Asian Journal of Agriculture and Rural Development
Volume 12, Issue 3 (2022): 201-209.

http://www.aessweb.com/journals/5005

DOES WOMEN'S EMPOWERMENT IMPROVE YIELDS AND INCOME? EVIDENCE FROM RICE FARMERS IN RWANDA

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Article History
Received: 14 June 2022
Revised: 3 August 2022
Accepted: 19 August 2022
Published: 6 September 2022

Keywords
Women's empowerment
Agricultural productivity
Income
Instrumental variable
Rice production
Rwanda.

ABSTRACT

This study aimed to assess the effects of women's empowerment in agriculture on rice yield and income in rural Rwanda. A multi-stage stratified sampling procedure was used to collect data through structured questionnaires (including both open-ended and closed questions). A sample of 561 rice farmers drawn from the Eastern and Western provinces of Rwanda was used. The study used an instrumental variable to estimate the causal impacts of women's empowerment, and controlled for the potential endogeneity of the same. The findings of the study showed that women's empowerment has a positive impact on rice yield and income. Overall, the study results call for policy interventions promoting female participation in financial inclusion mechanisms, farmers' cooperatives, and agricultural production decisions. In addition, the results highlighted the importance of building strategies and mechanisms for increasing women's control and decisions over assets. The study makes contributions to the empirical literature on the United Nations Sustainable Development Goals, such as achieving gender equality, women's empowerment, and food security in developing countries. Future research should attempt to use nationally representative panel data to fully understand the effects of women's empowerment on rice productivity and other income outcomes.

Contribution/Originality: This study contributes to the existing literature on the United Nations Sustainable Development Goals, such as achieving gender equality, women's empowerment, and food security in developing countries. The study contributes also to the literature by applying the Abbreviated Women's Empowerment in Agriculture Index.

DOI: 10.55493/5005.v12i3.4602
ISSN(P): 2304-1455/ ISSN(E): 2224-4433

How to cite: Jules Ngango (2022). Does Women's Empowerment Improve Yields and Income? Evidence from Rice Farmers in Rwanda. *Asian Journal of Agriculture and Rural Development*, 12(3), 201-209. 10.55493/5005.v12i3.4602

1. INTRODUCTION

An extensive body of literature contends that women play a significant role in the agricultural production sector of most Sub-Saharan African (SSA) countries (Sell & Minot, 2018). In particular, women account for over 50% of the agricultural labour force in SSA (Donald, Lawin, & Rouanet, 2020; Efobi, Beecroft, & Atata, 2019). However, empirical evidence asserts that there is a continuing gender gap between male and female farmers in terms of the access, control and use of the land, harvested produce, credit, extension services, labour, livestock, fertilizers, seeds, pesticides,

irrigation, and mechanization (Baliamoune-Lutz & McGillivray, 2007; Diiro, Seymour, Kassie, Muricho, & Muriithi, 2018; Sell & Minot, 2018; Seymour, 2017). For instance, gender-based discrimination in land tenure systems is a critical problem prevalent in many SSA countries. Due to the lack of effective legal land tenure reforms in SSA, women do not have the same rights as men to inherit land (Diiro et al., 2018). In Rwanda, gender inequality is highly influenced by the inaccessibility that women face when it comes to having access and control over land and the revenue coming from farming activities (Ali, Deininger, & Goldstein, 2014; Djurfeldt, 2020). Moreover, women spend far more of their time doing domestic activities than men, which limits their participation in some farm activities (i.e. extension services) and off-farm income-generating work (Diiro et al., 2018; Djurfeldt, 2020). Based on the recognized importance of women in agriculture, it is necessary to reduce the gender inequality in agricultural production as much as possible through a sustained improvement in the real condition for women.

In recent decades, the push to liberate women from patriarchal socioeconomic constraints has taken a global turn because it has been documented that improving the conditions and the accessibility to rights that women enjoy can contribute to the attainment of development goals such as poverty alleviation (Zereyesus, 2017). Previous studies on gender and agriculture have shown that women's empowerment in agriculture is strongly linked to the improvement in agricultural productivity, income, and food security (Diiro et al., 2018; Murugani & Thamaga-Chitja, 2019; Seymour, 2017; Zereyesus, 2017). Therefore, it is imperative that we attempt to formulate policies that aim to support female farmers and also attain poverty reduction and food security.

