Gendered dynamics of environmental taxation and food security in Sub-Saharan Africa

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ABSTRACT

The complex nexus between environmental taxation and food security is gaining attention in the SSA context. Notwithstanding, policy outcomes remain low and require intervention. This research gap is critical given that SSA continues to struggle with intense food insecurity, driven by climatic shocks, weak infrastructure, and socio-political instability. This study investigates the complex nexus between environmental taxation and food security in SSA with a novel emphasis on gender equity as a moderating factor. Drawing on a balanced panel dataset of 15 SSA nations from 2006 to 2024, the study employs robust econometric techniques including fixed effects (with Driscoll-Kraay standard errors), fully modified ordinary least squares (FMOLS), and panel generalized methods of moments (GMM) to estimate the direct and interaction effects of environmental taxation and gender parity on two core aspects of food security: food availability and food accessibility. Results show that environmental taxation positively impacts food availability when isolated. When moderated with gender equity, the interaction (EGGI) significantly alters the direction and strength of the relationship across models. Specifically, the mediating effect of gender equity enhances food accessibility but reduces food availability, suggesting a slight trade-off in policy design. These findings carry critical implications for policymakers: SSA governments should adopt a policy of revenue earmarking, allocating a predetermined share of environmental tax revenues to gender-responsive agricultural investments.

Contribution/ Originality: This research captures both short-term impacts and long-term policy implications to ensure impactful findings and recommendations. Lastly, by adopting a multidimensional econometric approach that covers both economic and social metrics, this research offers a comprehensive evaluation of the efficacy of environmental taxes. Additionally, the role of gender equity in shaping outcomes in resource-constrained economies is examined.

1. INTRODUCTION

Recently, environmental taxation has emerged as a crucial policy instrument in the global fight against climate change, embodying the "polluter pays" principle and aligning financial systems with environmental externalities (Ben Youssef & Dahmani, 2024; Cannas, 2024). In continents like Africa, where ecological concerns intersect with urgent developmental issues (Kanayo, Maponya, & Semenya, 2025; Sibanda, 2025), the green tax system can be transformed not just to achieve ecological goals (reducing greenhouse gas emissions and fostering sustainability) but also strategically harnessed to resolve the growing food security issue in Africa. Nevertheless, its broader socio-economic effects, particularly in low- and middle-income countries, remain debated.

Furthermore, the complex nexus between environmental taxation and food is gaining attention in the SSA context. Notwithstanding, policy outcomes remain low and require intervention. The food system of SSA presents a puzzling policy question: how can fiscal tools designed to correct environmental distortions also support food security in environments plagued by persistent poverty, informal agriculture, and gender inequalities?

Furthermore, most existing research on environmental taxation concentrates solely on the environmental and revenue aspects of green taxes (Dahmani, 2024), with limited attention to their distributive or developmental impacts. Additionally, studies exploring food security often assume a uniform effect of taxation policies across diverse demographic groups and national systems, ignoring the socio-institutional pathways through which these policies can be implemented. This research gap is critical, given that SSA continues to struggle with intense food insecurity driven by climatic shocks, weak infrastructure, and socio-political instability (Karume, Mondo, & Kiyala, 2024).

A vital omission in this discussion is a gender-sensitive perspective when assessing the welfare effects of environmental taxation (Naheed & Rukhsana, 2024). In most SSA countries, women constitute the majority of smallholder farmers and bear a disproportionate burden of household provisioning (Addo et al., 2024). Yet, structural barriers such as unequal land rights and limited access to finance and inputs undermine their agricultural productivity and economic agency. This gender gap in food systems is not merely background but a key factor mediating the effectiveness of fiscal and environmental policies. Ignoring this mediation risks overstating the neutrality or progressive nature of environmental tax policies.

Thus, this study addresses a significant gap in both theory and policy in SSA. While previous research has explored gender issues within food system development and environmental fiscal reforms in Africa (Elias et al., 2024; Naheed & Rukhsana, 2024; Snider, Adraki, Lolig, & McNamara, 2024), a notable gap remains at their intersection. This research is among the first to empirically integrate environmental fiscal theory, gender-based models, and food security outcomes within a panel economic framework tailored to the SSA context.

By using the gender gap index (GGI) as a mediating variable, the study aims to deepen understanding of how environmental taxation interacts with socio-economic structures to shape food system outcomes. This objective advances the theory by integrating gender equity into environmental fiscal theory, showing that welfare issues in Pigouvian tax systems are not uniform but may depend on institutional factors. By incorporating gender as a transformative framework rather than a control variable, the study repositions environmental tax as a gendered fiscal tool.

This invariably extends discussions on taxation and food security into an under-examined area of gender-based policies. It also calls for adaptive, integrated strategies to achieve the Sustainable Development Goals (SDGs), demonstrating how progress on SDG 13 (Climate Action) and SDG 5 (Gender Equality) can mutually reinforce efforts towards SDG 2 (Zero Hunger) in SSA. In doing so, this research not only enhances academic understanding of environmental fiscal policy and development economics but also provides practical policy advice for transforming green taxes into gender-responsive, food-security-enhancing instruments.

