

Access to credit, rice productivity and farmers' welfare in Ghana: a conditional mixed process approach

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Abstract

Purpose – This paper assessed the impact of access to credit and associated productivity variations on rice farmers' welfare in Ghana.

Design/methodology/approach – The authors employed a quasi-experimental research design and the conditional mixed process (CMP) approach with micro-level secondary data from the Ghana Statistical Service (GSS) to jointly estimate the determinants of rice farmers' access to credit, the impact of access to credit on rice productivity and the welfare effect of rice productivity. The joint estimation of these equations and the use of a recursive CMP approach rule out simultaneous feedback within the production cycle and correct for endogeneity while accounting for the mixed (binary and continuous) nature of the dependent variables.

Findings – The model estimates show that access to credit increases rice productivity, which in turn improves rice farmers' welfare. Specifically, access to credit positively impacted rice productivity, with an extra 958.270 kg/ha for credit users. In turn, a unit increase in productivity increased rice producers' welfare by GHC 2.98. Factors influencing access to credit include age, education, marital status, rice output and ownership of mobile phones and bank accounts. While male farmers demonstrated higher productivity, female farmers were associated with superior welfare impacts.

Research limitations/implications – A study is required to understand how changes in productivity arising from access to credit influence farmers' assets and wealth.

Practical implications – Pursuit of policies for improving farmers' access to agricultural credit can improve farm productivity and rice farmers' welfare.

Originality/value – This study incorporates farmer welfare as a function of productivity in the access to credit-productivity model, creating a tri-variate model to understand the farmer welfare effect of rice productivity dynamics in Ghana.

Keywords Access to credit, Rice productivity, Farmer welfare, Conditional mixed process (CMP) approach, Bidirectional causality, Endogeneity

Paper type Research article

1. Introduction

Rice is a major cereal crop cultivated by farmers in Ghana (Osei-Asare, 2010), and as a food security crop it is second only to maize. Despite this, 53.9% of rice producers use fertilizers, compared to 46.9% of maize producers (GSS, 2020). Data from the Ghana Census of Agriculture (2017/2018) show that, while only 7.7% of rice farmers use irrigation, an estimated 74.3% use pesticides. During the 2017/2018 production season, an estimated 260,210 households reported harvesting rice with an estimated value of 269.70 million Ghana cedis. An estimated 83.95% of households reporting rice harvests in 2017/2018 were in the savannah ecological zones (GSS, 2020), which has always contributed the most to total poverty in Ghana. Although most are smallholder farmers, 45% of producers reported rice sales (albeit unprocessed) with an estimated value of 94.63 million Ghana cedis.

Between 2011 and 2020 rice production in Ghana more than doubled from 463 thousand metric tons to 973 thousand metric tons (MoFA, 2021), at a compound annual growth rate of 7.7%. Over the same period, the area under rice cultivation expanded at a compound annual



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growth rate of 4% compared to yield which had a growth rate of 3.6%. Indeed, others have noted that despite several efforts at promoting its production as part of an import substitution strategy, rice productivity is still very low. The average rice yield in the year 2020 was estimated to be 3.34 metric tons per hectare, about 42% higher than it was in 2011. However, this yield is still much lower than its potential of 6–8 metric tons per hectare (MoFA, 2011; USDA, 2019). The underwhelming production performance of rice farmers can be linked to the low utilization of technology, production inefficiencies and the scarcity of credit (Nordjo and Adjasi, 2020). While these factors indubitably hinder the productivity of rice farms, several authors, such as Martey *et al.* (2019) and Awotide *et al.* (2015), have argued for greater access to credit for producers. They argue that this will help in alleviating liquidity constraints and enable farmers to procure advanced technology to increase productivity and output. Duong and Izumida (2002) argue that access to credit plays a pivotal role in enhancing agricultural productivity, which ultimately leads to improved welfare through increased smallholder income and/or consumption. Despite its significance, however, access to credit remains a challenge for many producers (Wampfler, 2002; Awotide *et al.*, 2015).

Indeed, the literature on the role of credit in enterprise or economic growth is vast and dates back over a century. The basic idea or hypothesis is that entrepreneurs, under credit constraints, may meet the need for capital by means of such credit which enables them to employ the right or appropriate technologies and/or optimal levels of required inputs (Schumpeter, 1912). Several past studies show that binding credit constraints may lead farmers to make production decisions not based on highest return choices or to simply employ suboptimal levels of farm inputs (Schultz, 1953; Feder *et al.*, 1989; Petric, 2004; Blancard *et al.*, 2006). Thus, in a market economy where both land and non-land inputs can be purchased, farmers' access to agricultural credit acts as a catalyst and a reagent in driving farm productivity (Carter and Weibe, 1990; Feder *et al.*, 1990; Nordjo and Adjasi, 2020).

Whereas it is important to stress the significance of improving producers' access to credit, it must be acknowledged that the connection between access to credit and agricultural productivity is not always positive. While many past studies argue for a positive correlation between credit and productivity (Diamoutene and Jatoe, 2021; Adesina and Djato, 1996; Martey *et al.*, 2019; Guiringer and Boucher, 2008), others show contrasting results (Diagne and Zeller, 2001; Anang *et al.*, 2016). In fact, others have found that the effect of access to agricultural credit on productivity depends on such factors as its adequacy to meet farmers' needs, and the credit framework as it relates to issues preventing diversion (Feder *et al.*, 1990; Agbogji and Johnson, 2021). This implies that the role that farmers' access to credit plays in agricultural productivity remains an unsettled empirical question, even as policymakers and implementers strive to improve farm productivity.

Furthermore, focusing solely on the use of access to credit to increase farm productivity to boost farmer-welfare in agriculture can be misleading, as increased productivity does not always guarantee improved welfare. Indeed, increased farm productivity ameliorates welfare through multiple pathways including changes in real income and multiplier effects of non-farm enterprise (Ravallion and Datt, 1999). However, it is not a sovereign remedy to alleviating poverty (Hasan and Quibria, 2004). This is due to risks such as price shocks, drought and pests and diseases associated with farming (Hasan and Quibria, 2004). Also, a rise in welfare due to increased productivity will depend on existing infrastructure, market and demographic set ups (Amare *et al.*, 2016), implying that increased productivity does not automatically boost welfare.

