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RESEARCH ARTICLE

Analysis of Gross Margin of Women Melon Processors With and Without Improved Melon Seed Shelling Technology: A Study in Benue and Niger States

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Abstract

Before the advent of Improved Melon Seed Shelling Technology (IMSST) a decade ago, raw melon seeds were shelled manually to obtain kernels for further processing into a cake, oil, and snack. The seed sheller was introduced to increase productivity, add value to melon products, and provide higher returns (gross margin) to rural women; the GM is an indicator of agribusiness's financial performance. The causal effect of IMSST adoption among countrywomen in their GM and economic empowerment status was examined. Five hundred and forty (540) rural women who engaged in melon seed processing were randomly chosen from thirty towns in Benue and Niger States. Data were solicited through Interview Guide (IG) and analysed with Logit and Linear Regression Model. The gross margin (G_w=₦232,564.35 ($506.68)) of mechanized sheller was higher than the GM of hand shelling (G_{wt}=₦1,894.43 ($4.13)). It was found that adopters of IMSST have high empowerment status (93%) and adequate achievements (76.9%) in all domains of WEAI. Linear regression shows that IMSST is a predictor of rural women's economic empowerment status (β = 0.91). The Logit model revealed that age (β = 0.49), education (β = 0.28), experience (β = 0.82), and credits (β = 0.14) were determinants of the IMSST adoption by the rural women. The Regression Discontinuity (RD) shows a jump at the cutoff point of 50 which depicts average treatment effect. This study concludes that the difference in the GM and economic empowerment of women melon processors in both the Benue and Niger States is caused by improved melon seed shelling technology adoption. Subsidized IMSST by the government would accelerate and sustain the adoption of IMSST to boost rural women's economic empowerment.

Introduction

Agricultural technology is a catalyst for revamping Nigerian agriculture; increasing productivity, value addition, food security, and farmers' gross margin. Agriculture's commitment could be fundamentally upgraded by reinforcing linkages with industry through agro-preparing and coordination[1]. Food processing, where family-based undertakings driven by

countrywomen is turning out to be progressively normal[2][3]. Small and medium-scale agro-handling ventures have played a vital role in the advancement of the economy of advanced nations and agricultural nations[4][5][6]. We are in an innovative era. Non-access to food processing technology by country women limits their productivity and attainment of sustainable income. Unfortunately, technology has not been used to fast-track women's economic development despite the available statistics that 80% of rural women in developing countries are into agriculture. The ensuing split among industrial and non- industrial nations was the aftereffect of lopsided relations of exchange, venture, and technological learning[7]. Technology has brought innovation and an expanding multiplication of digitized gadgets and administrations[7][8]. As far as agribusiness, in Nigeria, 60 to 79% of the provincial labor force is countrywomen who are dominatingly ranchers and homestead laborers, and they are additionally multiple times more uncertain than men to claim property. The country women process and add value to cassava, rice, maize, cowpea, and melon using combined methods, traditional food handling, and modern.

Improved technology in the food sector increases women's empowerment status and thus contributes to women's poverty reduction. Although researches on food products are very low in SSA[9][10] findings have shown that improved technology assisted its adopters to increase productivity and entrepreneurial skills[11]. For instance, findings from SSA revealed that increment is achieved in agriculture through rural women's access to production resources[12][13][14]. Through the earnings from agriculture, rural women can make a significant impact on the welfare of their children, families, and societies[15][11]. The adoption of improved technology facilitates social interaction.

It is however worrisome those Nigerian rural women are in abject poverty and constrained by high food crises despite the global trends in agricultural technology. FAOSTAT[16] showed that Nigeria produced 60% of the world melon seed and ranked the highest producer with 585,347 tonnes output. In 2021, Nigeria exported 42,000 tonnes egusi to India, Guatemala, and Brazil[17][18]. Egusi is projected as one of the agricultural products that boost the Gross Domestic Product (GDP) of Nigerian however it did not receive mechanize support to increase its production[16].

It has been reported by Oyediran et al.[19]; Oyediran[20] Tchoupou et al.[21] that over time the shelling of melon seed is through hand shelling by country women. This shelling is the first stage to obtain kernels that are further processed to its finished products like oil, cake, *robo*, *sagba*, *igbalo*, and *ogiri*. Melon processors undergo pains in fingers, legs, mid-region, and spine while in a deferred sitting position shelling melon. Thus, the products and income are affected[21]. The intervention of NCAM to change the trend through the launching of IMSST has not been significant due to little financial support. The IMSST are categorized according to the power source as electric, gas, and petrol engine. The commitments to the prosperity of provincial ladies are all around recorded[20].

Consequently, this study calculated the GM from the processed melon through IMSST and looked at the benefits of IMSST adoption to rural women. Country women will dependably feature, as their commitment to the transforming of melon is on the extension.

Specific objectives are to:

i. estimate profits from the processed melon with and without IMSST

ii. examine the empowerment through IMSST
iii. assess rural women's decision to adopt IMSST

The hypothesis of this study is in null form

- H01: The study hypothesized that no difference exists in the GM and economic empowerment of countrywomen with and without IMSST in both Benue and Niger States, Nigeria.

Purpose of the study

The challenges of low output, poor earnings, and body pains triggered this study. Poor transformation of agricultural produce progresses to food setbacks, vulnerable food quality, and low earnings[22][23][24]. A prototype of a melon sheller is fabricated and promoted in Nigeria to relieve countrywomen of these problems[25][26]. From 2012 to 2019, provincial women progressively received IMSST in the overviewed regions. Adopters are the provincial women who had and applied IMSST in the melon venture. Additionally, Women's empowerment is paramount in the developing world, a situation where over 1.7 billion are marginalized[27]. More than sixty percent of Sub-Saharan African (SSA) women practiced agriculture[28], but still, women's accessibility is low than men's[29]. These resources include agro-inputs, credit, skills, and equipment – in this case IMSST. The roles countrywomen played cannot be over-emphasized in post-production handlings and the transformation of melon into finished goods for human consumption. Value addition to melon seeds provides multiple opportunities, such as food and income, for rural women.

Melon (Citrullus colocynthis L.) is grown across the world and it is an economically important vegetable crop[30]. Cultivation of melon is mostly done by men due to its tedious nature of land preparation, seed selection, fertilizer application, weeding, and harvesting while women purchase the seeds from farmers and process these into oil, cake, or soup condiment. However, the production of melons is increasing in Nigeria due to its socioeconomic values and profitability. It is an important food complement that contains essential minerals for body growth and maintenance. According to Mello[31], Hussain et al.[32], and Dhakad et al.[33] melon contains 53.1% dietary oil and 33.8% protein while its amino acids are higher than that soybean. Melon has biomedical properties that encourage its traditional uses against inflammation of breast cancer, tuberculosis, diabetes, asthma, and menstrual pains[34][33][30]. Melon soup is a nourishing food recipe. Margarine, pomade, soap, adhesives, candles, and lubricants are industrial derivatives of melon[35][30].

The existing kinds of literature depicting income-technology relationships are concentrated on global data. Most studies on technology adoption overlook the income effect on farmers' adoption[36], the concentration has been on simplicity[37][38] whereas income effects and technology adoption incentives are very germane in technology adoption[39]. Enhancing productivity in agriculture relies on the adoption of technology and the creativity of farmers[40]. This paper, however, adopted an exploration method in examining the income- technology impacts among rural women. The data gathered through face interviews with melon processors formed a robust sample size. In our study, we add to pieces of literature on the agric- tech and profitability by showcasing the IMSST intervention for melon processing in Nigeria. Therefore, it suggests that findings and conclusion would be more reliable.

Literature Review

Almost all the reviewed studies indicated that improved technology adoption has a positive and significant effect on farmers' livelihood and welfare although the location and duration of studies are different along with the results found[41]. Agricultural technology can effectively improve agricultural income. Increasing income is a necessity for the poverty reduction and well-being of countrywomen. In their study on the assessment of agricultural technology, Deng et al.[42] investigated its impact. In 2020, significant cost savings were discovered along with enhancements in the quality and efficiency of agricultural machinery, resulting in improved agricultural production. According to Luo and Qiu[43], the use of agricultural machinery can lead to a significant reduction in labor costs. Li et al.[44], it was reported that increasing labor costs have played a significant role in the decrease of agricultural profitability. The adoption of standardized agricultural machinery has been found to lower agricultural losses and enhance product quality[45]. In Zambia, Zimbabwe and Benin, technology has led to increase farm income[46]. Because of technology, smallholder maize growers in South Africa reported a high revenue[47]. According to Kabunga et al.[48] banana farmers in Kenya attribute their increased revenue to the use of technology. A positive impact of improved wheat technology on income was reported in Kenya[49]. Agricultural technology adoption contributes to improving productivity and raising the income of farm households[41].

Previous studies examine effect of agricultural technology on farmer's gross margin. Ma and Abdulai[50] found that the adoption of integrated pest management (IPM) technology significantly increased apple production, profits, and agricultural income for 481 apple growers in China. A recent study using regression analysis looked at how technology impacts the income of 822 rice growers in the Yangtze Basin. The study found that these techniques have managed to lower costs and increase income for the growers, although the improvement in cost income is not significant[51]. These characteristics promote the adoption of new technology.

Similarly, the review by Gao et al.[52] on the impact of agricultural technology on farmers' income shows that the application of ecological control techniques has a significant impact on increasing farmers' agricultural income. Survey of apple farmers in Shaanxi, Gansu and Henan by Hou et al.[53] show that the soil nourishment technology helped farmers increased their average annual agricultural income by 8%.

In Ghana, empirical result shows that quality crop selection and soil and water conservation practice is beneficial to improve crop income[54]. In Malawi, Tufa et al.[55] examined the productivity and income impacts of the adoption of improved soybean varieties and agronomic practices among 1,237 soybean farmers in the country, and found that the adoption of ISVAPs leads to 61 percent increase in production and 53 percent increase in income among adopters. Agricultural technology adoption is beneficial to increase the household income of farmers[36].

