the long term. These factors pose a threat to environmental sustainability in the region. This environmental degrading effect of resource utilization in the region shows that the techniques utilized in these economies in resource extraction are not environmentally friendly. Our outcome is in line with Alhassan and Kwakwa (2023), Sun et al. (2020), Caglar et al. (2022) and Onifade et al. (2023) while differing from those of Adebayo et al. (2023), Jahanger et al. (2022), Saud et al. (2022) and Tufail et al. (2021). Our study also showed that globalization instigates pollution decay. This is because globalization usually

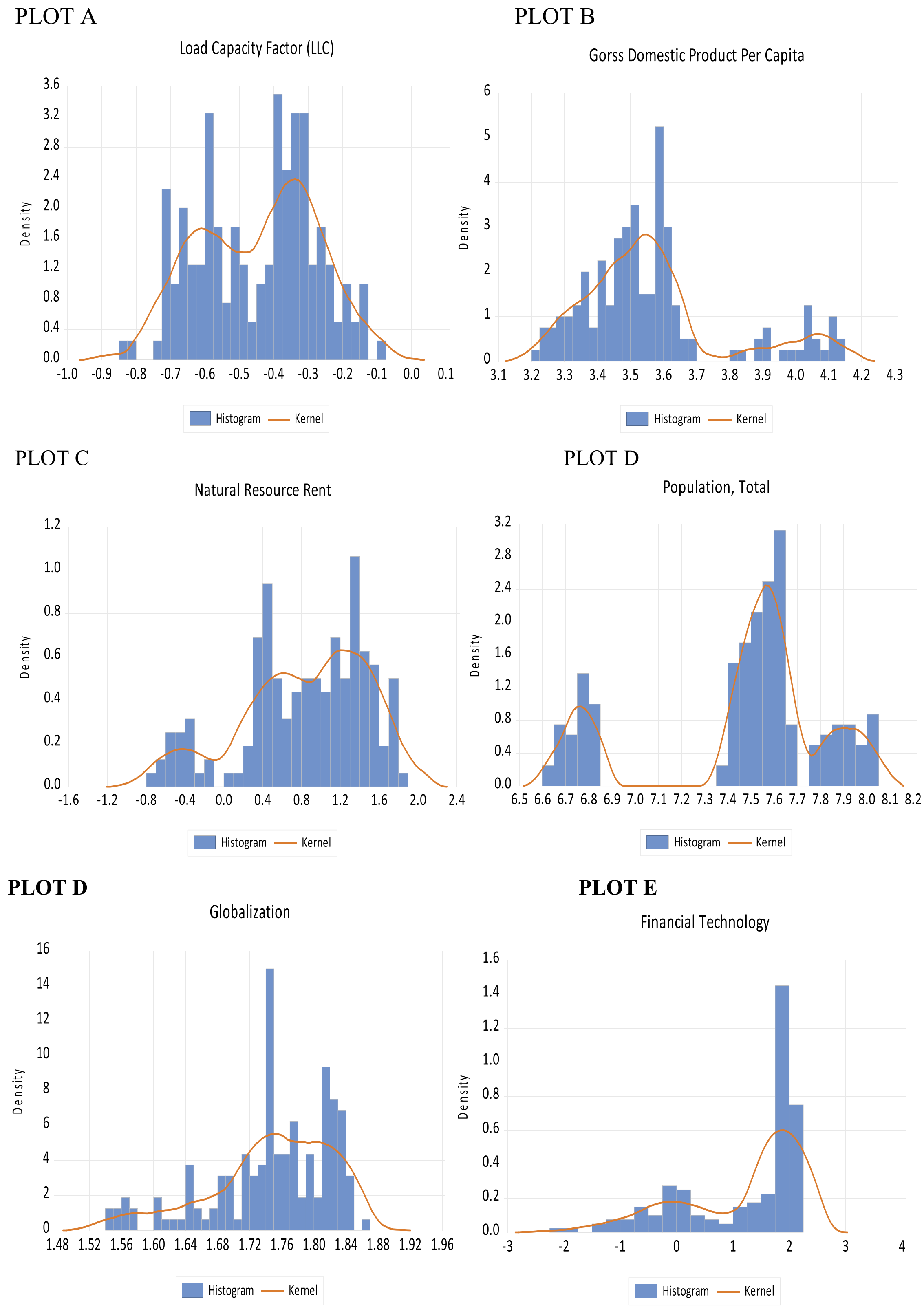

Figure 1. Distributional plots of the variables.

