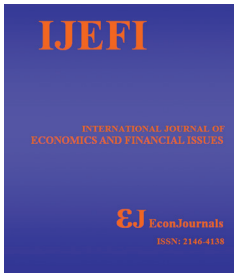

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Environmental Taxation and Food Security in Sub-Saharan Africa: Does Information and Communications Technology Penetration Matter?

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ABSTRACT

This study examines the mediating role of information and communications technology in the relationship between environmental tax and food security across 15 sub-Saharan African countries from 2006 to 2024. Based on the Digital Development Theory and supported by the Environmental Kuznets Curve Theory, the research utilised the panel autoregressive distributed lag model, fully modified ordinary least squares, and mediation analysis to address the research objectives. The results showed that environmental tax significantly improves food security in the long term. Additionally, ICT not only enhances food availability and accessibility but also mediates the effects of green tax policies. The interaction between ICT and environmental tax further boosts food security outcomes, illustrating that digitalisation is a vital driver of fiscal environmental interventions. This research offers empirical evidence for integrated and environmental policy reforms and advances the theoretical understanding of how digital development and green taxation collectively support food systems in emerging nations.

Keywords: SDG 2, Climate Actions, Information and Communication Technology, Green Tax, Digitalisation, Sub-Saharan Africa
JEL Classifications: E02, I3, 1320, Q1

1. INTRODUCTION

Food security remains a critical development and humanitarian issue in Sub-Saharan Africa (SSA). This region accounts for the largest share of the global population facing severe food insecurity (Onyeaka et al., 2024). Despite its abundant natural resources, endowments, and mainly agrarian economies, SSA continues to encounter structural barriers that limit sustainable food production, fair food access, and climate-resilient agriculture. These problems are worsened by a large and growing population, expected to reach 3.07 billion by 2100, alongside a persistent dependence on imports amid stagnant agricultural productivity (Olarewaju et al., 2025).

To find more sustainable solutions, environmental taxation has become a policy tool with the potential to both reduce environmental damage and encourage sustainable farming practices. Environmental taxes, such as those on carbon dioxide emissions and resource extraction, aim to account for the external costs of pollution and motivate environmentally friendly behaviours (Du and Li, 2024). Theoretically, fiscal measures can support climate-smart agriculture, improve soil and water resource management, and align farming activities with low-carbon adaptation strategies. Yet, there is growing concern that poorly designed carbon tax policies could inadvertently burden the agricultural sector by increasing operational costs, especially for fuel and fertiliser, which could decrease productivity and make food less affordable (Batan, 2025).

Concurrently, the spread of Information and communication technology (ICT) across emerging nations offers new

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opportunities to enhance food accessibility, manage agricultural data, and support institutional accountability (Chandio et al., 2024). However, the isolated effect of these variables has received far more evaluation than their interactive dynamics. Conversely, environmental taxes could foster long-term ecological sustainability. They also carry the risk of inducing short-term economic trade-offs that disproportionately affect vulnerable populations reliant on subsistence farming and informal food markets. The debate over environmental protection versus food security raises critical issues about the appropriateness, design, and implementation of green fiscal policies in resource-dependent economies (Wisdom et al., 2022). Since over 50% of SSA countries derive at least a quarter of their total export revenues from natural resource sectors, environmental taxes, particularly in extractive industries, serve not only as macroeconomic instruments but also as social levers with far-reaching impacts on human welfare.

Despite increasing research focus on the role of ICT in promoting environmental sustainability (Cosmas et al., 2025; Okere et al., 2024) and food security, several gaps remain unaddressed. Rahaman and Islam (2025) and Rahaman et al. (2024) highlighted ICT's positive impact on food security, while Adeshola et al. (2024) found that ICT and green taxes jointly improve environmental sustainability in the European Union. However, these studies are limited to developing nations, with limited conceptual application to the SSA context, where the digital divide and food insecurity are more pronounced. Furthermore, Deng et al. (2024) and Ajeigbe and Ganda (2024) linked policy, ICT and green tax to environmental outcomes but overlooked the interactive or mediating roles that ICT could play in intensifying or mitigating the effects of environmental tax on food accessibility and availability.