Recent literature that links credit to farm productivity in African agriculture is extensive (see for example, Peprah *et al.*, 2021; Siaw *et al.*, 2021; Nordjo and Adjasi, 2020; Sekyi *et al.*, 2019). Similarly, there is recent literature linking productivity to farm household welfare (Wongnaa *et al.*, 2023; Okoyo *et al.*, 2020). However, following an extensive review, Alhassan *et al.* (2020) noted the absence of empirical studies that test, in a structural fashion, the composite transmission mechanism that underlie most agricultural policies in Ghana. The hypothesis that access to agricultural credit will raise farm productivity which will in turn

increase farm household welfare, the subject of this study. [Alhassan et al. \(2020\)](#), however, focused on the transmission mechanism from credit through productivity to market participation by farmers.

In the literature, several methods including ordinary least squares regression, propensity score matching, endogenous switching regression, difference-in-difference, instrumental variables and selection models have been employed to evaluate the impact of access to credit on farm productivity ([Diamoutene and Jatoe, 2021](#)). However, these methods have shortcomings including their ineffectiveness at addressing the simultaneity issue or potential bi-directional causality in the specified relationship (linking access to credit to productivity) in cross-sectional data ([Varian, 1992](#); [Adeline and Moussa, 2020](#)).

Therefore, this paper aims to fill this gap by first, incorporating farmer welfare as a function of productivity to understand the farmer-welfare effect of rice productivity dynamics in Ghana. Then finally, to address the simultaneity and endogeneity issues, we jointly estimated this mixed and recursive trivariate model using the conditional mixed process (CMP) approach. The three equations jointly estimated were determinants of access to credit, impact of access to credit on productivity, and in turn the productivity impact on welfare. For the analysis, we use micro-level data, the Ghana Living Standards Survey round 7 which has an agriculture module as its main focus and was collected by the Ghana Statistical Service (GSS).

To increase financial services by encouraging competition and efficiency in the credit market, Government of Ghana under the aegis of IMF rolled out a structural adjustment program in the 1980s to shift the national monopoly of the credit market to a liberalized market. These reforms led to a significant establishment of credit institutions across the country ([Akudugu, 2016](#)). In addition to these market reforms, past governments have implemented policies with the intention of alleviating liquidity constraints, especially of farmers ([MoFA & IFPRI, 2020](#)). Indeed, predating the market reforms was the establishment of specialized credit institutions including the Agricultural Development Bank (ADB) to provide direct funds to farmers. As of 2017, while 85% of institutional credit to agriculture emanated from ADB, only 28% of total funds loaned out by the bank was advanced to the agriculture sector. Recent evidence suggests that many agricultural producers remain credit-constrained to date ([Martey et al., 2019](#)), and the share of loans for agriculture-related activities in household borrowing in 2017/2018 was 13.5% compared to 41% for business purposes ([GSS, 2019](#)).

Thus, the issue of ensuring farmers' access to agricultural credit in Ghana is both age-old and contemporary. This is reflected in other government interventions to improve farmers' access to agricultural inputs and increase farm productivity, especially input subsidies. Since 2008, the government has run a farm input subsidy program, except in 2014, and this was replaced with the Planting for Food and Jobs (PFJ) program, introduced in 2017. The PFJ program put a 50% subsidy on the price of fertilizer and seed cost for selected crops including rice, maize and soya beans. Also, as part of renewed effort to increase credit to farmers ADB set itself a goal of raising the share of funds to the agriculture sector to 50% by 2022 ([ADB, 2019](#)).

2. Rice production and consumption in Ghana

Rice is cultivated across all regions of the country, with the main production regions being Volta, Northern, Upper East, Eastern and Ashanti ([USDA, 2019](#)). The crop is mostly cultivated once a year due to heavy dependence on rain-fed farming in Ghana. Rice farming in Ghana was mostly driven by smallholders in precise locations using traditional production techniques. This system has undergone changes and transformations due to state interventions over time that promoted large-scale commercial rice farms as their agricultural modernization policy goal. Smallholders were displaced owing to attempts to acquire huge swaths of land to meet this policy-driven production objective, resulting in the destruction of lands, homes and indigenous staples and in the formation of settler communities. Despite the state's efforts to promote

large-scale commercial farms that received significant financial assistance, the system collapsed, owing in large part to the commercial farmers' failure to repay their bank debts (Amanor, 2011). This resulted in a paradigm shift, with a focus on smallholders' inclusion in the national agricultural modernization program, which is based on a culturally homogeneous food cropping system wherein high crop yields correspond to the usage of external inputs.

Currently, the country is producing far below its potential yield, which is reported to be over 6 t/ha while the current national average is only 2.75 t/ha (USDA, 2019), with the highest output realized in 2019, which stood at 963,000 metric tons of paddy rice (MoFA, 2020). In contrast, the nation's consumption of paddy rice exceeded one million tons in 2019/20, making it the second most consumed cereal after maize (USDA, 2019). Annual per capita consumption of rice was estimated at 24 kg in 2012/2013, rising to 35 kg by 2016/2017 (GSS, 2018). And since 2012, rice consistently maintained the highest consumption expenditure per capita relative to all other cereals, with a ratio of 3.3 times that of maize in 2012/13 (Andam *et al.*, 2019). Aromatic long-grain rice is preferred by both urban and rural consumers, with urban dwellers consuming 70% of it (MoFA & IFPRI, 2020).

3. Methods

The analysis focused on rice production in the 2016/2017 farming season. We employed quasi-experimental research design to filter credit-constrained rice farmers. These are those who need credit but were unable to secure it either because their applications were not granted, or they refused to apply for reasons other than a lack of need. Thus, rice farmers who responded "no-need" to the reason they did not apply for loan were excluded, leaving 294 observations for the analysis. The modest sample size may constrain the precision of estimates, statistical power, and granular analysis. We sought to mitigate these limitations via parsimonious model specification and robust statistical techniques. The CMP approach was employed to recursively estimate the trivariate model, thereby correcting for potential bidirectional causality, and underlining confounding factors that have the potential to cause endogeneity (Roodman, 2011). Quasi-experimental design is a research design used to analyze the causal impact of treatment on the target population without randomization. It differs from the experimental design because of the non-random assignment of the intervention (Dinardo, 2008). The extent of the treatment's cause on the outcome variable using this research design is of concern to researchers if there are uncontrolled confounding variables potentially causing endogeneity (Rossi *et al.*, 2004). It is for this reason that this paper used the CMP approach to control endogeneity and ensure consistent and efficient system estimation.

