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Mohammed Elhaj Mustafa Ali

Ebaidalla Mahajoub Ebaidalla

Working Paper 060-2026

Bringing Rigour and Evidence to Economic Policy Making in Africa

CONSORTIUM POUR LA RECHERCHE ÉCONOMIQUE EN AFRIQUE

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Mohammed Elhaj Mustafa Ali
Development Studies and Research Institute (DSRI), University of Khartoum

Ebaidalla Mahajoub Ebaidalla
Ibn Khaldon Center for Humanities & Social Sciences, Qatar University

AERC Research Paper 060-2026
African Economic Research Consortium,
Nairobi
March 2026

Published by: The African Economic Research Consortium
P.O. Box 62882 - City Square
Nairobi 00200, Kenya

Abstract

Despite the growing prevalence of non-farm activities (NFA) in rural Sudan, their implications for household consumption and welfare remain underexplored. This study investigates the determinants of rural household participation in NFAs and assesses their impact on household consumption levels in Sudan.

The research utilizes data from the 2015 Sudan National Baseline Household Survey (NBHS) and applies an endogenous switching regression model (ESRM) to address potential selection bias and endogeneity. This methodology jointly estimates the decision to participate in NFAs and the corresponding consumption outcomes for participant and non-participant households.

The results show that household head gender, education, age, media access, credit access, rain-fed irrigation, farm income, distance to urban centers, and regional location significantly impact both NFA participation and household consumption. Treatment effect estimates indicate that NFA engagement significantly increases total and food consumption, with results consistent across wage employment and self-employment types.

This study makes key contributions to the literature by being the first to empirically assess the impact of NFAs on household consumption in Sudan. Additionally, it provides novel insights into the heterogeneous welfare outcomes of wage-based versus self-employment NFAs in rural areas.

Keywords: Non-farm activities, Household consumption, Food consumption, endogenous switching regression model.

1. Introduction

Non-farm activities (NFA) are a defining feature of rural economies in developing countries (De Janvry, 2005; World Bank, 2007; Haggblade et al., 2010). Their rapid expansion over recent decades has made them a crucial economic component (Barrett et al., 2001; Imai et al., 2015). Scholars have increasingly examined the drivers and livelihood impacts of NFA (Che-Mat, 2011; Di Falco and Veronesi, 2013; Ebaidalla, 2022), with many view them as a strategy for alleviating rural poverty and bridging rural–urban disparities (Foster and Rosenzweig, 2004; Abdul-Hakim and Hadijah, 2011).

Evidence suggests that NFA supports rural development by generating employment, reducing agricultural land pressure, increasing per capita income, and boosting household consumption (Reardon et al., 2001). While its income-generating role is well-documented, the link between NFA and improved household consumption is particularly critical, as consumption more accurately reflects material well-being than income, which is often underreported (Mukherjee and Benson, 2003; Varlamova and Larionova, 2015). Empirical studies confirm that NFA enhances household welfare through increased consumption (Hoang et al., 2014; Seng, 2015; Zereyesus et al., 2017; Hossain and Al-Amin, 2019).

In Sudan, similar to other Sub-Saharan African (SSA) countries, rural households engage in diverse NFAs. According to the 2015 National Baseline Household Survey (NBHS), 45% of rural households participate in at least one NFA. These activities are presumed to enhance consumption by supplementing income, thereby increasing purchasing power and enabling access to food, education, healthcare, and other essentials. Nonetheless, despite high NFA participation, rural poverty remains elevated, with a headcount of 39.6%. This raises critical questions about NFA's actual impact on household consumption. To date, no empirical study has thoroughly investigated this relationship in the Sudanese context.

This study addresses this gap by assessing whether NFA participation improves total household consumption, measured per adult equivalent, and whether the effect varies by employment type (wage vs. self-employment). It offers four main contributions. First, it underscores the economic development potential of NFAs in enhancing rural livelihoods. Second, by examining NFA's contribution to household consumption, a core component of aggregate demand, it informs macroeconomic policy, particularly in relation to GDP growth. Third, it employs an Endogenous Switching Regression Model (ESRM) with Average Treatment Effect on the Treated to address selection bias and unobserved heterogeneity in household decisions regarding NFA participation. Finally, it provides timely insights into how NFAs can support capital accumulation and rural development in Sudan's fragile, undercapitalized economy. Sudan's unique challenges, political instability, weak institutions, and low diversification make it a compelling case for broader SSA policy implications.

The remainder of the paper is organized as follows: Section 2 reviews the literature; Section 3 outlines the data and methodology; Section 4 presents and discusses the results; and Section 5 concludes with policy recommendations and future research directions.

2. Conceptual Framework and Literature Review

2.1 Conceptual framework

This study uses Hoffman's (1991) theoretical framework to examine the factors influencing participation in NFA and their effect on household consumption. The model assumes that farm households aim to maximize utility (U) by optimizing income from both farm and non-farm activities. The utility is derived from consumption (Y_1) and leisure (L), with exogenous factors (Y_2) affecting household preferences. The utility-maximizing function is expressed as:

$$U = f\left(Y_{1,}L; Y_{2,}\right)$$

The utility function is maximized subject to the time allocation constraint:

$$T = F_t + F_{non} + L$$

And the budget constraint:

$$P_c Y_1 = (P_f Q_f - W_1 F_t) + W_2 F_{non} + V$$

Where:

T is total time, allocated between farm activities (F_t), non-farm activities (F_{non}), and leisure (L); W_1 and W_2 are wages for farm and non-farm activities; P_k is the price of consumption goods, Y_1 is the consumed commodity, Q_f and P_f are the farm's output and market price; W_1F_t represents the cost of farm production, while $(P_f Q_f - W_1 F_t)$ is the farm's net income; $W_2 F_{non}$ denotes income from NFA, and V represents non-labor income.

The exogenous factors affecting farm output include factor inputs (Z_1) like labor, and household characteristics (Z_2) such as education, gender, and physical ability of the household head. Solving for the utility maximization problem leads to the non-farm labor supply function:

$$F_{non} = f\left(W_1, W_2, P_f, P_c\, ; Z\right)$$

According to Huffman (1991), a household will allocate time to non-farm activities if the market wage (W_i^m) exceeds the reservation wage (W_i^r). Thus, F_{non} is a dummy variable:

$$F_{non} = 1 \text{ if } W_i^m > W_i^r \text{ and } F_{non} = 0 \text{ if } W_i^m \leq W_i^r$$

Therefore, the household's decision to participate in NFA can be modeled as an index function:

$$F_{non}^* = \beta Z_i + \mu_i$$

Where $F_{non} = 1\ if\ F_{non}^* > 0, F_{non} = 0\ if\ F_{non}^* \leq 0$. The vector Z_i includes household and geographical characteristics influencing both reservation and non-farm income. Participation in NFA generates additional income, which is expected to increase total consumption for rural households.

2.2 Literature Review

The literature on NFA primarily addresses two issues: the factors driving participation and the impact on well-being. Participation is shaped by push, pull, and evolutionary economic factors. Push factors, such as poverty, disasters, vulnerability, and food insecurity, compel households to engage in NFA out of necessity (De Janvry et al., 2005; Che-Mat, 2011; Di Falco and Veronesi, 2013; Fox, 2015; Ebaidalla, 2022). In contrast, pull factors view NFA as a voluntary strategy to improve living standards, generate profits, and accumulate wealth (Corral and Reardon, 2001).

