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Does access to credit influence smallholder farmers' maize productivity and food security in Malawi? A panel conditional mixed process analysis

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Abstract

This study used panel data from the 2016 and 2019 waves of the Malawi Integrated Household Survey, part of the Living Standards Measurement Study of the World Bank and National Statistical Office, to examine the impact of credit access on smallholder farmers' maize productivity and household food security. Despite the recognised importance of credit in agricultural development, many Malawian smallholders lack sufficient access, constraining investments in essential inputs. Previous research has examined the effect of credit on productivity or food security separately, leaving a gap in understanding their joint dynamics. Addressing this gap, this study employed a panel conditional *mixed process (CMP) approach to jointly estimate the effect of credit on maize yields and food security, showing that access to credit increases maize productivity by 18% and improves food security by 1.5 points, while controlling for endogeneity and selection bias. Given the significant influence of soil quality and market accessibility revealed in the results, policies should prioritise linking credit provision with soil fertility interventions and rural infrastructure development to maximise the effect on productivity and food security.*

Key words: credit access, food consumption score, maize productivity, food security

1. Introduction

Malawi's agriculture remains the predominant driver of its economy, providing livelihoods for over 80% of the population and playing a critical role in food security and poverty reduction (Malawi Government 2018). Maize, the staple crop in most parts of the country, is central to these outcomes. Many smallholder farmers in Malawi struggle with low productivity due to small land parcels, climate variability, limited financial resources and inadequate access to improved inputs such as seeds and fertilisers (Makate & Makate 2022; Touch *et al*. 2024). The National Agriculture Policy (NAP) of 2016 acknowledges that addressing these barriers is key to improving agricultural sector performance and ensuring food security (Joala *et al*. 2019; Olivier *et al*. 2019).

Access to credit is widely recognised across Sub-Saharan Africa as a critical factor driving agricultural productivity (Yi *et al*. 2021; Zawadzka *et al*. 2021). Credit enables farmers to invest in essential inputs such as certified seeds, fertilisers and irrigation technologies, which are crucial for increasing yields (Giller *et al*. 2021b; Kambali & Panakaje 2022). In addition, credit provides a safety net against production risks, encouraging the adoption of innovations and improved farm management. Despite these benefits, the majority of Malawian households remain excluded from formal credit systems, with only about 17.7% accessing credit and less than one third (29.8%) of those loans used for agricultural inputs (Malawi National Statistical Office 2020).

While previous studies in Malawi have examined either the effect of access to credit on maize productivity or on household food security separately, the need remains to link credit access to both outcomes simultaneously. This linkage is important because it is possible to experience food insecurity even with higher productivity due to factors such as income distribution, market access and post-harvest losses, a phenomenon known as the food security paradox. Jointly analysing the influence of credit on these interrelated outcomes provides a more comprehensive understanding of the effect of credit interventions on a smallholder farmer. Moreover, most existing research relies on cross-sectional data, limiting insights into time-based dynamics and causal relationships. Empirical evidence from Malawi that specifically links credit access to both maize productivity and household food security simultaneously using panel data remains limited (Salima *et al*. 2023; Zimani *et al*. 2025). This gap limits policymakers from designing effective interventions that simultaneously address productivity and food security challenges.

This study utilised panel data from Malawi's Integrated Household Survey (the 2016 and 2019 waves), which forms part of the Living Standards Measurement Study by the World Bank, because these waves provide nationally representative, longitudinal data that capture changes in credit access, agricultural productivity and food security over time. Employing a panel conditional mixed process (CMP) analysis enables the joint estimation of the effects of credit access on maize productivity and food security, while controlling for potential endogeneity and interdependencies between these outcomes. This provides a more robust understanding of the credit-productivity-food security nexus. This paper contributes to the limited literature on how credit access influences both maize productivity and food security outcomes simultaneously. Addressing these dual objectives is important for Malawi's efforts to achieve Sustainable Development Goal 2 (ending hunger and promoting sustainable agriculture).

2. Methodology

2.1 Data and data sources

The study utilised panel data from Malawi's Integrated Household Survey (2016 and 2019 waves), which provides nationally representative data from all 28 districts, collected using a stratified two-stage cluster sampling design. A total of 2 982 maize farming households were systematically selected to ensure comprehensive coverage of both rural and urban areas. The survey gathered information on household welfare, credit access, agricultural production and food security, providing a robust foundation for analysing the effects of credit access on maize productivity and household food security among smallholder farmers (Malawi National Statistical Office 2020).