In addition, earlier studies often rely on descriptive analysis (Adefila, Ajayi, Toromade, & Sam-Bulya, 2024), literature reviews, or single-country case studies limit generalizability. Notwithstanding, a methodological gap exists in empirical literature due to the lack of robust panel econometric methods that account for endogeneity, heterogeneity, and cross-country structural differences in the SSA environment.

Furthermore, while studies (Ferraro & Garofalo, 2025; Sibdari & Asayesh, 2024) demonstrate how tax incentives can promote eco-friendly behavior, there is limited empirical evidence on how environmental taxes translate into quantifiable sustainability outcomes across critical economic dimensions such as environmental quality and food security in emerging economies. Moreover, this research gap is particularly relevant in SSA, where environmental and carbon tax policies are still nascent and poorly integrated with broader fiscal and social systems. Additionally, very few countries, like South Africa, have made significant strides toward institutional enforcement.

Therefore, this lacuna necessitates bridging theoretical and methodological gaps by empirically analyzing the impact of environmental taxation on food security in SSA, adopting a comprehensive dataset and advanced econometric methodology, notably the General Method of Moments (GMM). This research captures both short-term impacts and long-term policy implications to ensure impactful findings and recommendations. Lastly, by adopting a multidimensional econometric approach that covers both economic and social metrics, this research offers a comprehensive evaluation of the efficacy of environmental taxes. In addition, the role of gender equity in shaping outcomes in resource-constrained economies.

2. LITERATURE REVIEW

2.1. Theoretical Framework

In recent decades, frameworks have been established to explain the green tax-economic development nexus. In the SSA context, the integration of the environmental fiscal theory (Kandemir, Lone, & Simsek, 2024), intra-household bargaining theory (Katz, 1997), and gender and development theory (Jaquette, 2017) provides a robust multidimensional framework for evaluating the relationship between environmental taxation and food security. At the apex of environmental taxation theories is the environmental fiscal theory, which emphasizes the dual role of green taxes.

That is, environmental taxes are corrective tools for internalizing environmental externalities and as instruments for generating public funds (Ljubičić, 2025).

Yet, adopting the environmental fiscal theory lens alone may overlook intra-household mechanisms and structural inequalities. Therefore, intra-household bargaining theory is applied to address these by highlighting the differentiated power dynamics between men and women within households (Wadei, Wadei, & Bonuedi, 2025).

This clarifies that the welfare outcomes of policies like green taxes are shaped not just by economic drivers but also by decision-making authorities in the household (Mohan, 2019). This recognizes that the household is not a unitary decision-making system but relies on different key members due to differing interests and bargaining power.

Furthermore, the gender and development (GAD) theory further extends this perspective by embedding the debate within a broader systemic structure of inequality in an economy, underlining the importance of incorporating gender equity in all facets of development policy (Newman et al., 2023). This theory underscores the role of women in development goals, emphasizing their participation and contribution to economic development.

It is also hinged upon gender-sensitive policy design and implementation (SDG 5), making gender equity not a routine concern but a central driver for policy effectiveness. Furthermore, this study introduces a novel perspective in which gender equity serves as a fiscal mechanism to support or limit the impact of environmental taxation. That is, in nations with gender gaps, environmental taxes can limit food access by raising food costs.

In contrast, where gender equity thrives (through land access, targeted subsidies for women), environmental taxes can promote food availability and accessibility by channeling tax revenues into sustainable agricultural projects and programs.