However, both perspectives tend to treat participation as involuntary and static, overlooking how sustained engagement in NFA can transform rural household behavior over time. As De Janvry et al. (2005) argue, diversification can become a self-reinforcing process. Tangible assets acquired through NFA facilitate its expansion, while intangible spillover effects among participants further accelerate its adoption. Thus, NFA may evolve beyond a temporary coping strategy into an autonomous engine of rural livelihood transformation.

Agricultural productivity influences NFA participation through both push and pull mechanisms, depending on the economic context. High productivity can reduce labor demand in farming, freeing workers for non-farm opportunities (Lanjouw & Lanjouw, 2001; Haggblade et al., 2010), while increased agricultural income can fund investments in non-farm enterprises, education, or migration (Barrett et al., 2001). In contrast, low or volatile productivity may push households toward NFA as a coping strategy for declining farm income (Reardon, 1997; Ellis, 1998). Thus, agricultural productivity acts as both a catalyst for opportunity-driven diversification and a response to economic distress.

The second strand of literature documents NFA's positive impact on well-being, including poverty reduction, reduced land pressure, technological adoption, and consumption smoothing (Foster and Rosenzweig, 2004; Abdul-Hakim and Hadijah, 2011). Economic theory posits consumption as a more accurate proxy for material well-being than income, especially in the short term (Deaton and Zaidi, 2002; World Bank, 2007). Consumption better reflects living standards, is less susceptible to seasonal fluctuations (Adjognon et al., 2017), and more accurately captures poverty at the lower end of the income distribution (Meyer and Sullivan, 2003). This is particularly relevant for vulnerable rural populations, who may underreport non-farm income, especially from self-employment (Martinez-Lopez, 2013).

Empirical evidence consistently shows that NFA enhances food and total consumption. Seng (2015) found significant increases in per capita food consumption among Cambodian NFA participants. Mishra et al. (2015) reported similar results in Bangladesh and Nigeria. Osarfo et al. (2016) showed that combining farming with NFA improved consumption smoothing in Ghana, while Zereyesus et al. (2017) and Adjognon et al. (2017) documented improvements in food security and poverty resilience in Ghana and Malawi, respectively.

Despite this growing evidence, the specific impact of NFA on household consumption in Sudan remains underexplored, even though 67% of the population resides in rural areas. This study addresses this gap by evaluating the consumption effects of NFA among Sudanese households and examining whether these effects vary by employment type, thus contributing novel insights to the literature.

3. Methodology and Data

3.1 Estimation Strategy

The decision to engage in NFA and its impact on household consumption is analyzed in two stages. First, a selection model identifies households that choose NFA based on expected benefits. Second, we assess the impact of NFA on total household consumption, including a specific focus on food consumption. To strengthen the analysis, NFA is further disaggregated by type of employment.

Determinants of NFA

Building on the earlier conceptual framework, rural households are more likely to engage in NFA when its returns exceed both their reservation wage and the value of leisure (Seng, 2015). Following Hoffman (1991) and Chang and Mishra (2008), the household's decision to participate in NFA can be formally expressed as:

$$I = \alpha Z + \varepsilon \qquad (1)$$

$$I^{*} = \begin{cases} 1, \text{if nonfarm participant} \\ 0, \text{otherwise} \end{cases} \qquad (2)$$

Equation (2) represents a probit model that captures the relationship between household and farm characteristics and the decision to engage in NFA. I^{*} is a latent variable representing the household's unobserved propensity to engage in NFA. It takes the value 1 if the household engages in NFA, and 0 otherwise. α is a vector of unknown parameters; ε is the error term; Z is a vector of household, farm, and locational factors influencing family's decision to engage in NFA.

Impact of NFA on household consumption

Changes in income significantly influence households' consumption decisions, making their consumption dependent on both farm and non-farm incomes. NFA enhances household budgets, leading to increased consumption expenditures that would otherwise be unattainable. To elaborate, let $\mathrm{C} = \mathrm{f(X)}$ represents the relationship between households' consumption (C) and a set of observed conventional variables (Z). Assuming that households' consumption is a linear function of these predictors (i.e. observed variables) along with a binary variable for NFA, the linear model to deliver NFA impact on households' consumption can be specified as:

$$C = \beta X + \delta I + \nu \qquad (3)$$

Where C represents households' total consumption; X are the observed variables that conventionally affect households' consumption; I is a dummy variable to capture NFA impact on household consumption; β and δ are the parameters to be estimated, and v is disturbance term. Again, the vectors of variables Z in Equation (1) and X in Equation (3) may overlap, however; at least one variable in the vector Z must impose no effect on household's consumption but could be having a probable effect on participation in NFA.

The concern centers on endogeneity and self-selection bias in the coefficient δ, which captures the impact of NFA on household consumption. This coefficient may be biased and inconsistent due to rural households' self-selection into NFA participation. Sample selection bias occurs when unobserved factors, known to households but not the researcher, influence NFA participation decisions. For instance, wealthier households are likely to have higher consumption levels, regardless of their NFA participation status. Additionally, the voluntary nature of NFA participation may reflect self-selection, with participants potentially differing systematically from non-participants in ways that affect their decision based on expected benefits. Thus, NFA participation is potentially endogenous, leading to biased estimates and inconsistent (Kassie et al., 2011).

The endogenous switching regression model (ESRM), proposed by Maddala (1983), effectively addresses key econometric challenges such as endogeneity and selection bias. It often outperforms alternative methods like propensity score matching and instrumental variable methods. ESRM first models the decision to participate in NFA, then estimates separate outcome equations for total household consumption under the two regimes: participants and non-participants. Based on the selection equation, the model specifies outcomes under these distinct regimes as follows:

$$\text{Regime 1: } C_1 = \beta_1 X_1 + \varepsilon_1 \quad if\ I = 1 \tag{4}$$

$$\text{Regime 2: } C_0 = \beta_0 X_0 + \varepsilon_0 \quad if\ I = 0 \tag{5}$$

Where C_j with $j = 1{,}2$ is a $n \times 1$ vector of continuous variables, representing households' total consumption for farm and non-farm participants, respectively; X_j represents a $\mathrm{n} \times \mathrm{k}$ matrix of predictors; β_j is $k \times 1$ vector of coefficients to be estimated for the two regimes; I^* is a latent variable that remains as defined in Equation (2). To capture the correct specification of ESRM, Z must contain all variables appearing in I^* along with at least one valid instrument variable (IV), which is included in the selection model and excluded from the outcome equation. The error terms $\varepsilon,\ \varepsilon_0\ and\ \varepsilon_1$, are assumed to follow a joint normal distribution with zero means and a non-singular covariance matrix, as expressed in Equation (6):

$$\operatorname{cov}(\varepsilon, \varepsilon_1, \varepsilon_0) = \begin{bmatrix} \sigma_{\varepsilon_1}^2 & \sigma_{\varepsilon_1\varepsilon_0} & \sigma_{\varepsilon_1\varepsilon} \\ \sigma_{\varepsilon_1\varepsilon_0} & \sigma_{\varepsilon_0}^2 & \sigma_{\varepsilon_0\varepsilon} \\ \sigma_{\varepsilon_1\varepsilon} & \sigma_{\varepsilon_0\varepsilon} & \sigma_{\varepsilon}^2 \end{bmatrix} \tag{6}$$

Where σ_ε^2 represents the variance of the error term ε in selection equation that is assumed to be equal to one as the coefficients are estimable up only up to a scale factor (Greene,2008 and Maddala, 1983). $\sigma_{\varepsilon_1}^2$ and $\sigma_{\varepsilon_0}^2$ are the variances of the error terms in Equations (4) and (5) and