The problem of concern for this essay is the low agricultural productivity and incomes among rural farmers in Rwanda. In particular, agricultural productivity growth in Rwanda remains a major developmental challenge for researchers and policymakers. Numerous studies reported the inadequate use of inputs such as fertilizers, improved seeds, irrigation, and mechanization as important causes of low agricultural productivity and output in Rwanda (Ali, Deininger, & Duponchel, 2014; Nahayo et al., 2017; Ngango & Hong, 2021b; Ngango & Hong, 2021a; Nilsson, 2019). However, no single study has assessed the effect of women's empowerment on agricultural productivity in Rwanda. Since women constitute the majority of the labour force in Rwandan agriculture, particularly rice farming, it is important to investigate this link between farm activities and the improvement in the conditions of female Rwandan agricultural workers.

Three research questions will be addressed through this study. They are: (i) what are the rice yields and incomes of households in the study area (i.e. the Muvumba and Bugarama rice schemes)? (ii) What would the effects of women's overall empowerment on rice yield and income be? (iii) What would the effects of individual indicators of women's empowerment on rice yield and income be? To achieve these objectives, the study used household-level data from 561 rice farmers in two major rice schemes in Rwanda, that is, the Muvumba and Bugarama rice schemes. This study contributes to the existing literature by applying the Abbreviated Women's Empowerment in Agriculture Index (A-WEAI), which is different from the Women's Empowerment in Agriculture Index (WEAI) previously used in other gender and agricultural productivity studies such as Sraboni, Malapit, Quisumbing, and Ahmed (2014); Malapit, Kadiyala, Quisumbing, Cunningham, and Tyagi (2015); Zereyesus (2017); Seymour (2017) and Murugani and Thamaga-Chitja (2019). The A-WEAI includes six empowerment indicators in the five domains of empowerment. Typically, the A-WEAI differs from the original WEAI, which uses ten empowerment indicators in the five domains of empowerment (Diiro et al., 2018; Kassie, Fisher, Muricho, & Diiro, 2020).

This study also makes a contribution to the literature from a methodological point of view, by using the instrumental variable (IV) method to estimate the causal impacts of women's empowerment in agriculture on rice yield and income from rice production. In particular, this study employs the IV technique to control for the endogeneity problem of women's empowerment.

2. MATERIALS AND METHODS

2.1. Conceptual and Econometric Framework

The conceptual framework that guides this study is based on the idea that women's empowerment as well as demographic, socio-economic, institutional, and locational-level characteristics are important factors that influence rice yield and income. In addition, farm inputs and agricultural practices such as labour, capital, fertilizers, seeds, chemicals, and row-planting are the major factors that affect rice yield and income.

To examine the impact of women's empowerment in agriculture on yield and income, the model was specified thus

$$Y_{ij} = f(X_i, V_{ij}, W_i). \quad (1)$$

where Y_{ij} represents the outcome variables, that is, rice yield and net income generation of the i^{th} farmer from rice plot j. X_i represents a vector of demographic, socio-economic, institutional, and locational-level characteristics. V_{ij} is a vector of inputs and farming practices such as labour, capital, fertilizers, seeds, chemicals, and row-planting used in rice production on plot j. W_i represents women's empowerment.

It should be noted in Equation 1 that W_i is endogenous to rice yield and income. In particular, unobservable factors such as women's management and leadership skills may influence both farm production and their empowerment status. Also, the reverse causality between women's empowerment and rice production outcomes (i.e. yield and income) may become a cause of endogeneity (Diiro et al., 2018). Seymour (2017) explains that women's empowerment is likely to enhance agricultural growth and rural development. Nevertheless, the improvement in farm productivity and income, on the other hand, may contribute to women's engagement in community leadership activities and participation in decisions related to asset acquisition, credit, and more investment in agriculture (Diiro et al., 2018; Zereyesus, 2017). Estimating the impact of women's empowerment in agriculture on yield and income without controlling for endogeneity problems may generate inconsistent and biased estimates. Thus, to manage the endogeneity bias in the

structural model, the instrumental variable (IV) approach was used. The IV is considered to be an efficient approach for controlling for the endogeneity problem if the appropriate instruments are identified (Cawley, O'Donoghue, Heanue, Hilliard, & Sheehan, 2018).

