Agricultural services and rural household welfare: empirical evidence from Ghana

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Abstract

Purpose – This paper aimed to examine the impacts of agricultural services on welfare of rural farmers in Ghana.

Design/methodology/approach – Using data from 1431 rural maize farmers, we employ multinomial endogenous switching regression and multivalued inverse probability weighted regression adjustment to assess the impacts.

Findings – Results show that 19.8%, 9.7% and 3.42% of farmers adopted solely irrigation, extension and mechanization, respectively. Furthermore, utilizing a range of agricultural services significantly improves maize yields, gross income and per capita food consumption.

Research limitations/implications – This study recommends strategies that target the adoption of combinations of agricultural services to enhance rural farmers’ welfare in Ghana and other developing countries.

Originality/value – While agricultural services are claimed to improve agricultural production and peasants’ welfare, their impacts are not studied exhaustively. This paper contributes by providing empirical evidence of the impacts of agricultural services on farmers’ welfare.

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Keywords Agricultural services, Adoption, Multinomial endogenous switching regression, Household welfare

Paper type Research paper

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Ethical statement: We prioritize respondent confidentiality, ensuring ethical research. Participants received a clear study explanation, gave informed consent and were assured of voluntary participation. We emphasized their right to discontinue interviews at any point. We also committed to handling responses diligently and using study insights for knowledge advancement.

In the interest of transparency, data sharing and reproducibility, the author(s) of this article have made the data underlying their research openly available. It can be accessed by following the link here: https://drive.google.com/file/d/1-Gb2rVncpph8Uck5NfGtTBYILx3FAtHe/view?usp=share_link

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1. Introduction
Agricultural services are crucial for crop production, yet many smallholder farmers in low-income countries have limited access to these services (Achandi et al., 2018; Kansiime et al., 2019). For example, most smallholder farmers in Ghana live in scattered villages with limited access to agricultural services (Anang and Asante, 2020). Therefore, several farmers are unable to receive agricultural services due to longer farm distances, the topography of their lands, poor road network and inaccessibility of many service providers (Anang et al., 2020). The most pressing concern is ensuring that agricultural services are made available to smallholder farmers to improve crop productivity. Thus, this study examines the determinants of access to agricultural services and their impact on smallholder farmers’ welfare in Ghana.

It is well established that enhancing agricultural production, especially in food crops, is crucial for achieving the sustainable development goals (SDGs), aimed at reducing poverty and enhancing food security. In Ghana, the government’s policy framework for economic growth and poverty reduction necessitates sustained agricultural growth and hunger alleviation. Despite progress in poverty reduction, projections indicate a slight increase in the poverty rate from 25% in 2019 to 25.5% in 2022 (World Bank, 2022). This underlines the persistent challenge of poverty in the agricultural sector, particularly for rural farmers (Danso-Abbeam et al., 2018; Cooke et al., 2016). To address this, governments in low-income countries, including Ghana, are actively providing rural farmers with essential agricultural services such as irrigation systems, agricultural extension, mechanization and credit (Masasi and Ng’ombe, 2019; Abdallah, 2016; Anang and Asante, 2020; Danso-Abbeam et al., 2018). These efforts aim to enhance crop productivity and elevate the well-being of smallholder farmers.

Cumulatively, sub-Saharan Africa (SSA) consistently grapples with food emergencies and insecurity, necessitating increased and stable agricultural food production (Ngomi et al., 2020; FAO, 2017). Smallholder farm households in SSA, including Ghana, predominantly employ traditional agricultural methods (Anang et al., 2020; Danso-Abbeam et al., 2018; GSS, 2014), resulting in suboptimal crop yields. In Ghana, crops like maize, rice, yam, cassava and plantain achieve less than half of their potential yields due to factors like primitive farming methods, rain-dependent production, limited adoption of modern agricultural technologies, insufficient credit access and inadequate agricultural services (Lu et al., 2021; Anang et al., 2020; Anang and Asante, 2020; Makate et al., 2019; Danso-Abbeam et al., 2018; Asfaw et al., 2012). With climate change and technological advancements, farmers require increased investment in their agricultural activities (Gebrehiwot, 2015; Asfaw et al., 2012). Among the many agricultural services that could enhance agricultural productivity are extension, mechanization and irrigation but access barriers persist (Anang et al., 2020; Kansiime et al., 2019). Extension builds capacity for improved practices (Ngomi et al., 2020; Ghimre et al., 2015) though services often overlook unique smallholder needs. Mechanization through tractor access boosts yields by enabling faster, higher quality land preparation yet availability constraints remain (Sims and Kienzle, 2016; Anang and Asante, 2020). Since most Ghanaian cropland is rainfed, irrigation allows more intensive production and income generation via year-round cropping (Kuwornu and Owusu, 2012; Makate et al., 2019). Expanding irrigation is viewed as critical for rural development (Anang and Asante, 2020). While essential, many services fail to reach remote smallholders in Ghana. Examining access determinants and productivity impacts can inform policies to extend services and reduce barriers.

Considering the increasing policy support, some studies have examined the impact of access of agricultural services on several agricultural outcomes, e.g. agricultural extension (Anang et al., 2020; Danso-Abbeam et al., 2018; Wossen et al., 2017), irrigation (Anang et al., 2020; Xie et al., 2014; You et al., 2014; Kuwornu and Owusu, 2012) and mechanization (Mehta et al., 2014; Houssou and Chapoto, 2015; Obi, 2011; Sims and Kienzle, 2016). However, none of these studies consider the possibility of these services being provided jointly or farmers
adopting/participating in them jointly. Most peasant farmers in Ghana and other parts of the world adopt agricultural technologies and services singly (Danso-Abbeam and Baiyegunhi, 2018; Kassie et al., 2015; Lu et al., 2021). But they can be adopted jointly as complements, substitutes or supplements in order to provide maximum payoffs like other agricultural technologies (Teklewold et al., 2013; Ng’ombe et al., 2017). While we hypothesize that smallholder farmers may reap more benefits from agricultural services that they adopt or participate in jointly, there is scant empirical evidence about the ceteris paribus effects of the potential joint adoption of multiple agricultural services on household welfare in low-income countries. This paper attempts to fill this gap by analyzing the determinants of the adoption of agricultural extension, agricultural mechanization and irrigation services and their impact on maize yield, gross income and per capita consumption expenditure in Ghana.