This dilemma highlights the complex and often underexplored relationship between environmental taxation, ICT and food security in SSA. Most existing literature has focused on the fiscal, environmental, and developmental effects of taxation in isolation, with little attention paid to how environmental tax regimes influence agricultural productivity, food availability, and access. This study aims to address these gaps by empirically examining the relationship between environmental taxation and food security in SSA, and also the mediating interaction of ICT on the relationship between environmental taxation and food security in SSA. Furthermore, drawing on the digital development theory and the Environmental Kuznets curve theory, the research explores whether ICT can serve as a digital enabler that transforms the environmental tax-food security nexus, particularly within the complexities of SSA's socio-economic and institutional landscape.

Through this analysis, the research seeks to offer a comprehensive understanding of whether environmental taxation in SSA functions as a catalyst for food insecurity or as a driver of sustainable food system transformation. By providing empirical insights into these relationships, this study endeavours to offer evidence-based guidance for policymakers seeking to balance climate action with sustainable food security outcomes in one of the world's most vulnerable regions.

2. LITERATURE REVIEW

2.1. Conceptual Review

Taxation serves as a key mechanism through which governments finance public services, redistribute wealth, and influence economic behaviour (Nurbekova et al., 2024). Beyond its fiscal functions, taxation is also a strategic tool for achieving environmental sustainability. Environmental taxation as a subset of fiscal policy aims to internalise the negative externalities of environmental degradation by levying charges on pollutants and resource-depleting activities by business entities, households and individuals (Kalaš et al., 2025). The "polluter pays" principle underpins this approach, thereby creating incentives for cleaner production and consumption patterns. Instruments such as carbon taxes, pollution levies and resource extraction fees serve dual objectives: raising revenue and discouraging environmentally harmful activities.

Food security covers four key dimensions: Availability, accessibility, utilisation and stability (Peng et al., 2024). It is also influenced by socio-economic, environmental and governance factors. Contemporary research emphasises the need for a holistic governance structure for food systems, focusing on institutional accountability and adaptive governance to manage shocks and ensure resilience. Achieving food security always requires a synergy of agricultural innovation, poverty alleviation, effective social protection and sustainable environmental management (Pal et al., 2025).

The integration of digital technologies into economic and governance systems, often referred to as digital development, has emerged as a transformative force in advancing sustainable development, particularly in emerging nations like SSA. Innovations such as mobile banking, e-agricultural platforms, and digital monitoring of environmental metrics are enhancing institutional efficiency and citizens' access to food, finance and resources (Akpabio et al., 2025). In the context of environmental tax and food security, ICT can serve as a critical enabler by intensifying transparency in environmental governance frameworks, facilitating subsidy delivery for green agriculture and improving access to food markets (Ovais and Jain, 2025). The potential mediating effect of ICT suggests that the success of environmental tax policies may depend on the degree of sustainable digital infrastructure and institutional digitalisation.

2.2. Theoretical Review

While numerous theories explain the relationship between environmental taxation and food security, the digital transformation theory highlights the transformative role of digital technologies in enabling inclusive economic growth, governance reforms, and sustainable development outcomes (Alojail and Khan, 2023). This theory suggests that ICT infrastructure, when effectively integrated into national development policies, improves information sharing, citizen engagement, institutional efficiency, and policy implementation. In this framework, ICT is not just a technological improvement but a socio-economic driver that bridges service delivery gaps, enhances access to agricultural inputs, and strengthens food systems (Alfonsi et al., 2024).

Table 1: Definition and measurement of variables

Variable	Proxy/indicator	Measurement	Sources
Food security	Food availability (FOODACCESS) Food accessibility (FOODAVAIL)	Food production index	World development indicators
Environmental tax (ENVTAX)	Environmentally related tax revenue	% of total tax revenue	OECD
ICT penetration (ICT/ICTPEN)	Mobile and internet penetration	Index (log of internet users per 100 people)	World development indicators
Control variables	Poverty (POV), foreign direct investments (FDI), and capital input (CAP)	% of GDP, index	World development indicators

Source: Authors' Computation (2025)