This sustainable framework makes two significant contributions. Initially, it transforms the environmental fiscal theory by integrating gender equity elements. Furthermore, it endows gender equity not as a one-off economic driver but as a transformative element that mediates the environmental tax-food security nexus. Collectively, these theories enhance the efficacy of environmental fiscal instruments in achieving food security (SDG 2) and climate action (SDG 13) in SSA.
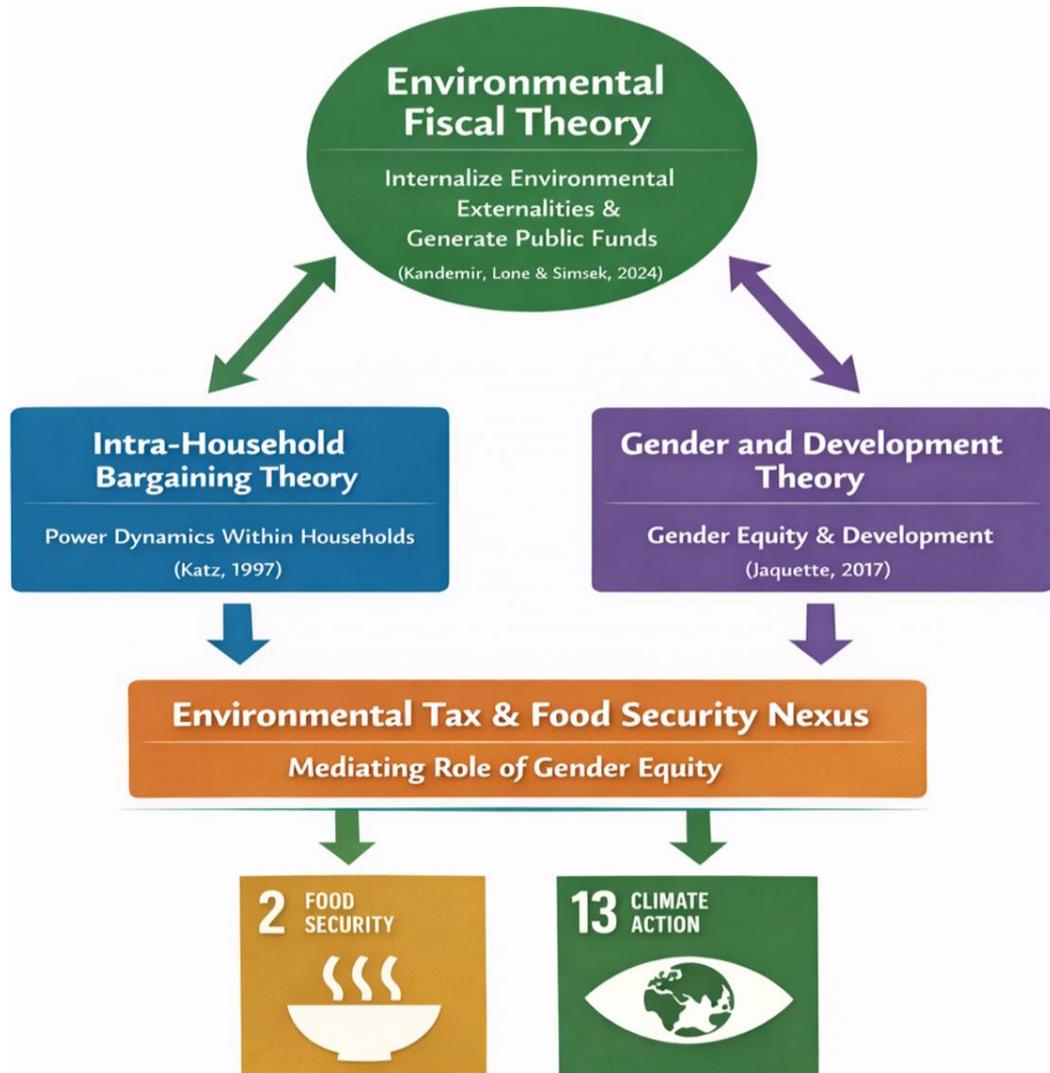
Figure 1. A multidimensional framework for analysing environmental tax and food security.

Source: Kandemir et al. (2024), Katz (1997), and Jaquette (2017).

Figure 1 illustrates the integrated relationship among the variables examined and their relation to the theories adopted in the study.

2.2. Review of Empirical Literature

The reviewed literature aims to capture discussions and findings on the green tax-food security nexus. Notably, studies such as Mpofu (2022) expressed the limited efficacy of environmental taxes in promoting eco-friendly businesses and advancing policy outcomes. This affirms the ineffectiveness of African tax systems in creating sustainable solutions. Other studies, such as those by Zhou, Adebayo, Yin, and Abbas (2023), examined the interplay between environmental levies and three key aspects of economic performance (environmental, energy, and economic security), revealing challenges in achieving synchronized success across these pillars.

Furthermore, in terms of methodology and estimation techniques, many studies have adopted advanced econometric tools, such as panel regressions, quantile regression (Andrew, Smith, & Carter, 2023), and auto-regressive distributed lag models (ARDL) (Yegana, Ali, & Khan, 2021). Notwithstanding, research findings remain context-bound to developed nations such as Europe. To affirm the current study's research focus, qualitative outputs such as Cnossen's (2023) study underscore excise duties as a revenue generation source. In addition, it promotes consumer health by raising the price of such goods. Furthermore, studies by Wisdom, Apollos, Samuel, and Lawrence

(2022) explored the relationship between environmental taxes and food security in Sub-Saharan Africa (SSA) and found a negative correlation. In contrast, Zhang, Wu, Guo, and Zhang (2023) demonstrated that imposing environmental taxes on non-green producers can promote social welfare, increase producers' surplus, and decrease consumer surplus, depending on market size and awareness of green goals. Additionally, Okere et al. (2025) focused on SSA and confirmed that environmental taxes negatively impact food security. Iyke-Ofoedu et al. (2024) also addressed the subject in SSA, emphasising that environmental taxes can serve as a powerful policy instrument. An empirical study by Adu and Ramfol (2024) examined the potential of carbon tax revenue in SSA to alleviate poverty, provided that an effective institutional framework is in place. Also, Samusevych, Kuzmenko, Vysochyna, Maroušek, and Streimikis (2021) used an optimisation model and revealed that environmental taxes should be maximised for national security through regulatory efficiency. Mahajan and Majumdar (2021) examined the relationship between environmental taxes and the comparative advantage of the food industry. Using an autoregressive distributed lag approach, they found that green taxes negatively affect food outcomes.