emphasizes economic expansion which most times occurs at the detriment of the ecosystem preservation. This outcome concurs with these studies (Sadiq et al. 2022; Kartal and Pata 2023; Ibrahim et al. 2024; Sharif et al. 2024)

Results particular to each country generally correspond with this, with the exception of Morocco and Tunisia, where natural resource rent favorably influences ELC, and Tunisia, where globalization enhances environmental quality. These results align with prior research. Policymakers must create policies to alleviate the adverse impacts of population expansion, globalization, and resource extraction on the environment. Enhancing knowledge and instituting birth control

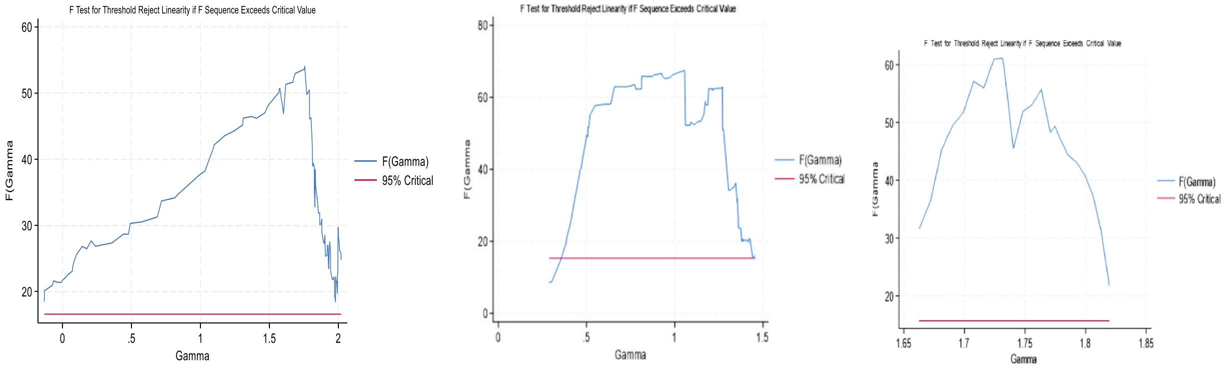

Figure 2. Test for threshold.

Table 1. Stationary test.

Series	CIPS (0)	CIPS (1)	TCIPS (0)	TCIPS (1)
P	−2.660	−4.617***	−2.660	−4.617***
GDP	−2.592	−5.538***	−2.592	−4.756***
GDPSQ	−2.886	−5.170***	−3.200	−5.208***
NR	−3.521**	−5.873***	−2.542	−4.916***
GLO	−3.200	−5.425***	−2.860	−4.851***
FinTech	−1.196	−3.520***	−1.196	−3.520***
LLC	−2.542**	−6.042***	−3.521	−5.540***

*** if $p < 0.01$, ** if $p < 0.05$, * if $p < 0.1$.

Table 2. Cointegration.

Statistic	Value Z	value	P-value	Robust P-value
Gt	−3.432***	1.388	0.000	0.000
Ga	−9.82***	1.822	0.000	0.000
Pt	−6.009***	0.231	0.000	0.000
Pa	−8.51***	1.194	0.000	0.000

*** if $p < 0.01$, ** if $p < 0.05$, * if $p < 0.1$.

Table 3. AMG regression results.

		Country Specific				
	1	2	3	4	5	6
VARIABLES	AMG POOLED	Algeria	Egypt	Libya	Morocco	Tunisia
P	−0.532**	0.735**	−0.115**	0.515**	−1.328**	−2.468**
	(0.602)	(0.193)	(0.446)	(0.553)	(1.026)	(4.687)
GDP	13.57	45.939	5.816	2.542	4.865	8.693
	(8.152)	(16.240)	(11.497)	(4.509)	(12.698)	(13.950)
GDPSQ	−1.862	6.515	−0.741	−0.302	−0.440	−1.311
	(1.176)	(2.293)	(1.619)	(0.576)	(1.901)	(2.013)
NR	−0.0238**	−0.074**	−0.025**	−0.177**	0.004**	0.006**
	(0.042)	(0.061)	(0.046)	(0.051)	(0.019)	(0.168)
GLO	−0.537**	−0.152**	−1.381**	−1.156**	−1.332**	1.033**
	(0.483)	(0.340)	(0.482)	(0.542)	(0.474)	(1.152)
FinTech	0.252	0.009	0.065	0.052	0.028	1.106
	(0.214)	(0.019)	(0.039)	(0.033)	(0.031)	(0.871)
Constant	−20.22	87.041	−8.266	−6.957	0.810	0.364
	(16.810)	(28.490)	(21.841)	(7.779)	(26.890)	(26.662)
Observations	160					