3.1 Data

The paper employed secondary data from the GSS – a national institution mandated to collect, process and store national data. The Ghana Living Standards Survey (GLSS) round 7, used in this study was carried out in 2016/2017. This round of the survey had agriculture module as its main focus and included important modules like household agriculture, health, employment, population, migration, education, housing conditions and time use on which extensive data were collected. In the GLSS7, sections 8 and 9 cover agriculture and household expenditure (food and non-food expenses) questions while section 12 focused on credit, assets and savings where information on loans contracted by the households, as well as assets and savings of the households were collected. The survey adopted the stratified random sampling technique to sample 15,000 households in 1,000 enumeration areas (EA) to represent the national population. Of these 1,000 EAs, 561 which forms 56.1% of the total households sampled were rural and 439 were urban enumeration areas. The World Bank's Living Standards Measurement Survey questionnaire was adapted and used in the survey.

The country has conducted seven different GLSS, with the first round conducted in 1987. The GLSS is a nationally representative household survey which makes available reliable,

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micro-level and internationally comparable welfare and living conditions statistics in Ghana (GSS, 2019). It provides government and institutions with relevant information about the welfare and living conditions in the country. The second round took place in 1988, followed by the third round in 1991/92. The fourth, fifth and sixth rounds were carried out in 1998/99, 2005/2006 and 2012/13 respectively.

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3.2 Theoretical model

The theory underpinning access to credit and its impact on productivity is the neoclassical theory of expected profit maximization. According to Schultz (1964), farmers make decisions in allocating resources within the neoclassical profit maximization context. That is, they are economically rational. This implies that the decision of a rice farmer to borrow or not depends on the expected gain or profit to be derived from each choice. A farmer whose production is classically conditioned by the availability and use of factors such as land and labor, farming inputs such as fertilizer and seed, and capital aims to maximize productivity. Under a credit constraint, such a farmer is confronted with the decision to either borrow or not in an assumed information-symmetry world. As noted earlier, a binding credit constraint may lead the farmer to make production decisions not based on highest return choices or to simply employ suboptimal levels of farm inputs. Hence, the decision to participate in the market for credit and thereby relieve such a credit constraint which is expressed in terms of a producer’s expected productivity is presented below.

Let M represent productivity gain or the difference in farm productivity with credit (πC) and without credit (πA). The rational credit-constrained producer chooses to borrow if:

$$M = \pi_i C - \pi_i A > 0$$

(1)

and otherwise, if

$$M = \pi_i C - \pi_i A \leq 0$$

(2)

Access to credit, which is a function of various farm and farmer socio-economic characteristics, is dichotomous, with an outcome of 1 if a producer has access to credit (i.e. a successful borrower) and zero otherwise. The function is expressed as follows:

$$AtC = X_i \beta + \varepsilon_i$$

(3)

where AtC denotes access to credit, which is either 1 or 0 and X_i is a vector of farm and farmer characteristics, and an error term (ε_i). The AtC in equation (3) is an argument in the productivity function, since access to credit (AtC) alleviates liquidity constraints. Therefore, to assess the impact of access to credit on productivity, with an assumption that the latter is a linear function of the former, the relationship is expressed as follows:

$$P = X_i \alpha + AtC \gamma + \varepsilon_i$$

(4)

where P is farm productivity which is conditioned by access to credit (AtC) and a vector of socioeconomic characteristics (X_i). In equation (4), α and γ represent the marginal effects of X_i and AtC respectively and capture the degree by which P must change when X_i and AtC changed by one unit, respectively.

In the case of welfare, real household per capita expenditure, the underpinning theory is the neo-classical utility maximization (Hentschel and Lanjouw, 2000). Subject to a given budget constraint, a household is assumed to maximize utility. The utility theory is anchored on assumptions such as individuals are rational and are fully knowledgeable in their quest to maximize utility from the purchase and consumption of goods and services. Utility is classified as either cardinal or ordinal, with the former being measurable by assigning monetary or

quantity values to the utility while the latter simply ranks utilities. The neo-classical utility analysis is based on the cardinal measurement of utility which assumes that utilities are measurable, additive and separable (Varian, 1992).

Consumption of goods and services which is an argument in the utility function is explained by the household's socioeconomic characteristics (Seshie-Nasser and Oduro, 2018). Therefore, a utility function can be expressed as follows:

$$U_i = U_i(C_i, X_i) \quad (5)$$

where U_i is the utility, C_i is vector of the consumption of goods and X_i is the vector of the socioeconomic characteristics of the household. However, because utility is unobserved, consumption expenditure can be used as a proxy, since it is assumed to be linearly correlated with utility (Deaton, 1997). The assumption here is that individuals attain welfare improvement from consumption expenditure, therefore the sum of their disaggregated household consumption represents the composite measure of welfare (Ligon, 2017). According to Deaton and Zaidi (2002), consumption expenditure is a good proxy for welfare since it is less affected by income variations, hence a better long-term measure compared to income. Also, in terms of data collection, respondents may be less sensitive to giving out information about their consumption expenditure than income (Deaton, 1997). Consumption expenditure is also preferred to asset/wealth measures of welfare because it is unaffected by depreciation (Deaton and Zaidi, 2002).

According to Varian (1992), an expenditure function can be expressed as follows:

$$E_h = E_h(P; X) \quad (6)$$

where E_h is the household expenditure which is a function of a price index (P) and household socioeconomic characteristics (X).

Applying this to our context of study, therefore, implies that farmers' welfare measured using their real household per capita consumption expenditure is a function of their socioeconomic characteristics. The use of household expenditure as a welfare measure relies on the implicit assumptions that their demand functions are linear or homothetic and additively separable (Ligon, 2017).

3.3 Conceptual framework

We posit that the average rice farmer in Ghana sets out to maximize household welfare through maximizing farm productivity, and the decision to participate in the market for credit is made to relieve existing credit constraints (Figure 1). Thus, a rice farmer with given socioeconomic and other characteristics who gains access to credit (formal or informal) increases their farm productivity. The access to credit eases their liquidity constraint which could lead to increases in both on-farm and off-farm investments (Awotite *et al.*, 2015). The on-farm investment could include purchase and use of improved technologies and other farm inputs like fertilizer, weedicides and pesticides (Duflo *et al.*, 2011; Rayhan *et al.*, 2023) that increase farm productivity. Off-farm investment covers investment in any business activity aside the farming (Rosenzweig, 2001). The income derived from off-farm investment augments farmers' income (and/or consumption expenditure) but could also be re-invested on-farm to further improve productivity and in effect improve welfare through increased household consumption expenditure on food and non-food products (Girabi and Mwakaje, 2013).