$\sigma_{\varepsilon_1\varepsilon}$ and $\sigma_{\varepsilon_0\varepsilon}$ are the covariance between ε , ε $_1$and ε_0, respectively. According to Maddala et al., (1986), when both $\sigma_{\varepsilon_1\varepsilon}$ = $\sigma_{\varepsilon_0\varepsilon}$ = 0, the model exhibits exogenous switching, implying no correlation between the selection and outcome equations. Conversely, if either $\sigma_{\varepsilon_1\varepsilon}$ or $\sigma_{\varepsilon_0\varepsilon}$ is nonzero, the model shows endogenous switching, which must be explicitly accounted for. This necessitates testing for the correlation between ε_1 and ε as well as between ε_0 and ε (Lokshin & Sajaia, 2004). Thus, the solution to the above-specified problem is to find expressions for the expected values of the error terms ε_0 and ε_1 , i.e. $E(\varepsilon_1 \,|\, I = 1)$ and $E(\varepsilon_0 \,|\, I = 0)$, as follows:

$$E(\varepsilon_1 \,|\, I = 1, X_1) = E(\varepsilon_1 \,|\, \varepsilon > -\alpha Z) = \sigma_{\varepsilon_1\varepsilon} \frac{\phi(Z\alpha)}{\Phi(Z\alpha)} = \sigma_{\varepsilon_1\varepsilon}\lambda_1 \qquad (7)$$

$$E(\varepsilon_0 \,|\, I = 0, X_0) = E(\varepsilon_0 \,|\, \varepsilon \leq -\alpha Z) = \sigma_{\varepsilon_0\varepsilon} \frac{-\phi(Z\alpha)}{1-\Phi(Z\alpha)} = \sigma_{\varepsilon_0\varepsilon}\lambda_0 \qquad (8)$$

Where ϕ and Φ represent the probability density and cumulative distribution functions of the standard normal distribution, respectively. $\lambda_1$and λ_0 in Equations (7) and (8) are the inverse Mills ratios (also known as selectivity terms) to account for selection bias. These ratios are evaluated at $Z'\alpha$ for farm and non-farm participants' regimes (Greene, 2008).

The ESRM specification enables a comparison between the expected household per capita consumption of participants and their counterfactual outcomes—that is, what their consumption would have been had they not participated in NFA. In the actual expectations observed case, the expected total consumption for those who have engaged in NFA and those who have not can be expressed in the following equations:

$$E(C_1 \,|\, I = 1) = \beta_1 X_1 + \sigma_{\varepsilon_1\varepsilon}\lambda_1 \qquad (9)$$

$$E(C_0 \,|\, I = 1) = \beta_1 X_0 + \sigma_{\varepsilon_0\varepsilon}\lambda_0 \qquad (10)$$

Where $\sigma_{\varepsilon_1\varepsilon}\lambda_1$ and $\sigma_{\varepsilon_0\varepsilon}\lambda_1$ acount for sample selection bias, which arises from the fact that a rural household engage in NFA differs from other households with the characteristics Z and X due to the presence of unobserved characteristics (Fuglie and Bosch, 1995 and Seng, 2015). Moreover, to obtain the net effect of NFA on households' consumption attributed to NFA, further estimation is required. Specifically, the effect of the average treatment on the treated (ATT) is calculated as the difference between Equations (9) and (10). Following Heckman et al. (2001) and Di Falco et al. (2011), the effect of the average treatment to participate in NFA on the treated (ATT) is calculated as:

$$E(C_1 \,|\, I = 1) - E(C_0 \,|\, I = 1) = (\beta_1 - \beta_0) X_1 + (\sigma_{\varepsilon_1\varepsilon} - \sigma_{\varepsilon_0\varepsilon})\lambda_1 \qquad (11)$$

The difference between the expected total consumption with and without NFA among rural households represents the parameter of interest. According to Maddala (1983) and Seng (2015), if a household chooses to engage or not to engage in NFA based on the comparative advantage, then $\sigma_{\varepsilon_1\varepsilon} - \sigma_{\varepsilon_0\varepsilon}$ would be positive. In this case, NFA is likely to yield a larger gain in terms of total consumption under self-selection than random assignment (Maddala 1983; and Seng, 2015).

The empirical equations to be estimated are the selection and outcome models. The selection model, which is analogous to Equation (2), can be expressed as follows:

$$I_i = \alpha_0 + \alpha_1 IV + \alpha_2 HHC_i + \alpha_3 ECC_i + \alpha_4 FAC_i + \alpha_5 LOC_i + \varepsilon \quad (12)$$

In line with Equations (4) and (5), the separate outcome (i.e. household's total consumption) models for participants and non- participants can be specified as follows:

$$C_{1i} = \beta_0 + \beta_1 I_{1i} + \beta_2 HHC_i + \beta_3 ECC_i + \beta_4 FAC_i + \beta_5 LOC_i + \varepsilon_1,\ if\ I_{1i} = 1 \quad (13)$$

$$C_{0i} = \beta_0' + \beta_1' I_{1i} + \beta_2' HHC_i + \beta_3' ECC_i + \beta_4' FAC_i + \beta_5' LOC_i + \varepsilon_0,\ if\ I_{1i} = 0 \quad (14)$$

In the outcome equations, C_{1i} and C_{0i} represent total household consumption for NFA participants and non-participants, respectively. The analysis employs per adult equivalent consumption instead than per capita consumption, as the latter fails to account for household composition and economies of scale. Prior studies highlight that per capita measures overlook consumption heterogeneity by age (Meenakshi & Ray, 2002; Deaton & Zaidi, 2002; Deaton, 2003). To identify the model, IV is a valid instrumental variable for I_i in Equation (12). Selecting a valid IV is inherently challenging, as it must influence NFA participation without directly affecting household consumption.

The ESRM relies on the joint normality of error terms in the selection and outcome equations (Lokshin & Sajaia, 2004). For model identification, at least one instrument must influence selection without directly affecting the outcome. In this study, distance to the nearest urban center serves as the instrumental variable for NFA participation. This choice is grounded in several considerations: (i) greater distance limits access to markets, information, and infrastructure, thereby constraining non-farm opportunities, as emphasized in the rural diversification literature (e.g., Lanjouw & Lanjouw, 2001; Barrett et al., 2001); (ii) proximity to urban centers enhances access to employment, entrepreneurship, and enabling infrastructure (e.g., transport, electricity, internet), increasing the viability of non-farm activities, as supported by empirical studies across Sub-Saharan Africa; and (iii) it facilitates the adoption of modern business practices by linking rural households to urban demand and innovation hubs. Conversely, household consumption is less sensitive to distance due to offsetting urban price levels and reliance on locally sourced goods, satisfying the exclusion restriction of the instrument. Following Seng (2015), the instrument's validity is assessed to confirm its relevance for participation and exogeneity to consumption outcomes (see Appendix II).

The remaining variables are defined as follows. HC_i captures household characteristics, including the gender, age, marital status, and education level of the household head. ECC_i denotes economic characteristics, such as farm income, access to media, electricity, piped water, and credit facilities. FAC_i represents farm characteristics, including land ownership and irrigation type. LOC_i reflects locational characteristics, captured through six regional dummies, Central, Kordofan, Darfur, Eastern, Northern, and Khartoum, to control for agro-ecological heterogeneity in NFA participation, driven by differences in resource endowments and farming conditions. Definitions and summary statistics of all variables are provided in Appendix I.

3.2 Data

The study utilizes data from the National Baseline Household Survey (NBHS), organized by the Central Bureau of Statistics (CBS) in 2015. This nationally representative survey includes questionnaires from 11,935 households. The analysis focuses on a sample of 8,361 observations from rural households, with heads aged between 14 and 65 years.