This paper contributes to existing literature in the following way. The study offers a new micro-perspective on the impact of various agricultural services on household welfare by focusing on multiple agricultural services when adopted in singles and jointly. Most impact studies ignore the cumulative impacts of adoption of agricultural services, however, ignoring their potential interdependence when evaluating their impacts may result in biased results. This study is relevant to the debate as to whether the farmers adopt agricultural services individually or as a package and unearths potential heterogeneity in effects across combinations of agricultural services, in so doing contributing to targeting effective service delivery. We therefore, provide a more comprehensive analysis of a unique set of agricultural services. This will inform policy as to whether these agricultural services should be provided in singles or in combinations to enhance rural household welfare.

2. Methodological framework

Agricultural services such as irrigation, mechanization and agricultural extension may be adopted in combinations because of their potential end effects. Farmers mostly choose agricultural services by selecting a specific service that they believed would provide them with greater utility (Anang and Asante, 2020; Danso-Abbeam and Baiyegunhi, 2018; Wossen et al., 2017; Bidzakin et al., 2018). Thus, farmers are likely to adopt agricultural services jointly or singly. In such scenarios, Bourguignon et al. (2007) proposed a multinomial endogenous switching regression (MESR) to measure the impact of such adoption behavior on potential outcomes. They also asserted that regardless of whether the independence of irrelevant alternatives assumption is met or not, the MESR provides consistent and bias-corrected choice estimations. In addition, the MESR accounts for selection biases that are likely to emanate from either observed or unobserved confounders (Lu et al., 2021; Mansur et al., 2008; Wooldridge, 2010).

2.1 Multinomial adoption selection model

Using the random utility maximization framework, farmers are assumed to be rational and always strive to maximize their returns $Z_i$ from the agricultural services they adopt. Given that an ith farmer chooses any of the combination, $k$ over another mix of $i$, expressed as $Z_i > D_{il} \neq k$, the latent outcome is $Z^*_i$, which is a farmer’s outcome from the choice of the combination $k$ given by identified socioeconomic, farm-level characteristics and institutional factors ($X_{ij}$) and other disturbance factors ($\mu_{ij}$). The latent model is specified as

$$Z^*_i = X_i \beta_j + \mu_{ij}$$  \hspace{1cm} (1)

where; $X_i$ = set of observed explanatory variables, $\beta_j$ = unknown parameters to be estimated, and $\mu_{ij}$ is the error term. Let $S$ be an indicator variable to represent farmers’ choice of the agricultural services. Then:
\[ S = \begin{cases} 
1 \text{ if } Z_{11}^* > \max_{l \neq j}(Z_{il}^*) \text{ or } \beta_{11} < 0 \\
\vdots \quad \vdots \quad \forall l \neq j \\
k \text{ if } Z_{11}^* > \max_{l \neq j}(Z_{oj}^*) \text{ or } \beta_{kj} < 0 
\end{cases} \]  

where; \( \delta_{ij} = \max_{l \neq j}(Z_{il}^* - Z_{11}^*) < 0 \) (Bourguignon et al., 2007). Accordingly, the \( i \)th farmer in equation (2) selects a combination \( k \) with the highest expected benefit from combination \( k \) results in higher economic benefits than any other combination \( l \neq k \) if \( \delta_{ij} = \max_{l \neq j}(Z_{il}^* - Z_{11}^*) > 0 \).

Assuming \( \mu \) is identically and independently distributed as a Gumbel distribution, the likelihood that farmer \( i \) will select a combination \( j \) then the model assumes a multinomial logit model (MLM). Such choices are modeled in a MLM environment (McFadden, 1973) as specified as:

\[ P_{ik} = \Pr(\delta_{ik} < 0 | X_i) = \frac{\exp(X_i \delta_{ik})}{\sum_{l=1}^{k} \exp(X_i \delta_{il})} \]  

2.2 Multinomial endogenous switching regression

For each combination of agricultural services, the outcome variables which include maize yield, maize gross income and per capita consumption are regressed on explanatory variables (i.e. socioeconomic characteristics, farm level and institutional factors). The combination \( I_0E_0M_0 \) is the base group signifying the non-adoption of all three agricultural services given as \( j = 1 \) while the rest of the choices are \( 2, 3, 4, \ldots, n \). Hence, the possible regimes of each outcome variable are specified as

\[ \begin{align*} 
\text{Regime 1: } F_{i1} &= C_i \varphi_1 + \varepsilon_{i1} \text{ if } S = 1 \\
\vdots & \quad \vdots \\
\text{Regime } ik: F_{ik} &= C_i \varphi_k + \varepsilon_{ik} \text{ if } S = 1 
\end{align*} \]  

where \( F_{i1}^* = i \)th farmer’s outcome variables in the regime \( k \) and error term \( \varepsilon \) specified as \( E(\varepsilon | X, T) = 0 \), and \( \text{var}(\varepsilon | X, T) = \eta_k^2 \). \( F_{ik} \) is assumed as identified if, and only if, the combination \( k \) is adopted, specified as \( F_{ik}^* > \max_{l \neq k}(F_{il}^*) \). With no independence of \( \mu \) and \( \varepsilon \), the ordinary least squares (OLS) estimations in equation (4) result in biased estimates. The \( \beta_k \) shows the need for selection correction terms in equation (4) that are more reliable and give consistent estimates. Dubin and Daniel (1984) hypothesized the linearity framework

\[ E(\varepsilon_{ik} | \mu_{i1} - \mu_{ik}) = \alpha_k \sum_{l \neq k} \kappa_k(\mu_{il} - E(\mu_{il})) \]  

where; \( \sum_{l}^{k} = 1^{0=0} \) shows the correlation between \( \mu \) and \( \varepsilon \) sum to zero. In this assumption, the MESR (based on equation 4) is specified as

\[ \begin{align*} 
\text{Regime 1: } F_{i1} &= T_i \psi_1 + \omega_i \hat{\mu}_{i1} \text{ if } S = 1 \\
\vdots & \quad \vdots \\
\text{Regime } ik: F_{ik} &= T_i \psi_k + \pi_i \hat{\mu}_{ik} \text{ if } S = 1 
\end{align*} \]
where; $\varpi_k$ = covariance of $\mu$ and $\eta_k$, $\rho_k$ = inverse Mills ratio in equation (3) whereby

$$\eta_k = \sum_{i \neq k} H_k \left[ \bar{U}_i \ln(\bar{U}_d) + \ln(\bar{U}_d) \right]$$

where; $H = \text{correlation parameter of } \mu \text{ and } \varepsilon, \delta = \text{error term. The standard errors (in equation 5) have to be bootstrapped to address any likely heteroskedasticity in the regressors ($\eta_k$).}$