3.4 Empirical model specification and estimation

To identify the factors influencing access to credit, the impact of access to credit on rice productivity and in turn the impact of productivity on household welfare, a trivariate

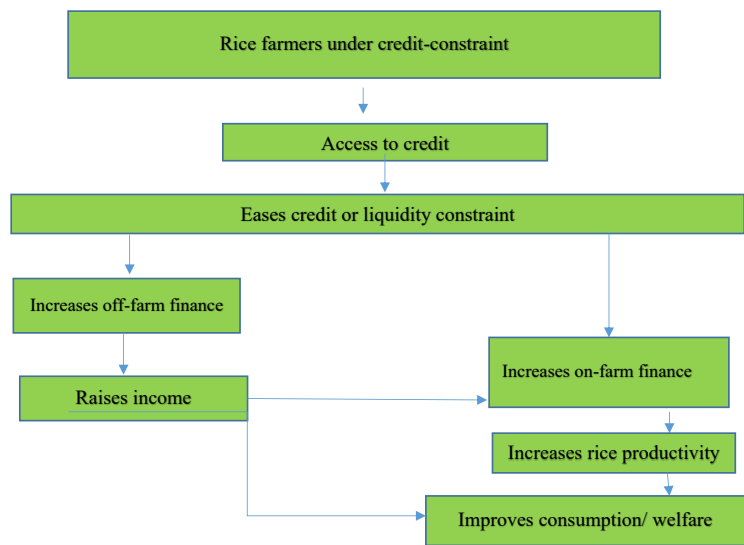


Figure 1. Conceptual framework illustrating the hypothesized relationships among credit access, rice productivity and household welfare. Source: Authors own work

(simultaneous equation) model seems more appropriate because access to credit and productivity are both exogenous and endogenous in this paper. While farmers' access to credit explains variations in farm productivity, productivity explains variations in household welfare. Thus, household welfare of rice farmers is a function of both access to credit and farm productivity, each of which is explained by a set of independent variables. A study on credit is also challenged by the substitutability and fungibility of credit (Diagne and Zeller, 2001). However, once the endogeneity problem is addressed and an appropriate sample selection and survey design are employed, a consistent and accurate welfare or productivity impact of credit is derived (Heckman *et al.*, 1997; Khonje *et al.*, 2015; Awotide *et al.*, 2015).

A recursive model expresses a multivariate model in an inter-dependent system of equations to explain the effects of the variables. The trivariate system of equations is specified below:

$$\text{Access to Credit} = \beta_0 + X_1 \beta_{11} + Y_1 \beta_{21} + K_1 \beta_{31} + \varepsilon_{11} \quad (7)$$

$$\text{Rice Productivity} = \alpha_0 + X_1 \alpha_1 + S_1 \alpha_{21} + \text{AtC} \gamma + \varepsilon_{21} \quad (8)$$

$$\text{Household Welfare} = \gamma_0 + X_1 \gamma_1 + \text{RP} \lambda + K_1 \gamma_{21} + \varepsilon_{31} \quad (9)$$

Equation (7) states that a rice farmer's access to credit is mainly a function of a vector of farmer and farm characteristics, X_1 (e.g. age, gender, etc.) which also condition the other two dependent variables, rice productivity and household welfare. Other factors are Y_1 (unobservable credit worthiness, e.g. bank account or mobile phone ownership) which only affect access to credit, and K_1 (other exogenous factors) which also explain household welfare and an error term, ε_{11} . The dependent variable (rice productivity) in equation (8) is further explained by access to credit (AtC) and an exclusive factor – S_1 (ecological zones). Finally, household welfare in equation (9) is explained by rice productivity, making the system

recursive (unidirectional), with variables that are determined upstream serving as endogenous regressors in downstream equations (e.g. access to credit is in (8) and rice productivity in (9)).

In equation (8), access to credit is treated as exogenous because we expect a positive impact on productivity as access to credit eases liquidity constraints which translates into adoption of improved technology or increased farm investment. Also, productivity is captured in equation (9) because higher productivity is expected to increase farm output and hence improve household welfare either through a rise in income or consumption. Thus, the empirical approach designed to identify the causal pathways linking credit, productivity and welfare as specified above is a recursive (unidirectional) system of equations which rules out simultaneous feedback within the production cycle. To obtain consistent estimates while accounting for the mixed (binary and continuous) nature of the dependent variables and the endogeneity of access to credit in the productivity equation and productivity in the welfare equation, a CMP estimator was employed. The CMP jointly estimates the system, allowing the error terms (ϵ) to be correlated, which controls for unobserved confounders that might jointly affect, for instance, a farmer's access to credit and their productivity. The above specifies the probit and OLS models nested within the CMP framework.

Identification within this recursive system relies on exclusion restrictions, variables that provide independent sources of variation for the endogenous regressors. Specifically, in the access to credit equation (7), bank account and mobile phone ownership were included as determinants of access to credit but excluded from the productivity equation (8). The assumption is mobile phone and bank account ownership affect productivity only indirectly through their respective impacts on access to credit since having a mobile phone and bank account are not expected to directly increase one's farming skills or labor efficiency. These mainly help a farmer to save securely and access loans, which then allows investment in farm inputs and technology. Similarly, in the productivity equation (8), ecological zone (S) directly determines agronomic potential (productivity) but is excluded from the welfare equation (9), as it is assumed to affect welfare solely through its impact on yield.

Instrument validity was assessed using two criteria, relevance and exogeneity. Whereas both bank account and mobile phone ownership were strong, positive determinants of access to credit, a reduced form regression of productivity on both variables produced no statistically significant direct relationship, with an F -statistic of 0.71 ($p = 0.492$). Similarly, a reduced form regression of welfare on ecological zone produced an F -statistic of 0.56 ($p = 0.575$). Thus, the instruments are deemed valid. In the exactly identified CMP framework, we further validate our specification by testing and presenting error correlations. Significant correlation between the errors of the equations confirms the presence of endogeneity and justifies the instrumental variable approach.