Table 2: Descriptive analysis

Variables	FOODACCESS	FOODAVAIL	POV	ICTPEN	FDI	ENVTAX	CAPINPUT
Mean	5813.02	97.39	0.56	27.47	6.79	4.19	11.00
Median	4154.70	100.45	0.55	21.70	8.46	1.19	12.41
Maximum	22989.30	135.50	0.81	81.80	18.80	26.00	78.06
Minimum	462.43	56.62	0.26	0.29	−3.40	0.00	−38.53
Standard deviation	4938.07	12.89	0.12	22.76	3.30	6.49	13.40
Skewness	1.29	−0.50	−0.04	0.72	−0.60	1.70	0.26
Kurtosis	4.054	3.61	2.72	2.38	2.70	4.50	6.39
Jarque-Bera	91.61	16.19	1.02	28.89	18.22	164.00	135.67
Probability	0.00	0.00	0.60	0.00	0.00	0.00	0.00
Observations	285	285	285	285	285	285	285

Source: Authors' Computation (2025)

Table 3: Correlation matrix

Variables	FOOD ACCESS	FOOD AVAIL	POV	ICTPEN	FDI	ENVTAX	CAPINPUT
FOOD ACCESS	1.00	0.08	0.78	0.33	−0.04	−0.24	−0.18
FOOD AVAIL	0.08	1.00	0.22	0.32	0.07	0.19	0.06
POV	0.78	0.22	1.00	0.62	−0.13	−0.04	−0.09
ICTPEN	0.33	0.32	0.62	1.00	−0.04	0.25	0.16
FDI	−0.04	0.07	−0.13	−0.03	1.00	0.06	0.01
ENVTAX	−0.24	0.19	−0.04	0.25	0.06	1.00	0.15
CAPINPUT	−0.18	0.07	−0.09	0.16	0.01	0.15	1.00

Source: Authors' Computation (2025)

As a mediating factor, ICT is expected to influence the effectiveness of environmental taxation by increasing awareness, compliance, and streamlining environmental monitoring and enforcement. Therefore, the digital development perspective provides a modern approach to understanding the dynamic interaction between environmental policy tools and food security outcomes in SSA. Another theory supporting this study's aim is the environmental Kuznets curve (EKC) theory. When applied to environmental taxation, the EKC framework indicates that developing countries may initially face resistance and unintended effects from green taxes (Ben Youssef and Dahmani, 2024).

However, as institutional capacity and technological innovations, especially through digital integration, improve, environmental outcomes are likely to improve as well, supporting sustainable food security over time. Collectively, these theories offer a comprehensive perspective on how environmental taxation can be utilised, particularly in digitally emerging SSA, to promote sustainable food security.

2.3. Empirical Review of Literature

Rahaman and Islam (2025), using data from 2002 to 2021, revealed that ICT could help regulate corruption, foreign direct investments and carbon dioxide emissions. Also, it revealed that ICT is crucial for sustaining food security in the Gulf Cooperation Council states. Also, Rahaman et al. (2024) investigated the impact of ICT on food security in south Asian nations, using a panel methodology covering the period of 1997-2021. The findings reveal a symmetric relationship between ICT and food security, with higher CO_2 boosting food security. Furthermore, Adeshola et al. (2024) explore the impact of ICT and environmental taxes on CO_2 in EU nations from 2000 to 2017. Findings reveal that ICT development and green tax promote environmental sustainability. Also, the relationship between ICT and CO_2 emissions is dependent on environmental taxes.

Deng et al. (2024) examined the impact of policy uncertainty, ICT and green taxes on environmental sustainability in 22 nations from 1997 to 2021. It revealed a significant link between economic policy uncertainty and environmental degradation, while green tax and ICT positively contribute to environmental sustainability by controlling emissions and ecological footprints. Shang et al. (2024) examined the impact of globalisation on food security in SSA from 2001 to 2021. Results revealed that globalisation had a negative impact on food availability, but innovation had a positive impact. Ajeigbe and Ganda (2024) examined the relationship between food security, environmental sustainability and sustainable growth in 63 global economies from 2010 to 2021. Using a GMM, FMOLS

and DOLS methodology, findings revealed that exportation; food production, FDI, population and employment positively impacted economic growth, while they negatively impact unemployment and poverty.