Following Lokshin and Glinskaya (2009), nonlinearities in the case of a set of the vectors of $X$ and $T$ variables overlapping are handled using equations (3) and (5). The use of instrumental variables gives robust estimates (Lokshin and Glinskaya, 2009; Lu et al., 2021). Instrumental variables are used for identification but not essentially as a requirement of equation systems (Chamberlain and Griliches, 1975). Several studies also showed an alternative selection model (see equation 4) based on the importance of instrumental variables (Anang et al., 2020; Bourguignon et al., 2007; Teklewold et al., 2013; Lu et al., 2021). In this paper, we used distance to farm location and information access as instrumental variables based on previous literature. Distance to farm location and information access strongly influence the adoption of agricultural services but do not affect the outcome variables directly. Furthermore, based on Di Falco et al. (2011), the admissibility test was conducted to check the validity of the instrumental variables jointly [$\chi^2 = 79.12$ and $p = 0.000$].

2.3 Counterfactual and treatment effect specification

We employed the multinomial endogenous switching regression model (MESRM) to assess the counterfactual and average selection impacts (Asante et al., 2023; Anang et al., 2020; Danso-Abbeam and Baiyegunhi, 2018; Di Falco et al., 2011; Lu et al., 2021). We compute the counterfactual as adopters’ outcome variables, thus the benefits (coefficient estimates) on their attributes (of adopters) give the same benefits (marginal effects) as the attributes of the nonadopters and vice versa. The average treatment effect (ATE) is compared to the likely effects on adopters either with or without the adoption of the agricultural services. Using the equation (5), we compute each outcome variable on the conditional expectations specified as

In the case of observed adopters in the sample:

$$\begin{align*}
E(F_{i1}|S = 2) &= M_i \xi_1 + \gamma_2 \alpha_2 \\
& \vdots \\
E(F_{i1}|S = K) &= M_i \xi_k + \gamma_k \alpha_k
\end{align*}$$

(6)

In the case of adopters, had they not decided to adopt (counterfactual):

$$\begin{align*}
E(F_{i1}|S = 2) &= M_i \xi_1 + \gamma_1 \alpha_2 \\
& \vdots \\
E(F_{i1}|S = K) &= M_i \xi_k + \gamma_k \alpha_k
\end{align*}$$

(7)

We compute the unbiased causal effects using the equations (6) and (7). Therefore, the difference between equations (6) and (7) is the average treatment effect on the treated (ATT) and is specified as

$$ATT = E[F_{12}|S = 2] - E[F_{11}|S = 2] = T_i (\gamma_2 - \gamma_1) + \alpha_2 (\gamma_2 - \gamma_1)$$

(8)

The right-hand side of equation (8) shows the difference in the average outcome of adopters’ thus if adopters’ attributes give equivalent benefits as non-adopters. Also, $\sigma_2 = \text{the second}$
part of the selection decision assumed all the likely differences in the unobserved variables of impacts.

While the MESRM demonstrates its capacity to discern causal effects when equipped with a suitable instrument, it is not without its set of challenges. One prominent constraint of the MESRM pertains to its data prerequisites. This model demands a significant volume of data for each treatment to produce results that are both reliable and credible. Nevertheless, amassing such expansive datasets is a costly and labor-intensive endeavor.

### 2.4 Multivalued inverse probability weighted regression adjustment (MIPWRA)

We defined a set of instrumental variables to satisfy the MESRM’s identification and exclusion restriction criterion. Although prior studies have employed the admissibility test of accepting instruments for use in impacts assessments (see; Asante et al., 2023; Kiwanuka-Lubinda et al., 2021; Ding and Abdulai, 2020; Di Falco et al., 2011; Addai et al., 2023) such a test does not mean the instruments are perfect. Therefore, we used the MIPWRA as a doubly robust check to the estimates obtained from the MESRM. The MIPWRA takes into consideration any potential confounders’ selection bias and allows for misspecifications of either the treatment or outcome equations. The MIPWRA computes the ATT by creating the inverse of the treatment probability weights using the missing data corrected regression. There are two stages to the MIPWRA. First, is the estimation of MLM to compute the propensity scores for each adoption combination of agricultural services (Asante et al., 2023; Linden et al., 2016; Lu et al., 2021; Manda et al., 2021). As a result, the inverse probability of treatment weights is estimated for each treatment combination. In the second stage, weights for each treatment combination are computed for outcome equations – maize yield, gross maize income and per capita consumption using weighted regression. The weighted regression parameters are then used to construct treatment specific predicted outcomes for each observation. The generalized method of moments is thus, used to accounts for any possible estimation errors from the propensity scores. The MIPWRA-based ATTs for farmers who adopted combinations of agricultural services are specified as

$$\text{ATT}_{\rho_e} = E \left[ \left( C_{\rho_i} - C_{\rho} \right) \mid \rho = \rho_e \right]$$  

where; $\rho_i$ denotes the $i$th sample farmer’s possible outcome (thus, maize yield, gross maize income, per capita consumption) from the $p$th treatment combinations, $\rho$ denotes the treatment status of the treated possible outcome, $\rho = \rho_e$ means the restriction that accounts for those farmers who received treatment only if $\rho$ and 0 is the control possible treatment status of each outcome.

### 3. Data and descriptive analysis

Our data were collected from Ghana’s Brong Ahafo region. The region is located in the southern half of the country. The region is bordered on the north by the Northern region, the south by the Ashanti and Western regions, the east by the Volta region and the west by the Eastern region. It has a population of 2,282,128 people and 69.1% of them are engaged in agriculture (Ghana Statistical Service, (GSS), 2014). The region has rich soil, favorable climatic conditions and a diverse vegetation cover. It is also considered an agricultural-based economic activity hub in Ghana, contributing 30% of the country’s food (GSS, 2014). Maize, rice, yam, cassava, sorghum, cashew and cocoa are among the crops cultivated in the region.