2.2 Theoretical framework

The study is underpinned by consumer choice theory, which posits that farmers, as rational decision-makers, aim to maximise their utility by efficiently allocating limited resources – such as credit – to agricultural inputs that yield the highest returns (Hands 2010; Feng *et al*. 2021). According to this theory, access to credit should enable farmers to invest optimally in inputs like seeds and fertilisers to enhance productivity and food security. However, in practice, factors such as financial literacy, household financial burdens and credit fungibility (using agricultural credit for nonfarm purposes) can lead to inefficient credit use, undermining the expected productivity gains. This theoretical framework provides a basis for analysing how credit access influences maize productivity and household food security, while also accounting for potential deviations from rational behaviour observed among smallholder farmers in developing countries like Malawi.

2.3 Estimation technique

Access to credit enables farmers to invest in inputs such as improved seeds, land, fertiliser and labour, which enhance maize productivity as modelled by the generalised Cobb-Douglas production function (Praveen *et al*. 2019):

$$\ln Y_{it} = \gamma_0 + \gamma_{1t} \ln L + \gamma_{2t} \ln land + \gamma_{3t} \ln fert + \gamma_{4t} \ln seeds + \beta_{it} Credit_{it} + \varepsilon_{it}, \qquad (1)$$

where Y_i is maize yield per acre for a household i; $Credit_i$ is a binary variable showing if a household accessed credit or not, and t is time factor for 2016 and 2019. This increase in productivity not only raises farm income, but also improves food availability, a key dimension of food security, by increasing supply and lowering prices. Thus, credit access could boost maize yields and therefore contributes to food security by ensuring more abundant and affordable food supplies.

The food consumption score (FCS) is measured by collecting data on how frequently households consume foods from 10 predefined food groups over a seven-day recall period. The consumption frequency of each food group is multiplied by a standardised weight reflecting its nutritional value, and these weighted scores are summed to produce the FCS, which serves as a proxy for food security. To explicitly model the effect of credit access on food security using this proxy, a linear regression is specified as follows:

$$FCS_{it} = \beta_0 + \beta_{1t}Credit_{it} + \beta_2 X_{it} + \mu_{it}, \tag{2}$$

where $Credit_i$ is a binary variable capturing if a household accessed credit or not, X_i is a vector of control variables, μ_i is the error term and t is a time factor for 2016 and 2019. Credit access is hypothesised to positively influence food security by increasing households' purchasing power and smoothing consumption. The coefficient β_1 captures the marginal effect of credit access on food security.

The two dependent variables, maize productivity and food security, are possibly correlated because higher agricultural productivity directly affects food availability and economic access, which are core components of food security (Edame *et al*. 2011; Ogunniyi *et al*. 2021). Increased maize yields translate into greater food stocks and income, enabling households to improve dietary diversity and consumption quality, thus raising the food consumption score. This correlation suggests a system of simultaneous relationships where credit access improves productivity, which in turn enhances food security. Melesse *et al*. (2021) and Zhu *et al*. (2022) have argued that a conditional mixed process is thus key to ensuring a joint modelling to capture this interdependence, reinforcing the critical role of credit in agricultural and food security outcomes.

2.4 Endogeneity problem

In examining the relationship between the effect of credit accessibility on maize productivity and FCS, endogeneity poses a significant challenge that can result in biased and inconsistent estimates (Assouto & Houngbeme 2023). This issue may arise from several sources, including omitted variable bias, where unobserved factors, such as farmer experience or soil quality, affect credit access, productivity and FCS, or simultaneity, where higher productivity may lead to both FCS and increased credit demand. In addition, measurement errors in assessing either credit access, productivity or FCS can further exacerbate the problem. It is crucial to address endogeneity to ensure the validity of the findings in order to draw correct conclusions about the effectiveness of credit accessibility.