Furthermore, Agarwal (2018) examined the impact of gender equity on maximising food security. The study's findings revealed significant potential for gender equality to improve women's access to resources. Nevertheless, this study also highlights a lack of clarity and potential to create synergy with other SDGs. Furthermore, Naheed and Rukhsana (2024) addressed social equity, environmental sustainability, and food security. They revealed a lack of research on gender responses to climate change and recommended that interdisciplinary research is needed for sustainable outcomes. The research solely focused on SDG 5.

Despite varied outcomes in prior literature, a common gap persists in the adoption of comprehensive methodological frameworks in emerging nations. This lacuna calls for context-specific analysis that integrates macroeconomic factors through advanced modeling suited to emerging nations such as those in SSA.

3. MATERIALS AND METHODS

This study models the impact of environmental taxation on food security in SSA, incorporating gender equity as a mediating factor. The food security outcome is assessed using the two primary dependent variables: food availability and accessibility. The models are estimated using fixed effects (FE) with Driscoll-Kraay standard errors, first-difference Generalized Method of Moments, and Fully Modified Ordinary Least Squares (FMOLS) to ensure robustness and address potential endogeneity, autocorrelation, and non-stationarity. This study adopts an ex post facto research design using an established and reliable dataset.

The study focused on 15 of the 49 SSA nations, covering the period from 2006 to 2024. The period was selected due to limited data on environmental taxation and was also guided by the inception of the gender gap index in 2006. The purposive sampling technique was employed to select the sample, as not all nations in SSA had adequate data for every variable examined. Also, the technique was adopted to ensure a mix of high-performing SSA countries and fragile economies. This approach ensures meaningful representations of all levels of SSA nations.

In addition, the study used Driscoll-Kraay standard errors to correct heteroscedasticity and cross-sectional dependence, suitable for macro-panel data with temporal correlation. Furthermore, the GMM method was applied to control for fixed effects and address reverse causality and simultaneity bias. Finally, FMOLS addresses non-stationarity and provides long-term elasticity estimates in co-integrated panels.

Finally, the use of GDP per Capita to capture food accessibility is justified, as in SSA, it is strongly correlated with purchasing power and household food affordability, making it a macro-level metric for economic access to food. Although it captures economic welfare, it remains a robust measure for food accessibility, particularly in SSA, where food expenditure constitutes over 50% of household income (Shang et al., 2024)

3.1. Model Specifications

To ensure a robust analysis, two models were estimated for each outcome. Model 1A (see Table 8) examines the direct effects of ENVTAX, GGI, FDI, and CAPINPUT on Food Availability using FE estimators. Model 1B (see Table 9) introduces the interaction term EGGI to capture the moderating role of gender equity. Similarly, models 2A and 2B (see tables 10 and 11, respectively) replicate this approach for food accessibility.

1. Baseline Fixed Effects Model (with Driscoll-Kraay Standard Errors)

   Model 1A: Direct effects of ENVTAX, GGI, FDI, and CAPINPUT on Food Availability

   $\text{FOODAVAIL} = \beta_0 + \beta_1\text{ENVTAX}_{it} + \beta_2\text{GGI}_{it} + \beta_3\text{FDI}_{it} + \beta_4\text{CAPINPUT}_{it} + U_{it}$ (i)

   Model 1B: Interaction Model with ENVTAX x GGI

   $\text{FOODAVAIL} = \beta_0 + \beta_1\text{EGGI}_{it} + \beta_2\text{FDI}_{it} + \beta_3\text{CAPINPUT}_{it} + U_{it}$ (ii)

   Where:

   $\text{EGGI}_{it} = \text{ENVTAX}_{it} \times \text{GGI}_{it}$: Interaction term capturing how gender equality conditions the effect of environmental tax on food security.

2. GMM Model (First Difference)

   This model was used to address endogeneity, omitted-variable bias, and autocorrelation.

   $\Delta\text{FOODAVAILit} = \delta1\Delta\text{EGGIit} + \delta2\Delta\text{FDIit} + \delta3\Delta\text{CAPINPUTit} + \eta\text{it}$ (iii)

Lagged levels of the dependent and independent variables are used as instruments.