Theoretical framework

Roger's Technology Adoption Theory

Rogers[37] postulates that for adoption to be sustainable, a promoted technology should be superior to the old one; it should have a relative advantage over existing ones, compatible to the users' needs, trial-able, simple, and observable. These attributes foster adoption of new technology.

Technologies are promoted due to observed deficiencies in a conventional way of doing things; it emanates from discoveries about things before innovation[56]. According to Ekong[56], technologies are partly or completely new and are designed to replace old practices. Adjei-Nsiah[57] argued that there is a need to embrace alternative practices to improve operations by small and medium-scale processors to improve products. Agricultural technology saves production costs, increases product types, improves the quality of the product and efficiency, and fast-tracks production modes[42][58]. The application of standardized agricultural machinery reduces wastage and improves product quality[59][60]. Farmers using agricultural technology significantly spend less on hired labour[43]. It was reported that a very important cause of the decline in agricultural profitability is labour wages[44]. Findings emanated from several international pieces of research have shown that income is technology-driven for adopters[61][58][59]. In line with other scholars[37][58][59], improved melon shelling technology would offer considerable benefits compared to traditional methods which would trigger production and gross margin of countrywomen.

Budgetary Concept (GM)

Several previous studies[62][63][64][65] have utilized income as a substitute to understand the impact of farm technology adoption on welfare. Gross margin (GM) measures variation of the production value (p) and the marginal cost (MC) for the production purpose in an enterprise[66]. The GM has been an important tool in the computation of budgeting and evaluation. The computation mostly covered the production season; it may be a year or more depending on the production stages. When it is applied as a budgeting tool, the GM identifies more profitable enterprises, calculates break-even yield and prices, and serves the purpose of building blocks of other farm budgets including the whole farm budget[66]. In post-implementation evaluation, GM analysis compares similar or different enterprises over time and space[67]. GM has been found useful along the agribusiness value chain, that is, from the input supply[51], production stage[68], processing operations,[69] and marketing[70]. Just like in our study, GM, and its drivers are subjected to regression models either linear or multiple[68][71]. Previous studies on agrictech versus farm incomes show positive correlations[61][60]. For instance, findings by Ma and Abdulai[50] among Chinese crop growers reveal that IPM adoption accounted for high crop production and farmers' incomes. The investigation by Tufaa[55] among soybean growers in Malawi indicates that ISVAPs adoption gives a 53 percent increase in farmers' incomes. In Ethiopia, technology is the key to achieving high production and welfare of farmers[59][72][73] and[74] found technology to be positively connected with the length of formal education. Hence, increased years of education for women agri- entrepreneurs would facilitate the improved technology adoption that would give higher GM. Shreds of evidence from Ghana have confirmed that for every year of experience in smallholder palm fruit processing, the gross margin of crude palm oil increased by GHS 6.82 (USD 4.16)[75][76]. This outcome explained the assertion that with time, women processors overcome challenges as they traverse the learning

curve. Productivity-enhancing agricultural innovations contribute to rural households' income in Sub- Saharan Africa[77]. The monthly income of 18 countries adopting modernized agricultural practices increased by 40 percent compared to the non-adopters[78]. This therefore provides an explanation for the low gross margin obtained by rural women food processors, despite their enormous degree of involvement in agri-preneurs, which resulted to declining in their commitment to household needs and overall well-being.

Research Methodology

Description of the Study Locations

Nigeria is a nation located in sub-Saharan Africa, therefore, agriculture remains the sustenance. There are six geo-political zones which further splitted to thirty-six states that make up the federation. As of 2022 the Nigeria population was projected to be 216,783,381 amounting to 108,350,410 males and 108,432,971 females[79]; this projection is a concerned for increased food production and supply to address hunger in the land. The study was conducted in north central Nigeria. North Central Zone is made up of six states (Benue, Kogi, Kwara, Nasarawa, Niger, and Plateau) and the Federal Capital Territory (FCT), Abuja. The zone is agrarian as the main employer of labour is agriculture with few commercial centers in form of modern and local markets[80]. Crops produced in the zone include melon, yam, rice, sorghum, maize, acha, beeniseed, fruits, and vegetables.

Rural women who processed melon are targeted population from Benue and Niger State. These states were selected based on their similarities in terms of regional agricultural engagements and also have presence of the IMSST in their domains. Benue State is the nation's food basket while Niger State is the largest producer of melon[81]. The estimated population of Benue State was 5,741,815, that is, 2,928,326 males and 2,813,489 females[82]. Niger State population stood at 5,556,247 comprising of 2,833,686 males and 2,722,561 females[82]. From the population figures, the women represent 48.99% of the population in Benue and Niger States.

Sampling procedure and sample size

Going by the[83] formula for the estimation of the sample which is:

$$n = z^2 \frac{pq}{c^2}$$

Where;

- z = confidence level of 2.576 for 99%
- p = proportion of population from previous survey (81.4%)
- q = desired level of precision (25%)
- c = c-f 5%

The estimated sample size (n) study is 540.152 (by approximation 540).

This study adopted a multi-stage, stratified, and proportional random sampling technique to gather data from the respondents. A similar method was utilized by Shira and Dorit[84]. Firstly, two of the six states in the north-central agroecological zone of the federation were selected on purpose, representing 33%. Secondly, one of the three ADP zones was chosen from each zone from where the communities for the baseline study were conducted, which is a 33% representative sample. Thirdly, Otukpa, Apa, and Agatu were the three communities that were purposively chosen from Zone C in the central ADP zone areas of Benue State while

The interview guide used for the data collection was designed on objectives and was used for the melon processors on socio-economic variables, the quantity of melon seed shelled, and products sold per week. Focus Group Discussion (12 women in a group) was deployed to enrich data collection in each location. Agents from Extension were trained to help with data gathering from February to December 2022.

The instrument validity

The University Centre for Research of the Federal University of Agriculture, Abeokuta approved the instrument for the survey. Also, the professionals from Agricultural Economics and Extension validated the questionnaire. Melon Trade Union (MPMAN), Benue, and Niger State Chapters gave consent to the conduct of this research. The study ensured the anonymity and assurance of respondents.

Analytical method

Age and years of experience were measured as the actual figures and converted to interval levels. To determine the empowerment of women in melon processing activities, the WEAI model was adopted for empowerment. Generally, there are 5 Domains of Women Empowerment (5DE) as related to agriculture, that is, (i) Production, (ii) Access to resources (iii) Income (iv) Leadership, and (v) Time. This study looked at the production domain in terms of output (kg); access to resources in the form of sources of technology; profit (estimated gross margin); leadership (social relationship); time (number of hours used to produce output kg/hr.). WEAI compares the empowerment of women to that of men in the same household taking cognizance of gender parity but this study concentrated on the dimension of economic empowerment (gross margin) of the adopters of IMSST; and the degree to which the economic returns are beneficial to the well-being of household members. Since gross margin is a continuous variable, it was measured at a ratio level. The numerical value of 5DE is 1 for high values indicate the highest degree of empowerment, and 0 for the low values. This study concentrated on the dimension of empowerment of the adopters and non-adopters of IMSST using 390 adapters and 150 non-adopters.

$$5DE0 = 0H_E + Hn(Aa)$$

- 5DE: 5 Domains of Women Empowerment
- H_E: Percentage of empowered women

- Hn: Those women are not yet empowered but demonstrate adequate achievements;
- Aa: Percentage of Dimensions of disempowered women had adequate achievements

  $H_E + Hn = 100\%$

  $0 < Aa < 100\%$

Determining the adoption decision of rural households

The Probit, Logit, and Tobit models serve as tools for analyzing the decision-making process regarding the adoption of modern agricultural technologies among rural households. In this research, a Logit model was utilized to assess the determinants influencing this adoption. The preference for the Logit model over the Probit and Tobit models is attributed to its mathematical ease and straightforwardness, as well as its ability to address the issue of heteroscedasticity, as noted by Greene[85].

In the parameters, P(Y = 1) would be 1 for the adopter and if otherwise P(Y = 0) it would take 0.

Logit Model

$$\log_e\left[\frac{P\left(Y=1 \mid X_1,\ldots,X_p\right)}{1-P\left(Y=1 \mid X_1,\ldots,X_p\right)}\right] = \log_e\left[\frac{\pi}{1-\pi}\right]$$

$$= \alpha + \beta_1 X_1 + \ldots + \beta_p X_p = \alpha + \sum_{j=1}^{p} \beta_j X_j$$

- $X_1 \ldots X_P$ are predictors, $\beta_1 \ldots \beta_p$ is parameters, α is intercept

The regression is explicitly presented:

- $E = \alpha + \beta_w G_w + et$
- $E = \alpha + \beta_{wt} G_{wt} + et$

Such that,

- E: Economic Status (WEAI);
- G_w: GM with IMSST (Naira);
- G_{wt}: GM without IMSST (Naira);
- α: Constant; and
- et: error term

Regression Discontinuity Design (RDD)

The regression discontinuity design (RDD) is one of the most popular research designs[86][87]. However, the statistical detail of RDD is not the focus of this study, the comprehensive models can be found in the works of Imbens & Lemieux[88], Lee & Lemieux[89], Schochet et al.[90], and Wuepper and Finger[91]. The RDD was first considered by Thistlethwaite and Campbell[92]. In many literatures, the RDD is often considered to be one of the strongest nonrandomized designs for drawing causal conclusions from data[86][87][93]. It provides a transparent method to estimate the causal effects of treatments or policies[87][93][91]. It identifies the average treatment effect at the discontinuity point. Thus, RDD is increasing in applied researches[94][95], health[93], agriculture, and environmental economics[91].