Distance to financial institutions was chosen as an instrument due to its established use in studies on credit access and agricultural outcomes, as it influences farmers' ability to obtain credit through physical proximity and transaction costs while plausibly being unrelated to productivity and food security except via credit access (Wooldridge 2015; Mgomezulu *et al*. 2023). The following is the structural equation:

$$Y_{ij} = x_i\beta_i + e_i \tag{3}$$

In the structural Equation (3), Y_{ij} is the exogenous variable of FCS, x_i is the vector of the endogenous variable (maize productivity), β_i is the parameter to be estimated and e_i is the error term. Then, we specify the reduced-form equation, as below:

$$X_i = Z_i\gamma_i + e_i \tag{4}$$

The reduced-form Equation (4) tests if the instrumental variable, Z_i (distance to financial institution), has a significant effect on the endogenous variable X_i (maize productivity); γ_i is the parameter to be estimated and e_i is the error term. The null hypothesis is that $\gamma_i = 0$, with the alternative hypothesis that $\gamma_i \neq 0$. Rejecting the null hypothesis means that we have endogeneity and a justification for using CMP to control for endogeneity.

2.5 Selection bias

The other potential problem is selectivity bias. Such selection bias refers to the systematic error that occurs when individuals in a sample are selected in a way that does not allow for proper randomisation, leading to a non-representative sample (Wooldridge 2015; Mgomezulu 2019). This lack of representativeness results in biased and inconsistent estimates, particularly evident when households with access to credit self-select into further stages of maize productivity and FCS analysis. To correct this, a Heckman two-stage approach is employed. The inverse Mills ratio (IMR) is used to test the null hypothesis of no selection bias. This model consists of two stages: the first stage is a selection equation that identifies whether an individual has access to credit, represented by a latent variable CA^*, while the second stage models the maize productivity and FCS of a household, denoted as P_i^*.

The selectivity problem arises when the outcome P_i^* (maize productivity or FCS) is only observable when $CA_1 = 1$ (indicating access to credit), and when the error terms of both equations are correlated. The IMR is integrated into the analysis through the equation below:

$$E(P_{it}^*|CA_{it}^* > 0) = \alpha + \beta_{it}X_{it} + \beta_\lambda \lambda_{it} + e_{it}, \tag{5}$$

where λ signifies the IMR. According to Wooldridge (2015) and Mgomezulu (2019), the presence of λ indicates that selection bias exists within the dataset, highlighting the importance of addressing this bias to ensure valid econometric estimates.

2.6 Hausman test for unobserved heterogeneity

The Hausman test was used to detect unobserved heterogeneity. The null hypothesis is that there is no unobserved heterogeneity. Failing to reject the null hypothesis suggest the use of random effects, while rejecting the null hypothesis suggests using fixed effects (Wooldridge 2015). This is derived as:

$$y_{it} = \beta_0 + \beta_1 maize\ productivity_{\ it} + \beta_2 access_{credit_{it}} + \cdots + \beta_k x_{kit} + \phi c + \mu_{it}, \tag{6}$$

where y_{it} is the time variant FCS, X_{kit} is the time variant independent variable, β_0 is the constant, ϕ and β_k are parameters to be estimated, μ is the error term and c is unobserved heterogeneity. The Hausman test tests that ϕ is equal to zero. When ϕ is zero, the panel data have no unobserved heterogeneity, hence random effects are efficient. If ϕ is greater than zero, unobserved heterogeneity is present, hence the fixed effects are efficient.

2.7 Conditional mixed regression model

The conditional mixed process (CMP) framework is a model that addresses both selection bias and endogeneity in the analysis of the effects of credit access on maize productivity and food security (Alhassan *et al*. 2020; Mbudzya *et al*. 2022; Hlatshwayo *et al*. 2023). The CMP model jointly estimates the multiple outcome equations for maize productivity or food consumption score (FCS), while allowing for correlated error terms across these equations. This simultaneous estimation via full-information maximum likelihood accounts for unobserved heterogeneity and endogeneity, effectively correcting for biases arising from self-selection and simultaneity without relying on two-step procedures.