Five instruments for both overall women's empowerment and the individual indicators of women's empowerment have been identified. These instruments include: (i) the number of farmers' groups in the village, (ii) difference in age between the male and female decision-makers in the family, (iii) difference in education between the male and female decision-makers in the family, (iv) whether a wife brought assets during the marriage, and (v) proportion of household members under 15 years of age. With regard to overall women's empowerment, the study used all five variables as potential instruments. Regarding individual indicators of women's empowerment, the study used information on education and age differences between the primary adult male and female in the family as the potential instruments for all the six empowerment indicators. The number of farmers' groups in the village was also used as an instrument for income and credit decisions. The variable capturing the information on whether the woman brought assets during the marriage is used as an instrument for production, asset ownership, and income decisions. The variable for the proportion of household members below 15 years of age is used as the instrument for the workload indicator.

As stated above, women's empowerment (W_i) is considered as potentially endogenous to yield and income outcomes (Y_{ij}) in this study. Therefore, the two-stage least squares (2SLS) IV approach is specified in the following system of equations.

$$Y_{ij} = \beta_0 + \beta_1 X_i + \beta_2 V_{ij} + \beta_3 W_i + \varepsilon_{ij} \quad (2)$$

$$W_i = \delta M_i + \theta Z_i + u_i \quad (3)$$

where $E(u_i|Z_i) = 0$ and $E(u_i, \varepsilon_{ij}) \neq 0$. In Equation 2, Y_{ij} is a vector of outcome variables, that is, rice yield and net rice income of the i^{th} farmer from rice plot j. X_i represents a vector of demographic, socio-economic, institutional, and locational-level characteristics, V_{ij} is a vector of inputs and farming practices such as labour, capital, fertilizers, seeds, chemicals, and row-planting used in rice production on plot j. W_i represents women's empowerment, β_i represents the unknown parameters to be estimated, and ε_{ij} is the error term. In Equation 3, M_i represents a vector of explanatory variables, Z_i represents a vector of instrumental variables, u_i is the error term, while δ and θ are the parameters to be estimated.

2.2. Analytical framework

The estimation involved alternative specifications. First, in the framework of clarifying the overall impact of women's empowerment in agriculture on yield and income generation, women's empowerment is operationalized in aggregate. Secondly, yield and income equations for each of the six indicators are estimated separately to assess the individual effect of each indicator on yield and income, respectively. Indicators such as input in production decisions, asset ownership, access to and decisions on credit, control over the use of income, and group membership are entered in the equation as counts. On the other hand, the workload indicator is entered in the equation as a dummy variable taking the value of 1 if the woman spent less than or equal to 10.5 hours working on the day prior to the survey interview, and 0 otherwise.

The IV approach involved a 2SLS procedure. In the first stage, the suspected endogenous variable was regressed on the chosen instruments and exogenous regressors to obtain the predicted value of the endogenous variable. The IV diagnostic tests were used to check the validity and relevance of the chosen instruments (i.e. over-identification and under-identification tests). Bootstrapping was also used to adjust the standard errors to account for the two-stage estimation procedure. In the second specification, the original structural model was estimated by inserting the predicted value of the endogenous variable (i.e. W_i in the case of this study) obtained from the first step. Bootstrapping was again used to adjust the standard errors to account for the two-stage estimation procedure. However, according to Cameron and Trivedi (2010) the IV regression assumes that endogenous explanatory variables are continuous, and its use may not be appropriate. In particular, when the IV probit is used, the predicted value of the endogenous explanatory variable (i.e. women's empowerment in this case) will be linear (Araya, 2020). To deal with this issue, econometric literature suggested the use of linear 2SLS IV regressions (Araya, 2020).

2.3. Study area and data

Cross-sectional data used were obtained from a household survey conducted in the 2020/2021 cropping season. In particular, the sample was drawn from rice farmers operating in Muvumba and Bugarama rice schemes located in the Eastern and Western provinces of Rwanda, respectively. The Eastern and Western provinces appear to have the most potential provinces in terms of rice production. In addition, Muvumba and Bugarama rice schemes are the largest in terms of area and rice production in Rwanda.