A multistage sampling technique was adopted to select the maize farmers. First, we chose the Brong Ahafo of Ghana because of its high maize output and availability of agricultural services for maize farmers. For the same reasons, we purposively selected sampled Kintampo
North and South districts from this region. A total of twenty (20) communities were chosen at random from each district. Seventy-two (72) farmers were randomly selected from each community and interviewed. As a result, we sampled a total of 1,431 farmers using a structured questionnaire.

Prior to commencing the interviews, we conducted a pilot survey aimed at detecting any shortcomings in the questionnaire and subsequently implementing essential refinements. This iterative approach played a pivotal role in elevating the research’s reliability and validity. To fortify the accuracy and uniformity of data collection, rigorous research designs were deployed, coupled with the utilization of standardized measurement instruments. Moreover, meticulous measures were taken to mitigate potential biases, thereby reinforcing the validity of the research findings.

The selection of explanatory variables in our econometric models draws from previous studies of technology adoption and agricultural productivity (Anang et al., 2020; Ngomi et al., 2020; Danso-Abbeam and Baiyegunhi, 2018). The outcome variables representing farmer welfare were maize yield (kg/ha), gross maize income and per capita consumption expenditure (Anang et al., 2020). We incorporated key socioeconomic factors like age, education and farming experience that influence adoption decisions (Wossen et al., 2017; Bidzakin et al., 2018). Institutional factors were also included such as farm size, credit access, farmer organizations and extension contacts (Danso-Abbeam et al., 2018; Anang et al., 2020). Environmental variables like rainfall and pest incidence were incorporated as well. Our central hypothesis is that adoption of key services – agricultural extension, mechanization and irrigation - will increase yield, income and consumption (Ngomi et al., 2020; Anang and Asante, 2020). We define extension as access to training and advice for improving operations and productivity. Irrigation refers to water supply from systems to the maize farm. Mechanization access involves ability to hire tractor services for land preparation and post-harvest activities. Details on all variables are presented in Table 1.

The average maize yield, gross maize income and per capita consumption was 2401.33 kg/ha, GHS3601.98 and GHS8.82, respectively. For comparison of outcome variables, the differences presented in Table 1 are reviewed as possible effects, which may lead to erroneous conclusions because they do not account for any potential confounders (Lu et al., 2021; Angrist and Pischke, 2014).

Table 2 summarizes the specific agricultural services that maize farmers use. The results indicate the most likely combinations of eight as 2³. The results show that 6.64% of the farmers did not adopt any of the agricultural services (I₀E₀M₀) but 16.90% of the farmers adopted all the agricultural services simultaneously. During the agricultural production year, approximately 60.37% of the overall sample used multiple combinations of agricultural services. Our results indicate that most farmers traditionally supported the adoption of multiple agricultural services in production.

4. Econometric results and discussions

4.1 Determinants of the choice of combinations of agricultural services

Table 3 shows the determinants of the choice of combinations of agricultural services. For the estimation, the MLM was used, with non-adoption (I₀E₀M₀) defined as the base group. The Wald $\chi^2$ and likelihood ratio (LR) $\chi^2$ (126) were significant indicating that the MLM appropriately fit the estimation of selection choice among farmers. The marginal effects were estimated and used to discuss the parameters because it shows the magnitude of each likelihood’s effect (Anang et al., 2020; Danso-Abbeam et al., 2018; Nguyen-Van et al., 2017). Given the combination of agricultural services, the results show a clear heterogeneity in marginal effects. Our results reveal that older farmers are more likely to adopt irrigation and extension services, possibly due to declining strength and a desire to reduce farming
Table 1. Descriptions and summary statistics by combinations of agricultural services

<table>
<thead>
<tr>
<th>Variables</th>
<th>Variable Definition</th>
<th>None Mean</th>
<th>Irrigation only Mean</th>
<th>Extension only Mean</th>
<th>Mechanization only Mean</th>
<th>Irrigation and extension Mean</th>
<th>Irrigation and mechanization Mean</th>
<th>Extension and mechanization Mean</th>
<th>All Mean</th>
<th>Overall Mean</th>
<th>Std. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Socioeconomic variables</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>Age of farmer in years</td>
<td>47.05</td>
<td>46.99</td>
<td>48.06</td>
<td>46.65</td>
<td>47.80</td>
<td>47.0</td>
<td>48.12</td>
<td>48.40</td>
<td>47.61</td>
<td>10.70</td>
</tr>
<tr>
<td>Gender</td>
<td>1 if a farmer is male and 0 = otherwise</td>
<td>0.757</td>
<td>0.837</td>
<td>0.870</td>
<td>0.877</td>
<td>0.909</td>
<td>0.874</td>
<td>0.851</td>
<td>0.893</td>
<td>0.860</td>
<td>0.336</td>
</tr>
<tr>
<td>Household size</td>
<td>Total number of household size</td>
<td>6.01</td>
<td>6.28</td>
<td>6.29</td>
<td>5.42</td>
<td>7.18</td>
<td>5.98</td>
<td>6.72</td>
<td>7.18</td>
<td>6.61</td>
<td>3.29</td>
</tr>
<tr>
<td>Marital status</td>
<td>1 if a farmer is married and 0 = otherwise</td>
<td>0.831</td>
<td>0.862</td>
<td>0.870</td>
<td>0.877</td>
<td>0.842</td>
<td>0.952</td>
<td>0.851</td>
<td>0.860</td>
<td>0.865</td>
<td>0.340</td>
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<tr>
<td>Education</td>
<td>Number years in education</td>
<td>8.89</td>
<td>8.96</td>
<td>9.26</td>
<td>7.72</td>
<td>9.15</td>
<td>8.50</td>
<td>8.48</td>
<td>9.51</td>
<td>8.94</td>
<td>4.40</td>
</tr>
<tr>
<td>Experience</td>
<td>Number of years in cocoa farming</td>
<td>16.42</td>
<td>20.12</td>
<td>21.41</td>
<td>13.46</td>
<td>22.46</td>
<td>24.00</td>
<td>19.22</td>
<td>23.30</td>
<td>23.05</td>
<td>12.33</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Farm size</td>
<td>Total farm size in hectares</td>
<td>1.93</td>
<td>1.56</td>
<td>2.58</td>
<td>2.19</td>
<td>2.01</td>
<td>1.72</td>
<td>2.61</td>
<td>1.89</td>
<td>1.96</td>
<td>1.27</td>
</tr>
<tr>
<td>Off-farm work</td>
<td>1 if a farmer engages in off-farm work and 0 = otherwise</td>
<td>0.610</td>
<td>0.678</td>
<td>0.568</td>
<td>0.673</td>
<td>0.695</td>
<td>0.694</td>
<td>0.592</td>
<td>0.740</td>
<td>0.675</td>
<td>0.468</td>
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<tr>
<td>Credit access</td>
<td>1 if a farmer access credit and 0 is otherwise</td>
<td>0.641</td>
<td>0.844</td>
<td>0.827</td>
<td>0.795</td>
<td>0.633</td>
<td>0.898</td>
<td>0.913</td>
<td>0.673</td>
<td>0.750</td>
<td>0.432</td>
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</table>