The CMP assumes that the error terms, ε_1 and ε_2, from the outcome equations are jointly normally distributed, with mean zero and a covariance matrix $\sum$, as shown below:

$$\epsilon = (\varepsilon_1, \varepsilon_2)' \sim N(0, \Sigma),$$

where

$$\Sigma = \begin{bmatrix} 1 & \rho_{12} \\ \rho_{21} & 1 \end{bmatrix} \tag{7}$$

ρ_{ij} represent the correlations between the error terms of maize productivity and the food consumption score equations, capturing the degree of unobserved heterogeneity shared across these outcomes. The normality assumption of the errors is critical, as it enables the joint likelihood to be constructed and maximised via full-information maximum likelihood, ensuring consistent and efficient parameter estimates. The structural equations are specified as:

$$y_1^* = \theta_1 + \varepsilon_1 \tag{8}$$

$$y_2^* = \theta_2 + \varepsilon_2 \tag{9}$$

where y_1^* and y_2^* represent latent variables corresponding to maize productivity and the food consumption score, respectively; θ_1 and θ_2 are the linear predictors based on the independent variables; and ε_1 and ε_2 are the error terms. The observed outcomes, y, are related to the latent variables y^* through the function:

$$y = g(y^*) = (1\{y_1^* > 0\}, y_2^*$$

Given that the error terms are correlated and the equations are conditioned on heterogeneity factors, Equations (8) and (9) become dependent. This dependence allows the joint probability function to be derived by multiplying the specific conditional likelihood functions (Alhassan *et al*. 2020; Hlatshwayo *et al*. 2023; Zegeye *et al*. 2023).

The ability of the CMP model to handle mixed dependent variable types and correlated disturbances makes it ideal for assessing the causal effect of credit on both productivity and food security (FCS). According to Zegeye *et al*. (2023), this approach facilitates the direct estimation of treatment effects equivalent to the average treatment effect (ATE) by comparing expected outcomes with and without credit access within the joint system, ensuring valid inference for policy evaluation in agricultural finance and food security contexts.

3. Results and discussion

3.1 Descriptive statistics

Table 1 presents the descriptive statistics of the sampled farmers that were used in the study. The dataset presents several key continuous variables that describe household characteristics and agricultural outputs across the years 2016 and 2019, and the combined panel. The food consumption score shows consistently higher averages in households with access to credit, with mean values ranging from 53.15 (SD 21.36) in 2016 to 57.53 (SD 19.64) in 2019, compared to 49.67 (SD 21.25) and 54.52 (SD 20.35) for households without access, respectively. Household size averages around five members – slightly larger in households with access to credit (mean ~5.4) than in those without access (~5.0). Land size allocated to maize by a household averages below one acre across all groups, with slight differences between credit access and no-access households. Households with access to credit tended to use relatively larger amounts of fertiliser (in kilograms) compared to those without access to credit.