A multi-stage stratified sampling procedure was used to select enumeration areas and respondents. The first stage consisted of stratifying the sample based on the country's two major rice schemes (i.e. Muvumba and Bugarama). In the second stage, based on weighted probabilities, 6 and 5 agricultural zones were randomly selected in Muvumba and Bugarama rice schemes, respectively. In the third stage, a certain number between 45 and 60 households were randomly selected from each zone, also based on weighted probabilities. In total, 332 households were selected under the Muvumba rice scheme and 257 households were selected under the Bugarama rice scheme, giving us a total sample size of 589 households. However, after cleaning the data collected, the dataset comprised a total sample of 561 households, with 315 households from the Muvumba rice scheme and 246 households from the Bugarama rice scheme.

Table 1 describes five domains of empowerment, namely, production, resources, income, leadership, and time. Additionally, definitions of the six empowerment indicators are given. Each indicator takes a value of one if a woman attains an adequacy criterion or zero otherwise (Malapit et al., 2017). The A-WEAI allowed us to determine the empowerment score, on one hand, by taking the woman's overall empowerment score, that is, the weighted sum of the six empowerment indicators. On the other hand, the empowerment score was determined by taking a woman's level of empowerment concerning each individual A-WEAI indicator. Indeed, Alkire et al. (2013) elucidate the concept of women's empowerment as the achievement of adequacy criteria in at least 80% of the weighted indicators.

Table 1. Description of indicators and domains of empowerment in the abbreviated women's empowerment in agriculture index (A-WEAI).

Domain	Indicator	Adequacy criteria	Weight
Production	Input in production decisions	A woman is adequate if she participates in at least one decision related to food and cash-crop farming, livestock, and fishery production.	1/5
Resources	Asset ownership	A woman is adequate if she has sole or joint ownership of at least one asset.	2/15
	Access to and decisions on credit	An adequate woman has access to credit and participates in decision-making over credit from at least one source.	1/15
Income	Control over the use of income	A woman is adequate if she has sole or joint control over income and expenditures for at least one of food and cash-crop farming, livestock, and fishery production.	1/5
Leadership	Group membership	A woman is considered adequate if she is an active member in at least one formal or informal group.	1/5
Time	Workload	An adequate woman spent less than or equal to 10.5 hours on paid and unpaid work in the previous 24 hours.	1/5

Source: Malapit et al. (2017).

3. RESULTS AND DISCUSSION

3.1. Descriptive Statistics

Variables used in the analysis of this study were selected based on previous literature on women's empowerment in agriculture (Diiro et al., 2018; Kassie et al., 2020; Malapit et al., 2015; Murugani & Thamaga-Chitja, 2019; Seymour, 2017; Sraboni et al., 2014; Zereyesus, 2017).

The main outcome variables of interest in this study are rice yield measured in kilograms per acre and farm income from rice production measured in Rwandan francs (RWF) per acre. According to the data of this study, the average rice yield in the study area is 1,828 kg per acre. Regarding the income, the study has considered the value of paddy rice harvested in the 2020/2021 crop season, evaluated using the average market price. The data shows that the average net rice income is approximately 843,380 RWF per acre (see Table 2). Coming to the independent variables, the primary variable of interest is women's empowerment in agriculture which is measured by the A-WEAI. The summary statistics indicate that 71% of women in the sample have achieved adequate empowerment as per the weighted indicators. Other independent variables considered in the analysis include farming practices, inputs, demographic, socio-economic, institutional, and locational-level characteristics. The descriptions and summary statistics of all variables used in the analysis are given in Table 2.

Table 2. Definition of variables used in the analysis and summary statistics.

Variables	Description	Mean	Std. Dev.
Outcome variables			
Rice yield	Quantity of paddy rice harvested per acre (Kg/acre)	1.828	1.562
Net crop income	Value of paddy rice harvested ('000 RWF/acre)	843.383	647.187
Women's empowerment in agriculture variables			
Empowerment score	Women's overall empowerment score (weighted sum across 6 indicators comprising the A-WEAI)	0.716	0.223
Production decisions	Number of production decisions in which the woman participates	2.071	0.910
Asset ownership	Number of assets over which the woman has control	2.629	1.494
Credit decisions	Number of credit-related decisions in which the woman participates	3.145	2.578
Income decisions	Number of income decisions in which the woman participates	5.211	2.859
Group membership	Number of formal and informal groups to which the woman belongs	1.295	1.762
Workload	Time adequacy (1 = woman worked less than or equal to 10.5 hours, 0 = worked	0.353	0.420