4. Empirical Results and Discussion

The empirical results are organized into three subsections: the first examines the determinants of non-farm participation, the second assesses the impact of NFA on household consumption, and the third presents robustness checks to validate the findings.

4.1 Determinant of Non-farm Participation

Table I presents the first-stage results of the ESRM, examining the determinants of rural household participation in NFA across total, self-employment, and wage-employment categories using probit regressions. The results align with expectations, showing that gender, education, and media access significantly influence NFA participation. Specifically, households with male, educated heads and media access are more likely to engage in NFA. The positive relationship between NFA participation and household head education is notable in rural Sudan, where illiteracy remains widespread.

The negative age coefficient suggests that older household heads are less likely to participate in NFA, likely due to physical limitations or risk aversion. However, the positive coefficients for age-squared indicate a non-linear relationship, with middle-aged heads more likely to engage in NFA, reflecting a balance of experience and physical capability.

As expected, farm income negatively affects NFA participation, with higher farm income reducing the likelihood of engaging in NFA. However, landholding has no significant impact on participation, contrary to previous studies suggesting that increased land access reduces reliance on NFA (Seng, 2015; Mishra & Goodwin, 1997). This insignificant effect of land ownership on NFA and consumption in the Sudanese context likely reflects communal tenure arrangements, limited land productivity, the absence of collateral value, and the growing reliance on non-agricultural income sources and remittances.

Table I: Determinants of participation in NFA: Total, Self and Wage-employment Models

	Total		**Self-employment**		**Wage-employment**	
Variables	Independent Probit	Joint Probit	Independent Probit	Joint Probit	Independent Probit	Joint Probit
Male	0.472***	0.503***	0.255	0.256	0.625***	0.650***
	(0.150)	(0.162)	(0.178)	(0.176)	(0.203)	(0.214)
Age	-0.037***	-0.038***	-0.0452**	-0.0403*	-0.0365***	-0.0373***

	(0.0102)	(0.0108)	(0.0188)	(0.0210)	(0.0138)	(0.0137)
Age square	0.773***	0.793***	0.674*	0.798*	0.830***	0.837***
	(0.217)	(0.230)	(0.409)	(0.452)	(0.292)	(0.290)
Education	0.0582***	0.0582***	0.0592***	0.0611***	0.0568***	0.0560***
	(0.00819)	(0.00817)	(0.0117)	(0.0121)	(0.0120)	(0.0122)
Married	-0.0262	-0.0305	-0.126	-0.00320	0.0230	0.0294
	(0.130)	(0.129)	(0.184)	(0.202)	(0.186)	(0.188)
Farm income	-0.248***	-0.247***	-0.250***	-0.241***	-0.238***	-0.240***
	(0.0219)	(0.0212)	(0.0428)	(0.0435)	(0.0252)	(0.0250)
Media	0.437***	0.439***	0.370***	0.460***	0.429***	0.435***
	(0.0574)	(0.0574)	(0.103)	(0.0930)	(0.0772)	(0.0771)
Land	0.0129	0.0175	-0.0156	-0.0407	0.0242	0.0326
	(0.0525)	(0.0521)	(0.108)	(0.0941)	(0.0731)	(0.0730)
Credit	0.211	0.175	0.206	0.0234	0.133	0.103
	(0.230)	(0.237)	(0.395)	(0.327)	(0.288)	(0.297)
Electricity	-0.0285	-0.0237	-0.0326	0.0653	-0.00922	-0.000894
	(0.107)	(0.107)	(0.182)	(0.201)	(0.116)	(0.123)
Water	0.0302	0.0175	0.105	0.168	0.0169	0.00653
	(0.0683)	(0.0679)	(0.115)	(0.112)	(0.0749)	(0.0746)
Rain-fed	-0.404***	-0.371**	-0.607***	-0.402*	-0.299*	-0.275
	(0.153)	(0.158)	(0.231)	(0.227)	(0.180)	(0.187)
Northern	-0.0821	-0.0315	3.374***	10.21***	-6.843***	-6.264***
	(0.693)	(0.698)	(0.186)	(0.327)	(0.278)	(1.471)
Eastern	0.915	0.925	4.783***	1.398	-6.289***	-5.714***
	(0.725)	(0.722)	(0.343)	(1.211)	(1.148)	(1.503)
Central	0.322	0.348	3.969***	10.73***	-6.846***	-6.270***
	(0.704)	(0.706)	(0.243)	(0.232)	(0.230)	(1.489)
Kordofan	0.302	0.301	4.342***	11.11***	-7.045***	-6.477***
	(0.705)	(0.704)	(0.365)	(0.233)	(0.179)	(1.492)
Darfur	0.635	0.633	4.497***	11.23***	-6.614***	-6.043***
	(0.716)	(0.712)	(0.312)	(0.208)	(0.190)	(1.507)
Distance	-0.00242*	-0.00317**	-0.000353	-0.000362	-0.00383**	-0.00436***
	(0.00126)	(0.00133)	(0.00159)	(0.000913)	(0.00155)	(0.00159)
Constant	-3.787***	-3.931***	-5.726**	-14.74***	2.800*	0.650***
	(1.417)	(1.480)	(2.255)	(2.554)	(1.535)	(0.214)
Pseudo R^2	0.106		0.107		0.120	
Prob. > Chi^2	(0.000)		(0.000)		(0.000)	
Observations	8,362	8,362	3,398	3,398	4,964	4,964

Probit model is jointly estimated with the consumption regime equations by using the FIML procedure. Standard errors in parentheses: ***p < 0.01, **p < 0.05, *p < 0.10. All estimates account for clustering at the village-level

Unexpectedly, the rain-fed irrigation variable has a negative and significant coefficient, suggesting that farmers dependent on rain-fed systems are less likely to engage in NFA than those using modern irrigation. This may be due to larger landholdings in rain-fed areas, reducing the need for supplementary income, and the prevalence of livestock raising during the dry season, which further limits non-farm participation.

Interestingly, the self-employment model shows positive and significant regional coefficients, suggesting that households in Khartoum are less likely to engage in self-employment NFAs than those in other regions. Conversely, as expected, the wage-employment model reveals negative and significant regional coefficients, indicating that households outside Khartoum are less likely to participate in wage-based NFAs compared to those in the capital.

As expected, distance from urban centers negatively and significantly affects NFA participation in both the total and wage-employment models. The effect is more pronounced in the wage-employment model, reflecting the urban concentration of such jobs and the associated commuting, time, and transportation costs that hinder rural household participation.

4.2 Impact of participating in NFA on households' consumption

Table II presents the second-stage ESRM results. The LR tests for joint independence between selection and outcome equations yield values of 9.16, 7.80, and 13.21 ($p > 0.05$) for the total, self-employment, and wage-employment models, respectively. These results confirm the joint significance of the error correlation terms, indicating self-selection endogeneity and validating the use of appropriate econometric techniques (Seng, 2015). Moreover, the findings demonstrate that NFA participation significantly enhances total consumption (measured by adult equivalent consumption), suggesting participants benefit more than non-participants would under similar conditions.

The correlation coefficients ($\rho\varepsilon 1\nu$) between the selection and outcome equation errors in all three models exhibit consistent signs, indicating hierarchical sorting in selection (Lokshin & Sajaia, 2004; Alene and Manyong, 2007). This implies that farmers who participate in NFA generally have above-average food consumption and gain more from participation than non-participation. Conversely, non-participants typically exhibit below-average consumption. Economically, the statistically significant covariance of non-participants ($\rho\varepsilon 0\nu$) across models suggests that unobservable factors do not significantly differentiate average consumption behavior between regimes in the presence of NFA participation.