Variables Measurement

Socio-economic elements of the study which influenced the respondent's opinion on IMSST are education, asset ownership, and family size, non-farm income, person-day, extension contact, and cooperative loans. We confirmed that the design assumptions of the RDD were fulfilled. Also, we assumed that the treatment effect only occurs at the threshold of economic status (wellbeing) 50 and not at other thresholds. The treatment is assumed to have an impact on dependent variable but not on independent variables.

Table 1. Variables Choice and expected outcomes

	Variables	Description	Variable type	Expected relationship
Dependent variables				
E	Economic status	Scores	Continuous	+
Independent variables				
G_w	GM with IMSST	Scores	Continuous	+
Gwt	GM without IMSST	Scores	Continuous	-
Y	Adoption	Dummy	Finite	+
Z_1	Age	Scores	Continuous	+
Z_2	Family size	Scores	Continuous	-
Z_3	Asset ownership	Dummy	Finite	+
Z_4	Non-farm income	Scores	Continuous	+
Z_5	Experience	Scores	Continuous	+
Z_6	Education	Dummy	Finite	+
Z_7	Contact with Extension	Dummy	Finite	+

α is Constant; and

et is error term

Results

Respondents' socio-economic characteristics

From the results in Table 2, it was found that ages of 57.4% were less than 40 years while 42.6% were above 40 years. Respondents' average age was 36.2 years which indicates that they are economically active. Most (85.7%) were in the category of married while 14.3% fell in the unmarried category. Marriage conferred some responsibilities on the rural women to take care of their family members with proceeds from melon processing activities. About sixty percent (58.4%) attended schools to get formal education whereas 41.6% did not go to school at. The implication is that high literacy would facilitate the adoption of IMSST. The mean experience was 14.1 years. Also, 66.8% of the respondents spent more than ₦51,000 to acquire the melon sheller. The average cost of an improved melon sheller was ₦52,267.40. Eighty-three percent of the respondents obtained ₦30,000.00 as credits from the thrift & cooperative societies while only very few (16.9%) sourced more than ₦31,000 loans respectively from the thrift & cooperative societies. The credit is too meager and not readily available which is an indication that most of the rural women looked outside the thrift & cooperative societies to get financial support either through personal savings, friends, or family.

Table 2. Distribution according to the respondents' socio-economic characteristics

Socio-economic Variables	Percentages	Mean
Age (yrs.)		
≤ 40	57.4	36.2
> 40	42.6	
Marital status		
Married	85.7	
Unmarried	14.3	
Educational Status		
Educated	58.4	
Uneducated	41.6	
Experience in processing melon		
(yrs.)		
11 – 20	88.7	14.1
> 21	11.3	
Assets of the respondents		
Improved shelling Technology (₦)		
41000 – 50000	33.2	
> 51000	66.8	52,267.40
Thrift & Cooperative societies (₦)		
≤ 30,000	83.1	27,960.30
> 31,000	16.9	

Source: Field Survey

The GM of processed melon products with and without IMSST

Results in Table 3 show GM from prepared melon products with and without IMSST. Melon processors usually purchased raw melon seeds from the farm gates and open markets. At the homestead door, shelled melon with IMSST is sold for ₦1,130/kg. The total variable cost to obtain shelled melon (kernels) was ₦106,587.10/day while the estimated total income was ₦389,340.00/day. In addition, the estimated GM was ₦232,564.35/day ($506.68; €480.33). The average GM generated from 26kg of processed melon kernels for cooking oil and snacks were ₦30,625.00/day ($66.72; €63.25) and ₦15,184.80/day ($33.08; €31.36) respectively. On the other hand, the average output without IMSST was 6.05kg/day while the GM for shelled melon, cooking oil, and snacks were ₦1,894.43/day ($4.13), ₦1,539.50/day ($4.53), and ₦3,470.50/day ($7.56) respectively. This means that processed melon with IMSST got a higher output and more income than without IMSST. If every rural woman has IMSST to extract cooking oil and processed the residue into melon snacks, they would all earn higher GM and breakeven. Provincial women invest more energy than metropolitan partners in conceptive and family work[96] and as such necessary innovation mediation in food.

Table 3. Estimation of weekly Gross Margin (GM) of processed melon

	With IMSST			**Without IMSST**	
Processed melon	**₦1,030/kg**	**$2.24/kg**	**€1.17/kg**	**₦1,190/kg**	**$1.42/kg**
Unshelled melon seed	**47,619.05**	**103.75**	**98.35**	**4,233.60**	**9.22**
Total Variable Cost (labour, transportation, market levy)	**106,587.10**	**232.22**	**220.14**	**1,071.47**	**2.33**
Total Fixed Cost (depreciation)	**2,569.50**	**5.60**	**5.30**	**0.00**	**0.00**
Total Cost (TVC+TFC)	**156,775.65**	**341.56**	**323.80**	**5,305.07**	**11.56**
Revenue (₦)					
Average shelled melon	378kg	378kg	378kg	6.05kg	30.24kg
TR of shelled melon	389,340.00	848.23	804.12	7,199.50	15.68
GM	232,564.35	506.68	480.33	1,894.43	4.13
Melon Oil (Litre/day)	**26**	**26**	**26**	**0.65**	**0.65**
TC	52,575.00	114.54	108.59	540.50	1.18
TR	83,200.00	181.26	171.84	2,080.00	4.53
GM	30,625.00	66.72	63.25	1,539.50	3.35
Melon Snacks (*Robo*)/6.05kg					
TC	4,345.20	9.47	8.97	1,120.30	2.44
TR	19,530.00	42.54	40.34	4,590.80	10.00
GM	15,184.80	33.08	31.36	3,470.50	7.56

Source: Data Analysis

$1 approximately equivalent to ₦459.00;; €1 approx. ₦484.18 (Nigeria Exchange Rate, Feb., 2023)

Empowerment of adopters and non-adopters of IMSST

Results of the 5DE presented in Table 4 show that 93% of adopters of IMSST were empowered compared to 61% of non-adopters. Also, inadequate achievement in all domains was higher for non-adopters (76.9%) than adopters (32.5%).

Table 4. Adopters and non-adopters of IMSST (5DE)

Indices	Adopters	Non-Adopters
Disempowerment head count (H)	32.5%	76.9%
Average Inadequacy (A)2	22.3%	51.3%
Disempowerment Index (M_0)	0.07	0.39
FiveDE (I - M_0)	0.93	0.61
N	390	150
% of data used	50%	19.8%

Source: Data Analysis. N - Observations

Test of hypothesis

The GM with IMSSTT and rural women's financial status

The effect of Gw on provincial women's financial strengthening status was presented in Table 5. The regression model shows that 83.1% of variations in the economic empowerment status of the country's women were achieved through moderating variable (R2 = 0.831b), and the remaining 16.9% were attributed to the residual factors excluded in the linear model. The model established that the use of IMSST significantly determines GM and women's economic empowerment (β = 0.912d) at $p < 0.05$. This can be explained that a rising in the IMSST incorporation wouldtranslate to the GM and women's economic empowerment increment by 91.2% provided other variables are constant. It can further be explained that rural women's access to IMSST would facilitate technology adoption, higher GM, and improved economic status. The p-score of F- statistics (F = 2.603E3, p = 0.000c) asserts that H01 is rejected at one percent. According to Hwang[8], the primary aim of adopting technologies is to increase productivity. Advancements have been seen as the motor for destitution decrease, particularly in non- industrial nations where agribusiness is the bedrock of their economies[97].

The equation is re-written as: $E = \alpha + 0.912G_w + 0.102$

Table 5. Linear regression of G_w and rural women's economic empowerment status

Md	R	R^2	Adj. R^2	SEE	D-W
1	0.912[a]	0.831 **ANOVA**[b]	0.831	57169.895	1.381
	SS	**Df**	**MS**	**F-S**	**Sg.**
Regression	8.506E12	1	8.506E12	2.603E3	0.000[c]
Residual	1.726E12	528	3.268E9		
Total	1.023E13	529			
Coefficients[a]					
MD	**Unstandardized**	**Coefficients**	**Standardized Coefficients**		
	B	**Std. Error**	**Beta**	**T**	**Sig.**
1 (constant)	14939.717	4580.963		3.261	0.001
G_w	5.197	0.102	0.912	51.015	0.000[d]

Source: Data Analysis. [a] *Predictor: (Constant), GM with IMSST;* [b] *Dependent variable: Economic empowerment status,* [c] *Predictor: (Constant), GM with IMSST;* [d] *Predictor: (Constant), GM with IMSST*

The GM without IMSST and rural women's strengthening

Table 6 shows the relationship between G_{wt} and country women's money-related strengthening status. The correlation between the G_{wt} and 5DE is very weak (R = 0.104a > 0.50 for 150 df). The regression model shows that 1.1% economic empowerment variations of the rural women was caused moderating variable (R2 = 0.011b), and the remaining 98.9% was attributed to the residual factors not included in the linear model. The model established that the non-adoption of IMSST was not significantly determined the GM and women's economic empowerment (β = 0.011d) at p > 0.05. The implication is that without the technology intervention, the GM will remain low thus, the country's women would remain in the cycle of abject poverty.