Table 1: Descriptive statistics of the selected farmers

Year	2016		2019		Panel	
Variable	**No access to credit: Mean (SD)/% N = 1 100**	**Access to credit Mean (SD)/% N = 391**	**No access to credit Mean (SD)/% N = 1 086**	**Access to credit Mean (SD)/% N = 405**	**No access to credit Mean (SD)/% N = 2 186**	**Access to credit Mean (SD)/% N = 796**
Food consumption score	49.67 (21.25)	53.15 (21.36)	54.52 (20.35)	57.53 (19.64)	51.84 (20.77)	55.24 (20.72)
Log of yield per acre	4.31 (1.50)	4.35 (1.46)	4.11 (1.38)	4.30 (1.41)	4.21 (1.44)	4.33 (1.43)
Household size	5.08 (2.34)	5.41 (2.31)	4.81 (2.30)	5.22 (2.17)	5.00 (2.31)	5.46 (2.25)
Maize land size (acres)	0.98 (0.99)	0.94 (0.70)	0.64 (0.67)	0.66 (0.66)	0.80 (0.84)	0.78 (0.71)
Age of household head	45.48 (16.14)	40.32 (12.00)	45.44 (15.76)	42.34 (12.72)	46.25 (15.84)	41.90 (12.11)
Maize seeds (kgs)	11.07 (58.97)	7.44 (6.60)	9.52 (29.87)	8.63 (23.41)	10.54 (47.44)	7.46 (6.33)
Maize output (kgs)	399.71 (658.87)	432.36 (643.66)	256.32 (578.72)	305.68 (642.11)	317.78 (629.44)	340.32 (548.68)
Distance to nearest market (kms)	21.46 (14.97)	20.93 (15.42)	21.14 (15.06)	20.41 (14.91)	21.44 (14.93)	20.55 (15.17)
Log inorganic fertiliser (kgs)	3.86 (0.90)	3.91 (0.96)	3.72 (1.08)	3.79 (1.00)	3.79 (0.99)	3.85 (0.98)
Extension service						
Percentage of no access	753 (69.1%)	287 (71.4%)	1546 (89.2%)	554 (87.4%)	1 724 (79.1%)	636 (79.2%)
Percentage of access	336 (30.9%)	115 (28.6%)	188 (10.8%)	80 (12.6%)	455 (20.9%)	167 (20.8%)
Gender of household head						
Percentage of females	284 (26.1%)	102 (25.4%)	472 (27.2%)	163 (25.7%)	608 (27.9%)	205 (25.5%)
Percentage of males	805 (73.9%)	300 (74.6%)	1 262 (72.8%)	471 (74.3%)	1 571 (72.1%)	598 (74.5%)
Wealth status						
Percentage of poorer	234 (21.5%)	72 (17.9%)	351 (20.2%)	87 (13.7%)	443 (20.3%)	113 (14.1%)
Percentage of poor	209 (19.2%)	88 (21.9%)	333 (19.2%)	125 (19.7%)	410 (18.8%)	162 (20.2%)
Percentage of middle	235 (21.6%)	79 (19.7%)	340 (19.6%)	132 (20.8%)	464 (21.3%)	183 (22.8%)
Percentage of richer	206 (18.9%)	81 (20.1%)	346 (20.0%)	144 (22.7%)	444 (20.4%)	165 (20.5%)
Percentage of richest	205 (18.8%)	82 (20.4%)	364 (21.0%)	146 (23.0%)	418 (19.2%)	180 (22.4%)
Experience of pest shocks						
Percentage of those who experienced	1 089 (100.0%)	402 (100.0%)	1 657 (95.6%)	611 (96.4%)	2 124 (97.5%)	788 (98.1%)
Percentage of those who did not	0	0	77 (4.4%)	23 (3.6%)	55 (2.5%)	15 (1.9%)
Residence						

Year	2016		2019		Panel	
Variable	**No access to credit: Mean (SD)/% N = 1 100**	**Access to credit Mean (SD)/% N = 391**	**No access to credit Mean (SD)/% N = 1 086**	**Access to credit Mean (SD)/% N = 405**	**No access to credit Mean (SD)/% N = 2 186**	**Access to credit Mean (SD)/% N = 796**
Percentage of rural	829 (76.1%)	290 (72.1%)	1 280 (73.8%)	466 (73.5%)	1 650 (75.7%)	584 (72.7%)
Percentage of urban	260 (23.9%)	112 (27.9%)	454 (26.2%)	168 (26.5%)	529 (24.3%)	219 (27.3%)
Region						
Percentage of north	121 (11.1%)	57 (14.2%)	193 (11.1%)	68 (10.7%)	250 (11.5%)	112 (13.9%)
Percentage of central	456 (41.9%)	164 (40.8%)	789 (45.5%)	281 (44.3%)	907 (41.6%)	329 (41.0%)
Percentage of south	512 (47.0%)	181 (45.0%)	752 (43.4%)	285 (45.0%)	1 022 (46.9%)	362 (45.1%)

The age of the household head tends to be higher in the no-access group, averaging approximately 45 years (SD ~16), compared to around 41 years (SD ~12) in the credit access group. Maize seed usage and maize output also vary, with maize output generally higher in households with access to credit, averaging 432.36 kg (SD 643.66) in 2016 and 305.68 kg (SD 642.11) in 2019, compared to 399.71 kg (SD 658.87) and 256.32 kg (SD 578.72) respectively for those without access. The distance to the nearest market remains fairly constant across groups and years, averaging about 21 km, indicating similar market accessibility.

Categorical variables reveal important demographic and socio-economic patterns. Approximately 79% of households across the panel dis not have access to extension services, with only about 21% having access. The gender distribution of the household heads was predominantly male, with men constituting roughly 73% to 74% and women about 25% to 26% across all years and groups. Wealth status was relatively evenly spread, with the poorest and poorer groups representing around 20% of households without access, and slightly lower percentages in the access group. The middle, richer and richest categories each accounted for roughly 20% of households, with a slight tendency for wealthier households to have better access to credit.