3. METHODOLOGY

This study adopts a quantitative research design using a panel methodology to explore the mediating role of ICT in the relationship between environmental tax and food security in SSA. The analysis covers 15 SSA nations purposively selected over the period from 2006 to 2024, based on the availability of consistent data on environmental tax, ICT penetration, and food security indicators. The selection criteria for these countries include the availability of data on ICT usage and access, consistency in food security reporting, and the implementation of environmental tax policies.

Table 4: Variance inflation factors

Variable	Coefficient Variance	Uncentered VIF
ENVTAX	0.040340	1.093805
ICTENV	0.000239	1.001737
FDI	0.484709	1.012379
CAPINPUT	0.007129	1.091546
POV	680.1621	1.014180

Source: Authors' Computation (2025)

Table 5: Stationarity test

Variable	Level (I[0])	First difference (I[1])	Order of integration
CAPINPUT	Stationary	Non-stationary	(I[0])
ENVTAX	Non-stationary	Stationary	(I[1])
FDI	Non-stationary	Stationary	(I[1])
FOODACCESS	Non-stationary	Stationary	(I[1])
FOODAVAIL	Non-stationary	Stationary	(I[1])
POV	Non-stationary	Stationary	(I[1])
ICT	Stationary	Non-stationary	(I[0])

Source: Authors' Computation (2025)

Table 6: Kao residual co-integration test

Tests	Values/interpretations
Test statistics (ADF)	−1.40838 (P=0.08)
RESID(−1)	−0.2325 (0.0000)
D(RESID[−1])	−0.1353 (0.0224)
R-squared	0.1636
Durbin Watson	2.0
Conclusion	Reject H_0: Co-integration exists

Source: Authors' Computation (2025)

The study employs secondary data from reputable global sources. Furthermore, the data set was analysed using descriptive and inferential statistics ((Fully Modified Ordinary Least Squares (FMOLS), autoregressive distributed lag (ARDL), Fixed Panel OLS, Robust least squares and the panel general methods of moments (GMM). The regressions were combined to ensure robustness of the research findings. Also, pre-diagnostic tests such as the correlation analysis, the variance inflation factor (VIF) test, the Unit root test for stationarity and the Cointegration test. Furthermore, the use of the ARDL methodology accommodates mixed order integration and a small panel sample, typical of SSA. Also, the GMM and FMOLS models ensured the outcomes were free from serial correlation and endogeneity.

3.1. Variable Measurement and Sources

Table 1 below captures the measurement of the variables used for this study.

3.2. Model Specifications

- Model one: Baseline model

$$FOODAVAIL = \beta_{oit} + \beta_1 ENVTAX_{it} + \beta_2 FDI_{it} + \beta_3 POV_{it} + \beta_4 CAP_{it} + U_{it} \quad (i)$$

$$FOODACCESS = \beta_{oit} + \beta_1 ENVTAX_{it} + \beta_2 FDI_{it} + \beta_3 POV_{it} + \beta_4 CAP_{it} + U_{it} \quad (ii)$$

- Model two: Mediation analysis with the interaction term (ENVTAX x ICTPEN)

$$FOODAVAIL = \beta_{oit} + \beta_1 ENVTAX_{it} + \beta_2 (ICTxENVTAX)_{it} + \beta_3 FDI_{it} + \beta_4 POV_{it} + \beta_5 CAP_{it} + U_{it} \quad (i)$$

$$FOODACCESS = \beta_{oit} + \beta_1 ENVTAX_{it} + \beta_2 (ICTxENVTAX)_{it} + \beta_3 FDI_{it} + \beta_4 POV_{it} + \beta_5 CAP_{it} + U_{it} \quad (ii)$$

4. RESULTS

4.1. Descriptive Statistics

Table II below highlights the characteristics of the dataset through a descriptive analysis. The table above captures the descriptive statistics, which highlight the characteristics of the dataset. The descriptive statistics show significant variation in food security indicators and economic variables across SSA. The mean values for FOODACCESS and FOODAVAIL suggest moderately distributed accessibility across SSA, though high standard deviations (SD = 4938.07; 12.89, respectively) indicate substantial disparities. Also, poverty has a relatively constant mean of 56%, and ICT penetration averages around 27%. Notably, the environmental tax is positively