The equation is re-written as: $E = \alpha + 0.104G_{wt} + 2.979$

Table 6: Linear regression of G_{wt} and rural women's economic empowerment status

Md	R	R^2	Adj. R^2	SEE	D-W
1	0.104[a]	0.011 **ANOVA[b]**	0.004	67346.910	8.529
	SS	**Df**	**Mean Square**	**F-S**	**Sg.**
Regression	7.337E9	1	7.337E9	1.618	0.205[c]
Residual	6.173E11	148	3.268E9		
Total	6.786E11	149			
		Coefficients[a]			
Mdel	**Unstandardized**	**Coefficients**	**Standardized Coefficients**		
	B	**SEr**	**Bt**	**T**	**Sg.**
1 (const.)	291676.311	5832.693		50.001	0.000
Gwt	3.789	2.979	0.104	1.272	0.205[d]

Source: Data Analysis. [a] *Predictor: (Constant), GM without IMSST;* [b] *Dependent variable: Economic empowerment status,* [c] *Predictor: (Constant), GM without IMSST;* [d] *Predictor: (Constant), GM without IMSST*

Determinants of Rural Women's Adoption of IMSST

Result of binary logic as shown in Table 7 followed Roger's adoption theory[37]. Feleke et al.[98] used binary logistic regression to examine factors influencing the adoption of Belete potato variety. The coefficient of adopting IMSST positively correlates with age (β = 0.47). Being educated represents a significant factor as expected (β = 0.28) at a 1% significant level. The implication is that education would inform the decision of melon processors on modern food processing techniques. The number of years of experience in melon processing shows a positive and significant coefficient (β = 0.82). Non-farm earnings support the decision of households to accept the new agricultural technology and have a positive correlation (β = 0.39). Similarly, in line with the economic constraint paradigm of adoption models, rural women with melon processing assets like labour and finance have a higher probability of adopting IMSST. The result indicates that access to credit from cooperatives (β = 0.14) has a positive and significant coefficient, suggesting that cooperatives' credit can have a significant impact in facilitating the adoption of IMSST among rural women in the study area.

Table 7: Logit Estimation

Predictors	Coefficient (β)	Standard Error	Z value	Pr(>|z|)
Constant	0.49	-0.35	-1.40	0.000***
Age	0.47	0.61	0.77	0.000***
Years of Education	0.28	0.54	0.51	0.001***
Marital status	0.44	0.09	4.89	0.040**
Years of experience	0.82	0.12	6.83	0.001***
Person-day	0.23	0.03	7.67	0.001***
Non-farm income	0.39	0.06	6.50	0.003***
Extension contact	0.40	0.68	0.59	0.010**
Cooperative Loans	0.14	0.04	3.50	0.000***
Model Statistics				
Observation	530			
Pseudo R2	0.83			
Log likelihood	-134.40			
p-value	0.00			
Chi square	38.59			
Akaike Information	52			
Criterion (AIC)				

*Source: Data Analysis. ***Sg. 1% level, **Sg. 5% level*

Regression Discontinuity

In consistency with RDD the threshold of 50 is strictly adhered to. A score below 50 is poor economic status while A score above 50 is good economic status. Fig. 1a illustrates the regression line that passes through the cutoff point (50). In Fig. 1b, discontinuity was observed at the same cutoff point of 50 on the vertical-axis at 0.5e+05 (₦50,000.00) to indicate the effect size. There is a jump on the vertical axis from +0.5e to -1e (₦150,000) which represents the causal effect at the cutoff point. This is an indication of positive effect of technology adoption on the gross margin of adopters. The Ordinary Least Square (OLS) for the RDD in Table 8 showed that 82.8% of the difference in gross margin of adopters and non-adopters was attributed to the underlying independent variable (treatment). The adoption (t = 4.56) and economic status (t = 20.37) were significant at 1%.