3. FMOLS Model for long run Elasticities (FOOD ACCESSIBILITY)

   $\text{FOODACCESS} = \beta_0 + \beta_1\text{EGGI}_{it} + \beta_2\text{FDI}_{it} + \beta_3\text{CAPINPUT}_{it} + U_{it}$ (iv)

   The FMOLS model corrects for endogeneity and serial correlation in non-stationary panels, allowing for co-integration relationships.

   Where:

   FOODACESS = Food Availability.

   FOODAVAIL = Food Accessibility.

   GGI = Gender Equity.

   FDI = Foreign Direct Investment.

   CAPINPUT = Capital Input.

   ENVTAX = Environmental Taxes.

3.2. Definition and Measurement of Variables

This section provides specific details on the variables employed in this study and how they were operationalised. Table 1 presents the measurements and sources of the variables.

Table 1. Definition and sources of variables.

Variable	Measurement	Sources
FOODAVAIL	Food production index	Czyżewski, Staniszewski, Staniszewska, and Guth (2025)
FOODACCESS	GDP per capita	Peng, Shuai, Yin, Qi, and Chen (2024)
ENVTAX	Environmental tax revenue as a share of GDP	(Okere et al., 2025)
GGI	Gender gap index score (0-100 scale)	Kramer (2025)
FDI	Net foreign direct investment inflows as a share of GDP	Alfalih (2024)
CAPINPUT	Gross fixed capital formation as a share of GDP	Achar, Luther, Ochieng, and Odhiambo (2024)
EGGI	Interaction term (ENVTAX x GGI)	Moderation Model (Section 3.1)
N	Number of country-year observations	Panel: SSA nations over multiple years (2006-2024)

The descriptive statistics of the variables used in this study are presented in Table 2.

Table 2. Descriptive tests.

Variable	Mean	SD	Min.	Max.	Skewness	Kurtosis
FOODAVAIL (kg cap-yr)	97.76	12.72	56.62	135.50	-0.51	3.85
FOODACCESS (GDP per capita)	6089	4979	580	22989	1.25	3.90
ENVTAX (% total tax)	3.11	5.37	0.00	21.93	2.22	6.62
GGI(0-1)	0.651	0.111	0.190	0.809	-2.40	9.60
FDI(%GDP)	6.65	3.36	-3.40	18.80	-0.52	2.59
CAPINPUT(%GDP)	10.53	12.71	-38.53	54.52	-0.23	4.74

4. RESULTS

4.1. Descriptive Analysis

This panel analysis covers 15 SSA countries (2006-2024, N = 263). The analysis shows that food supply is generally adequate (97.8 kg per year), but the left-skewed tail indicates a vulnerable tail of chronically food-deficient economies. Furthermore, economic accessibility is more evenly distributed: the mean daily food expenditure is equivalent to #6089, but the range extends from #600 to nearly #23,000, resulting in high dispersion and a long right tail. Additionally, environmental tax efforts average just 3.1% of total taxation but are highly concentrated; most observations are near zero, while a few countries are significant green-tax leaders. The gender gap index (GGI) centers on 0.65 (0 = perfect inequality; 1 = full parity) but ranges from 0.19 to 0.81, indicating considerable diversity in women's economic agency. Moreover, pairwise correlation already hints at the regression story.

Table 3. Correlation analysis.

Variables	FOODAVAIL	FOODACCESS	ENVTAX	FDI	GGI	POV	CAPINPUT
FOODAVAIL	1.00	0.09	0.29	0.06	0.32	0.25	0.11
FOODACCESS	0.09	1.00	-0.16	0.01	0.37	0.77	-0.21
ENVTAX	0.29	-0.16	1.00	-0.06	0.16	0.12	0.23
FDI	0.06	0.01	-0.06	1.00	-0.10	-0.07	0.01
GGI	0.32	0.37	0.16	-0.10	1.00	0.61	-0.02
POV	0.25	0.77	0.12	-0.07	0.61	1.00	-0.12
CAPINPUT	0.11	-0.21	0.23	0.01	-0.02	-0.12	1.00

4.2. Diagnostic Test

Table 3 above captures the correlation analysis of the variables. The goal is to test for multi-collinearity, which posits a benchmark of less than 80% for positive outcomes (Okere et al., 2025). From the associations above, there is no multicollinearity. Table 4 presents the Variance Inflation Factor tests for multicollinearity.

Table 4. Variance inflation factor test for food availability and food accessibility models.

Variables	Food Availability	Food Accessibility	Interpretation
EGGI	1.120	1.120	No multicollinearity
FDI	1.005	1.005	No multicollinearity
CAPINPUT	1.126	1.126	No multicollinearity

From the VIF test above, all VIF values are below the acceptable threshold of five, indicating no multicollinearity. Table 5 presents the stationarity test using a unit root analysis

Table 5. Unit root analysis.