Table 7: Regression analysis

Model type	ENVTAX	ICTENV	FDI	CAPINPUT	POV	ICTENV (mediator) Significant?
ARDL (FoodAvail)	0.3149 (0.01)	0.03 (0.23)	0.11 (0.15)	−0.06 (0.16)	426.28 (0.00)	No
FMOLS	0.33 (0.10)	0.01 (0.60)	0.68 (0.33)	0.04 (0.62)	41.77 (0.11)	No
Fixed panel OLS	0.41 (0.00)	−0.00 (0.93)	0.09 (0.59)	0.01 (0.72)	72.79 (0.00)	No
Robust LS	0.28 (0.00)	0.02 (0.03)	0.04 (0.86)	0.08 (0.11)	1.57 (0.77)	Yes
GMM	0.63 (0.78)	0.05 (0.50)	−0.17 (0.84)	0.06 (0.00)	2.56 (0.89)	No
ARDL (FoodAccess)	−420.5 (0.00)	−594.31 (0.00)	−198.58 (0.21)	25.57 (0.13)	49982.1 (0.00)	yes

Source: Authors' Computation (2025)

skewed and leptokurtic, suggesting concentration of lower values with occasional spikes. These statistical properties highlight structural differences in tax regimes and ICT infrastructures across nations in SSA.

4.2. Diagnostic Statistics

4.2.1. Correlation analysis

Table 3 below examines the association among the variables in the dataset. The correlation analysis was conducted to understand the relationship between the variables and to test for multicollinearity among the independent variables. The results show that the strongest association is between poverty and food accessibility, with a coefficient of 78%. Additionally, all correlations fall within the 80% benchmark, indicating an absence of multicollinearity.

4.2.2. Variance inflation factor test

Table 4 below captures test for multicollinearity from the VIF analysis. The VIF test was also conducted to assess multicollinearity among all explanatory variables. The analysis shows that the VIF values are significantly below the threshold of 5. This suggests that there is no multicollinearity among the independent variables, and the coefficient estimates remain unbiased. Additionally, this supports the robustness of the estimated relationship.

4.2.3. Unit root stationarity test

Table 5 below reveals the outcomes from the stationarity test. From the unit root test above, it can be seen that all key variables are stationary at first difference, confirming I (1) processes, except capital input and ICT penetration, which are stationary at levels. This mix of stationarity in the variables justifies the use of the ARDL model.

4.2.4. Cointegration test

From the Cointegration test, the Kao residual-based Cointegration test confirms a long-run equilibrium relationship among food availability, environmental tax, poverty and other variables, with a borderline significant ADF statistics of 1.40 (0.08). The Durbin Watson equates of 2.0 indicates an absence of autocorrelation, supporting the robustness of the Cointegration.

4.3. Summary of Key Regression Results

Table VII below captures a key summary from the regression estimations.

4.3.1. Discussion of findings

The table above summarises all key regression results. The ARDL long-run equation indicates that environmental tax positively (0.3149) and significantly (0.01) influences food availability in SSA. These findings support the idea that environmental taxes can be reinvested into sustainable agriculture, thereby improving food systems in the long term. However, ICT as a mediator does not produce a significant outcome in the ARDL or FMOLS models, although it becomes significant (0.03) under robust least squares regression, and is negatively significant in the ARDL model for food accessibility. These outcomes align closely with Deng et al. (2024) and Adeshola et al. (2024), both of whom established that environmental taxes positively impact environmental and economic outcomes. While their focus was on environmental sustainability, this study extends the narrative to food security, particularly food availability in emerging nations.

Interestingly, poverty consistently predicts food availability and is significant across all models. This aligns with FAO (2022), which finds that poverty remains a key determinant of food insecurity in SSA. This echoes the outcomes of FAO (2022) and aligns with those of Ajeigbe and Ganda (2024), who outline the role of socio-economic factors like employment and poverty in shaping food outcomes. This depicts that poverty alleviation remains central to addressing food insecurity, regardless of environmental or ICT interventions.