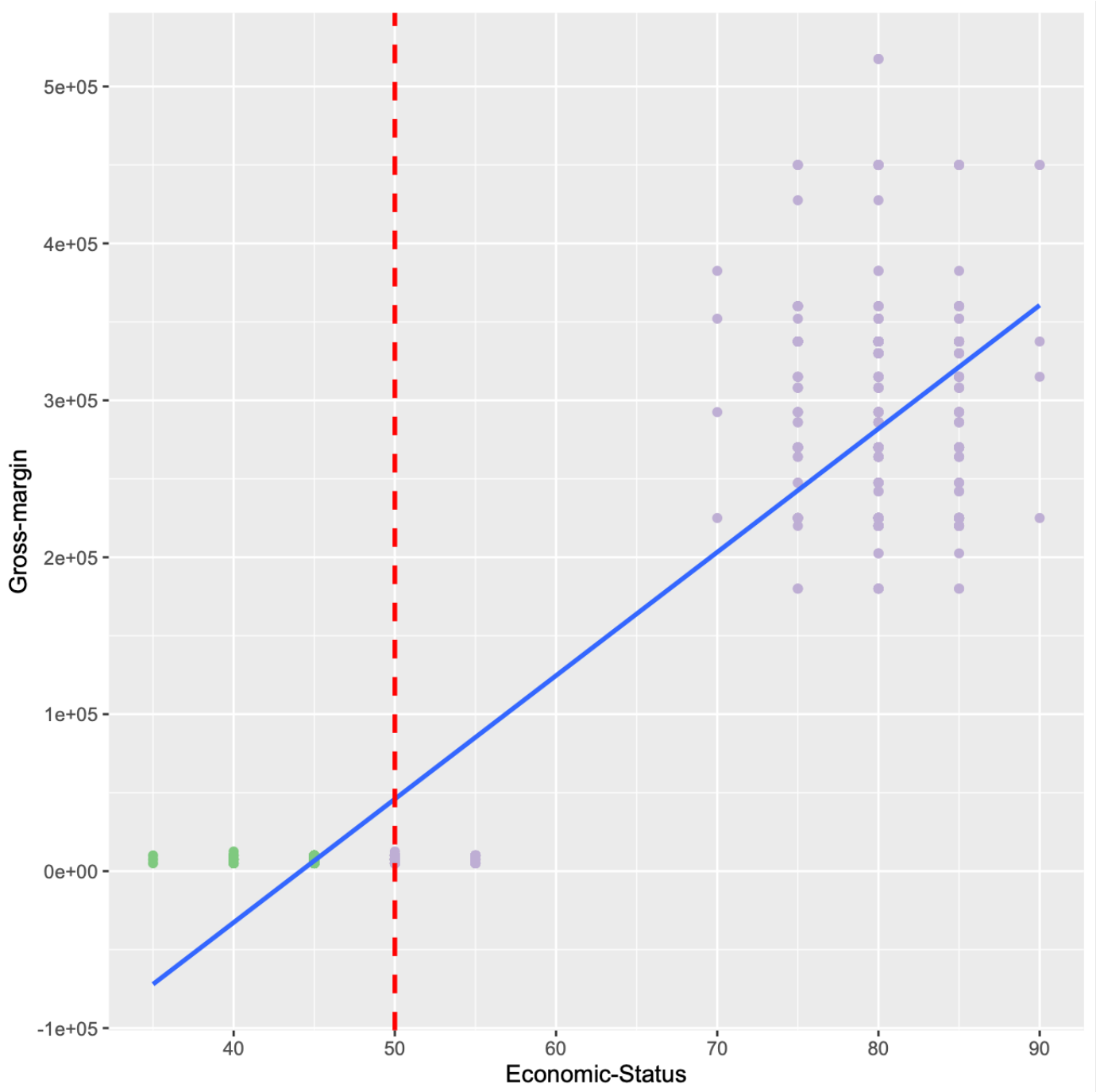

Figure 1a. The Sharp RDD indicating GM without treatment

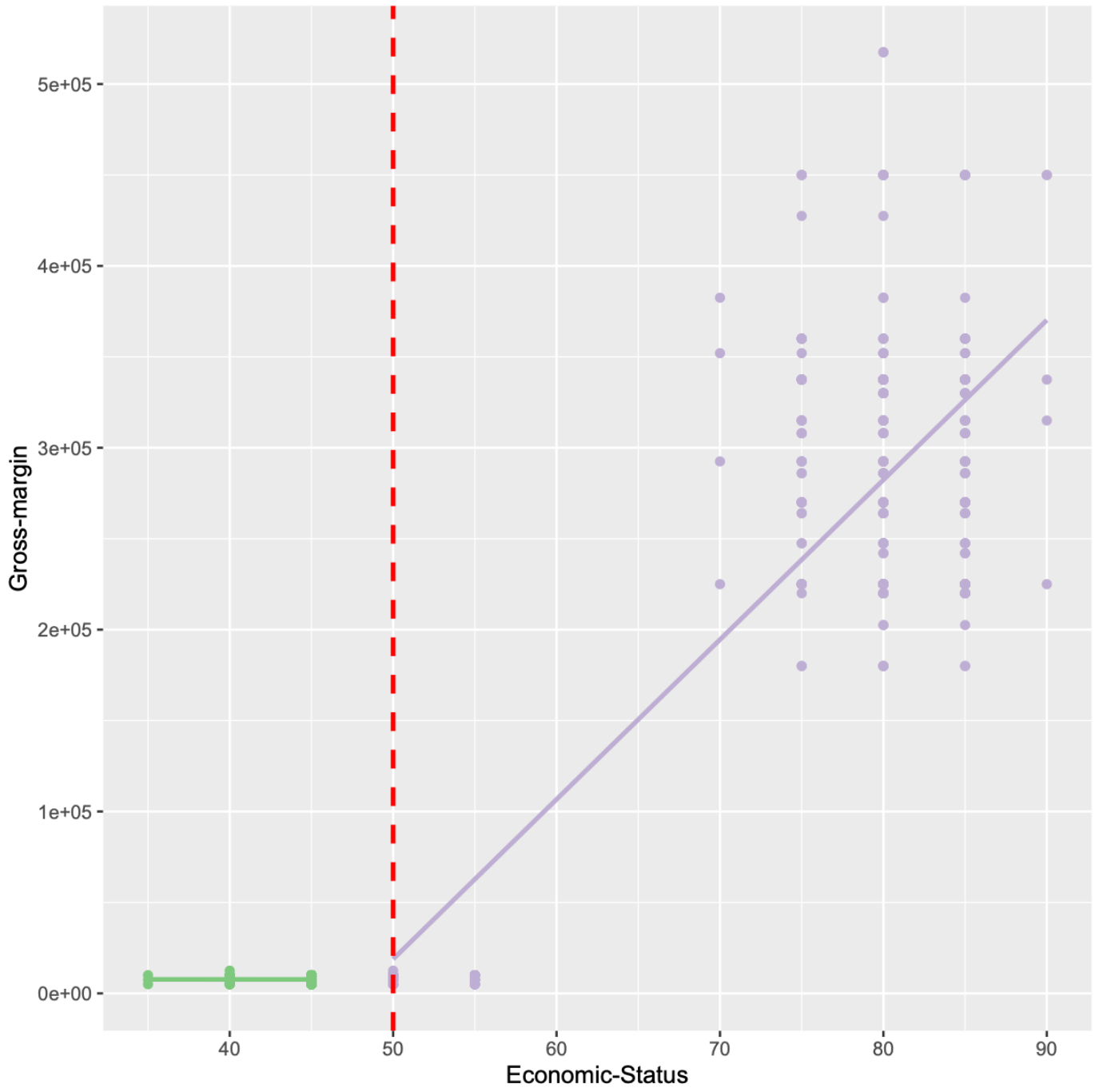

Figure 1b. The Sharp RDD indicating GM with treatment

Table 8. Ordinary Least Square

Coefficient	Estimate	Standard Error	t-value	Pr(>|t|)
Intercept	43080	6800	6.335	$5.03e^{-10***}$
Threshold	-30985	10813	-2.866	0.00433**
Economic Status – 50	7516	369	20.367	$< 2e^{-16}$ ***
Adoption	45816	10043	4.562	$6.29e^{-06}$ ***
Model statistics				
Residual standard error:	60560 on 536 degrees of freedom			
Multiple R-squared:	0.8290			
Adjusted R-squared:	0.828			
F-statistic:	865.9 on 3 and 536 DF, p-value: < 2.2e-16			

*Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

Discussion

The respondents have a mean age of 36.2 years (Table 2). Rural households' survey by Sodiya et al.[99] and Anate et al.[100] indicated that most Nigerian rural women are within this age group (30 – 50 years) and constitute the economically active part of the population. The mean active age range is from 40 to 50 years among rural households in Ogun State according to[101].

Above half has formal education (Table 2). The countrywomen's educational status is an impressive academic exploit on the part when compared with the records of educational discrimination and neglect[102][100]. Anate et al.[100] reported higher education among rural women (92.8%). Also, Xia et al.[103] found that longer education and training influence green production technology. Education has a positive influence on economic output and growth[104]. Women's low level of education lowers their average level of human capital and thus has a direct negative bearing on income growth. Melon processing which is undertaken by countrywomen has the capacity of promoting the status of women if they are given relevant educational support in these activities. Findings show that 85.7% were in the married stratum (Table 2). The studies of Anate et al.[102] and Ketheeswaran[105] among countrywomen in southwest, of Nigeria, indicated that 97.2% were married.

The average cost of an improved melon sheller was ₦52,267.40 which is an indication that the sheller is not too expensive for rural women (Table 2). Most of the rural women used personal savings as capital while many sourced credits (up to ₦30,000) from thrift & cooperative societies. Sharon et al.[106] maintained that finance is 18%, which is the largest gender divide in the world. Anyanwu[107] and Agbodji & Johnson[108] advocated that promoting access to productive assets by women through savings clubs, credit associations and micro-finance would help in reducing poverty and ill-being. Credits obtained from thrift and cooperative societies were used as the capital by rural women (Table 2). This implies that the credit facilitiesprovided by the cooperatives would enable the melon processors to acquire the improved melon shellers, that are capable of producing a high quantity of melon and thus increase the economic returns

of the rural women.

The estimated GM from the shelled melon was ₦232,564.35/week ($506.68; €480.33) for 46kg. Similarly, the GM of melon oil was ₦30,625.00/week ($66.72; €63.25) and that of snacks was ₦15,184.80/week ($33.08; €31.36) for 25.2kg of shelled melon (Table 3). This shows that melon processing is profitable with technology. But, oil extraction and production of snacks are carried out manually which limited the melon processors to 10 mudus per week (126kg/week) and smaller GM. If rural women have improved technology to extract cooking oil and processed the residue for melon snacks, they would earn higher GM and breakeven. This is an indication that the adoption of IMSST contributed to the income generation of melon processors, thereby increasing their prospect of overcoming poverty and hardship[109]. Findings of Hwang & Kim[8] and World Economic Forum[110] show that agricultural technology contributes to production output, revenue, and improved well-being of rural women in developing countries. Nwanyanwu et al.,[78] established that the income generated per month in eighteen countries that adopted agricultural technology was 40% more than those using traditional methods of farming.

The GM from IMSST would further consolidate rural women's economic empowerment and well-being status in terms of having money to purchase food, and sponsoring children's education, and clothing. FAO[2] reported that agricultural productivity is crucial to income distribution, household food security, and poverty mitigation. Also, the results fell in line with the position of Klasen[15], Meinzen-Dick et al.[12], and Adu et al.[13] that high income controlled by women correlates with care for children's nutrition and food security. Similar reports by World Bank[14], Adu et al.[13], and Doss et al.[5] indicated that women with higher earnings provide good health care for their children compared to women with lower earnings.

The IMSST contributed to the empowerment of adopters and domain achievements in WEAI (Table 4). According to Fadilah et al.[77] and Africa Union Development Agency and NEPAD,[111] agricultural innovations enhance productivity and women's economic empowerment in Sub-Saharan Africa. The GM with IMSST is positive and significant to women's economic status compared to the GM without IMSST (Tables 5 and 6). This is an indication that the technological status of the countrywomen dictates their income and empowerment. Technology adoption is targeted at increasing productivity[7][8][41].

We looked at the influence of SEVs on adoption. The positive correlation of age with IMSST (Table 7) can be interpreted in terms of the risk-bearing ability of younger melon processors assuming that rural women continue adopting improved technology after considering the risk involved. Adherence of old people to conventional methods of transforming melon is high compared to young people; this reluctance is often attributed to the risk accompanied innovation. On the other hand, older melon processors have wealth of experience and therefore in a better position to make a sound judgment regarding the adoption of new technology, suggesting that older melon processors could be quick to adopt improved technology that offers better returns than younger and inexperienced melon processors. The research result of Diriba et al.[112] and Begum, et al.[113] revealed that as age of household increased their adoption increases.

Marital status positively influences melon technology adoption (Table 7). The married are expected to have family

responsibilities and enough experience to co-ordinate their homes, and melon processing activities to cater to the needs of their families. Onwurafor and Enwelu[102] confirmed that married people have the responsibility for the household as well as the sale of processed agricultural products to generate income. Years of experience correlate with the IMSST adoption (Table 7). Melon processors with higher experience can judge whether or not to adopt improved technology.

Furthermore, access to credit from cooperatives has a positive influence on IMSSTT (Table 7), suggesting that cooperatives' credit can have a significant impact in facilitating the adoption of IMSST among the rural women in the study area. This finding is concurring with that of Cornejo and McBride[114] that access to credit is a determinant of most agricultural innovations. This implies that there exists great scope for increasing the adoption of IMSST through improved access of melon processors to credit markets which may enable them to purchase melon shelling machines, fuel, melon seeds, and other related inputs. The revival of cooperatives in sub-Saharan Africa has been identified as a promising avenue for enhancing empowerment. Being a member of cooperative have significant benefits for women empowerment and considerable indirect benefits on household living standards[115][116].

Conclusion

It was established that through the IMSST increased productivity was realized; higher income and household food security were also achieved thus, the technology contributed to rural women's economic empowerment status and domains' achievement. Existing research has shown that technology adoption has a favorable impact on productivity, poverty reduction, and welfare around the world[40]. The Logit model revealed that socio-economic indicators influenced the rural women's adoption decision on IMSST. Wu[36] argued that the adoption behavior of farmers is often determined by farmers' personal characteristics, financial capability, and prevailing production environment. The GM from melon oil and snacks was meager due to the small quantity of melon processed, that is, less than 126kg per week. It was also found that IMSST is a predictor of the earnings and economic progress of rural women. The outcome of this study thus means the socioeconomic status of countrywomen should be improved including group formation by the country women to increase access to finance while government at the grassroots provides affordable educational opportunities and rural infrastructure to sustain the adoption of IMSST. Technology for oil extraction and snack making from melon kernels should be designed by Engineers and made available to rural women through Extension Service Providers at affordable prices. Also, efforts should be made by extension agents in the form of awareness, enlightenment, exhibition, field demonstration, and training to encourage non-adopters to adopt IMSST in their melon processing activities to obtain higher and cleaned melon seeds for high gross margin and empowerment.