The coefficients of most explanatory variables in the model are statistically significant and align with expectations. However, the coefficients for participants' models show greater statistical significance compared to those for non-participants. Consistent with the inverse relationship between age and consumption, the age-squared variable in the total and self-employment models is negative and significant, suggesting that household consumption declines beyond a certain age. This may be attributed to increased health-related expenses among older individuals, which crowd out general consumption. As expected, the coefficients for farm income in the three participants' models are positive and significant, indicating that higher farm income increases household consumption. In contrast to self- and wage-employment models, the coefficient for education in the total sample model is positive and significant, suggesting a positive relationship between the head's educational attainment and consumption among participants.

Other notable results show that the coefficients for media and water variables are generally positive and statistically significant, suggesting that access to media and piped water facilitates and promotes household consumption. The coefficient for the credit variable in the total sample model is also positive and significant, highlighting the beneficial impact of credit access on household consumption. Additionally, the positive and significant coefficient for the rain-fed variable in the self-employment model indicates that farmers in rain-irrigated regions who engage in self-employment NFA have higher total consumption compared to those using other types of NFA or irrigation.

Table II: Determinants of Rural Households' Total Consumption by Employment Type

	Total Sample		**Self-employment**		**Wage-employment**	
Variables	Participants	Non-Participant	Participants	Non-Participants	Participants	Non-Participants
Male	-0.0470	0.0102	-0.0679	0.106	-0.0796	0.0974
	(0.0544)	(0.165)	(0.0562)	(0.265)	(0.0817)	(0.270)
Age	0.00664	-0.00253	0.0189***	-0.0477*	-0.000581	-0.00271
	(0.00409)	(0.0116)	(0.00500)	(0.0287)	(0.00528)	(0.0121)
Age square	-0.282***	-0.127	-0.515***	0.990	-0.144	-0.153
	(0.0882)	(0.239)	(0.117)	(0.641)	(0.111)	(0.256)
Education	0.0100***	0.0136	0.00366	0.0691***	0.00584	0.0157
	(0.00238)	(0.00916)	(0.00395)	(0.0181)	(0.00401)	(0.00960)
Farm's income	0.0434***	0.0277	0.0729***	-0.321***	0.0504***	0.0370
	(0.00803)	(0.0379)	(0.0137)	(0.0726)	(0.0119)	(0.0380)
Media	0.128***	0.172**	0.0346	0.209*	0.138***	0.162**
	(0.0228)	(0.0729)	(0.0283)	(0.125)	(0.0312)	(0.0764)
Land	-0.0137	-0.0250	-0.0190	0.0184	-0.0111	-0.00708
	(0.0198)	(0.0341)	(0.0262)	(0.128)	(0.0279)	(0.0427)
Credit	0.161**	0.0771	0.185	0.112	0.125	0.169**
	(0.0723)	(0.0962)	(0.121)	(0.401)	(0.0988)	(0.0852)
Electricity	-0.00110	-0.0145	0.0124	-0.0244	0.00557	0.00681
	(0.0382)	(0.0463)	(0.0478)	(0.238)	(0.0611)	(0.0493)
Water	0.154***	0.127***	0.104***	0.336**	0.178***	0.102**
	(0.0288)	(0.0433)	(0.0383)	(0.142)	(0.0414)	(0.0451)
Married	0.0462	0.170*	0.0145	-0.143	0.0816	0.237*
	(0.0640)	(0.0880)	(0.0707)	(0.254)	(0.0673)	(0.124)
Rain-fed	-0.0244	-0.0910	0.0799*	-0.484*	-0.0254	-0.109
	(0.0457)	(0.0799)	(0.0480)	(0.274)	(0.0586)	(0.0874)
Northern	0.0886	-0.584***	0.110	-1.250***	-0.232***	-0.789**
	(0.241)	(0.129)	(0.222)	(0.397)	(0.0786)	(0.312)
Eastern	0.193	-0.380**	-0.0989	-	-	-0.670**
	(0.252)	(0.190)	(0.243)			(0.261)
Central	0.0933	-0.538***	-0.0567	-0.711**	-0.153***	-0.812***
	(0.244)	(0.128)	(0.230)	(0.335)	(0.0552)	(0.301)
Kordofan	-0.0958	-0.765***	-0.274	-0.896***	-0.362***	-1.028***
	(0.252)	(0.150)	(0.239)	(0.295)	(0.0511)	(0.330)
Darfur	-0.111	-0.740***	-0.369	-0.848***	-0.332***	-0.967***
	(0.252)	(0.153)	(0.240)	(0.273)	(0.0612)	(0.313)
Constant	10.43***	10.10***	11.45***	5.121	9.933***	10.30***
	(0.536)	(1.349)	(0.712)	(3.716)	(0.586)	(1.303)
Ln $\sigma\varepsilon_1\nu$	-0.827***		-0.202***		-0.876***	
	(0.0949)		(0.071)		(0.214)	
$\rho\varepsilon_1\nu$	0.337		0.730		0.556	
	(0.500)		(0.606)		(0.717)	
Ln $\sigma\varepsilon_0\nu$		-0.900***		-0.932***		-0.882***
		(0.0302)		(0.0446)		(0.0373)
$\rho\varepsilon_0\nu$		0.463***		-0.667***		0.398***
		(0.134)		(0.222)		(0.112)
LR test		9.16(0.010)		7.80(0.020)		13.21(0.001)
Log likelihood		-2649.6756		-1583.568		-1665.4905
Observations	2,693	5,669	660	2,738	2,033	2,931

Standard errors in parentheses: ***p < 0.01, **p < 0.05, *p < 0.10.
All estimates account for clustering at the village-level

Continuing with the treatment effect of NFA participation on households' consumption, Table III presents the expected total consumption values under both actual and counterfactual scenarios. For the total household sample, NFA participants have an expected total consumption of SDG 10,516.66 ($E(y_1|I=1)$), compared to SDG 9,259.40 if they had not participated ($E(y_0|I=1)$), indicating a 13.5% increase in consumption due to NFA participation. In the context of rural Sudan, this increase can significantly improve household quality of life, enhancing access to goods and services, which could lead to better health, education, and well-being.

However, the contribution of NFA to total consumption differs by employment type. The difference between self-employment participants and non-participants is SDG 2,339.17 (SDG 16,561.29 vs. SDG 14,222.12), representing a 16.4% higher consumption for participants. In contrast, participants in wage employment show a 12.4% increase in consumption (SDG 10,636.28 vs. SDG 9,459.78). These findings indicate that self-employment in NFA yields greater consumption gains than wage employment.

Overall, households engaged in NFA show significantly higher consumption compared to non-participants. However, it is important to interpret these results with caution. The observed increase in consumption may not be solely attributed to NFA participation, as other factors—such as macroeconomic conditions, inflation, and household characteristics—may also influence consumption outcomes.