Regarding environmental and locational factors, nearly all households (about 98%) had experienced pest shocks, highlighting a widespread challenge for agricultural production. Residence patterns show that about 75% of households were rural, with the remaining 25% urban, consistent across access groups. Regionally, households were fairly evenly distributed between the North (around 11% to 13%), Central (about 41% to 43%), and South (approximately 45% to 46%), with no statistically significant differences between those with or without access to credit. These descriptive statistics provide a comprehensive overview of the household, agricultural and environmental characteristics relevant for the analysis.

3.2 Estimated effects of access to credit on FCS and Maize productivity in Malawi.

Table 2 presents the parametric estimates of factors influencing food security, measured by the food consumption score (FCS), and maize productivity in Malawi, using a panel conditional mixed process model for each survey wave and the combined panel. The model was significant at the 1% level, indicating that the explanatory variables effectively explained variations in the dependent variables. In addition, the arc hyperbolic arctangent of rho (atanh rho) was also significant at 1%, demonstrating a correlation between the error terms of the equations for FCS and maize productivity. This correlation was appropriately accounted for within the model, ensuring robust and reliable estimates.

Table 2: Estimates of determinants of maize productivity and food security (FCS) in Malawi, from the CMP regression model

Variables	FCS-2016	Log yield/acre: 2016	FCS-2019	Log yield/acre:2019	FCS panel	Log yield/acre: panel
credit_access	0.3852 (1.166)	-0.0518 (0.113)	1.7704* (1.044)	0.1806** (0.085)	1.4850* (0.892)	-0.0427 (0.113)
access_extension	-0.4992 (1.024)		1.5267 (1.369)		-0.9086 (0.869)	
wealth_quantiles	3.8090** (1.483)		2.8005** (1.388)		3.6958*** (1.156)	
wealth_quantiles	7.5436*** (1.511)		6.4923*** (1.448)		7.2616*** (1.181)	
wealth_quantiles	14.4449*** (1.647)		13.0267*** (1.505)		14.6923*** (1.282)	
wealth_quantiles	27.9361*** (2.180)		24.7809*** (1.854)		26.554*** (1.612)	
Gender (male)	0.0159 (1.179)		1.1759 (1.045)		0.7872 (0.893)	
Household size	-0.0741 (0.229)		-0.1391 (0.217)		-0.0744 (0.178)	
Residence (urban)	7.8445*** (1.807)		5.6045*** (1.569)		7.8495*** (1.378)	
Annual precipitation	-0.0048** (0.002)	-0.0017*** (0.000)	0.0038* (0.002)	-0.0011*** (0.000)	-0.0012 (0.002)	-0.0017*** (0.000)
Distance to market (kms)	-0.0726* (0.041)		-0.0928** (0.036)		-0.0750** (0.031)	
Fair soil quality	0.8591 (1.070)	-0.1820* (0.106)	-0.1704 (1.010)	-0.2127** (0.085)	0.5888 (0.830)	-0.1830* (0.106)
Poor soil quality	-3.5891** (1.641)	-0.3716** (0.162)	-2.7365* (1.426)	-0.0855 (0.120)	-2.2830* (1.242)	-0.3624** (0.162)
Age of household head	-0.0680** (0.033)		-0.0920*** (0.030)		-0.0598** (0.025)	
Primary	0.9096 (1.760)		1.3561 (1.553)		0.0440 (1.336)	
Secondary	2.0931 (1.601)		4.7057*** (1.494)		1.6705 (1.268)	
Tertiary	26.3435*** (6.054)		9.4183*** (3.567)		14.5836*** (3.768)	
Log labour manhours		0.0123 (0.042)		-0.0099 (0.028)		0.0150 (0.042)
Log maize land (acres)		0.0739 (0.071)		0.2097*** (0.048)		0.0730 (0.071)
Log maize seed (kgs)		-0.0389 (0.057)		0.2281*** (0.048)		-0.0390 (0.057)
Log inorganic fertiliser (kgs)		0.5336*** (0.060)		0.4535*** (0.044)		0.5309*** (0.060)
_cons	47.2138*** (3.733)	4.3264*** (0.452)	45.1000*** (3.255)	3.6598*** (0.299)	44.7099*** (2.801)	4.3035*** (0.450)