Variables	Description	Mean	Std. Dev.
	more than 10.5 hours)		
Farming practices and inputs			
Land	Area of land planted with rice (acre)	0.195	0.149
Capital	Value of agricultural and household assets owned by the farmer ('000 RWF)	314.733	306.116
Labour	Total value of labour input ('000 RWF/acre)	99.851	100.130
Seeds	Value of seeds used ('000 RWF/acre)	18.574	13.487
Fertilizers	Value of fertilizers used ('000 RWF/acre)	62.302	54.075
Pesticides	Value of pesticides used ('000 RWF/acre)	28.442	29.783
Row-planting	1 if farmer plants rice seeds in rows, and 0 otherwise	0.468	0.505
Demographic and socio-economic variables			
Gender	Sex of household head (1 if the farmer is a male, and 0 otherwise)	0.534	0.481
Male's age	Age of primary male decision-maker (years)	51.208	18.154
Female's age	Age of primary female decision-maker (years)	49.656	18.503
Male's education	Education of the primary male decision-maker (years)	6.552	4.240
Female's education	Education of the primary female decision-maker (years)	6.080	3.879
Household size	Number of people in the household	7.315	2.964
Livestock ownership	Livestock ownership in tropical livestock units (TLU)	1.869	1.432
Plot tenure	1 if the farmer owns the plot of land, 0 if rented	0.785	0.383
Off-farm income	1 if a farmer has other sources of income off-farm, 0 otherwise	0.357	0.428
Institutional and locational-level characteristics			
Access to extension	1 if the farmer has access to extension contact, and 0 otherwise	0.634	0.541
Access to credit	1 if the farmer has access to credit, and 0 otherwise	0.476	0.392
Distance to market	Distance from home to the market (km)	2.885	1.023
Location dummy	1 if the farmer is located in Eastern province, 0 in Western province	0.547	0.506
Observations		561	

3.2. Empirical Results

Table 3 reports the results for the impact of women's overall empowerment on rice yield and farm-level income. The results show that women's overall empowerment in agriculture has a positive and statistically significant impact on rice yield and income. Based on the IV estimator, a unit increase in women's overall empowerment leads to a 45.3% and 63.7% increase in rice yield and income, respectively (these numbers were computed based on the $100 \times (e^{\beta} - 1)$ formula because the study used log-level regression specifications). This result is consistent with the findings of Diiro et al. (2018) who found that women's empowerment in agriculture significantly improved maize productivity in western Kenya.

Additionally, Anik and Rahman (2021) revealed that women's empowerment in agriculture has a positive impact on crop productivity and efficiency in Bangladesh. Traditionally, women play an important role in the agricultural sector and constitute a large percentage of the agricultural labour force in developing countries (Diiro et al., 2018; Seymour, 2017).

Thus, empowering women through the access, use, ownership, and control of land and financial resources can influence women's ability to improve agricultural productivity and income (Sraboni et al., 2014).

Other explanatory variables that have a positive and significant effect on rice yield include capital, seeds, fertilizers, row-planting, livestock ownership, off-farm income, access to extension, access to credit, and the location dummy. Similarly, farm-level income is positively influenced by other variables such as capital, seeds, fertilizers, livestock ownership, plot tenure, off-farm income, access to extension, access to credit, and the location dummy. Conversely, the distance to the market has a negative and significant effect on farm-level income.

Concerning the impact of individual indicators of women's empowerment on rice yield, Table 4 shows that production decisions, asset ownership, income decisions, and group membership indicators of women's empowerment are positively and significantly correlated with rice yield. These findings corroborate the study of Anik and Rahman (2021) who found that women's access to production decisions and asset ownership indicators were associated with higher productivity and efficiency.

Theoretically, it is believed that the improvement of women's access to production decisions and asset ownership may help farmers to efficiently manage farm operations and hence increase productivity (Murugani & Thamaga-Chitja,

2019). Moreover, our findings are consistent with the recent literature, which indicates that female farmers with access group membership and income decisions were linked to a statistically significant positive effect on crop productivity (Bonis-Profumo, Stacey, & Brimblecombe, 2021; Diiro et al., 2018). However, our results are inconsistent with the study of Cunningham et al. (2015), which indicated that production decisions, asset ownership, group membership, and workload are associated with low agricultural productivity.