Guided by empirical literature, this paper modelled farmers having access to credit as those who applied for loans (cash credit) and were granted. Farmers who need credit but did not apply for any loans or applied but were not granted were categorized as credit constrained. Productivity was measured as rice yield or rice output per hectare of harvested land, and for welfare we used a proxy, real per capita household consumption expenditure.

Although the simultaneous equations approach addresses the endogeneity problem, applying it to these set of equations may lead to difficulty and inconsistent estimates because the equations at hand are a combination of linear and discrete dependent variables (Adeline and Moussa, 2020). In other words, the equations are mixed, one has a dichotomous dependent variable, while the other two have continuous contingent variables. To this end, the paper adopted Roodman's CMP approach which allows the joint estimation of mixed dependent variables (Roodman, 2011).

Following Suarez-Varela *et al.* (2015), Bradley and Crouchley (2019), Danso-Abbeam and Baiyegunhi (2020) and Alhassan *et al.* (2020), and for a three-dimensional model, we express equations (7–9) in the CMP form below:

$$Z_1^* = \theta_1 + \mu_1 \quad (10)$$

$$Z_2^* = \theta_2 + \mu_2 \quad (11)$$

$$Z_3^* = \theta_3 + \mu_3 \quad (12)$$

where θ_1, θ_2 and θ_3 are defined as follows:

$$\theta_1 = X\beta_1$$

$$\theta_2 = X\beta_2 + \gamma Z_1$$

$$\theta_3 = X\beta_3 + \lambda Z_2$$

and

$$Z = g(Z^*) = (1\{Z_1^* > 0\}, Z_2^*, Z_3^*), \quad (13)$$

The Z_1^*, Z_2^* and Z_3^* are latent determinants of the three dependent variables: access to credit (binary), productivity (continuous) and welfare (continuous), respectively, and X is the farmer characteristics earlier on mentioned.

With a trivariate normally distributed correlated error terms, $\mu = (\mu_1, \mu_2, \mu_3)' \sim N(0, \Sigma)$

$$\text{where the } \Sigma = \begin{pmatrix} 1 & \delta_{12} & \delta_{13} \\ \delta_{12} & 1 & \delta_{23} \\ \delta_{13} & \delta_{23} & 1 \end{pmatrix}$$

where δ_{12}, δ_{13} and δ_{23} are correlated error terms of access to credit and productivity, access to credit and welfare, and productivity and welfare, respectively.

Assuming $Z_i = (0, Z_{i2}, Z_{i3})$ is observed, then, the corresponding likelihood function (L) to be estimated which is an integral of the probability distribution of the errors is expressed as:

$$L(\beta_1, \beta_2, \beta_3, \gamma, \lambda, \Sigma; z_i/x_i) = \int_{-\infty}^{-\theta_1} \int_{-\infty}^{-\theta_2} \int_{-\infty}^{-\theta_3} \phi_i(\{\mu_1, Z_{i2} - \theta_{i2}, Z_{i3} - \theta_{i3}\}'; \Sigma) d\mu_1 d\mu_2 d\mu_3 \quad (14)$$

Although this function is accurate, it is impossible to directly compute it in standard statistical software (Roodman, 2011). According to Roodman (2011), to make it work, we need to factor $\phi_i(\{\mu_1, Z_{i2} - \theta_{i2}, Z_{i3} - \theta_{i3}\}'; \Sigma)$ into the probability distribution functions for $\mu_1, \mu_2/\mu_1, \mu_3/\mu_2$.

The $\phi_i(\{\mu_1, \mu_2\mu_3\}'; \Sigma)$ -factored conditional probability distribution of a normal distribution is given as:

$$\phi_i(\mu_1, \mu_2\mu_3'; \Sigma) = \phi_1\left(\mu_1 - \frac{\delta_{13}}{\delta_{33}}\mu_3; 1 - \frac{\delta_{13}\delta_{31}}{\delta_{33}}\right) \phi_2\left(\mu_2 - \frac{\delta_{23}}{\delta_{33}}\mu_3; 1 - \frac{\delta_{23}\delta_{22}}{\delta_{33}}\right) (Z_{i3} - \theta_{i3}; \delta_{33}) \quad (15)$$

Plugging this into equation (14) gives:

$$\begin{aligned} L(\beta_1, \beta_2, \beta_3, \gamma, \lambda, \mathfrak{E}; z_i/x_i) &= \int_{-\infty}^{-\theta_1} \int_{-\infty}^{-\theta_2} \int_{-\infty}^{-\theta_3} \left\{ \phi_1 \left(\mu_1 - \frac{\delta_{13}}{\delta_{33}} \mu_3; 1 - \frac{\delta_{13}\delta_{31}}{\delta_{33}} \right) \right. \\ &\quad \left. \phi_2 \left(\mu_2 - \frac{\delta_{23}}{\delta_{33}} \mu_3; 1 - \frac{\delta_{23}\delta_{32}}{\delta_{33}} \right) d\mu_1 d\mu_2 d\mu_3 \right\} (Z_{i3} - \theta_{i3}; \delta_{33}) \\ &= \phi(Z_{i3} - \theta_{i3}; \delta_{33}) \int_{-\infty}^{-\theta_1} \int_{-\infty}^{-\theta_2} \int_{-\infty}^{-\theta_3} \left\{ \phi_1 \left(\mu_1 - \frac{\delta_{13}}{\delta_{33}} \mu_3; 1 - \frac{\delta_{13}\delta_{31}}{\delta_{33}} \right) \right. \\ &\quad \left. \phi_2 \left(\mu_2 - \frac{\delta_{23}}{\delta_{33}} \mu_3; 1 - \frac{\delta_{23}\delta_{32}}{\delta_{33}} \right) d\mu_1 d\mu_2 d\mu_3 \right\} \end{aligned} \quad (16)$$

where $\mu_3 = Z_{i3} - \theta_{i3}$

Equation (16), according to Roodman (2011), can be computed with standard functions in STATA. All estimations were conducted using Stata's CMP framework.