Variables	Level stationarity	1st Difference stationarity	Order of integration
CAPINPUT	Stationary (p < 0.01)	-	I(0)
EGGI	Non-stationary	Stationary (p < 0.01)	I(1)
ENVTAX	Non-stationary	Stationary (p < 0.01)	I(1)
FDI	Non-stationary	Stationary (p < 0.01)	I(1)
FOODACCESS	Non-stationary	Stationary (p < 0.01)	I(1)
FOODAVAIL	Non-stationary	Stationary (p < 0.01)	I(1)
GGI	Non-stationary	Stationary (p < 0.01)	I(1)

From the unit root analysis in Table 5, the P-values indicate mixed stationarity. While CAPINPUT is stationary at level I(0), all other variables are stationary at first difference I(1). These outcomes justify the use of panel cointegration estimation, such as FMOLS, to evaluate the long-run relationship. Table 6 presents the cointegration statistics relating to the analysis.

Table 6. Kao residual co-integration test.

Test statistics (ADF)	-2.1133(p = 0.0173)
RESID(-1)	-0.2859(0.0000)
D(RESID(-1))	-0.1087(0.0656)
R-squared	0.19
Durbin-Watson	2.0
Conclusion	Reject H_0: Co-integration exists

The Augmented Dickey-Fuller test was performed to determine stationarity in the cointegration residuals. The significant negative coefficient of RESID (-1) affirms that the residuals are stationary, indicating cointegration. Also, the Durbin-Watson is approximately 2.0, suggesting no autocorrelation in the residuals.

Table 7. Key Diagnostic Tests.

Tests	Statistics (range)	P-value	Inference
Pesaran CD (cross-section dependence)	14.3-29.4	< 0.001	Presence of dependence = Robust SEs needed
ADF-Fisher (unit root, levels)	54.4-59.9	0.00 - 0.01	Non-stationary
ADF-Fisher (first diff.)	61.8-95.3	< 0.001	Stationary at I(1)
VIF (all regressors)	1.00-1.13	-	No multi-collinearity
Hausman (FE vs. RE) FOODAVAIL	X^2 = 47.64	< 0.001	FE Preferred
Hansen/J (GMM)	J = 12.64 (df = 14)	0.24	Instrument valid

Table 7 synthesises the key diagnostic tests. The analysis shows that all key variables are first-difference stationarity. (ADF-Fisher; p < 0.01) and exhibit strong cross-sectional dependence (Pesaran CD > 14, p < 0.001). Also, multi-collinearity is negligible (VIF = 1.1).

Consequently, the analysis relies on (i) Driscoll-Kraay fixed effects (FE) to accommodate cross-sectional correlation, (ii) fully modified ordinary least squares (FMOLS) for long-run co-integration relations, and (iii) dynamic panel GMM to handle endogeneity and serial correlation.

Table 8. Summary of all regressions.

Dependent Variable	Model	Variables	Coef.	P-Value	Adj R²
FOODAVAIL	Pooled OLS	ENVTAX	0.546	0.0001*	0.162
		GGI	34.373	0.0000*	
		FDI	0.382	0.0770	
		CAPINPUT	0.057	0.3250	
FOODAVAIL	Random Effects	ENVTAX	0.546	0.0000*	0.169
		GGI	37.916	0.0000*	
		FDI	0.401	0.0608	
		CAPINPUT	0.064	0.2423	
FOODAVAIL	Fixed Effects	ENVTAX	0.492	0.0000*	0.410
		GGI	106.467	0.0000*	
		FDI	0.615	0.0027*	
		CAPINPUT	0.029	0.3689	
FOODAVAIL	Mediating (ENVTAX×GGI)	EGGI	0.937	0.0000*	0.156
		FDI	-0.251	0.3215	
		CAPINPUT	0.068	0.1098	
FOODAVAIL	FMOLS	EGGI	0.969	0.0063*	0.076
		FDI	0.495	0.4866	
		CAPINPUT	0.174	0.0898	
FOODAVAIL	GMM	FOODAVAIL (-1)	0.713	0.0000*	−
		EGGI	1.018	0.7762	
		FDI	-1.086	0.1147	
		CAPINPUT	0.096	0.0000*	
	Robust OLS	EGGI	0.668	0.0005	0.031
		FDI	0.163	0.4287	
		CAPINPUT	0.031	0.5820	
FOODACCESS	Pooled OLS	EGGI	-317.830	0.0000	0.322
		FDI	60.298	0.3473	
		CAPINPUT	-20.214	0.0286	
FOODACCESS	Fixed Effects	EGGI	-266.568	0.0000	0.945
		FDI	-21.572	0.2742	
		CAPINPUT	-10.006	0.0006	
FOODACCESS	FMOLS	EGGI	-306.477	0.0000	0.887
		FDI	121.284	0.2262	
		CAPINPUT	-30.338	0.0359	

Note: $p < 0.05$, *.