References

1. ^*Fani DCR, Henrietta UU, Oben EN, Dzever DD, Obekpa OH, Nde AT, Sani M, Annih MG, Martin DNP (2021). "Assessing the Performance and Participation among Young Male and Female Entrepreneurs in Agribusiness: A Case Study of the Rice and Maize Subsectors in Cameroon." Sustainability. 13: 1-19. doi:10.3390/su13052690.*

2. [a, b]*FAO (2017). Productivity and Efficiency Measurement in Agriculture: Literature Review and Gaps Analysis. Rome. 77pp. https://www.fao.org/3/ca6428en/ca6428en.pdf.*
3. [^]*FAO (2016). Promoting Gender Equality and Women's Empowerment in Fisheries and Aquaculture. (Food and Agriculture Organization of the United Nations. Rome). http://www.fao.org/3/a-i6623e.pdf.*
4. [^]*Uzoejinwa BB, Ani AO, Abada UC, Ugwuishiwu BO, Ohagwu CJ, Nwakaire JN (2016). "Small-scale food processing enterprises: measures for national development and addressing food security challenges in Nigeria." International Journal of scientific and technical research in engineering (IJSTRE). 1(5): 72-82. https://www.ijstre.com/Publish/082016/597342083.pdf.*
5. [a, b]*Doss C, Swaminathan HC, Deere CD, Suchitra J, Oduro AD, Anglade B (2020). "Women, assets, and formal savings: a comparative analysis of Ecuador, Ghana and India." Dev. Policy Rev.. 38(2): 180-205. doi:10.1111/dpr.12424.*
6. [^]*Okoronkwo FC, Onya SC, Amah JE (2020). "Comparative Analysis of the Profitability of Small and Medium Scale Cassava and Palm Fruit Processing in Abia State, Nigeria." Journal of Tropical Agriculture, Food, Environment and Extension. 19(2): 1 – 5. doi:10.4314/as.v19i2.1.*
7. [a, b, c]*United Nations Conference on Trade and Development (2021). Technology and Innovation Report 2021. Catching Technological Waves with Equity. New York, Geneva. 196p. https://unctad.org/system/files/official-document/tir2020_en.pdf.*
8. [a, b, c, d]*Hwang WS, Kim HS (2022). "Does the adoption of emerging technologies improve technical efficiency? Evidence from Korean manufacturing SMEs." Small Bus Econ. 59: 627–643. doi:10.1007/s11187-021-00554-w.*
9. [^]*Sibanda S, Workneh TS (2020). "Potential causes of postharvest losses, low-cost cooling technology for fresh produce farmers in Sub-Saharan Africa." African Journal of Agricultural Research. 16(5): 553 – 566. https://academicjournals.org/journal/AJAR/article-full-text-pdf/BF1684363518.*
10. [^]*Sugri I, Abubakari M, Owusu RK, Bidzakin JK (2021). "Postharvest losses and mitigating technologies: evidence from Upper East Region of Ghana." Sustainable Future. 3(2021): 1 – 13. doi:10.1016/j.sftr.2021.100048.*
11. [a, b]*United Nations (2019). The Sustainable Development Goals Report 2019. United Nations. New York, NY. https://unstats.un.org/sdgs/report/2019/The-Sustainable-Development-Goals-Report-2019.pdf.*
12. [a, b]*Meinzen-Dick AR, Quisumbing CD, Theis S (2019). "Women's land rights as a pathway to poverty reduction: Framework and review of available evidence." Agric. Syst.. 172(2019): 72–82. doi:10.1016/j.agsy.2017.10.009.*
13. [a, b, c]*Adu AD, Freeman CY, Afful A (2020). "Gendered access to productive resources – evidence from smallholder farmers in Awutu Senya West District of Ghana." Scientific African. 10: e00604. doi:10.1016/j.sciaf.2020.e00604.*
14. [a, b]*World Bank (2012). World Development Indicator. World Data Bank. http://data.worldbank.org/country/nigeria. Accessed on 20th January, 2023.*
15. [a, b]*Klasen S (2018). "The impact of gender inequality on economic performance in developing countries." Annual Review of Resource Economics. 10(1): 279–298. doi:10.1146/annurev-resource-100517-023429.*
16. [a, b]*FAOSTAT (2018). "Food and Agricultural Organization of the United Nation Statistics". Retrieved from: http://www.fao.org/faostat/en/#data/QC.*

17. ^*Volza Grow Global (2023). Melon seed export data Nigeria. Retrieved from https://www.volza.com/p/melon-seed/export/export-from-nigeria/.*
18. ^*Tridge (2023). Overview of melon seed market in Nigeria. Retrieved from https://www.tridge.com/intelligences/melon-seed/NG.*
19. ^*Oyediran WO, Omoare AM, Olanrewaju OO, Abubakar AA (2018). "Implication of Technology Adoption on Economic Returns of Melon Processors in North Central, Nigeria." Annals of Advanced Agricultural Sciences (AS). 2(3): 31 – 36. doi:10.22606/as.2018.23001. http://isaac-scientific.com/8/1626/2/3/08/2018/AS.html.*
20. a, b*Oyediran WO (2021). "Influence of melon processing technology on social dynamism and well-being of melon processors in the provincial territories of Nigeria." Journal of Agricultural Research, Development, Extension, and Technology (JARDET). 3(1): 10 – 24. https://www.jardet.usm.edu.ph/index.php/jardet/article/download/48/42/.*
21. a, b*Tchoupou KT, Bisong SM, Fotsing BS (2024). "Optimal settings of a melon seed sheller using statistical design of experiments." International Journal of Mechanical Engineering Technologies and Applications. 5(1): 38 – 50. doi:10.21776/MECHTA.2024.005.01.5. https://mechta.ub.ac.id/.*
22. ^*Cherono K, Sibomana M, Workneh TS (2018). "Effect of infield handling conditions and time to pre-cooling on the shelf-life and quality of tomatoes." Brazilian Journal of Food Technology. doi:10.1590/1981-6723.01617.*
23. ^*Maduri D (2020). "Post-Harvest Challenges that Affect Quality of Agricultural Produce and How to Prevent Them." https://tecnosolucionescr.net/en/tecno-blog/202-post-harvest-challenges-that-affect-quality-of-agricultural-produce-and-how-to-prevent-them.*
24. ^*Kamda Silapeux AG, Ponka R, Frazzoli C, Fokou E (2021). "Waste of Fresh Fruits in Yaoundé, Cameroon: Challenges for Retailers and Impacts on Consumer Health." Agriculture. 2021,11: 89. doi:10.3390/agriculture11020089.*
25. ^*Giwa SO, Akanbi TO (2020). "Mechanization of melon processing and novel extraction technologies: A short review." Scientific African. 9: e00478. doi:10.1016/j.sciaf.2020.e00478.*
26. ^*Osuji C, Uche C, Iheagwara M (2023). "The effect of mechanized shelling and packaging on the quality of melon seeds." Potravinarstvo Slovak Journal of Food Sciences. 17: 565-580. doi:10.5219/1884.*
27. ^*UN-Women (2022). Rural Women, What we do: Economic empowerment. UN. https://www.unwomen.org/en/what-we-do/economic-empowerment/rural-women.*
28. ^*World Bank (2020). Women, Business and the Law 2020. World Bank. Washington, DC. https://openknowledge.worldbank.org/server/api/core/bitstreams/6c2b5974-9a3b-5249-995b-2b22e5fd7909/content.*
29. ^*World Food Programme (2021). Empowering women and girls is crucial to ensure sustainable food security in the aftermath of COVID-19, say UN food agency heads on International Women's Day. 8th March 2021. https://www.wfp.org/news/empowering-women-and-girls-crucial-ensure-sustainable-food-security-aftermath-covid-19-say-un.*
30. a, b, c*Kapoor M, Kaur N, Sharma C, Kaur G, Kaur R, Batra K, Rani J (2020). "Citrullus colocynthis an Important Plant in Indian Traditional System of Medicine." Pharmacog Rev.. 14(27): 22-7.*

https://www.phcogrev.com/sites/default/files/PharmacognRev-14-27-22.pdf.

31. ^*de Mello ML, Bora PS, Narain N. (2001). "Fatty and amino acids composition of melon seeds (Cucumis melo var. saccharinus)". Journal of Food Component Analysis. 14: 69-74. doi:10.1006/jfca.2000.0952.*
32. ^*Hussain AI, Rathore HA, Sattar MZ, Chatha SA, Sarker SD, Gilani AH. (2014). "Citrullus colocynthis (L.) Schrad (bitter apple fruit): A review of its phytochemistry, pharmacology, traditional uses and nutritional potential". Journal of Ethnopharmacology. 155(1): 54-66. doi:10.1016/j.jep.2014.06.011.*
33. a, b*Dhakad PK, Sharma PK, Kumar S. (2017). "A Review on Phytochemical Studies and Biological Potential of Citrullus colocynthis (L.) Schrad (Cucurbitaceae)". J. Bioeng Biosci. 5(4): 55-64. DOI: 10.13189/bb.2017.050401*
34. ^*Gurudeeban S, Satyavani K, Ramanathan T. (2010). "Bitter Apple (Citrullus colocynthis): An Overview of Chemical Composition and Biomedical Potentials". Asian Journal of Plant Sciences. 9: 394-401. DOI: 10.3923/ajps.2010.394.401*
35. ^*Kolawole SS, Ndrika VIO. (2012). "Development and performance tests of a melon (egusi) seed shelling machine". Agricultural Engineering International: CIGR Journal. 14(1): 157-164. https://cigrjournal.org/index.php/Ejounral/article/view/2027.*
36. a, b, c*Wu F. (2022). "Adoption and income effects of new agricultural technology on family farms in China". PLoS ONE. 17(4): e0267101. doi:10.1371/journal.pone.0267101.*
37. a, b, c, d*Rogers EM. (2003). Diffusion of innovations (5th edition). New York. Free Press.*
38. ^*Gao Y, Zhang X, Lu J, Wu L, Yin S. (2017). "Adoption behavior of green control techniques by family farms in China: Evidence from 676 family farms in Huang-huai-hai Plain". Crop Protection. 99: 76–84. doi:10.1016/j.cropro.2017.05.012.*
39. ^*Chen XT, Huang WH, Qi ZH, Feng ZC. (2020). "Farmers' cognition, adoption intensity and income effect of ecological breeding mode: A case study of rice-shrimp co-cultivation mode in the middle and lower reaches of Yangtze River". Chinese Rural Economy. 10: 1–20. https://www.cabidigitallibrary.org/doi/full/10.5555/20219977554.*
40. a, b*Awotide B, Karimov A, Diagne A. (2016). "Agricultural technology adoption, commercialization and smallholder rice farmers' welfare in rural Nigeria". Agricultural and Food Economics. 4(3): 1-24. DOI: 10.1186/s40100-016-0047-8.*
41. a, b, c*Abune G. (2023). "Contribution of Improved Wheat Technology Adoption to Farm Household Income in Ethiopia: Review". World Journal of Agricultural Science and Technology. 1(4): 98-102. doi: 10.11648/j.wjast.20230104.1*
42. a, b*Deng X, Yan Z, Xu D, Qi Y. (2020). "Land Registration, Adjustment Experience, and Agricultural Machinery Adoption: Empirical Analysis from Rural China". Land. 9: 89. doi:10.3390/land9030089.*
43. a, b*Luo MZ, Qiu HL. (2021). "Agricultural Machinery Socialization Service Adoption, Endowment Difference and Alleviation of Rural Economic Relative Poverty". South. China J. Econ. 2: 1–18. doi:10.19592/j.cnki.scje.381027.*
44. a, b*Li T, Yu W, Baležentis T, Zhu J, Ji Y. (2017). "Rural Demographic Change, Rising Wages and the Restructuring of Chinese Agriculture". China Agric. Econ. Rev. 9: 478–503. doi:10.1108/caer-02-2016-0025.*
45. ^*Qu X, Kojima D, Nishihara Y, Wu LP, Ando M. (2021). "Can Harvest Outsourcing Services Reduce Field Harvest Losses of rice in China?". J. Integr. Agric. 20: 1396–1406. doi:10.1016/S2095-3119(20)63263-4.*
46. ^*Khonje M, Manda J, Alene AD, Kassie M. (2015). "Analysis of adoption and impacts of improved maize varieties in*