4. Results

4.1 Descriptive summary of qualitative variables

The summary statistics of the variables employed show that 50% of the rice farmers in this paper were males (Table 1). This implies that, the proportion of females in rice production is increasing since previous studies in Ghana suggest a dominant male gender in the farming sector (Alhassan, 2008). This may also suggest some progress toward the attainment of the United Nations Sustainable Development Goal 5 of gender equality in rice production. About fifty-three (53.06) percent of rice farmers had at least a basic education while 46.93% had never been to school. Konu (2013) also found that most rice farmers at Kpong were educated and argued that education has implications for a farmer's level of productivity through its influence on adoption of new and improved technology. About 33% of the rice producers were married, while the rest were single. Marriage increases responsibilities which may influence loan accessibility, usage and productivity.

Less than 15% of the rice farmers had access to credit; that is only 14.68% of the 294 credit-constrained rice farmers in this study applied for credit and were granted. The rest of the rice farmers (85.36%) who needed credit were unable to access it and thus had no access to credit. This low access to credit by smallholder farmers in the country corroborates the findings of Alhassan et al. (2020). Access to credit has an impact on productivity through an increase in off-farm and on-farm investment, and the adoption and use of improved technology. Like

Table 1. Summary of qualitative variables

Qualitative variables percentage	Measurement	(1)
Gender	Dummy: (1 if male and 0 if female)	50.00
Education	Dummy: (1 if educated and 0 if not educated)	53.06
Marital status	Dummy: (1 if married and 0 if not married)	32.65
Credit access	Dummy: (1 if yes and 0 if no)	14.68
Savannah	Dummy: (1 if yes and 0 if no)	9.18
Forest	Dummy: (1 if yes and 0 if no)	34.01
Bank account	Dummy: (1 if yes and 0 if no)	39.80
Own mobile phone	Dummy: (1 if and 0 if no)	63.27
Non-farm work	Dummy: (1 if yes and 0 if no)	13.19
Ecological zone base: coastal		
Source: Author's computation		

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credit, only 13% of the rice farmers have non-farm work as an additional source of income. However, higher percentages of farmers own bank accounts and mobile phones, 39.80% and 63.27%, respectively. On the ecological zone, 9.18% of the rice producers were in the savannah, 34.01% in the forest and the rest located in the coastal ecological zone. The sample shows no significant gender differences in access to selected services including credit, ownership of bank accounts or mobile phone and education (Table 2).

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4.2 Descriptive summary of quantitative variables

The average rice farmer is relatively young (mean age 33 years), operates a small farm (1.44 hectares) and achieves a mean yield of 758 kg/ha (Table 3). The age of farmers has implication on their productivity and welfare since all things being equal, the older a farmer, the less energy and time employed on farm, but the more experience garnered. Households are of moderate size (5 persons), and welfare levels, measured by per capita expenditure, show substantial variation, highlighting significant economic diversity within the sample. The moderate household size and low amount of hired labor appear consistent with the prevalence of small farms. While the average farm size was 1.44 hectares, 25% of rice farms are 0.20 hectares or less and the median farm size was 0.48 hectares. Productivity (measured as rice yield) ranges from 7.5 to 2,500 kg/ha, with a mean of 758.06 kg/ha. The mean annual real household per capita expenditure for the rice farmers was GH¢3,757.98, and the minimum and maximum were GH¢178.30 and GH¢39,884.84, respectively.

Non-bank financial institutions, primarily savings and loans schemes, are the dominant source of credit, accounting for over 80% of loans (Table 4). This underscores the marginal role of formal banks (16%) in serving smallholder rice farmers' credit needs. The two other important sources of credit to rice farmers during the period are self-help schemes (cooperatives and susu or revolving savings), which account for almost a quarter of all credit received (23.25%) and social networks (relative or friend or neighbor) with about 14%.

Table 2. Gender and access to selected services

Variable	% Male	% Female	Total (% Female)
Access to credit	14.98	14.38	48.84
Bank account ownership	41.50	38.10	47.86
Mobile phone ownership	62.59	63.95	50.54
Education	56.46	49.66	46.79

Source(s): Author's computation

Table 3. Summary statistics of quantitative variables

Quantitative variables	Measurement	Mean	SD	Min	Max
Age	Number of years	33.11	16.04	18	76
Welfare	Ghana cedi	3757.98	6524.64	178.30	39884.84
Productivity	kg per hectare	758.06	512.96	7.5	2,500
Hired Labor Qty	Number of persons	2.35	3.66	0	17
Farm size	Hectares	1.44	4.33	0.0006	50
Household	Size number of persons	4.74	3.03	1	16

Source(s): Author's computation

Table 4. Sources of credit (loans)

Source	Percentage
Private bank	16.28
Cooperative	9.30
Money lender	4.65
Savings and loan scheme	34.88
Susu scheme	13.95
Relative/friend/neighbor	13.95
Other	6.98
Total (N = 43)	100

Source(s): Author's computation

4.3 Comparison between respondents with and without access to credit

Farmers with credit access are systematically different as they are more likely to be educated, married and own a bank account. Most consequentially, they demonstrate substantially higher productivity (+39%) and welfare levels than their counterparts without credit, consistent with the central hypothesized relationships under investigation. More specifically, credit users had significantly higher farm productivity (yield), estimated at 988.92 Kg/ha compared to 711.39 Kg/ha, and GHS6,913.46 more in real household consumption expenditure (household welfare) (Table 5). There are also statistically significant differences in sample proportions of credit users and non-users for selected qualitative variables including ownership of a bank account, being educated and marital status. However, the proportions of credit users and non-users showed no differences across gender, involvement in non-farm work or not, and location. This means that being a male-gender, engagement in non-farm work, living in savannah and forest ecological zone does not improve or influence a farmer's access to credit.