(continued)
<table>
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<tr>
<th>Variables</th>
<th>Variable Definition</th>
<th>None Mean</th>
<th>Irrigation only Mean</th>
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<th>Irrigation and extension Mean</th>
<th>Irrigation and mechanization Mean</th>
<th>Extension and mechanization Mean</th>
<th>Mean All</th>
<th>Mean Overall</th>
<th>Std. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information access</td>
<td>1 if a farmer had information access and 0 = otherwise</td>
<td>0.419</td>
<td>0.268</td>
<td>0.539</td>
<td>0.326</td>
<td>0.318</td>
<td>0.389</td>
<td>0.271</td>
<td>0.494</td>
<td>0.364</td>
<td>0.481</td>
</tr>
<tr>
<td>Farm distance</td>
<td>Distance from farmer’s homestead to farm location (kilometers)</td>
<td>3.19</td>
<td>2.28</td>
<td>2.48</td>
<td>2.60</td>
<td>3.28</td>
<td>2.48</td>
<td>2.65</td>
<td>3.06</td>
<td>2.86</td>
<td>2.55</td>
</tr>
<tr>
<td>Land ownership</td>
<td>1 if a farmer owns land and 0 = otherwise</td>
<td>0.625</td>
<td>0.671</td>
<td>0.683</td>
<td>0.775</td>
<td>0.617</td>
<td>0.586</td>
<td>0.691</td>
<td>0.80</td>
<td>0.654</td>
<td>0.475</td>
</tr>
<tr>
<td>Production shocks</td>
<td>Drought stress</td>
<td>0.568</td>
<td>0.406</td>
<td>0.410</td>
<td>0.632</td>
<td>0.352</td>
<td>0.443</td>
<td>0.370</td>
<td>0.333</td>
<td>0.401</td>
<td>0.490</td>
</tr>
<tr>
<td></td>
<td>Pest and disease</td>
<td>0.588</td>
<td>0.512</td>
<td>0.575</td>
<td>0.530</td>
<td>0.625</td>
<td>0.538</td>
<td>0.580</td>
<td>0.410</td>
<td>0.561</td>
<td>0.496</td>
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</table>

(continued)
<table>
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<tr>
<th>Variables</th>
<th>Variable Definition</th>
<th>None Mean</th>
<th>Irrigation only Mean</th>
<th>Extension only Mean</th>
<th>Mechanization only Mean</th>
<th>Irrigation and extension Mean</th>
<th>Irrigation and mechanization Mean</th>
<th>Extension and mechanization Mean</th>
<th>All Mean</th>
<th>Overall Mean</th>
<th>Std. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outcome variables</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield</td>
<td>Maize output in kilogram per hectares</td>
<td>2461.42</td>
<td>2151.30</td>
<td>2460.79</td>
<td>2763.26</td>
<td>2257.88</td>
<td>2583.23</td>
<td>2579.63</td>
<td>2811.68</td>
<td>2401.33</td>
<td>1440.31</td>
</tr>
<tr>
<td>Gross income</td>
<td>Gross income of farmer in GHS</td>
<td>2736.46</td>
<td>4069.55</td>
<td>4180.89</td>
<td>3441.42</td>
<td>2805.82</td>
<td>4114.49</td>
<td>4169.01</td>
<td>5408.68</td>
<td>3601.98</td>
<td>2843.17</td>
</tr>
<tr>
<td>Per capita consumption</td>
<td>Per capita consumption of a farmer in GHS</td>
<td>13.07</td>
<td>7.63</td>
<td>12.51</td>
<td>9.69</td>
<td>7.30</td>
<td>10.49</td>
<td>7.71</td>
<td>8.36</td>
<td>8.82</td>
<td>7.41</td>
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</tbody>
</table>

**Source(s):** Created by authors
<table>
<thead>
<tr>
<th>Choice (j)</th>
<th>Agricultural services</th>
<th>Irrigation (I)</th>
<th>Extension (E)</th>
<th>Mechanization (M)</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I₀E₀M₀</td>
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</tr>
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<td>✓</td>
<td>✓</td>
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<td>9.71</td>
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<td>4</td>
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<td>✓</td>
<td>✓</td>
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<td>3.42</td>
</tr>
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<td>I₁E₁M₀</td>
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<td>✓</td>
<td>✓</td>
<td>374</td>
<td>26.14</td>
</tr>
<tr>
<td>6</td>
<td>I₁E₁M₁</td>
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<td>✓</td>
<td>✓</td>
<td>167</td>
<td>11.67</td>
</tr>
<tr>
<td>7</td>
<td>I₀E₁M₁</td>
<td>✓</td>
<td>✓</td>
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<td>8</td>
<td>I₁E₁M₁</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>243</td>
<td>16.90</td>
</tr>
</tbody>
</table>

**Note(s):** Subscript 1 = adoption and 0 = non-adoption. I₀E₀M₀ = non-adoption, I₁E₀M₀ = irrigation only, I₀E₁M₀ = extension only, I₀E₀M₁ = mechanization only, I₁E₁M₀ = irrigation and extension, I₁E₀M₁ = irrigation and mechanization, I₀E₁M₁ = extension and mechanization, and I₁E₁M₁ = irrigation, extension and mechanization.