***if $p < 0.01$, **if $p < 0.05$, *if $p < 0$.

strategies may mitigate ecological imbalances. The findings indicate that the LCC hypothesis is not valid in the region. The possible reasons for the invalidity of the LCC hypothesis in the region are contingent on these factors. The industrialization drive in this region is majorly resource-intensive combined with lax ecological regulations, which has obstructed the usual enhancements witnessed as income expands. The region is heavily dependent on exporting fossil fuels, especially in nations like Libya and Algeria (Charfeddine and Mrabet 2017), establishing an economic inducement that sustains ecological decline even with increased income. Political instability in the region has prevented the implementation of effective environmental strategies and infrastructure development that usually emanate from higher income. The distinctive geographical challenges of the region, like water shortages and susceptibility to climate change, worsen the ecological strain notwithstanding the economic expansion. The poor technological innovation and transfer relative to other developing regions has stalled the uptake of sustainable production techniques (Shouwu et al. 2024). Besides, swift urbanization without matching ecological infrastructure has kept pollution high despite increased income. The economic structure of the region still relies on extracting resources and basic production instead of transitioning to service-based and knowledge sectors that often drive environmental progress in the LCC model. FinTech exerts a favorable albeit statistically negligible influence on ELC, indicating its potential to mitigate environmental degradation, albeit without statistical significance. To further examine and validate these findings, other econometric methods, including Hansen's (1999) threshold estimation, are utilized.

4.3. Threshold effect test

Building on the critical insights gained from examining country-specific effects, the key question we are poised to answer in this section is: At what threshold level do FinTech, natural resource rents, and globalization intensify or mitigate their impact on environmental sustainability? By leveraging the robust capabilities of the threshold regression model, we deliver compelling results presented in Table 4 that illuminate these crucial dynamics.

We first determine if a threshold analysis[3] is applicable for each model. Accordingly, Figure 3 illustrates the confidence interval construction for the threshold model encompassing FinTech, natural resource rents, and globalization. The blue curve represents the likelihood ratio statistic (LR gamma). The horizontal line (red line) marks the alpha percentile of the asymptotic distribution of the likelihood ratio statistic. When the curve (blue line) exceeds the red line (95% critical value), it signifies the presence of a threshold in the model. Having established the existence of a threshold, we discuss the findings of the threshold effects results as presented in the lower part of Table 4.

4.3.1. Threshold estimations

Table 4 shows the non-linear (threshold) and linear (Global OLS without Threshold) estimations. With the

Table 4. Threshold result of first sample split.

Threshold variables		FinTech		Natural Resources Rents		Globalization	
VARIABLES	Global OLS without Threshold	Regime 1 FinTech<1.75	Regime 2 Fintech>1.75	Regime 1 nr<0.87	Regime 2 nr>0.89	Regime 1 glo<1.77	Regime 2 glo>1.77
pop	−0.143**	0.014	−0.183**	−0.843**	0.190 **	0.075	−0.948**
	(0.062)	(0.064)	(0.052)	(0.054)	(0.044)	(0.051)	(0.038)
gdp	−1.117	−1.516	−11.333	−6.568	2.344	−8.609	16.055
	(1.407)	(1.949)	(1.940)	(5.689)	(1.642)	(1.466)	(12.866)
gdpsq	0.078	0.174	1.396	1.030	−0.323	1.093	−2.112
	(0.187)	(0.254)	(0.264)	(0.801)	(0.219)	(0.189)	(1.825)
nr	−0.123**	−0.113**	−0.124**	−0.069**	0.150**	−0.046**	0.020
	(0.024)	(0.029)	(0.059)	(0.021)	(0.053)	(0.028)	(0.016)
glo	−1.351**	−1.807*	−1.487**	−2.625**	−1.844**	−2.675**	2.569**
	(0.077)	(0.084)	(0.008)	(0.066)	(0.084)	(0.055)	(0.060)
FinTech	0.079**	−0.055**	0.656**	0.065	−0.008**	0.115**	−0.040
	(0.015)	(0.019)	(0.050)	(0.017)	(0.015)	(0.015)	(0.022)
Constant	5.974	5.793	25.042	21.043	−3.193	20.268	−18.737
	(2.769)	(3.970)	(3.271)	(9.571)	(3.382)	(3.037)	(21.925)
R-Sq	0.616	0.788		0.857		0.803	
Heteroskedasticity test (p-value)	0.197						
Observations	160	77	83	77	83	99	61