Table 5. Mean differences between respondents with and without access to credit

Variables	Measurement	Credit		Difference	p-value [Z-test (T)]
		Users	Non-users		
Productivity	Kg/ha	988.92	711.39	277.53***	(0.003)
Welfare	Ghana Cedi	9668.27	2754.80	6913.46***	(0.000)
Farm size	Hectare (ha)	1.09	1.50	-0.41	(0.239)
Output	Kilogram	515.31	450.37	65.94	(0.520)
Age	Years	33.56	33.06	0.50	(0.850)
Household size	Number	4.42	4.78	-0.36	(0.390)
Labor	Number	2.14	2.36	-0.22	(0.740)
Gender	Male gender	0.15	0.14	0.01	0.890
Educ	Educated	0.24	0.04	0.20***	0.000
Marital Status	Married	0.35	0.05	0.30***	0.000
Non-farm work	Engaged	0.18	0.14	0.04	0.520
Bank Acc	Owned	0.29	0.05	0.24***	0.000
Phone	Owned	0.16	0.12	0.04	0.330
Savannah	Located	0.11	0.15	-0.04	0.580
Forest	Located	0.18	0.13	0.05	0.250

Note(s): *** denote statistical significance at 1%

Source(s): Author's computation

4.4 Mixed process regression estimates

The CMP regression model fits the data well with a log likelihood ratio $\chi^2(30)$ of 140.28 and p -value = 0.000 (Table 6). Based on the likelihood ration test, the null hypothesis that the error correlations between credit and productivity, productivity and welfare, and credit and welfare (joint test of ρ) are zero is rejected. The results show statistically significant correlation between the error terms (transformed ρ) of access to credit and productivity (atanrho_12, [-1.334; p = 0.004]), access to credit and welfare (atanrho_13, [0.498; p = 0.000]), and productivity and welfare (atanrho_23, [-0.280; p = 0.037]) equations. This indicates that the CMP approach successfully addressed the selection bias and endogeneity issues in the model (Roodman, 2011). It therefore validates our core modeling assumption and empirically justifies the use of joint estimation via the CMP over separate, single-equation methods. The atanrho is preferred relative to the rho since it is unbounded while rho is bounded between -1 and $+1$ (Roodman, 2011).

From the estimates of the three equations, determinants of access to credit, impact of access to credit on productivity and the impact of productivity on welfare, factors like age, education, marital status, output, ownership of bank account and mobile phone play significant roles in determining access to credit (Table 6). Additionally, the study found a negative and significant coefficient for the age of farmer in the access to credit model, suggesting that older rice farmers are less likely to have access to credit. This finding has a positive implication for the youth in agriculture. It suggests that younger farmers have a better chance of successfully obtaining

Table 6. CMP regression estimates of access to credit, productivity and welfare

Variables	Equation (1): Access to credit		Equation (2): Productivity		Equation (3): Welfare	
	M.E	Prob	M.E	Prob	M.E	Prob
Access to credit	—	—	958.270***	0.000	—	—
Productivity	—	—	—	—	2.980*	0.060
Age	-0.026***	0.002	-0.708	0.751	-7.945	0.753
Gender	0.002	0.992	149.546**	0.018	-1261.9*	0.085
Education	1.130***	0.000	-23.424	0.749	1068.8	0.165
Marital status	1.363***	0.000	-216.779**	0.024	939.4	0.270
Household size	-0.050	0.188	-7.194	0.495	19.5	0.870
Farm size	0.024	0.169	-108.948**	0.021	—	—
Output	0.001***	0.001	—	—	—	—
Non-farm work	0.438	0.136	-3.969	0.966	3281.6***	0.002
Labor quantity	—	—	9.241	0.228	—	—
Bank account	1.088***	0.000	—	—	1788.3**	0.020
Own Mobile phone	0.547**	0.012	—	—	258.8	0.722
Savannah	—	—	92.583	0.354	—	—
Forest	—	—	98.602*	0.102	—	—
Constant	-3.044	0.000	684.925	0.000	-15.2	0.993
Mixed-process log likelihood = -5145.7781			LR χ^2 = 140.28 Std error		p -value = 0.000 p -value	
Coefficient						
/atanrho_12	-1.334***		0.469		0.004	
/atanrho_13	0.498***		0.103		0.000	
/atanrho_23	-0.280**		0.134		0.037	
Note(s): *, **, *** denote statistical significance at 10%, 5% and 1%, respectively						
Source(s): Authors' estimation with GLSS7 data						

credit or having access to credit compared to their older counterparts, possibly due to the risk-averse nature of older farmers.

The education variable is positively correlated with access to credit. This signifies that rice farmers who received formal education have a higher likelihood of having access to credit compared to those who did not [Diamoutene and Jatoe \(2021\)](#). The positive coefficient for marital status similarly indicates that rice farmers who were married have a higher likelihood of having access to credit compared those not married. This result is in line with previous studies like [Awotide et al. \(2015\)](#) and can be attributed to the perception that married people tend to be more financially responsible, making them more likely to be eligible for credit. Moreover, married farmers can depend on their spouse for financial support.

The coefficients for both ownership of a bank account and mobile phone were positively correlated with access to credit like [Alhassan et al. \(2020\)](#). Similarly, [Suri and Jack \(2016\)](#) and [Ghosal et al. \(2015\)](#) found that firms or individuals with mobile money accounts are more likely to obtain loans. Such findings are not surprising as almost every bank requires a borrower to have an account prior to loan processing, and owning a mobile phone can reduce information asymmetry by giving access to relevant information. Finally, output was positively correlated with access to credit, like [Awotide et al. \(2015\)](#) which suggest a positive link between farm output and access to credit.

Results from the model on the impact of access to credit on rice yield show a statistically significant estimate of 958.27 kg/ha for access to credit (at the 1% level of significance). This indicates that access to credit by a farmer has a positive impact on farm productivity (rice yield). The coefficient of 958.27 kg/ha suggests that access to credit by a rice farmer raises their productivity by as much relative to being without access. This translates to a farmer with access to credit achieving an average yield that is 39% higher than without it (711.39 kg/ha) and 27.77% above the sample median yield, a difference that is consequential. This outcome aligns with theoretical predictions and a significant number of past empirical studies including [Shuaibu and Nchake \(2021\)](#), [Diamoutene and Jatoe \(2021\)](#), [Alhassan et al. \(2020\)](#), [Martey et al. \(2019\)](#), and [Musaka et al. \(2017\)](#). For instance, [Diamoutene and Jatoe \(2021\)](#) and [Musaka et al. \(2017\)](#) examined the influence of access to credit on farm productivity in Mali and Ethiopia, respectively, using the endogenous switching regression model. Both studies reported a significant positive impact of access to credit on farm productivity. Additionally, [Alhassan et al. \(2020\)](#) utilized the CMP method to model the productivity impact of access to credit among maize farmers in Ghana, as well as its influence on their market participation. It was found that maize productivity was positively impacted by farmers' access to credit, which in turn enhanced their market participation. These studies illustrate that credit constraints on farm households have an adverse effect on their farm productivity. Indeed, it is widely understood that access to credit can enhance productivity by alleviating liquidity constraints and facilitating the adoption of new and improved technologies, and/or increase farm investments and consequently increase farm productivity. This theory has been supported by past studies including [Awotide et al. \(2015\)](#) and [Duong and Izumida \(2002\)](#).