Table III: Treatment and Heterogeneity Effects of NFA on Household Consumption

	NFA participants	Non-NFA participants	Treatment effects
Total Sample			
NFA participants	10516.66 (77.25)	9259.39 (39.40)	TT= 1257.28***
Non-NFA participants	8831.27 (39.40)	7994.28 (42.64)	TU= 836.99***
Heterogeneity effects	BH1= 1685.66	BH2= 1265.11	TH= 420.55***
Self-employment			
NFA participants	16561.29 (3262.78)	14222.12 (3016.17)	TT=2339.17***
Non-NFA participants	14843.12 (987.63)	13050.72 (1031.66)	TU= 1792.40***
Heterogeneity effects	BH1= 1718.17	BH2= 1171.42	TH= 546.75***
Wage-employment			
NFA participants	10636.28 (1987.57)	9459.78 (1793.69)	TT=1176.50***
Non-NFA participants	8743.56 (1432.11)	8077.31 (1276.17)	TU= 666.25***
Heterogeneity effects	BH1= 1892.72	BH2= 1382.47	TH= 510.25***

Note: The expected values of per equivalent adult consumption are transformed from log terms. Standard errors in parentheses.
*** Significant at 1% level.
TT = Treatment effects on the treated; TU = Treatment effects on the untreated; BH = base heterogeneity and TH = transitional heterogeneity (i.e., TH = TT-TU).

4.3 Heterogeneous impacts of treatment

The findings on the average treatment effect on the treated (ATT) of NFA participation highlight its positive potential impact on rural household consumption. However, the benefits of NFA engagement are not uniform and may vary across different rural households. Table III illustrates these heterogeneous treatment effects of NFA participation based on household characteristics.

Following the methods of Kumar et al. (2020), we applied an OLS regression framework, with ATT for total household consumption as the dependent variable. The results, shown in Appendix III, reveal considerable heterogeneity in the effects of NFA participation (see also Appendix IV and Appendix V). In all three model specifications (full sample, self-employment, and wage employment), most explanatory variables, except access to electricity and marital status, exhibit a positive and statistically significant association with household consumption. However, variables such as the age of the household head, farmland ownership, and farm income show negative effects on consumption among NFA participants. Additionally, the positive transitional heterogeneity values indicate that farm households engaging in NFA generally achieve better welfare outcomes compared to non-participants, with notably larger gains among those who participate.

4.4 Robustness checks

As previously mentioned, the study also examines the impact of NFA on households' food consumption. The results are presented in Tables IV and V. A quick review of Table IV shows that the findings are consistent with those in Table II. For example, the coefficient of the age variable in the self-employment model is positive and statistically significant, indicating that an increase in the head's age raises household food consumption. In contrast, the coefficients of the age-squared variable in both the total and self-employment models are negative and significant, consistent with the earlier findings. Likewise, the coefficient of the education variable in the total sample model is positive and significant, similar to the results in Table II.

Table IV: Determinants of Household Food Consumption (Robustness checks)

	Total Sample		Self-employment		Wage-employment	
Variables	Participants	Non-Particip	Participants	Non-Particip	Participants	Non-Particip
Male	-0.0189	0.0403	-0.0732	-0.0419	-0.0186	0.142
	(0.0614)	(0.177)	(0.0645)	(0.203)	(0.0932)	(0.320)
Age	0.00583	-0.000165	0.0178***	0.00537	-0.000307	-0.000466
	(0.00489)	(0.0117)	(0.00615)	(0.0172)	(0.00572)	(0.0128)
Age square	-0.273***	-0.184	-0.496***	-0.176	-0.161	-0.212
	(0.104)	(0.237)	(0.138)	(0.369)	(0.122)	(0.269)
Education	0.00878***	0.0111	0.00386	0.0190	0.00242	0.0134
	(0.00260)	(0.00807)	(0.00444)	(0.0122)	(0.00446)	(0.00903)
Farm's income	0.0373***	0.0171	0.0650***	-0.0650	0.0469***	0.0226
	(0.0107)	(0.0330)	(0.0189)	(0.0418)	(0.0158)	(0.0351)
Media	0.109***	0.143**	0.0166	0.195**	0.123***	0.139*

	(0.0274)	(0.0675)	(0.0352)	(0.0889)	(0.0327)	(0.0785)
Land	-0.000542	-0.0232	-0.0199	-0.0800	0.00805	-0.0115
	(0.0219)	(0.0351)	(0.0294)	(0.0705)	(0.0277)	(0.0451)
Credit	0.105*	0.0683	0.157*	-0.517***	0.0461	0.186**
	(0.0589)	(0.104)	(0.0866)	(0.126)	(0.0810)	(0.0926)
Electricity	-0.00747	-0.0590	0.00907	-0.121	0.000384	-0.0268
	(0.0388)	(0.0460)	(0.0495)	(0.107)	(0.0603)	(0.0526)
Water	0.123***	0.103**	0.0666	0.285***	0.152***	0.0661
	(0.0356)	(0.0474)	(0.0427)	(0.0869)	(0.0500)	(0.0484)
Married	0.0180	0.140	-0.00570	0.00400	0.0484	0.221
	(0.0628)	(0.102)	(0.0705)	(0.153)	(0.0723)	(0.141)
Rain-fed	-0.0674	-0.201***	0.0477	-0.115	-0.0731	-0.223**
	(0.0473)	(0.0758)	(0.0540)	(0.178)	(0.0554)	(0.0875)
Northern	0.163	-0.650***	0.191	-0.431	-0.294***	-0.885***
	(0.230)	(0.131)	(0.217)	(0.278)	(0.0918)	(0.282)
Eastern	0.321	-0.320	0.0338	-	-	-0.625***
	(0.244)	(0.196)	(0.253)			(0.222)
Central	0.173	-0.522***	0.0238	-0.318	-0.195***	-0.832***
	(0.233)	(0.131)	(0.230)	(0.203)	(0.0627)	(0.265)
Kordofan	0.00829	-0.680***	-0.180	-0.566***	-0.369***	-0.968***
	(0.244)	(0.152)	(0.243)	(0.137)	(0.0592)	(0.290)
Darfur	0.00289	-0.668***	-0.289	-0.619***	-0.304***	-0.909***
	(0.245)	(0.159)	(0.249)	(0.162)	(0.0714)	(0.284)
Constant	9.952***	10.14***	10.95***	10.26***	9.676***	10.36***
	(0.594)	(1.322)	(0.788)	(2.006)	(0.622)	(1.403)
Ln $\sigma_{\varepsilon_1 \nu}$	-0.769***		-0.740***		-0.756***	
	(0.0953)		(0.109)		(0.145)	
$\rho_{\varepsilon_1 \nu}$	0.351		0.384		-0.598	
	(0.394)		(0.313)		(0.487)	
Ln $\sigma_{\varepsilon_0 \nu}$		-0.817***		-0.869***		-0.804***
		(0.0323)		(0.0564)		(0.0374)
$\rho_{\varepsilon_0 \nu}$		0.437**		0.526*		-0.371***
		(0.169)		(0.290)		(0.145)
LR test		5.53 (0.63)		6.28(0.034)		16.13(0.000)
Log likelihood		-2867.428		-1693.7466		-977.889
Observations	2,693	5,669	660	2,738	2,033	2,931

Standard errors in parentheses: ***p < 0.01, **p < 0.05, *p < 0.10.

Similar to total consumption, farm income, media access, and credit access have positive and significant coefficients across all three participant models, reinforcing their role in enhancing food consumption. The water variable is also significant in the total and wage-employment models. As access to piped water may reflect broader infrastructural improvements, this suggests that rural infrastructure development can positively influence household food consumption.

Moreover, the correlation coefficients ($\rho\varepsilon1\nu$) between the error terms in the NFA participation and consumption outcome equations show consistent signs across models, indicating hierarchical sorting in selection (Alene and Manyong, 2007). This implies that individuals who engage in NFA tend to have above-average food consumption, regardless of participation status, but benefit even more from engaging. Conversely, non-participants generally have below-average consumption, though their welfare is relatively better when they remain non-participants.