eastern Zambia". World Dev. 66(2015): 695–706. DOI: 10.1016/j.worlddev.2014.09.008.

47. ^*Bahta YT, Owusu-Sekyere E, Tlalang BE. (2018). "Assessing participation in homestead food garden programmes, land ownership and their impact on productivity and net returns of smallholder maize producers in South Africa". Agrekon. 57(1): 1 – 16. DOI: 10.1080/03031853.2018.1437051*
48. ^*Kabunga NS, Dubois T, Qaim M. (2014). "Impact of tissue culture banana technology on farm household income and food security in Kenya". Food Policy. 45(1): 25–34. DOI: 10.1016/j.foodpol.2013.12.009*
49. ^*Tesfaye S, Bedada B, Mesay Y. (2016). "Impact of improved wheat technology adoption on productivity and income In Ethiopia". African Crop Sci J. 24 (Issue Supplement s1): 127–135. doi:10.4314/acsj.v24i1.14S.*
50. a, b*Ma W, Abdulai A. (2019). "IPM adoption, cooperative membership and farm economic performance: Insight from apple farmers in China". China Agricultural Economic Review. 11(2): 218–236. DOI: 10.1108/CAER-12-2017-0251*
51. a, b*Huang B, Wu A, Chiang D. (2018). "Supporting small suppliers through buyer-backed purchase order financing". Int. J. Prod. Res. 56(18): 6066-6089. DOI: 10.1080/00207543.2018.1454614.*
52. ^*Gao Y, Niu ZH, Yang H, YL. (2019). "Impact of green control techniques on family farms' welfare". Ecological Economics. 161: 91– 99. DOI: 10.1016/j.ecolecon.2019.03.015.*
53. ^*Hou XK, Liu TJ, Huang T, Yuang ZP. (2019). "Adoption behavior and income effects of green agricultural technology for farmers". Journal of Northwest University of Agriculture and Forestry (Social Science Edition). 3: 121–130. https://scholar.google.com/scholar?q=Adoption+behavior+and+income+effects+of+green+agricultural+technology+for+farmers+Hou+2019.*
54. ^*Issahaku G, Abdulai A. (2020). "Adoption of climate-smart practices and its impact on farm performance and risk exposure among smallholder farmers in Ghana". Australian Journal of Agricultural and Resource Economics. 64: 396–420. DOI: 10.1111/1467-8489.12357.*
55. a, b*Tufaa AH, Alenea AD, Manda J, Akinwale MG, Chikoye D, Feleke S, Manyong VM. (2019). "The productivity and income effects of adoption of improved soybean varieties and agronomic practices in Malawi". World Development. 124(2): 1–10. DOI: 10.1016/j.worlddev.2019.104631*
56. a, b*Ekong EE. (2010). An Introduction to Rural Sociology (3rd ed.). Uyo, Nigeria. 431p. Dove Educational Publishers.*
57. ^*Adjei-Nsiah S, Klerkx L. (2016). "Innovation platforms and institutional change: the case of Smallholder palm oil processing in Ghana". Cahiers Agricultures. 25(6): 1 - 9. DOI: 10.1051/cagri/2016046.*
58. a, b, c*Lin B, Wu CC. (2021). "Study on the Impact of Agricultural Technology Progress on Grain Production and Farmers' Income". Open Access Library Journal. 8: 1-9. doi:10.4236/oalib.1107991.*
59. a, b, c, d*Biru WD, Zeller M, Loos TK. (2020). "The impact of agricultural technologies on poverty and vulnerability of smallholders in Ethiopia: a panel data analysis". Social Indicators Research. 147(2): 517- 544. doi:10.1007/s11205-019-02166-0.*
60. a, b*Peng J, Zhao Z, Liu D. (2022). "Impact of Agricultural Mechanization on Agricultural Production, Income, and Mechanism: Evidence From Hubei Province, China". Front. Environ. Sci. 10: 838686. doi: 10.3389/fenvs.2022.838686.*
61. a, b*Bezu S, Kassie GT, Shiferaw B, Ricker-Gilbert J (2014). "Impact of improved maize adoption on welfare of farm*

households in Malawi: A panel data analysis". World Development. 59: 120–131. doi:10.1016/j.worlddev.2014.01.023.

62. ^*Ahmed H, Anang BT (2019). "Does farmer group membership enhance technology adoption? Empirical evidence from Tolon district of Ghana". Rev. Agric. Appl. Econ.. 22: 26-32. doi:10.1016/j.worlddev.2014.01.023.*
63. ^*Natnael AB (2019). "Impact of technology adoption on agricultural productivity and income: a case study of improved teff variety adoption in north-eastern Ethiopia". Agric. Res. Technol. Open Access J.. 20 (4): 205 – 216. doi:10.19080/ARTOAJ.2019.20.556139.*
64. ^*Shita A, Kumar N, Singh S (2020). "The impact of agricultural technology adoption on income inequality: a propensity score matching analysis for rural Ethiopia". Int. J. Inf. Decis. Sci.. 12: 102-114. doi:10.1504/IJIDS.2020.10026774.*
65. ^*Wordofa MG, Hassen JY, Endris GS, Aweke CS, Moges DK, Rorisa DT (2021). "Adoption of improved agricultural technology and its impact on household income: a propensity score matching estimation in eastern Ethiopia". Agric. Food Secur.. 10: 1-12. doi:10.1186/s40066-020-00278-2.*
66. a, b*Stephenson G (2019). Whole Farm Management: From Start-Up to Sustainability. Storey Building Publishing, LLC. https://books.google.com.ng/books/about/Whole_Farm_Management.html?id=9WR1vwEACAAJ&redir_esc=y.*
67. ^*Heard J, Jackson T, Tocker J, Graham P, White A (2013). "Whole farm analysis versus activity gross margin analysis: a sheep farm example". Austr. Farm Bus. Manag. J.. 10: 16. doi:10.22004/ag.econ.198721.*
68. a, b*Katundu MA, Mhina ML, Mbeiyererwa AG (2014). "Socio-economic factors limiting smallholder groundnut production in Tabora region". Research Report. 14/1, Policy Research for Development, Tanzania. https://www.repoa.or.tz/wp-content/uploads/2020/07/REPOA_RR_14.1.pdf.*
69. ^*Nuraeni M (2019). "Analysis accounting treatment of the main product and by-products and its implications for profit case study of mandar coconut oil processing business in Majene regency". First International Conference on Materials Engineering and Management-Management Section ICMEMm 2018. Atlantis Press. doi:10.2991/icmemm-18.2019.24.*
70. ^*Betancourt RR (2018). "Understanding the Digital Economy in Retailing and its Economic Impacts". Marketing. 37: 44-56. http://econweb.umd.edu/~betancou/distribution/Understanding%20the%20Digital%20Economy%20in%20Retailing%20and%20Its%20Impact%20on%20All%20Service%20Sectors.pdf.*
71. ^*Yohanna JK, Waktroda GN, Gofwan GP, Golkus JI, Agontu JA (2015). "Farm machinery selection for agricultural production based on gross-margin costing analysis in Lafia Local Government Area of Nasarawa State, Nigeria". J. Agric. Eng. Technol.. 23 (1): 57-74. https://www.niae.net/journals/Vol23no1yr2015.pdf.*
72. ^*Workineh A, Tayech L, Ehite HK (2020). "Agricultural technology adoption and its impact on smallholder farmer's welfare in Ethiopia". African Journal of Agricultural Research. 15 (3): 431-445. doi:10.5897/AJAR2019.14302.*
73. ^*Janssen J, Arends J, Scholten J, Verhorst R, van Berlo E (2020). "Agricultural Technology Adoption by Rural Farmers in Malawi: A Case Study of a Small Enterprise in Malawi". (Doctoral Thesis). Google Scholar.*
74. ^*Khai TT, Dung PTP (2020). "Determinants of agricultural technology adoption: a case study in floricultural sector of Lam Dong province and Ho Chi Minh City, Vietnam". J. Asian Bus. Econ. Stud.. 26 (S02): 25-46.*
75. ^*Chavas JP, Nauges C (2020). "Uncertainty, learning, and technology adoption in agriculture". Appl. Econ. Perspect. Pol.. 42 (1): 42-53. doi:10.1002/aepp.13003.*