4.3. Regression Analysis

The regression output reveals complex outcomes from the analysis. Across all models, gender equity (GGI) and its mediating effect on environmental tax (EGGI) consistently have a positive and significant impact on food availability. These findings highlight the importance of social inclusion in the formulation of food security policy. Furthermore, environmental taxes significantly increase food availability, suggesting that green taxes positively affect agricultural outcomes and resource management. Also, the control variables (FDI & CAPINPUT) show mixed outcomes. While FDI is occasionally significant, CAPINPUT is consistently impactful across all models, indicating its contribution to the model.

In contrast, the impact of gender equity mediation and environmental taxes on food accessibility shows a negative and significant relationship. This negative extends to the effects of capital input, suggesting that investment in agriculture may not automatically translate into positive outcomes.

Table 9. Summary of key regression output.

Dependent variable	Estimator	ENVTAX	GGI	ENVTAX x GGI (EGGI)	FDI	CAPINPUT	N	R² Adj.
FOODAVAIL	FE(D-K)	0.49*** (0.11)	106.47*** (10.89)	-	0.61** (0.20)	0.03 (0.03)	263	0.41
	FE(D-K) with moderator	-	-	0.94*** (0.20)	-0.25 (0.25)	0.07 (0.04)	263	0.16
	GMM (1st diff.)	-	-	1.02 (3.58)	-1.09 (0.69)	0.10*** (0.02)	233	-
FOODACCESS	FE(D-K)	-	-	-266.6*** (17.5)	-21.6 (19.7)	-10.0*** (2.9)	263	0.954
	FMOLS (long run)	-	-	-306.5*** (49.4)	121.3 (100.0)	-30.3** (14.4)	247	0.887

Note: Robust (Driscoll-Kraay) standard errors in parentheses. ***$p < 0.01$, **$p < 0.05$.

5. DISCUSSION

This study examines the relationship between environmental taxes and food security in SSA. According to the regression analyses in the table above, environmental taxation has a dual, contrasting effect on food security. On the supply side (FOODAVAIL), a percentage increase in environmental tax revenue raises per-capita food availability by 0.5kg annually. This suggests that the fiscal space created by green taxes is directed (either directly or through broader public finance) into agricultural R&D, rural roads, and irrigation investments that expand a country's domestic food supply. Conversely, the distribution (FOODACCESS) channel presents a different picture. When the gender gap is wide, the interaction (EGGI) is strongly negative for food accessibility, suggesting that the cost-push effects of taxation raise food prices, which disproportionately harm nations where women have limited earning power or control over assets. In contrast, the same interaction is positive for food availability, indicating that gender-inclusive economies are better able to convert green tax revenue into productive gains effectively. The dynamic GMM underscores considerable inertia (Lagged FOODAVAIL = 0.71), indicating today's calorie supply largely depends on yesterday's food availability levels, and the mediating effect appears mainly in the medium to long run (FMOLS). Furthermore, capital deepening, when labor-saving, tends to worsen food accessibility, while FDI offers a modest supply-side benefit. The research findings contradict those of Mahajan and Majumdar (2021) and Wisdom et al. (2022), which suggest a negative relationship between environmental tax and food security. Also, the research outcome aligns with those of Zhang et al. (2023), who noted that environmental taxes can improve social welfare, especially where green awareness is established. Furthermore, when food accessibility is considered, the outcomes are complex. The research findings align with those of Mpofu (2022), who underscored the misalignment of environmental tax systems with real-world economic constraints, especially in emerging economies. However, our findings align with those of Cnossen (2023), who cautioned that environmental taxes, though capable of improving public health and revenue, may burden low-income consumers through price hikes on essential goods. In addition, the inclusion of gender equity adds an important layer of policy relevance, as Agarwal (2018) and Naheed and Rukhsana (2024) emphasise that gender-responsive climate action promotes inclusive development and more SDG synergies. Finally, the role of capital input is shown to be statistically significant and positive, underscoring the importance of investments toward sustainable food systems. In contrast, FDI showed a negative outcome, consistent with Zhou et al. (2023), who cautioned against overreliance on external investment as a vehicle for sustainability.

5.1. Economic and Theoretical Implications

Theoretically, this study offers a significant contribution to the evolving literature on environmental fiscal policy by integrating principles of environmental taxation theories with intra-household bargaining models. It moves beyond the traditional view of Pigouvian taxation as a uniformly efficient tool for internalizing environmental

externalities by illustrating that its distributive and welfare impacts are institutionally contingent. Specifically, the findings suggest that the effect of environmental tax reforms on food security is mediated by gender dynamics, particularly the degree of economic parity between men and women.

This intersectional lens enriches existing theoretical frameworks by revealing that the same tax instrument can yield divergent welfare outcomes across contexts, depending on structural inequalities such as the gender gap. Furthermore, the study empirically expands the notion of sustainable development goals (SDG) complementarity; progress in climate mitigation (SDG 13) and gender equality (SDG 5) are not merely parallel aspirations but synergistic drivers of food security outcomes (SDG 2). This triadic relationship highlights the theoretical necessity of incorporating gender-sensitive analysis into the design of climate and food security policies.