**Source(s):** Created by authors.
Table 3. Multinomial logit model for the selection of various combinations of agricultural services.

<table>
<thead>
<tr>
<th></th>
<th>Irrigation only only</th>
<th>Extension only only</th>
<th>Mechanization only</th>
<th>Irrigation and extension only</th>
<th>Irrigation and mechanization only</th>
<th>Extension and mechanization only</th>
<th>All only</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ME</td>
<td>SE</td>
<td>ME</td>
<td>SE</td>
<td>ME</td>
<td>SE</td>
<td>ME</td>
</tr>
<tr>
<td>Age</td>
<td>0.249***</td>
<td>0.131</td>
<td>0.213*</td>
<td>0.120</td>
<td>0.109</td>
<td>0.114</td>
<td>0.179</td>
</tr>
<tr>
<td>Gender</td>
<td>0.126**</td>
<td>0.064</td>
<td>0.264</td>
<td>0.564</td>
<td>0.425</td>
<td>0.544</td>
<td>0.103</td>
</tr>
<tr>
<td>Household size</td>
<td>0.171***</td>
<td>0.361</td>
<td>0.120</td>
<td>0.636</td>
<td>0.263</td>
<td>0.416</td>
<td>0.005</td>
</tr>
<tr>
<td>Marital status</td>
<td>0.391</td>
<td>0.768</td>
<td>0.252</td>
<td>0.752</td>
<td>0.084</td>
<td>0.127</td>
<td>0.135</td>
</tr>
<tr>
<td>Years of education</td>
<td>-0.201</td>
<td>0.361</td>
<td>-0.288</td>
<td>0.324</td>
<td>0.288</td>
<td>0.489</td>
<td>-0.099</td>
</tr>
<tr>
<td>Experience</td>
<td>-0.131</td>
<td>0.461</td>
<td>-0.260</td>
<td>0.438</td>
<td>-0.546</td>
<td>0.600</td>
<td>-0.016</td>
</tr>
<tr>
<td>Farm size</td>
<td>-0.656**</td>
<td>0.063</td>
<td>0.200</td>
<td>0.323</td>
<td>0.303</td>
<td>0.447</td>
<td>0.017</td>
</tr>
<tr>
<td>Off farm work</td>
<td>0.164***</td>
<td>0.049</td>
<td>0.328</td>
<td>0.430</td>
<td>0.444</td>
<td>0.636</td>
<td>0.122***</td>
</tr>
<tr>
<td>Credit access</td>
<td>0.452</td>
<td>0.591</td>
<td>-0.020</td>
<td>0.552</td>
<td>0.271</td>
<td>0.809</td>
<td>-0.185***</td>
</tr>
<tr>
<td>Land ownership</td>
<td>-0.397</td>
<td>0.648</td>
<td>-0.162***</td>
<td>0.061</td>
<td>0.017</td>
<td>0.971</td>
<td>-0.126**</td>
</tr>
<tr>
<td>Drought stress</td>
<td>-0.429</td>
<td>0.456</td>
<td>-0.032</td>
<td>0.437</td>
<td>-0.017</td>
<td>0.643</td>
<td>-0.015</td>
</tr>
<tr>
<td>Pest and disease</td>
<td>0.035</td>
<td>0.466</td>
<td>-0.392</td>
<td>0.447</td>
<td>0.862</td>
<td>0.682</td>
<td>0.783*</td>
</tr>
<tr>
<td>Farm distance</td>
<td>-0.328***</td>
<td>0.101</td>
<td>-0.150</td>
<td>0.098</td>
<td>0.079</td>
<td>0.118</td>
<td>-0.217***</td>
</tr>
<tr>
<td>Information access</td>
<td>-0.072</td>
<td>0.482</td>
<td>0.378</td>
<td>0.469</td>
<td>-0.000</td>
<td>0.685</td>
<td>-0.163***</td>
</tr>
<tr>
<td>Observations</td>
<td>283</td>
<td>139</td>
<td>49</td>
<td>374</td>
<td>167</td>
<td>80</td>
<td>243</td>
</tr>
<tr>
<td>Wald $\chi^2$</td>
<td>392.10***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LR $\chi^2$ (126)</td>
<td>75.84***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note(s):** ME is Marginal Effects and SE is robust errors. $i_oE_oM_o$ is the reference base group (non-adoption). ***p < 0.01, **p < 0.05, *p < 0.1

**Source(s):** Created by authors
drudgery (Anang et al., 2020; Etwire et al., 2013). Gender also significantly influences irrigation adoption, with men more likely to use irrigation given their greater access to productive resources in Ghana (Addai et al., 2022). Additionally, educated farmers have higher probability of jointly adopting extension and mechanization. Education enables better understanding of productivity benefits from modern services (Wossen et al., 2017).

Larger households can more easily participate in multiple services by leveraging their labor endowment (Anang et al., 2020). Farm size exhibits contrasting effects – positively influencing joint extension-mechanization adoption but negatively affecting irrigation. Larger farms create labor demands met by mechanization, but also allow focus on fewer high-return services like irrigation on small optimal plots (Abdulai and Huffman, 2014; Anang and Asante, 2020). Off-farm activity has a positive and significant influence on adopting a combination of irrigation, extension and mechanization services. This result suggests that farmers engaged in off-farm work are more likely to adopt this combination. Additional income from off-farm activities can help reduce credit challenge issues, allowing farmers to invest in innovative services to improve crop productivity (Kousar and Abdulai, 2016; Addai et al., 2023).

Credit access shows a negative and significant influence on the adoption of the combination of irrigation and extension. This implies that farmers without credit access and are less likely to adopt the irrigation and extension service combination. Credit access enhances farmers’ capacity to invest in and acquire, productive agricultural resources such as mechanization, inputs, etc. to improve crop production. The use of credit for the acquisition of inputs and the sourcing of additional complementary services are key factors in the adoption of technology packages (Anang and Asante, 2020; Anang et al., 2020; Wossen et al., 2017). Smallholder farmers are confronted with initial investment barriers in agricultural services adoption, and access to financing helps them overcome liquidity constraints, increasing their capacity for adopting agricultural services (Mottaleb et al., 2016; Awunyo-Vitor et al., 2014).