***if $p < 0.01$, **if $p < 0.05$, *if $p < 0.1$.

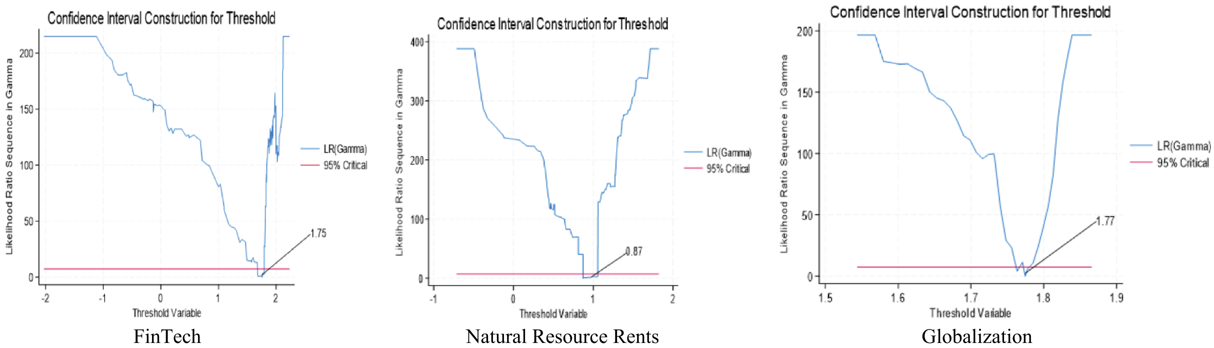

Figure 3. Graphical representation of threshold point.

linear estimate, all exogenous variables – except from GDP and GDP squared – show signs of significance. Thus, the quadratic formulation of the LCC hypothesis helps one to evaluate the environmental effect of wealth, expressed as measured by GDP per capita. The results reveal that the coefficients for GDP and its quadratic factor are statistically nonsistent. This suggests that the LCC theory does not fit the chosen group of five North African countries. Regimes 1 and 2 depict the non-linear model.

Focusing on the threshold estimates, we reveal the impactful results of the threshold estimations for q = (FinTech, natural resources, globalization) showcased in Table 4. By defining Regime 1 (low) and Regime 2 (high) through the threshold values of 1.75, 0.87, and 1.77, respectively, we provide clear insights into how these exogenous variables influence environmental sustainability across different regimes. Consider Regime 1, where countries fall below the FinTech threshold. Here, FinTech's impact on environmental sustainability appears insignificant, likely due to the region's weak financial infrastructure. However, the story changes dramatically in Regime 2. In this upper regime, the coefficients on financial technologies (FinTech) are positive and statistically significant, indicating that FinTech significantly boosts environmental sustainability in North African economies. Specifically, a 1% increase in FinTech correlates with a 0.656% improvement in environmental sustainability. This suggests that the region's biocapacity exceeds its ecological footprint by 0.656%, highlighting sustainable resource use and effective waste absorption. FinTech is ideally positioned to drive environmentally sustainable investments in North African economies. Financial technology (FinTech) companies may encourage SMEs and prospective customers to make greener choices by using machine learning and big data insights. This strategic role of FinTech may explain the positive empirical findings observed in the upper regime.

Natural resource rents represent a complex issue in the context of environmental sustainability, highlighting a time-sensitive relationship with the ecological load capacity factor. While they offer immediate benefits, the long-term drawbacks are significant. In the lower regime (Regime 1: nr < 0.87), environmental quality suffers, with biodiversity loss estimated at 0.069% for each additional resource extraction. This decline is exacerbated by increasing pollution linked to resource exploitation. However, in the higher regime (nr > 0.89), greater natural resource rents can mitigate the negative impacts of other human activities by an additional 0.150%. By strategically managing these rents, these countries can seize the opportunity to transition towards a more sustainable future.