Table 1. Effects of women's overall empowerment on rice yield and income.

Variables	Log (yield)		Log (income)	
	OLS	2SLS-IV	OLS	2SLS-IV
Women's overall empowerment score	0.402**	0.374***	0.425***	0.493***
	(0.104)	(0.126)	(0.218	(0.196)
Log (Land)	-0.116	-0.112	0.055	0.071
	(0.057)	(0.055)	(0.063)	(0.067)
Log (Capital)	0.458*	0.409**	0.392**	0.354**
	(0.561)	(0.376)	(0.146)	(0.173)
Log (Labour)	0.095	0.107	0.137*	0.135
	(0.052)	(0.042)	(0.102)	(0.099)
Log (Seeds)	0.284***	0.250**	0.565**	0.562**
	(0.118)	(0.145)	(0.213)	(0.186)
Log (Fertilizers)	0.357*	0.374***	0.720***	0.704***
	(0.205)	(0.201)	(0.443)	(0.368)
Log (Pesticides)	0.136	0.123	0.086	0.084
	(0.068)	(0.085)	(0.039)	(0.038)
Row-planting	0.143**	0.130**	-0.235	-0.227
	(0.057)	(0.062)	(0.092)	(0.084)
Gender	0.049	0.046	0.067	0.078
	(0.025)	(0.028)	(0.031)	(0.036)
Household size	-0.036	-0.036	-0.080	-0.073
	(0.042)	(0.042)	(0.110)	(0.085)
Livestock ownership	0.244**	0.277***	0.289*	0.292**
	(0.220)	(0.209)	(0.174)	(0.162)
Plot tenure	0.641	0.622	0.261**	0.266**
	(0.453)	(0.417)	(0.094)	(0.102)
Off-farm income	0.147*	0.125*	0.346***	0.329***
	(0.085)	(0.093)	(0.138)	(0.120)
Access to extension	0.129**	0.123**	0.210	0.065*
	(0.102)	(0.098)	(0.088)	(0.224)
Access to credit	0.214***	0.192**	0.441**	0.325**
	(0.208)	(0.130)	(0.028)	(0.137)
Distance to market	-1.153	-1.146	-0.756*	-0.584*
	(1.091)	(1.086)	(0.405)	(0.414)
Location dummy	0.075*	0.097*	0.058**	0.051**
	(0.057)	(0.069)	(0.022)	(0.018)
Constant	2.454***	2.410***	3.168***	4.206***
	(0.326)	(0.338)	(0.295)	(0.272)
Observations	561	561	561	561
F-test	19.450***	18.640***	21.524***	20.863***
R-squared	0.22	0.21	0.29	0.27

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Bootstrapped standard errors for 2SLS-IV and robust standard errors for OLS are reported in parentheses.

Similarly, Table 5 suggests that indicators of production decisions, asset ownership, income decisions, group membership, and credit decisions are positively and significantly associated with farm-level income. These results concur with the findings of Anik and Rahman (2021) who noted that individual indicators of women's empowerment in agriculture have a positive relationship with income.

Empowering women through access to production decisions, asset ownership, income decisions, group membership, and credit decisions is believed to be the best path to reducing household vulnerability to poverty and food insecurity by increasing agricultural incomes and food availability (Sharaunga, Mudhara, & Bogale, 2015).

Table 4. Effects of individual indicators of women's empowerment on rice yield (Dependent variable: Log (yield)).