From a practical standpoint, this study calls for a transformation in how policymakers conceptualize and implement environmental policies. That is, rather than treating green taxes solely as revenue-generating or emission-reducing mechanisms, the research suggests they should be seen as policy tools capable of advancing or limiting the SDGs depending on the institutional setting. These outcomes have profound implications for public finance management in SSA, where both environmental degradation and gender inequality remain pressing concerns. It necessitates multi-sectoral coordination, particularly between the Ministry of Finance and the Ministries of Environment, Agriculture, and Gender, to ensure that environmental fiscal reforms are not only economically efficient but also socially equitable and developmentally inclusive. The practical outcomes are that fiscal instruments must be embedded in a broader governance framework that is sensitive to the social, economic, and institutional landscape in which they operate.

5.2. Policy Implications

The policy implications of these research findings are both far-reaching and urgent. This can be achieved by

i. SSA governments should adopt a policy of revenue earmarking whereby a predetermined share of environmental tax revenues is allocated to gender-responsive agricultural investments. These may include subsidizing access to climate-resilient inputs for women farmers, enhancing their adaptive capacity and productivity.

ii. Second, institutionalizing gender budgeting across all stages of green tax policy, from legislative design to budgetary allocation, would ensure that differential impacts across genders are identified, quantified, and mitigated. This would embed equity considerations within the technical apparatus of tax reform, making policies not only greener but fairer.

iii. Moreover, investment promotion policies, such as tax holidays and preferential licensing, should be linked to inclusive sourcing requirements. For example, foreign direct investment (FDI) incentives in the agri-food sector could be conditioned on sourcing a percentage of inputs or services from women-led enterprises. This would not only promote local economic empowerment but also ensure that climate-smart investments are equitably distributed.

iv. Finally, to counteract the potential labour-displacing effects of capital-intensive adaptation technologies, the government should introduce tax incentives for firms that adopt labour-absorbing, environmentally sustainable technologies. Such a policy mix would harmonize the goals of employment generation, gender equity, and environmental sustainability in SSA.

6. CONCLUSIONS

This study concludes that environmental taxation holds the potential to serve as a dual-purpose policy instrument, simultaneously promoting climate mitigation and enhancing food security in SSA. However, its success in achieving these dual objectives is not automatic; instead, it is critically hinged on the degree of gender equality

within the economy. In contexts characterized by high gender parity, environmental taxes are more likely to catalyze inclusive agricultural productivity growth without eroding food availability.

Conversely, in gender-unequal settings, such taxes may inadvertently impose regressive burdens, particularly on women and low-income households, by raising the cost of food and exacerbating accessibility inequalities. The central policy insight is that integrating gender-sensitive reforms into environmental fiscal strategies transforms what might otherwise be a regressive tax instrument into a pro-poor, climate-smart, and inclusive development tool.

Accordingly, achieving equity-enhancing climate adaptation in the region requires not only good fiscal design but also deliberate institutional investments in social inclusion. Therefore, the study recommends the following pathways.

i. The government should systematically integrate gender impact assessments into all stages of green tax policy formulation.

ii. A defined proportion of environmental tax revenue should be channeled into initiatives that directly enhance food security and gender equity. These include climate-smart agricultural technologies for women, support for land access, and targeted rural extension services.

iii. Investment promotion strategies should embed local sourcing thresholds that favor women-led agribusinesses. This would help channel environmentally tax-incentivized investments toward inclusive value chains.

iv. The government should consciously invest in robust data systems to track the gender-disaggregated impacts of environmental taxation and food security indicators. This will support dynamic, adaptive policymaking grounded in practical realities.

6.1. Limitations of the Study

While the findings of this study provide valuable insights into the interconnectedness between environmental taxation, gender equity, and food security in SSA, several limitations must be acknowledged. First, data constraints pose a significant limitation. The absence of household-level or individual-level data restricts the ability to capture distributional effects across socio-economic groups. Second, the use of food availability and accessibility may not fully capture the multidimensionality of food security. Similarly, the use of the gender gap index, though widely accepted, may not reflect context-specific gender power dynamics, particularly in the informal economy.

Furthermore, although estimators applied strengthen internal validity, the analysis remains correlational due to the absence of exogenous instruments or randomized interventions. Thus, while associations are statistically robust, we refrain from assuming definitive causality and recommend that future studies adopt quasi-experimental designs to establish causal effects.

In addition, a key limitation of the study is its dataset, which uses GDP per capita to capture not only food accessibility but also broader economic welfare. However, given the unique nature of SSA, it is a robust metric to capture food accessibility. Finally, the data on environmental taxes aggregate multiple forms of fiscal instruments, which may mask heterogeneity in research design and the application of research outcomes across SSA. The study addressed this by adopting a multi-estimator methodology.

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