From the estimated impact of rice productivity on the welfare of rice farmers, the results show that the coefficient of rice productivity in the welfare equation is positive and statistically significant, with a magnitude of GH¢2.98. This means that a 1 kg/ha increase in rice productivity (yield) leads to a GH¢2.98 increase in real household per capita expenditure. In other words, given its associated productivity gain, access to credit results in an average welfare increase of approximately GH¢2,855.64 per capita, which is 76% of the average household per capita consumption expenditure. This result supports the theory that enhanced farm productivity (yield) can positively impact welfare by increasing real consumption and is consistent with other studies in the past such as [Mujeyi et al. \(2021\)](#), [Abdulai \(2016\)](#), [Amare and Shiferaw \(2017\)](#), [Amare et al. \(2016\)](#), [Foster and Rosenzweig \(2004\)](#) and [Nguezet et al. \(2011\)](#). The finding means or suggests that highly productive rice farmers have greater output, and as a result, they have an increased capacity to either directly consume out of own production or more freely sell their produce. The earnings from these sales can be used to

purchase other consumables, further increasing consumption and ultimately leading to an increase in real household per capita consumption or expenditure.

Finally, productivity was significantly influenced by factors such as gender, marital status, farm size and location in the forest ecological zone. On the other hand, significant factors explaining changes in welfare were non-farm work, bank account ownership and gender of farmer. Specifically, gender had a positive coefficient in the rice productivity equation, while it was negative in the welfare equation. This suggests that male farmers tended to be more productive than their female counterparts by 149.55 kg/ha. This magnitude suggests that productivity differences between male and female farmers is 149.55 kg/ha in favor of male farmers. This may be because women in farm households in developing countries are mostly the home keepers and therefore may have less time available for their farm work. However, despite this productivity difference, female farmers had higher welfare.

Another significant finding from the research is the inverse relationship between the size of farm and rice productivity, like [Amare et al. \(2016\)](#). This result indicates that smaller farms tend to have higher land productivity, which is possibly because they are easier to manage and require fewer resources. Additionally, unmarried farmers and those situated in the forest ecological zone were more productive, with a productivity difference of 216.78 and 98.60 kg/ha, respectively. The coefficient of non-farm work and bank account ownership in the welfare equation were positive and statistically significant, with estimated magnitudes of GH¢3,281.60 and GH¢1,788.30, respectively. This suggests that farmers who engage in non-farm work, as extra activities, and those who have a bank account, have extra GH¢3,281.60 and GH¢1,788.30, respectively, in real household per capita expenditure compared to those who rely solely on farming, and those who did not have a bank account during the 2016–2017 production year. These results are consistent with the research findings of [Owusu et al. \(2011\)](#). The explanation is that farmers who engage in a non-farm enterprise in addition to the farming business obtain extra income from these enterprises which then improves their welfare through increased income and real expenditure. With respect to bank account ownership, it increases the probability of access to credit, thereby increasing non-farm and farm investment and consequently welfare.

These findings have important implications for policy and practice. Attempts to promote access to credit based on factors identified could be effective but simultaneously increase the flow of credit to the already advantaged (educated, married, phone owners), widening gaps (inequality). This calls for agricultural credit policies that are pro-poor by design. For example, government can facilitate linkages between credit institutions and mobile money platforms to reduce the transaction costs, support subsidized digital accounts for farmers and integrate financial education, all in a package. Improving the financial literacy of farmers will lower their vulnerability and risk of falling into over-indebtedness. Government policy deliberately targeting credit products to women or women's groups will enhance household welfare of rice farmers. Also, by promoting joint spousal lending products rice farming households may enjoy a double-dividend, the higher productivity of the male as well as the higher welfare of the female. Credit policies should aim to maximize the benefits of available credit by fostering responsible, equitable and sustainable credit ecosystems that enhance productivity and welfare while safeguarding farmers from new forms of vulnerability.

5. Conclusion and recommendations

The study found education, marital status, output, mobile phone ownership and bank account ownership to be the determinants of access to credit. Also, access to credit positively impacts productivity of rice farmers in Ghana which in turn, ameliorates welfare of the farmers. Specifically, access to credit positively impacted rice productivity, with an extra 958.27 kg/Ha for credit users, and in turn productivity directly impacted rice producers' real household per capita expenditure (welfare) with a coefficient magnitude of GHC 2.98.

Given these conclusions, the following recommendations will facilitate rice producers' access to credit and increase farm productivity and thereby ultimately enhance their welfare. Stakeholders in the sector must empower and intensify literacy and numeracy education for farmers to improve productivity and in turn the welfare of producers. The Ministry of Food and Agriculture (MoFA) and partner institutions, including NGOs, must encourage and promote formal as well as other forms of education of farmers. This will ensure farmers are equipped to obtain the necessary information and gain access to credit. Stakeholders, including MoFA, farmer interest groups or organizations in the agricultural sector should encourage farmers to adopt digital technology like the use of mobile phones and bank account ownership to enhance producers' ability to access credit. Governments, NGOs and institutions interested in uplifting the welfare of smallholder farmers through increased productivity must help farmers have access to credit by encouraging and supporting non-bank financial institutions like savings and loan schemes, susu, cooperatives and money lenders which form the major sources of loans for the farmers. For effective implementation, MoFA can partner with mobile operators (Digital Inclusion Hubs) to bundle farmer ID registration with low-cost mobile money accounts and agricultural information SMS services to overcome initial access barriers and improve outreach. Also, development banks (e.g. ADB) should fund FinTech to create credit products using digital profiles of potential borrowers (e.g. satellite yield data, mobile transaction history) for risk assessment. To ensure productive use such credit lenders should disburse it digitally to approved input dealers as payment for inputs and other services to the farmers. In addition, the Youth Employment Agency (YEA) and GIRSAL should offer partial digital credit guarantees to cover young farmers who complete mobile-based agri-entrepreneurship training. Finally, under an integrated enterprise support scheme District Assemblies should work with NGOs to run centers offering combined training in improved farming and non-farm agribusiness, backed by tied-credit products that fund both to improve financial literacy.

Ethical approval

This study used secondary data, available to the public from the GSS, and did not require ethical clearance for data collection.

Consent for publication

All authors consent to the publication of the paper.

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