Globalization's impact on environmental sustainability varies depending on its level. Below certain thresholds (Regime 1: glo < 1.77), globalization can exacerbate environmental degradation by up to −2.675%. For example, globalization has been linked to an increased ecological footprint and worsening environmental sustainability in developing economies. However, when globalization is effectively managed and exceeds the threshold (Regime 1: glo > 1.77), it can lead to cleaner practices and sustainable development, improving environmental conditions by up to 2.569% in North Africa.

4.4. Causality results

We employ the Half-Panel Jackknife (HPJ) Wald-type test established by Juodis and Sarafidis (2022) to reinforce our conclusions and offer policy recommendations for attaining environmental sustainability. This test improves the dependability of our results, providing enhanced size and power performance relative to comparable procedures. It estimates multivariate and heterogeneous panel data models using a bias-corrected pooled estimator and robust standard errors for cross-sectional heteroskedasticity. The findings are presented in Table 5. In specification (1), we investigate if P, GDP, GDP squared, NR, GLO, and FinTech Granger-cause ELC. The HPJ Wald statistic is substantial, hence rejecting the null hypothesis that these factors do not Granger-cause ELC. Furthermore, the regression results in Panel B demonstrate that historical values of P, GDP, GDP squared, NR, and FinTech exert a considerable impact on the multivariate equation. Evidence indicates bidirectional correlation between ELC and GDP, GDP squared, and FinTech (columns 3, 4, and 7). There exists a unidirectional positive correlation between GLO and ELC (column 1).

5. Summary, conclusion and recommendations

The present study focuses on the optimal utilization of FinTech, natural resources, and globalization level to strike a balance between Biocapacity and Ecological Footprint. It is based on a panel dataset in North Africa spanning from 1991 to 2022 and the employed empirical techniques are the country-specific effect of augmented mean group (AMG) and Hansen (1999) threshold estimation. The estimation protocol is streamlined to identify thresholds for FinTech, natural resource rents, and globalization that balance Biocapacity and Ecological Footprint. The following research outcome is established: The study confirms that FinTech, natural resources, and globalization have threshold effects on environmental sustainability in North Africa, with more favorable environmental outcomes observed at higher levels. While the relationship between economic growth and ELC do not support the first research question – Is the LCC hypothesis valid for

Table 5. JKS multivariate non-causality test.

Equation	1 LCF	2 P	3 GDP	4 GDPSQ	5 NR	6 GLO	7 FinTech
Panel A: Non-causality test							
	83.309***	13.2611***	281.784***	310.252***	365.774***	87.495***	52.732***
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Panel B: -Panel Jackknife estimates of Selected covariates							
L.P	0.283		−0.119	−0.566	−3.536***	−0.370***	−0.627
	(0.262)		(0.274)	(2.227)	(1.093)	(0.057)	(1.152)
L.GDP	−6.009***	−0.244		273.3***	15.79***	1.056***	−7.473
	(2.040)	(0.244)		(24.970)	(0.964)	(0.285)	(6.426)
L.GDPSQ	0.767***	0.0328	−4.432***		−1.832***	−0.134***	1.107
	(0.259)	(0.031)	(0.406)		(0.123)	(0.036)	(0.799)
L.NR	0.0352***	0.00300***	0.0159***	0.105***		0.00012	0.0513
	(0.005)	(0.001)	(0.003)	(0.024)		(0.005)	(0.048)
L.GLO	−0.678***	−0.0744***	0.518***	4.646***	−1.221***		−0.799
	(0.415)	(0.027)	(0.188)	(1.426)	(0.422)		(1.144)
L. FinTech	0.0386***	−0.000617	0.0484***	0.334***	0.273***	0.0283***	
	(0.003)	(0.001)	(0.005)	(0.039)	(0.051)	(0.005)	
L.LCF		−0.0155	0.338**	2.634**	0.279	0.0133	0.421**
		(0.010)	(0.148)	(1.133)	(0.391)	(0.022)	(0.203)
No of ID	5	5	5	5	5	5	5

***p<0.01, **p<0.05, *p<0.1.

the North African region? – our key findings substantiate the roles of FinTech, natural resources, and globalization in influencing environmental sustainability, thus answering research questions (2) and (3).