76. ^Ogunmodede AM, Awotide OD (2020). "Profitability and technical efficiency of leafy vegetable production: a stochastic frontier production function analysis". Int. J. Veg. Sci.. (2020): 1-7. doi:10.1080/19315260.2019.1711283.
77. a, bFadilah M, Seth B, Seidu A (2013). "Effects of Adoption of Improved Sheabutter Processing Technology on Women's Livelihoods and their Microenterprise Growth". American Journal of Humanities and Social Sciences. 1 (4): 244 – 250. doi:10.11634/232907811301419.
78. a, bNwanyanwu DH, Amadi C, Nyekachi A (2014). "Assessment of farm outputs and Rural income generation of School to Land Agricultural Programme (STLAP) in River State, Nigeria". Journal of Biology, Agriculture and Healthcare. 4 (14): 126 – 134.
79. ^NBS (2022). "Demographic Statistical Bulletin". https://www.nigerianstat.gov.ng/pdfuploads/DEMOGRAPHIC_BULLETIN_2022_FINAL.pdf.
80. ^The Civil Resource Development and Documentation Centre (2016). https://cirddoc.org/wp-content/uploads/2016/06/ZONAL-North-Centra.pdf.
81. ^Vincent AY, Hope AE (2019). "Egusi. The hidden treasure farmers ignore". The Daily Trust. Thursday, 21 Feb 2019. 7:44:39 WAT. https://dailytrust.com/egusi-the-hidden-treasure-melon-farmers-ignore/.
82. a, bNPC (2017). "National Population Estimates". file:///C:/Users/Dr%20Ayodeji%20Omoare/Downloads/Population%20Forecasts-2.pdf.
83. ^Kothari CR (2004). Research Methodology: Methods and Techniques. New Delhi. New Age International Publishing Limited. 414p.
84. ^Shira B, Dorit K (2020). "Character strengths and sustainable technology adoption by smallholder farmers". Heliyon. 6 (2020): 1 – 9. doi:10.1016/j.heliyon.2020.e04694.
85. ^Greene WH (2008). Econometric Analysis. (Fifth Edition). Upper Saddle River, New Jersey. Prentice Hall International Incorporation. pp. 567 – 745.
86. a, bAbadie A, Cattaneo MD (2018). "Econometric methods for program evaluation". Annual Review of Economics. 10: 465–503. doi:10.1146/annurev-economics-080217-053402.
87. a, b, cBrodeur A, Cook N, Heyes A (2020). "Methods matter: P-hacking and publication bias in causal analysis in economics". American Economic Review. 110 (11): 3634–3660. doi:10.1257/aer.20190687.
88. ^Imbens G, Lemieux T (2008). "Regression discontinuity designs: A guide to practice". Journal of Econometrics. 142: 615–635. doi:10.1016/j.jeconom.2007.05.001.
89. ^Lee DS, Lemieux T (2010). "Regression discontinuity designs in economics". Journal of Economic Literature. 48: 281–355. http://www.jstor.org/stable/20778728.
90. ^Schochet P, Cook T, Deke J, Imbens G, Lockwood JR, Porter J, Smith J (2010). "Standards for regression discontinuity designs". http://ies.ed.gov/ncee/wwc/pdf/wwc_rd.pdf.
91. a, b, cWuepper D, Finger R (2023). "Regression discontinuity designs in agricultural and environmental economics". European Review of Agricultural Economics. 50 (1): 1–28. doi:10.1093/erae/jbac023.
92. ^Thistlethwaite DL, Campbell DT (1960). "Regression-discontinuity analysis: An alternative to the ex post facto

experiment". Journal of Educational Psychology. 51: 309–317. doi:10.1037/h0044319.

93. [a, b, c] *Boon HM, Craig P, Thomson H, Campbell M, Moore L (2021). "Regression discontinuity designs in health: a systematic review". Epidemiology. 32: 87–93. doi:10.1097/EDE.0000000000001274.*
94. [^] *Melguizo T, Bos JM, Ngo F, Mills N, Prather G (2016). "Using a regression discontinuity design to estimate the impact of placement decisions in developmental math". Research in Higher Education. 57: 123–151. doi:10.1007/s11162-015-9382-y.*
95. [^] *Porter KE, Reardon SF, Unlu F, Bloom HS, Cimpian JR (2016). "Estimating causal effects of education interventions using a two-rating regression discontinuity design: Lessons from a simulation study and an application". Journal of Research on Educational Effectiveness. doi:10.1080/19345747.2016.1219436.*
96. [^] *ILO (2019). Empowering Women in the Rural Economy. Decent Work in the Rural Economy Policy Guidance Notes. 16pp.*
97. [^] *Mwangi M, Kariuki S (2015). "Factors determining adoption of new agricultural technology by smallholder farmers in developing countries". J. Econ. Sustain. Dev.. 6 (5): 208–216. https://core.ac.uk/download/pdf/234646919.pdf.*
98. [^] *Feleke A, Regasa G, Muche M (2019). "Factors Influencing Adoption of Improved Potato (Belete) Variety: Evidence from Ethiopian Smallholder Farmers". Journal of Agricultural Science. 30: 85-92. https://bit.ly/3uXON7j.*
99. [^] *Sodiya CI, Oyediran WO, Ayinde IA, Fakoya EO (2019). "Comparative assessment of economic returns on the well-being of adopters and non-adopters of improved melon processing technology in Niger State, Nigeria". International Journal of Agricultural Economics and Rural Development (IJAERD). 10 (1): 7 – 15. https://ijaerd.org.ng/editions/10.1-1.pdf.*
100. [a, b, c] *Anate BC, Balogun MR, Olubodun T, Adejimi AA (2021). "Knowledge and utilization of family planning among rural postpartum women in Southwest Nigeria". Journal of Family Medicine and Primary Care. 10 (2): 730-737. doi:10.4103/jfmpc.jfmpc_1312_20.*
101. [^] *Ogunniyi AI, Omotoso SO, Salman KK, Omotayo AO, Olagunju KO, Aremu AO (2021). "Socio-economic Drivers of Food Security among Rural Households in Nigeria: Evidence from Smallholder Maize Farmers". Soc Indic Res. 155: 583–599. doi:10.1007/s11205-020-02590-7.*
102. [a, b, c] *Onwurafor EU, Enwelu IA (2013). "Rural women entrepreneurship in agro-food processing in Enugu State, Nigeria". International Journal of Research in Applied, Natural and Social Sciences (IJRANSS). 1 (2): 13 – 30. https://paper.researchbib.com/view/paper/6744.*
103. [^] *Xia WW, Du ZX, Kao LL (2019). "Research on the factors affecting the application of green production technology by family farm operators: Based on survey data of 452 family farms in three provinces". Economic Review Journal. 6: 101–108. (in Chinese).*
104. [^] *Baliamoune–Lutz M, McGillivray M (2015). "The impact of gender inequality in education on income in Africa and the Middle East". Economic Modelling. 47: 1-11. doi:10.1016/j.econmod.2014.11.031.*
105. [^] *Ketheeswaran K (2021). "Supporting the Special Education Unit System in Promoting Inclusive Education". European Journal of Special Education Research. 7 (3): 17 – 36. doi:10.46827/ejse.v7i3.3869.*
106. [^] *Sharon C, Doerr S, Frost J, Gambacorta L, Shin HS (2021). "BIS Working Papers, No 931, The fintech gender gap,*

Monetary and Economic Department, March 2021". https://www.bis.org/publ/work931.pdf.

107. ^*Anyanwu JC (2010). "Poverty in Nigeria: A Gendered Analysis". The African Statistical Journal. 11: 38 – 61. https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/Poverty%20in%20Nigeria%20A%20Gendered%20Analysis.pdf.*
108. ^*Agbodji E, Johnson KA (2019). "Agricultural Creditand Its Impact on the Productivity of Certain Cereals in Togo". Emerging Markets Finance and Trade. In Press. doi:10.1080/1540496X.2019.1602038.*
109. ^*Oyediran WO (2020). "Productivity of Melon Shelling Technology and preference by Rural Women in Nigeria". Journal of Agriculture and Crops. 6 (8): 119 – 125. doi:10.32861/jac.68.119.125.*
110. ^*World Economic Forum (2022). "How technology can help address challenges in agriculture". World Economic Forum Annual Meeting. March 22, 2022. https://www.weforum.org/agenda/2022/03/how-technology-can-help-address-challenges-in-agriculture/*
111. ^*Africa Union Development Agency- New Partnership for Africa's Development (AUDA- NEPAD), (2021). "Gendering Agriculture: Empowering African Women Farmers Using Modern Technologies". May 10, 2021. https://www.nepad.org/blog/gendering-agriculture-empowering-african-women-farmers-using-modern-technologies#_ftn1.*
112. ^*Diriba S, Debela M, Alemayehu M, Dechassa N (2019). "Adoption Spells of Improved Potato Varieties by Smallholder Farmers in Eastern Ethiopia: The Duration Approach". Scientific Journal Warsaw University of Life Sciences –SGGW. 19: 103–118. https://bit.ly/3Dque6v.*
113. ^*Begum E, Miah M, Rashid MA, Matin MA, Mohammad Ismail H (2015). "Socioeconomic Determinants of Modern Potato Varieties Adoption and Resource Use Efficiency in Northern Bangladesh". Bangladesh J Agric Econs. 37: 103-113. https://bit.ly/3lu1pQv.*
114. ^*Cornejo J, McBride W (2002). "Adoption of bioengineered crops". Development and Cultural Change. 34: 351–368.*
115. ^*Jones E, Smith S, Wills C (2012). "Women producers and the benefits of collective forms of enterprise". Gender & Development. 20 (1): 13–32. doi:10.2307/23408745.*
116. ^*Majurin E (2012). "How Women Fare in East African Co-operatives: The Case of Kenya, Uganda and Tanzania, Dares Salaam, International Labour Organization".*