Variables	Production decisions	Asset ownership	Income decisions	Credit decisions	Group membership	Workload
Number of production decisions made by the woman	0.194** (0.076)					
Number of assets solely or jointly owned by the woman		0.157** (0.048)				
Number of income decisions in which the woman participates			0.203*** (0.112)			
Number of decisions over credit made by the woman				0.169 (0.104)		
Number of groups to which the woman is an active member					0.272*** (0.088)	
Time adequacy						0.096 (0.080)
Log (Land)	-0.115 (0.153)	-0.127 (0.171)	-0.110 (0.123)	-0.162 (0.135)	-0.158 (0.138)	-0.151 (0.139)
Log (Capital)	0.362*** (0.078)	0.542** (0.106)	0.518*** (0.086)	0.504*** (0.095)	0.436*** (0.061)	0.480*** (0.059)
Log (Labour)	0.086** (0.014)	0.083** (0.012)	0.077** (0.009)	0.079** (0.008)	0.091** (0.018)	0.097** (0.022)
Log (Seeds)	0.245*** (0.082)	0.268*** (0.087)	0.284*** (0.093)	0.252** (0.077)	0.294*** (0.121)	0.286*** (0.095)
Log (Fertilizers)	0.165* (0.032)	0.148*** (0.026)	0.182** (0.025)	0.193*** (0.041)	0.180*** (0.036)	0.162*** (0.018)
Log (Pesticides)	-0.074 (0.150)	-0.075 (0.145)	-0.061 (0.113)	-0.080 (0.098)	-0.073 (0.137)	-0.058 (0.081)
Row-planting	0.207*** (0.126)	0.131** (0.098)	0.225** (0.106)	0.214** (0.113)	0.249*** (0.105)	0.197** (0.106)
Gender	0.062* (0.041)	0.050 (0.022)	0.056 (0.018)	0.072 (0.025)	0.060 (0.034)	0.057 (0.023)
Household size	-0.048 (0.063)	-0.051 (0.059)	-0.033 (0.054)	-0.056 (0.047)	-0.088 (0.073)	-0.035 (0.009)
Livestock ownership	0.104** (0.075)	0.120** (0.053)	0.107** (0.062)	0.114*** (0.035)	0.102** (0.028)	0.138** (0.082)
Plot tenure	0.038 (0.007)	0.051 (0.018)	0.025 (0.013)	0.056 (0.021)	0.034 (0.005)	0.042 (0.019)
Off-farm income	0.083 (0.029)	0.067 (0.034)	0.092 (0.051)	0.074 (0.043)	0.062 (0.029)	0.058 (0.023)
Access to extension	0.445*** (0.206)	0.414*** (0.180)	0.412*** (0.185)	0.428*** (0.140)	0.536*** (0.097)	0.430*** (0.118)
Access to credit	0.196*** (0.087)	0.163** (0.088)	0.189*** (0.101)	0.232*** (0.113)	0.175*** (0.091)	0.187*** (0.096)
Distance to market	-0.333** (0.061)	-0.320** (0.059)	-0.296** (0.102)	-0.309** (0.114)	-0.265** (0.088)	-0.217** (0.095)
Location dummy	0.716*** (0.302)	0.773*** (0.327)	0.722*** (0.275)	0.708*** (0.230)	0.781*** (0.318)	0.785*** (0.307)
Constant	1.758*** (0.114)	1.629*** (0.120)	1.914*** (0.089)	1.720*** (0.077)	1.855*** (0.103)	1.932*** (0.116)
R-squared	0.275	0.278	0.271	0.280	0.273	0.269
Observations	561	561	561	561	561	561

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Bootstrapped standard errors are reported in parentheses.

Table 5. Effects of individual indicators of women's empowerment on income (Dependent variable: Log (income)).

Variables	Production decisions	Asset ownership	Income decisions	Credit decisions	Group membership	Workload
Number of production decisions made by the woman	0.216*** (0.092)					
Number of assets solely or jointly owned by the woman		0.181*** (0.054)				
Number of income decisions in which the woman participates			0.348*** (0.090)			
Number of decisions over credit made by the woman				0.272* (0.129)		
Number of groups to which the woman is an active member					0.185** (0.047)	
Time adequacy						-0.052 (0.078)