Policy implications are highlighted in line with the threshold and causality results: The evidence from the empirical narrative suggests that FinTech has the potential to significantly impact the environmental landscape in North Africa, promoting and facilitating eco-friendly investments, and contributing to carbon mitigation targets. Policyholders are encouraged to enhance digital infrastructure, advocate for sustainable behaviors, and establish regulations that incentivize investment in eco-friendly activities and technologies. The study on the threshold effects of natural resource dependence on environmental sustainability in North Africa was found to be negative at below 0.87% threshold, but as the rents increase above 0.87%, it exerts a significant positive effect on ecological load capacity leading to a significant reduction in environmental decay. The threshold analysis reveals critical points for natural resource rents in North Africa, offering actionable insights for policymakers. Accordingly, below a 0.87% threshold, natural resource dependence harms environmental sustainability, necessitating strict extraction regulations, sustainable management practices, and investments in conservation. Above this threshold, increased resource rents should fund renewable energy projects, green technologies, and ecosystem restoration to enhance ecological resilience.

At a threshold below 1.77%, globalization initially contributes to environmental degradation in North Africa through increased economic activities, resulting in higher ecological footprints. This is due to the scale effect of globalization, which boosts economic activities and relocates polluting industries to developing countries, thereby exacerbating environmental degradation. However, in the upper regime, above the 1.77% threshold, globalization can lead to mitigation effects through the technique effect. This involves the adoption of cleaner technologies and more efficient practices, which play a significant role in promoting better environmental practices, particularly when supported by effective policies and investments in biodiversity. The threshold analysis reveals critical points for globalization in North Africa, offering actionable insights for policymakers. First, for globalization, below a 1.77% threshold, stricter environmental standards and incentives for cleaner production are needed to counter the scale effect, alongside carbon tariffs to deter polluting industries. Above this threshold, policymakers should leverage the technique effect by fostering international collaboration to transfer advanced technologies and promote green innovation. Second, to balance biodiversity and ecological footprint in the region, stakeholders must invest in and promote the adoption of clean and renewable energy technologies to mitigate the negative environmental impacts of globalization when the threshold is below 1.77%. Policy makers in this region should implement stringent environmental regulations to leverage the benefits of globalization while minimizing its adverse effects when the threshold is above 1.77%. This includes setting environmental footprint standards and encouraging sustainable practices, developing trade policies that incentivize the import and export of environmentally friendly goods and technologies, balancing the initial negative impacts of globalization with long-term environmental benefits, planning and managing urban growth to reduce its environmental footprint by investing in sustainable infrastructure and promoting green urban planning. There is also a need for the decision-makers in this region to foster regional cooperation to address transboundary environmental issues and share best practices in environmental management and sustainable development.

Above all, this study recommends that policymakers in North Africa adopt a phased approach to environmental management, beginning with the implementation of regulatory measures. These should focus on establishing laws and regulations that mandate sustainable environmental and social practices across industries. Additionally, efforts should be directed towards promoting green initiatives and the adoption of eco-friendly practices within organizations. A strong emphasis on international collaboration is also essential, with potential partnerships leveraging successful models like the European Green Deal in EU. These frameworks, when adapted to the local context, can guide North African countries towards achieving long-term environmental sustainability.

Our research is not without limitations. The study focused specifically on the North African region and, for broader applicability, other regional and economic contexts such as ASEAN, MINT, BRICS, CIVETS, and E7 economies should be considered. Additionally, future scholars can utilize other variables like technological innovations, ecological governance, energy poverty, and green growth, which potentially could influence ecological balance but were not utilized in this study and are yet to be given research attention in the North African region. Furthermore, this study employed a single proxy to capture environmental quality; for broader policy insights, other studies should consider utilizing multiple ecological indicators. Lastly, as new econometric techniques continue to emerge, we urge future studies to employ these techniques for more extensive insights into the subject matter

Notes

1. LCF is chosen over other sustainability indicators due to its comprehensive nature that offers a more holistic view of environmental sustainability compared to traditional indicators such as ecological footprint alone. By encapsulating the capacity of ecosystems to regenerate and sustain human activities, It provides a more accurate and actionable measure of whether human activities are within sustainable limits (Altıntaş et al. 2023).
2. Hansen's (1999) threshold regression is a technique employed to ascertain a point (threshold) at which the connection between variables alters. This technique enables the identification of several regimes within the data, illustrating varying impacts of an independent variable on a dependent variable based on whether the threshold variable exceeds or falls below a specified value.
3. The threshold determines the point at which the relationship between variables changes, enabling us to identify tipping points in social segregation problems (Lee and Wang 2023). In the study the tipping point or threshold variable and point are FinTech = 1.75 and nr = 0.89 respectively.