Table V presents the results on the ATT heterogeneity Effects of NFA participation on household food consumption. As shown in the table, the conditional expected food consumption for participant households is SDG 6601.94, SDG 6000.72, and SDG 6746.99 for the total, self-employment, and wage-employment models, respectively. In contrast, the expected food consumption for the same households had they chosen not to participate is approximately SDG 6209.45, SDG 5826.90, and SDG 6140.32 in the total, self-employment, and wage-employment models, respectively. This indicates that participating in NFA positively affects food consumption, with an average increase of 6% across all types of employment. Specifically, self-employed households experience a 3% increase, while wage-employed households see a 9.8% increase in food consumption.

These findings suggest that rural households engaged in wage-employment NFA exhibit higher food consumption compared to those in self-employment. One possible explanation for this disparity is the more stable income from wage employment, which may allow households to allocate more resources towards food purchases. Additionally, wage-employed individuals may have better access to credit and financial services, further enabling them to invest in food and nutrition. In rural Sudan, where agricultural productivity is vulnerable to climate fluctuations, wage employment can provide a more reliable safety net, ensuring consistent food consumption. Moreover, the positive and statistically significant transitional heterogeneity across all samples indicates that households participating in NFA experience higher food consumption levels, reinforcing the earlier findings.

Table V: Treatment and Heterogeneity Effects of NFA on Food Consumption

	NFA participants	Non-NFA participants	Treatment effects
Total Sample			
NFA participants	6601.94 (42.23)	)676209.45 (18.	TT= 392.49***
Non-NFA participants	4706.27 (25.21)	)90.71.28 (4462	TU= 243.99***
Heterogeneity effects	BH1= 1895.67	BH2= 1747.17	TH= 148.50***
Self-employment			
NFA participants	6000.71 (126.08)	5826.90 (31.9)	TT=173.81***
Non-NFA participants	5631.27 (31.09)	5494.28 (37.01)	TU= 136.99***
Heterogeneity effects	BH1= 369.44	BH2= 332.62	TH= 36.82***
Wage-employment			
NFA participants	6746.99 (51.48)	6340.32 (31.55)	TT=406.67***
Non-NFA participants	7304.73 (31.72)	7140.85 (31.55)	TU= 163.88***
Heterogeneity effects	BH1= -557.74	BH2= -800.53	TH= 242.79***

Note: The expected values of per equivalent adult consumption are transformed from log terms. Standard errors in parentheses.
*** Significant at 1% level.
TT = Treatment effects on the treated; TU = Treatment effects on the untreated; BH = base heterogeneity and TH = transitional heterogeneity (i.e., TH = TT-TU).

In summary, these findings are fully aligned with those of studies conducted in the SSA context, such as Zereyesus et al. (2017) and Osarfo et al. (2016), both of which demonstrated the significant role of NFA in increasing food consumption levels for a large segment of the rural population.

5. Conclusion and Recommendations

This study examines the effect of non-farm activity (NFA) participation on rural household welfare in Sudan, focusing on total and food consumption. Despite the recognized role of NFA in poverty reduction and income diversification, its impact in Sudan remains understudied. Drawing on theories of structural transformation and rural diversification (e.g., Lanjouw & Lanjouw, 2001; Barrett et al., 2001), the study addresses two core questions: (i) how NFA participation influences household consumption, and (ii) how this effect varies by employment type and household characteristics. To address selection bias and endogeneity, the analysis applies an Endogenous Switching Regression Model (ESRM) to data from the 2015 Sudan National Baseline Household Survey.

The results show that NFA participation is influenced by factors including gender, age, education, farm income, media access, irrigation type, proximity to urban centers, and geographical location. The joint significance of the error correlation coefficients in both the selection and outcome equations highlights the presence of self-selection and endogeneity, which must be accounted for in the estimation. NFA participation significantly increases total consumption, with participants showing greater consumption gains compared to non-participants. When disaggregated by employment type, non-farm wage employment has a more substantial positive impact on both total and food consumption compared to self-employment. Overall, NFA participants experience higher levels of consumption than non-participants.

Based on the findings, the study recommends several policy interventions to strengthen the impact of NFA on rural household consumption. First, expanding access to rural education, particularly technical and vocational training, is essential for equipping individuals with labor market-relevant skills and mitigating persistent poverty. Second, targeted microfinance initiatives should enhance rural households' access to productive resources and financial services, thereby fostering NFA engagement and improving welfare outcomes. Third, investments in rural infrastructure, such as electricity, communication, and transport networks, are critical for creating an enabling environment for NFA development.

Despite offering important insights, the study has limitations. It relies on cross-sectional data from the 2015 NBHS survey, which restricts causal inference over time. Future studies could benefit from panel data to capture the dynamic effects of NFA participation on household welfare. Moreover, the absence of variables related to technological advancement, infrastructure and socioeconomic setting, i.e., entrepreneurial ability, risk preferences, and social capital, limits the scope of the analysis. Potential omitted variable bias may also arise from unobserved factors such as entrepreneurial capacity, risk preferences, and social capital, which may jointly influence NFA participation and consumption. Future surveys should incorporate these dimensions to enhance the robustness and policy relevance of empirical analyses on NFA and rural livelihoods.

Availability of data: The data and replication code used in the analysis are available from the authors upon request.

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Appendices

Appendix I: Definition and Summary Statistics

Variable	Definition	Mean	Std. Dev
Treatment variables			
Consumption	per capita consumption in last 30 days	5966.8280	3906.0990
Non-farm participation	= 1 if the household engages in at least one non-farm activity and 0 otherwise	0.3221	0.4673
Independent variables			
Male	=1 if the household head is male	0.8505	0.3566
age	household head's age in years	46.0413	15.0254
Education	household head's educational attainment (in years)	6.2101	4.0147
Farm' income	Farm income in SDG	6617.5130	20669.3200
Media	= 1 if household owns a radio or a TV and 0 if not	0.3809	0.4856
Land	=1 if a household own land and 0 if not	0.3640	0.4812
Credit	=1 if a household has access to formal credit	0.0122	0.1098
Electricity	=1 if household has access to electricity	0.2104	0.4076
Water	=1 if household has access to piped water	0.3710	0.4831
Married	=1 if head married and 0 otherwise	0.8871	0.3165

Distance	Distance to urban centers in minutes	22.2591	32.6168
Rain-fed	=1 if rain-fed scheme and 0 if not	0.7279	0.4450
Central	=Geizera, Blue Nile, White Nile States	0.2338	0.4233
Kordofan	= Northern and Southern Kordofan States	0.2000	0.4000
Darfur	= Northern Darfur, Southern Darfur, Eastern Darfur and Middle Darfur States	0.3238	0.4680
Khartoum	= Khartoum State	0.0228	0.1494
Northern	= River Nile and Northern States	0.0932	0.2907
Eastern	= Red Sea, Kassala and Gadarif States	0.2338	0.4233
Distance	Distance to the nearest urban center in minutes	22.2591	32.6168

Appendix II. Evaluating validity of the instrument

Variables	Non-farm participation (Probit)	Consumption (OLS)
Male	0.472***	-484.1
	(0.150)	(453.4)
Age	-0.0373***	58.05**
	(0.0102)	(27.70)
Age square	0.773***	-2,153***
	(0.217)	(597.0)
Education	0.0582***	25.65
	(0.00819)	(16.38)
Log Farm's income	-0.248***	299.7***
	(0.0219)	(38.53)
Media	0.437***	509.7***
	(0.0574)	(133.7)
Land	0.0129	-73.89
	(0.0525)	(124.2)
Credit	0.211	451.8
	(0.230)	(298.9)
Electricity	-0.0285	-182.9
	(0.107)	(204.3)
Water	0.0302	756.0***
	(0.0683)	(212.4)
Married	-0.0262	305.6
	(0.130)	(368.6)
Rain-fed	-0.404***	-619.9**
	(0.153)	(244.3)
Northern	-0.0821	-960.2
	(0.693)	(1,988)
Eastern	0.915	125.0
	(0.725)	(2,071)
Central	0.322	-851.3
	(0.704)	(1,987)
Kordofan	0.302	-1,617
	(0.705)	(2,049)
Darfur	0.635	-1,493
	(0.716)	(2,069)