Our findings reveal distance from homestead to farm significantly hinders joint adoption of irrigation and mechanization services. Longer travel distance increases transaction costs and logistical challenges, especially for transporting mechanization equipment (Danso-Abbeam et al., 2018; Khonje et al., 2015). This aligns with evidence that farm remoteness constrains machinery adoption in Ghana (Addai et al., 2021; Ma and Abdulai, 2019). Surprisingly, access to agricultural information negatively influences adoption of irrigation, extension and mechanization combinations, contrary to expectations. We hypothesized information access would reduce input transaction costs and enable adoption (Mutenje et al., 2016). Further investigation into potential explanatory mechanisms is warranted.

Additionally, land ownership reduces likelihood of joint irrigation-mechanization uptake, contradicting some previous studies (Abdulai et al., 2011; Bacha et al., 2011). On the other hand, pest and disease burden positively affects adoption of irrigation and extension, consistent with literature on stressors spurring technology adoption (Teklewold et al., 2013).

**4.2 Impact of adoption of combinations of agricultural services on household welfare**

Table 4 shows the casual effects of adopting agricultural services singly or jointly on household welfare using the MESR. The MESR model results were re-estimated using the doubly robust, multivalued inverse probability weighted regression (MIPWRA) as a robustness check. The results of the welfare indicators such as maize yield in kilogram per hectare, maize gross income in Ghana cedis and per capita consumption in Ghana cedis are presented in columns 3, 4, and 5, respectively. Compared to non-adopt, adopting a combination of irrigation, extension and mechanization services has a positive and significant causal effects on maize yield (the unconditional average effect results). The
A combination of agricultural services that gives the lowest (1291.60 kg/ha), yield per hectare is the adoption of mechanization, whereas combining irrigation, extension and mechanization services gives the highest (3173.87 kg/ha) impact on yields.

A combination of irrigation, extension and mechanization services significantly boosts maize gross income, aligning with previous findings (Anang et al., 2020; Ngomi et al., 2020) indicating that agricultural service adoption enhances production and income in Ghana and Cameroon. Among the unconditional ATE results, the combination of irrigation, extension and mechanization provides the highest maize gross income, while mechanization alone yields the lowest income. This aligns with other studies modeling the impacts of agricultural technologies (Anang et al., 2020; Khonje et al., 2015; Lu et al., 2021; Teklewold et al., 2013). For per capita consumption expenditure (column 5 in Table 5), six out of seven agricultural service combinations have a positive and significant impact, indicating their favorable influence on household consumption. Employing ATEs that consider both observed and unobserved attributes allows a deeper understanding of service adoption impacts.

### Table 4.
Unconditional average effect and average treatment effect on treated from the MESR results

<table>
<thead>
<tr>
<th>Combinations</th>
<th>Maize yield (kg/ha)</th>
<th>Maize gross income (GHS)</th>
<th>Per capita consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_1E_0M_0$</td>
<td>1714.44*** (62.53)</td>
<td>3893.65*** (314.3)</td>
<td>10.47*** (0.84)</td>
</tr>
<tr>
<td>$I_0E_1M_0$</td>
<td>2411.99*** (53.70)</td>
<td>4798.03** (227.27)</td>
<td>9.89*** (0.16)</td>
</tr>
<tr>
<td>$I_1E_0M_1$</td>
<td>1291.6** (145.99)</td>
<td>1333.31*** (363.49)</td>
<td>2.87*** (0.39)</td>
</tr>
<tr>
<td>$I_0E_1M_1$</td>
<td>2213.85*** (35.17)</td>
<td>2744.08*** (120.08)</td>
<td>3.66*** (0.18)</td>
</tr>
<tr>
<td>$I_1E_0M_1$</td>
<td>2390.97*** (223.22)</td>
<td>4704.47*** (803.14)</td>
<td>8.16 (0.59)</td>
</tr>
<tr>
<td>$I_0E_1M_1$</td>
<td>2281.26*** (36.57)</td>
<td>2537.27*** (93.78)</td>
<td>3.57*** (0.13)</td>
</tr>
<tr>
<td>$I_1E_1M_0$</td>
<td>3173.87*** (197.43)</td>
<td>5253.30*** (1015.94)</td>
<td>8.85 (3.30)</td>
</tr>
<tr>
<td>$I_0E_1M_0$</td>
<td>2149.84*** (250.7)</td>
<td>3921.67*** (1061.42)</td>
<td>9.11** (3.30)</td>
</tr>
<tr>
<td>$I_1E_0M_0$</td>
<td>2615.88*** (261.17)</td>
<td>4537.76*** (449.72)</td>
<td>7.33*** (0.15)</td>
</tr>
<tr>
<td>$I_0E_1M_1$</td>
<td>1280** (103.02)</td>
<td>3782.73*** (466.64)</td>
<td>3.66*** (0.81)</td>
</tr>
<tr>
<td>$I_1E_0M_0$</td>
<td>2384.43*** (140.98)</td>
<td>3693.19*** (741.12)</td>
<td>6.44 (0.52)</td>
</tr>
<tr>
<td>$I_1E_0M_0$</td>
<td>2287.30** (496.66)</td>
<td>2703.26** (1085.37)</td>
<td>4.42** (0.68)</td>
</tr>
<tr>
<td>$I_0E_1M_0$</td>
<td>2810.29*** (229.44)</td>
<td>2037.4*** (427.70)</td>
<td>1.14 (0.61)</td>
</tr>
<tr>
<td>$I_1E_1M_0$</td>
<td>2345.16*** (155.38)</td>
<td>3526.20*** (577.21)</td>
<td>3.67*** (0.45)</td>
</tr>
</tbody>
</table>

Note(s): Robust standard errors in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. 120 kg = 1 bag of maize.