Acronyms

AMG	Augmented Mean Group
ASEAN	Association of Southeast Asian Nations
BRICS	Brazil, Russia, India, China, and South Africa
BRICST	Brazil, Russia, India, China, South Africa and Turkey
CD	Cross-Sectional Dependence
CIVETS	Colombia, Indonesia, Vietnam, Egypt, Turkey and South Africa
EF	Ecological Footprint
ELC	Ecological Load Capacity
EU	European Union
E7	Emerging Seven
FINTECH	Financial Technology
GHG	Greenhouse Gas
HPJ	Half-Panel Jackknife
JKS	Juodis, Karavias, and Sarafidis
LCC	Load Capacity Curve
LCF	Load Capacity Factor
MENA	Middle East and North Africa
MINT	Mexico, Indonesia, Nigeria, and Turkey
ND-GAIN	Notre Dame Global Adaptation Initiative
OECD	Organization for Economic Co-operation and Development
SDGs	Sustainable Development Goals
STIRPAT	Stochastic Impacts by Regression on Population, Affluence, and Technology
USA	United States of America

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Authors' contributions

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

Consent for publication

The authors are willing to permit the Journal to publish the article.

Data availability statement

Data will be made available on request.

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APPENDIX

Appendix A. Results from Preliminary Tests

Globalization index KOF is from https://kof.ethz.ch/en/forecasts-and-indicators/indicators/kof-globalisation-index.html. Ecological Load Capacity Factor from https://www.footprintnetwork.org/while. other variables are sourced from https://databank.worldbank.org/source/world-development-indicators. Countries sample (Algeria, Egypt, Libya, Morocco and Tunisia

Table A1. Descriptive statistics and correlation matrix.

Definition		Variables	Mean	Maximum	Minimum	Std. Dev.
Panel A: Descriptive Statistics						
Population, total		P	39228699	110000000	4300000	26297615
GDP per capita in constant 2015 US dollars		GDP	4257	13729	1668	2853
Total natural resources rents (% of GDP)		NR	14.56	66.06	0.195	15.767
Overall Globalization index		GLO	56.65	73.35	35.00	9.171
Fixed broadband subscriptions (per 100 people).						
Individuals using the Internet (% of population),						
Mobile						
cellular subscriptions(per 100 people)						
Principal component analysis of the above three variables		FinTech	56.696	168.492	0.009	47.969
Ecological Load Capacity Factor = Biocapacity divided by Ecological Footprint		ELC	0.386	0.812	0.147	0.145
Panel B: Correlation Matrix						
	POP	GDP	NR	GLO	FinTech	ELC
P	1.000					
GDP	−0.498	1.000				
NR	−0.484	0.824	1.000			
GLO	0.609	−0.270	−0.492	1.000		
FinTech	0.129	0.098	−0.176	0.697	1.000	
ELC	−0.278	−0.443	−0.466	−0.121	−0.052	1.000

Table A2. Tests for normality.

Variable	Obs	Pr(skewness)	Pr(kurtosis)
Skewness and kurtosis tests for normality			
P	160	0.000	0.635
GDP	160	0.000	0.067
GDPSQ	160	0.000	0.029
NR	160	0.002	0.333
GLO	160	0.000	0.522
FinTech	160	0.000	0.9726
ELC	160	0.464	0.000
		W	V
Shapiro – Wilk W test for normal data			
P	160	0.853	18.039
GDP	160	0.880	14.815
GDPSQ	160	0.859	17.394
NR	160	0.943	6.953
GLO	160	0.927	9.028
FinTech	160	0.80435	24.062
ELC	160	0.968	3.945

Note: ****p* < 0.01 @1% significance level.

Table A3. Cross-sectional dependency & slope heterogeneity tests.

Variable	CD-test	p-value	average joint T
Panel A: CD test			
P	17.505	0.000	32
GDP	14.564	0.000	32
GDPSQ	14.453	0.000	32
NR	5.262	0.000	32
GLO	16.754	0.000	32
FinTech	16.701	0.000	32
LCF	13.722	0.000	32
	SH	p value	
Panel B: SH test			
Delta	3.570	0.000	
Adj.	4.122	0.000	

p < 0.01, ***p* < 0.05, **p* < 0.1.

Table A4. Variance inflation factor.

variable	VIF	1/VIF
GDP	1.363	0.734
GDPSQ	1.331	0.751
GLO	2.211	0.452
P	1.060	0.943
FinTech	2.050	0.488
NR	1.050	0.952
Mean VIF	9.065	