Notably, the robust least squares model highlights a significant mediating effect of ICT on the relationship between environmental tax and food availability. This suggests that ICT infrastructure can help translate environmental tax into tangible improvements in food security. Conversely, the ARDL for food accessibility shows a negative long-run coefficient for ICT (-594.31, $P < 0.001$), indicating that without equitable digital inclusion, ICT expansion could widen gaps in food accessibility. This negates the findings of Rahaman and Islam (2025) and Rahaman et al. (2024), which revealed a positive and significant impact of ICT in promoting food security and reducing CO_2 emissions. This study leaves a mixed outcome, implying that ICT may only be an effective enabler of food security when governance quality, access equity and other underlying factors are addressed.

More strikingly, the ARDL model for food accessibility suggests that ICT infrastructure, if inequitably distributed in SSA, could worsen digital exclusion, limiting access to food systems for marginalised populations. This contradicts the optimistic assertions by Rahaman and Islam (2024) but is indirectly supported by Shang et al. (2024), who observed that globalisation negatively affected food availability in SSA. This reflects the dual-edged nature of ICT, where benefits are skewed toward a more connected, urban population.

4.4. Economic and Theoretical Implications

The analysis indicates that environmental taxes can create fiscal space for green investments, aligning with the Pigouvian tax principle. However, the mediating role of ICT is complex. While it proves beneficial in some models, its potential negative impact—particularly on food accessibility—raises concerns about unequal access linked to income levels and inefficient digital infrastructure investments. Therefore, considering the strong positive influence of poverty on food insecurity, broad-based social protection and targeted poverty reduction strategies remain crucial alongside environmental tax reforms. Additionally, the study supports the environmental Kuznets curve and digital development theories, suggesting that as digital infrastructure expands, it can help reduce the negative externalities of taxation.

Nonetheless, the inconsistent mediation effects highlight gaps in institutional capacity, indicating that without strong support and governance frameworks, digital tools cannot effectively mediate policy. Consequently, policymakers must not depend solely on environmental taxes to improve food security. Instead, investments in inclusive ICT—such as rural digital infrastructure and digital

literacy—are vital. Furthermore, revenue from environmental taxes should be allocated specifically for food programmes, agricultural subsidies, and poverty alleviation efforts.

5. CONCLUSION AND RECOMMENDATION

This research assessed the impact of environmental taxation on food security. It also examined the mediating role of ICT in the relationship between environmental taxation and food security in SSA. The study provides empirical evidence on the potential of environmental taxation to enhance food security in SSA, but emphasises that this impact depends on effective mediation through ICT infrastructure. The interaction between environmental and digital infrastructure policies must be carefully managed to prevent the exacerbation of existing inequalities. Although some models show promising roles for ICT, its mediating power remains inconsistent, highlighting the need for more inclusive and accountable digital policy frameworks in SSA.

From the findings, the study recommends that:

i. Governments should channel environmental taxes into agro-ecological investments and food systems resilience programs.
ii. The government should bridge the rural-urban digital divide through subsidies, mobile broadband deployment and e-agricultural platforms.
iii. Given the dominant role of poverty in the models, food security interventions must be integrated with broader anti-poverty initiatives.
iv. A mandated ICT sector reform is needed to ensure that digital transformation benefits the vulnerable population, particularly in agriculture and food distribution systems.

5.1. Contribution to Knowledge

This study makes several contributions to the literature:

i. By focusing on SSA, the study offers a comprehensive understanding of how environmental taxes and ICT interact within fragile institutional settings, contrasting the outcomes in developed nations.
ii. The integration of digital development theory as a primary lens alongside EKC theory provides a unique framework to explain the dynamic pathways through which ICT mediates environmental and food policy outcomes.
iii. Through its comprehensive methodology, employing advanced econometric analyses (ARDL, FMOLS, Robust LS, and mediation modelling), the study delivers robust empirical evidence on the triadic relationship between environmental tax, ICT, and food security.
iv. The study presents critical insights for policymakers on how digital transformation can enhance the effectiveness of green fiscal policies to sustainably address food insecurity.

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