Variables	Production decisions	Asset ownership	Income decisions	Credit decisions	Group membership	Workload
Log (Land)	0.208	0.077**	0.134	0.169	0.125	0.092
	(0.072)	(0.049)	(0.030)	(0.027)	(0.018)	(0.011)
Log (Capital)	0.515***	0.588***	0.652***	0.697***	0.680***	0.598***
	(0.146)	(0.134)	(0.211)	(0.182)	(0.167)	(0.085)
Log (Labour)	0.274***	0.191***	0.159***	0.165***	0.238***	0.183***
	(0.087)	(0.026)	(0.023)	(0.019)	(0.090)	(0.034)
Log (Seeds)	0.141**	0.148**	0.194**	0.146**	0.137**	0.150**
	(0.052)	(0.057)	(0.065)	(0.041)	(0.029)	(0.046)
Log (Fertilizers)	0.223***	0.218***	0.301***	0.254***	0.243***	0.249***
	(0.080)	(0.076)	(0.118)	(0.066)	(0.072)	(0.083)
Log (Pesticides)	-0.110	-0.099	-0.102	0.068	-0.125	-0.121
	(0.235)	(0.202)	(0.157)	(0.097)	(0.173)	(0.178)
Row-planting	0.076***	0.140*	0.087***	0.093***	0.124**	0.095***
	(0.044)	(0.051)	(0.036)	(0.040)	(0.079)	(0.064)
Gender	0.302	0.227	0.205	0.184	0.258	0.187
	(0.288)	(0.253)	(0.171)	(0.205)	(0.312)	(0.222)
Household size	-0.036	-0.045	-0.039	-0.088	-0.032	-0.026
	(0.041)	(0.055)	(0.060)	(0.086)	(0.045)	(0.050)
Livestock ownership	0.310**	0.368*	0.345*	0.403*	0.374*	0.325*
	(0.142)	(0.139)	(0.094)	(0.251)	(0.158)	(0.088)
Plot tenure	0.062**	0.080**	0.076**	0.107**	0.074**	0.082**
	(0.012)	(0.025)	(0.021)	(0.039)	(0.026)	(0.033)
Off-farm income	0.409***	0.436***	0.523**	0.415**	0.251*	0.304**
	(0.148)	(0.145)	(0.280)	(0.163)	(0.117)	(0.126)
Access to extension	0.182	0.186	0.160	0.236	0.179	0.211
	(0.169)	(0.170)	(0.095)	(0.194)	(0.102)	(0.225)
Access to credit	0.247**	0.224**	0.306**	0.292**	0.258**	0.275**
	(0.083)	(0.068)	(0.053)	(0.050)	(0.062)	(0.068)
Distance to market	-0.157**	-0.149*	-0.111**	-0.184**	-0.155**	-0.123*
	(0.040)	(0.042)	(0.028)	(0.067)	(0.079)	(0.061)
Location dummy	0.620***	0.597***	0.572***	0.619***	0.585***	0.552***
	(0.295)	(0.186)	(0.191)	(0.226)	(0.170)	(0.194)
Constant	2.361***	2.003***	2.087***	1.821***	1.998***	2.144***
	(0.124)	(0.095)	(0.091)	(0.102)	(0.105)	(0.108)
R-squared	0.354***	0.370***	0.394***	0.400***	0.383***	0.382***
Observations	561	561	561	561	561	561

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Bootstrapped standard errors are reported in parentheses.

4. CONCLUSION AND RECOMMENDATIONS

This study used the IV method to examine the impact of women's empowerment in agriculture on yield and income generation in rural Rwanda. For the first research question, the descriptive results revealed that the average rice yield in the study area is approximately 1,828 kg per acre and the average net rice income is about 843,380 RWF per acre. For the remaining two research questions, empirical results revealed that women's overall empowerment in agriculture has a positive and statistically significant impact on rice yield and income. Indeed, this finding highlights the significance of improving women's empowerment in agriculture to boost rice productivity outcomes and to ensure food security and poverty reduction. Moreover, the results indicate that production decisions, asset ownership, income decisions, and group membership indicators of women's empowerment are positively and significantly correlated with rice yield. On the other hand, production decisions, asset ownership, income decisions, group membership, and credit decisions indicators of women's empowerment are positively and significantly associated with farm-level income from rice production. These findings call for policy interventions in favour of women's participation in financial inclusion mechanisms, cooperatives, and agricultural production decisions. Additionally, the findings of this study highlight the importance of building strategies and mechanisms for increasing women's control and decisions over assets.

Overall, this study argues for the need for policy interventions aimed at improving women's empowerment in agriculture to boost rice productivity and rural income in Rwanda. However, this study is limited in the sense that the cross-sectional nature of the data does not support a rigorous examination of the impact of women's empowerment in agriculture on yield and income generation. An additional limitation of this study is that the data are not nationally representative and thus cannot reflect the status of women's empowerment across all parts of Rwanda. Consequently, future studies should employ nationally representative panel data to assess the effects of women's empowerment on rice productivity and income outcomes.

Funding: This study received no specific financial support.
Competing Interests: The author declares that there are no conflicts of interests regarding the publication of this paper.

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