Source(s): Created by authors

### Table 5.
Results of average treatment effects from the MIPWRA model

<table>
<thead>
<tr>
<th>Combinations</th>
<th>Treatment effects</th>
<th>Maize yield (kg/ha)</th>
<th>Maize gross income (GHS)</th>
<th>Per capita consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_1E_0M_0$</td>
<td>ATT</td>
<td>2428.59*** (95.15)</td>
<td>3201.93*** (326.94)</td>
<td>9.85*** (3.74)</td>
</tr>
<tr>
<td>$I_0E_1M_0$</td>
<td>ATT</td>
<td>2661.11*** (208.50)</td>
<td>4652.47*** (391.21)</td>
<td>7.02*** (1.28)</td>
</tr>
<tr>
<td>$I_0E_0M_1$</td>
<td>ATT</td>
<td>2608.79*** (137.27)</td>
<td>3097.37*** (228.77)</td>
<td>3.49*** (0.93)</td>
</tr>
<tr>
<td>$I_1E_0M_0$</td>
<td>ATT</td>
<td>2550.29*** (186.60)</td>
<td>2642.51*** (179.19)</td>
<td>5.68*** (0.88)</td>
</tr>
<tr>
<td>$I_1E_0M_0$</td>
<td>ATT</td>
<td>2384.43*** (140.98)</td>
<td>3693.19*** (741.12)</td>
<td>6.44 (0.52)</td>
</tr>
<tr>
<td>$I_0E_1M_0$</td>
<td>ATT</td>
<td>2810.29*** (229.44)</td>
<td>2037.4*** (427.70)</td>
<td>1.14 (0.61)</td>
</tr>
<tr>
<td>$I_1E_1M_0$</td>
<td>ATT</td>
<td>2345.16*** (155.38)</td>
<td>3526.20*** (577.21)</td>
<td>3.67*** (0.45)</td>
</tr>
</tbody>
</table>

Note(s): Robust standard errors in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. 120 kg = 1 bag of maize.

Source(s): Created by authors
The results of ATTs demonstrate that adopting a combination of extension and mechanization services significantly increases yield (2810.29 kg/ha). In contrast, mechanization alone results in the lowest yield (1280.0 kg/ha). Similarly, mechanization alone positively affects maize gross income, corroborating other studies. For instance, farmers who adopt irrigation, extension and mechanization jointly achieve higher maize gross income (GHS5253.30). Impact results also indicate a positive and significant impact on per capita consumption expenditure when farmers adopt multiple services. On average, farmers attain GHS8.85 per-capita consumption by adopting irrigation, extension and mechanization, significantly improving their well-being. In conclusion, farmers benefit most by embracing multiple agricultural services, leading to increased yields, income and higher per capita consumption.

Furthermore, the ATT results have smaller magnitudes than the unconditional average causal effects indicating that unobserved factors do account for some variations in the results. Nevertheless, relying alone on the unconditional ATEs may be misleading because of the unexplained observed and unobserved confounding effects. Therefore, we use the ATT to account for the confounding effects. This gives lower values of the causal effects as compared to the unconditional average effects. Under unconditional average effects, the impact of adopting a combination of irrigation, extension and mechanization services is exaggerated by 36.11%, indicating that the MESRM model was more appropriate.

4.3 Impact results from the multivalued inverse probability weighted regression adjustment (MIPWRA) model

The estimates from the MIPWRA model are shown in Table 5. The MIPWRA indicated that in each agricultural service, one might adopt one of the numerous treatments or not be treated. Adopting a combination of agricultural services improves maize yields, maize gross income and per capita consumption among smallholder farmers in Ghana. Furthermore, the results indicate that the combination of irrigation, extension and mechanization services produced the highest maize yields and maize gross income. The adoption of irrigation services resulted in the lowest yield and highest per capita consumption. On the contrary, the adoption of mechanization services gives the highest yield but least per capita consumption. Therefore, the results suggest that farmers who considered more than one of the agricultural services obtained the highest yield, gross income and per capita consumption. This finding is consistent with other studies in Ghana (Lu et al., 2021; Anang et al., 2020), Cameroon (Ngomi et al., 2020) and Tanzania (Manda et al., 2021). Lu et al. (2021) asserted that the MESRM provides more confidence over the MIPWRA because the propensity scores and marginal treatment effect of the causal inference methods produce different estimates on how their estimates are calculated which could be a possible explanation for the results.

5. Conclusions and policy recommendations

Agricultural stakeholders in low-income countries have paid close attention to the adoption of agricultural services and examined their possible impacts on farm household welfare. Although the enormous investment in efforts to encourage the adoption of combinations of agricultural services, adoption rates are still low. Studies on agricultural services have focused on modeling participation/adoption of such services singly and are unable to obtain the full impacts on production and welfare due to the potential interdependence of these services. We evaluated the impacts of adopting distinct combinations of agricultural services on household welfare using a data from sample maize of farmers in Ghana. To account for any selection bias due to observed and unobserved confounders, we use the MESRM and the multivalued inverse probability regression adjustment (MIPWRA) model.
The results show that various socioeconomic, institutional and production shocks variables influence the probability of adopting various combinations of agricultural services. These findings can aid in developing well-informed and targeted strategies to increase the adoption of relevant interrelated agricultural production services for increased welfare. Also, the importance of information in the adoption of agricultural services is highlighted. Information flow is essential especially regarding agricultural services such as irrigation, extension and mechanization as these major services thrive heavily on access to vital and relevant information. Thus, to enhance the welfare of rural farm households through enhancing access to these services, there is the need for government and respective stakeholders to increase information flow among farmers and other agricultural stakeholders.

Additionally, the results show that adopting agricultural services enhances maize yields, gross income and per capita consumption on average. Specifically, the adoption of a combination of irrigation, extension and mechanization increased maize yields, gross income and household per capita consumption. We advocate strategies that target the adoption of several agricultural services than adopting these services in isolation. Furthermore, maize farmers embrace the combination of agricultural services rather than separately to maximize the complementary benefits of these services in crop production.

To increase yields, income and per capita expenditure, there is the need for increased adoption of these services as a composite. Various agricultural stakeholders should aim at encouraging the farmer education and engagement in off-farm work to promote the adoption of these services in combinations. Moreover, various governments should push for land reforms especially in rural areas to encourage the adoption of these agricultural services by farmers. Besides, governments need to enhance farmers’ access to information to enhance the adoption of these services. This could be achieved through the adoption of innovative technologies such as mobile phones, mobile information vans and efficient community-based radios. This will have profound implications on the welfare of farm households. To add various governments should help bridge the rural infrastructure gap to promote the adoption of such services.

As in every empirical study, our study is not without a limitation. Our study’s limitation is that it relied on maize production data from a single growing season. Future research could improve our results by exploring overtime impacts by using data from multiple crops and periods. This would provide a more comprehensive and insightful analysis, making it an interesting avenue for further research.

References


**Further reading**


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