Notes: Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

3.3 Test for endogeneity

After running an instrumental variable regression with 2SLS on both the FCS and maize productivity models, a test for endogeneity was conducted using the "estat endog" command in STATA. Table 3 presents the Durbin (score) chi-square test and the Wu-Hausman F-test, both of which yield statistically insignificant results, with p-values of 0.1974 and 0.1984, for the FCS model, and statistically significant results, with p-values of 0.0642 and 0.0653, for the maize productivity model, respectively, which are below the 10% significance level. This leads us to fail to reject the null hypothesis of exogeneity for the FCS model, indicating that the explanatory variables in this model are exogenous; that is, they are not correlated with the error term. Conversely, we reject the null hypothesis of exogeneity for the maize productivity model, indicating that the explanatory variables in this model are endogenous, that is, they are correlated with the error term.

Table 3: Tests of endogeneity (H_0: Variables are exogenous)

Durbin (score) $chi^2(1)$ (FCS)	1.66186 (p = 0.1974)
Wu-Hausman F(1,2351) (FCS)	1.65497 (p = 0.1984)
Durbin (score) $chi^2(1)$ (maize productivity)	3.42602 (p = 0.0642)
Wu-Hausman F(1,2351) (maize productivity)	3.4045 (p = 0.0653)

3.4 Test for selection bias

After estimating the Heckman selection model for both the FCS and maize productivity models, the lambda (inverse Mills ratio) values obtained were 25.257 and -2.4606, respectively. Both lambda coefficients are significant, with p-values of 0.0000. This leads us to reject the null hypothesis of no selection bias (rho = 0) (see Table 4). Therefore, we conclude that there is clear evidence of selection bias in the dataset.

Table 4: Test for selection bias

Lambda (coefficient and standard error)	Prob > chi^2
FCS 25.257 (1.9559)	0.0000
Maize productivity -2.4604 (0.1630)	0.0000

3.5 Test for unobserved heterogeneity

Table 5 presents the results of a test conducted to detect the presence of unobserved heterogeneity in the dataset. To determine whether unobserved heterogeneity exists, a Hausman test was performed following the estimation of both fixed effects (FE) and random effects (RE) models. The test yielded a p-value of 0.1327, which is greater than the conventional significance levels. This implies that we fail to reject the null hypothesis of no systematic difference between the FE and RE estimators, indicating the absence of unobserved heterogeneity.

Table 3.4 Test of H_0: Difference in coefficients not systematic

Unobserved heterogeneity	Prob > chi^2
$chi^2(11) = 16$	0.1327

The coefficient for credit access on food security (FCS) was positive in 2019 (1.7704*) and in the panel data (1.4850*), highlighting the critical role that credit access play in enabling smallholder farmers to improve their food security. Access to credit allows farmers to purchase inputs, invest in productivity-enhancing technologies, and smooth consumption during lean periods. This finding aligns with recent evidence from Malawi showing that, despite challenges in input affordability, farmers with credit access tend to achieve better food security outcomes (Salima *et al*. 2023; Zimani *et al*. 2025). The effect of credit on maize productivity was positive in 2019 (0.1806**), indicating that access to credit led to an 18% increase in maize productivity in that year, likely because credit enabled farmers to invest in inputs and technologies that directly enhanced productivity (Phiri *et al*. 2012; Maertens *et al*. 2021). In contrast, the effect in 2016 was not statistically significant, reflecting lower credit access that limited the effectiveness of credit in that year.

Wealth quantiles have positive effects on both food security and maize productivity across all years and panel data. For instance, the highest wealth quantile shows coefficients of 27.9361*** in 2016 for the food consumption score and 26.5544*** in the panel, indicating that wealthier households benefit from better access to land, inputs and markets, leading to higher productivity and food availability. These findings align with the literature emphasising wealth disparities in access to improved seeds, fertilisers and technologies (Burke & Jayne 2021; Makate & Mutenje 2021) and support the poverty reduction goals of the International Fund for Agricultural Development ([IFAD] 2023).

Urban residence had a positive effect on food security across all years and panel data (7.8445*** in 2016, 5.6045*** in 2019 and 7.8495*** for the panel data), reflecting better market access, income diversification and infrastructure in urban areas compared to rural Malawi. This aligns with Diehl *et al*. (2019), who argue that urban households generally enjoy greater food security due to more stable food supplies and income sources.