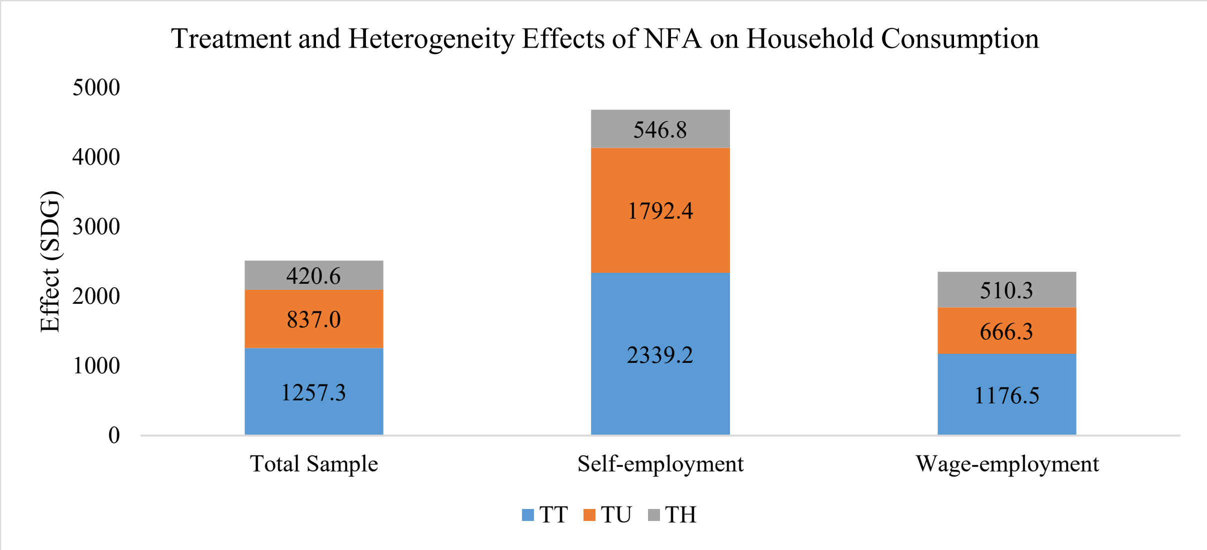
Distance	-0.00242*	3.735
	(0.00126)	(3.256)
Constant	-3.787***	18,243***
	(1.417)	(3,749)
Pseudo R^2	0.106	
R^2		0.114

Standard errors in parentheses
***p < 0.01, **p < 0.05, *p < 0.10.

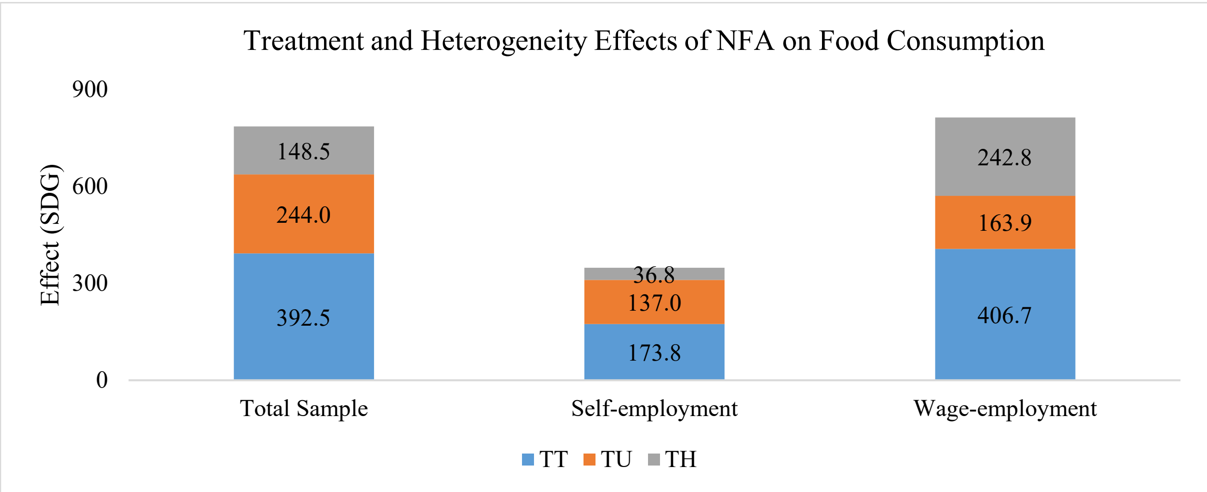
Appendix III: Heterogeneous treatment effects on total consumption: OLS regressions

Variable	**Total Sample**	**Self-employment**	**Wage-employment**
Male	0.0979***	0.0359***	0.0767***
	(0.00229)	(0.00103)	(0.00321)
Age	-0.00775***	-0.00502***	-0.00429***
	(0.000196)	(9.13e-05)	(0.000265)
Age square	0.156***	0.0904***	0.104***
	(0.00421)	(0.00201)	(0.00558)
Education	0.0159***	0.00513***	0.0173***
	(0.000132)	(6.46e-05)	(0.000170)
Farm's income	-0.0630***	-0.0222***	-0.0646***
	(0.000429)	(0.000225)	(0.000529)
Media	0.131***	0.0687***	0.117***
	(0.00105)	(0.000546)	(0.00130)
Land	-0.00533***	0.0108***	-0.00449***
	(0.000991)	(0.000499)	(0.00126)
Credit	0.0601***	0.0444***	0.0177***
	(0.00380)	(0.00218)	(0.00446)
Electricity	0.00667	-0.0126	0.0376
	(0.0175)	(0.0838)	(0.0230)
Water	0.0176***	-0.00770***	-0.000453
	(0.00114)	(0.000588)	(0.00141)
Married	-0.00227	-0.00678	0.0370
	(0.00225)	(0.0107)	(0.0298)
Rain-fed	-0.100***	-0.162***	-0.0720***
	(0.00221)	(0.00116)	(0.00271)
Northern	0.0161	0.182***	-0.781***
	(0.0114)	(0.00407)	(0.0246)
Eastern	0.310***	0.447***	-0.622***
	(0.0116)	(0.00427)	(0.0247)
Central	0.126***	0.290***	-0.795***
	(0.0114)	(0.00411)	(0.0245)
Kordofan	0.118***	0.402***	-0.825***
	(0.0115)	(0.00423)	(0.0246)
Darfur	0.210***	0.398***	-0.718***
	(0.0115)	(0.00422)	(0.0246)
Constant	-0.359***	-0.342***	0.826***
	(0.0255)	(0.0118)	(0.0389)
R^2	0.85	0.81	0.83

Appendix IV: Treatment and Heterogeneity Effects of NFA on Household Consumption



Appendix V: Treatment and Heterogeneity Effects of NFA on Food Consumption



https://figshare.com/s/e3f2db2c86f0e85fa907

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Consortium pour la Recherche Economique en Afrique
Middle East Bank Towers,
3rd Floor, Jakaya Kikwete Road
Nairobi 00200, Kenya
Tel: +254 (0) 20 273 4150