Annual precipitation reduced maize productivity by 0.17% in 2016 and the panel data, and by 0.11% in 2019, reflecting Malawi's vulnerability to climate variability such as excessive rainfall and flooding. Food security was negatively affected in 2016 (-0.0048), mainly due to drought-induced crop failures from the 2015/2016 El Niño. In 2019, food security showed a positive effect (0.0038), likely due to partial recovery and localised rainfall benefits, despite ongoing climate challenges.

Distance to market negatively affected food security in 2016 and 2019, at -0.0726* and -0.0928**, respectively, and in the panel data (-0.0750**), highlighting the challenges faced by remote rural farmers in accessing inputs and selling produce at fair prices. Poor market access limits farmers' ability to improve livelihoods and food availability (Giller *et al*. 2021a).

Poor soil quality reduced maize productivity by 37% in 2016 and 36% in the panel data, and lowered food security by 3.59 points in 2016, 2.74 points in 2019, and 2.28 points in the panel. Fair soil quality reduced maize productivity by 18% in 2016. These results highlight the critical impact of soil fertility on agricultural productivity and food security in Malawi. Recent research stresses the critical need for integrated soil fertility management combining organic and inorganic inputs to rehabilitate degraded soils (Shahane & Shivay 2021; Srivastava *et al*. 2021).

Age of household head negatively affected food security across years (-0.0680** in 2016, -0.0920*** in 2019 and -0.0598** in the panel), suggesting that younger farmers may be more productive and better able to adopt innovations, which ensures that a household is food secure. This is consistent with the work of Żmija *et al*. (2020).

Education levels positively influenced food security, with tertiary education showing an effect of 26.3435*** in 2016, secondary education showing an effect of 4.7057*** in 2019, and primary education being positive but insignificant. This highlights the importance of education in enabling farmers to adopt improved technologies and diversify income sources, aligning with evidence that education is a key driver of food security outcomes in Malawi (Manea 2020).

Regarding land and seed inputs, the coefficients for maize land were positive in 2019 (0.2097***); maize seed was positive and significant in 2019 (0.2281***), but statistically insignificant in 2016 and in the panel data. These results suggest that, while these inputs are important, their effectiveness may be constrained by other factors such as soil fertility, pest pressure or input quality.

Inorganic fertiliser had a positive effect on maize yield across all years and panel data (0.5336*** in 2016), confirming its critical role in boosting productivity. Thus, a 1% increase in fertiliser (kgs) led to a 53% increase maize productivity in 2016 and in the panel data. This is consistent with Burke *et al*. (2020) and Omondi *et al*. (2023), whose findings emphasise fertiliser use as a key to closing yield gaps.

4. Conclusion and recommendations

The findings reveal that access to credit improves household food security and maize productivity among smallholder maize farmers in Malawi. Wealth status, urban residence and higher education levels showed positive associations with both food security and maize productivity, underscoring the critical role of education in agricultural success. Poor soil quality emerged as a major and consistent constraint, significantly reducing maize yields and food security outcomes, and thereby highlighting the need to address soil fertility. Distance to markets also negatively affected both productivity and food security. In addition, the use of inorganic fertiliser consistently had a positive effect on maize productivity, emphasising its importance in closing yield gaps.

4.1 Practical recommendations

The practical recommendations arising from this study include the need to invest in integrated soil fertility management using inorganic fertiliser to restore soils and increase productivity. Furthermore, it is essential to improve market infrastructure to enhance farmers' access to inputs and markets. Credit accessibility should be supported alongside complementary interventions, such as integrated soil fertility management, education programmes and improved market access so as to maximise the impact on productivity and food security.

4.2 Policy recommendations

Finally, among the policy recommendations arising from this study are the need to develop integrated agricultural programmes that address access to credit, the restoration of soil fertility, education and market challenges simultaneously. Rural education and training should be prioritised to enhance productivity and food security, and large-scale soil quality improvement should be implemented through sustainable land management. Market policies that reduce transaction costs and improve connectivity should be designed, as this will ensure that smallholder farmers have better access critical agricultural inputs and markets.

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