

ADOPTION OF IMPROVED AGRICULTURAL TECHNOLOGY AND THE OUTPUT OF IRRIGATED RICE FARMERS IN NORTH-WESTERN NIGERIA

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Abstract

Higher yields, income and gross margin are the key indicators of farmers' performance used to measure the adoptability of improved agricultural technology. This study intends to estimate the impact of HYVs adoption on yield and income of irrigated rice farmers and gross margin difference between adopters and non-adopters of tractor service in the North Western Nigeria. Cross sectional data were collected from 564 irrigated rice farmers across Kaduna, Jigawa and Kano States based on Multi-stage sampling technique. Endogenous Switching Regression model is used as major analytical tool to address the potential self-selectivity bias. The results show that adoption of HYVs has positive impact on yields and income of irrigated rice farmers, pointing strong and positive correlation with irrigated rice farmers' yield and income but the effect on non-adopters due to the existence of self-selectivity is lower. The yield-increasing effects and income-increasing effects of adopting HYVs for the adopters are higher than the non-adopters. The cost of adopting tractor service has negative and significant impact on gross margin of irrigated rice farmers, pointing negative correlation with the irrigated rice farmers' gross margin but the negative effect on non-adopters due to self-selectivity as indicated from the estimates of treatment effects is lower. Also, the gross margin-increasing effect for adopters of tractor service is higher, and the gross margin difference between adopters and non-adopters of tractor service is about 1.044. It is concluded that adoption of improved agricultural technology has positive effect on output performance. The study recommends for the need of promoting technology adoption among the non-adopters by making its information accessible to the irrigated rice farmers in the right time.

Keywords: Adoption, Irrigated Rice Farmers, Improved Agricultural Technology, North-Western, Nigeria and Output.

Introduction

Higher yields, income and gross margin are the key indicators of farmers' output performance used to measure the adoptability of improved agricultural technology in rice production. Rice has been growing in importance globally due to its pervasive use and utility. The persistent rise in the demand for rice and continuous decrease in the farm labour supply are the major factors that made improved agricultural technology imperative globally. Insufficient rice production, shift in consumers' preferences towards the rice consumption and the rapidly increasing population amounted to the hot rice demand in the world in one hand. Also, the growing urban sector as well as the rural non-farm economy is the driving forces for the continuous decrease in the farm labour supply on the other hand; and of course necessitated for the urgent need for the technology

(Sarkar & Gosh, 2023; OECD, 2021). More than half of the world's population today relies on rice as a main supplier of food energy and if not because all economic resources are naturally scarce, the volume of rice supply should have been large enough to accommodate for the world rising demand (GEMS4, 2019). Global rice production has increased by about 55 million metric tonnes since 2008 and Asian countries particularly China, India, Thailand and Sri Lanka are the giant producers with China (148.99 million) and India (129.47 million) alone producing 50% of the entire rice grown and consumed globally (Shahbandeh, 2023).

Like in other colonized countries of Africa, rice production in Nigeria had started with a low yielding local variety called *Oryza Glaberrima Stued* around 1500 BC that spread all over the Niger delta areas (Imolehin & Wada, 2000). White grain both *Indica* and *Japonica*, *Oryza Sativa* was introduced to Nigeria around 1890 but by 1960, it accounted for 60% of the entire rice planted and consumed in the nation (Imolehin & Wada, 2000). Though Nigeria is endowed with several rice farming ecologies but rice production across the ecologies is carried out under the rainfall and irrigated systems (GEMS4, 2019). Rain-fed is a farming practice that relies on rainfall as major source of water while irrigated farming is a farming system that involves application of water by humans in order to help the growth of crops and pastures (Aiyedun, 1991; Otchia, 2014). Despite the fact that rice farming in Nigeria is dominantly rain-fed, relative advantage of irrigation made it preferable today (Erenstein et al., 2023). In facts, 910,210 hectares are currently utilized for the irrigated rice farming with a total of 27 active and functioning dams for irrigating more than 550,000 hectares of land for rice farming (FMARD, 2020). Besides the prolong drought of 1970 to 1975, climatic instability particularly severe temperature, unstable rainfall season, regular flooding, as well as salty water supply are the main factors for considering irrigation as a farming practice in Nigeria (Joshua, Ajiboye & Rashid. 2010). With all the endowments, programmes and policies by several administration (such as River Basin Development Authority, FADAMA I, II & III, National Rice Development Authority I & II, R-I-C-E approach, Presidential Initiative on Rice and Anchor Brower Programme) in the country with intention to establish farming enabling environment, self-sufficiency in rice production is yet to be attained (Mohammed et al., 2019). Consequently, huge amount of money is spent yearly by governments in order to close the domestic rice supply deficit. Between 1960 and 1990, Nigeria spent a total of ₦5,017.52 billion on rice importation (Anyanwu et al., 1997). The improvement in domestic rice production for the past 8 years, thought resulted to a serious drop in the quantity of imported rice from 1.2 million metric tonnes in the year 2014 to only 438,000 metric tonnes in 2022 but total rice supply still could not keep pace with the rising demand (Houssou & Chapoto, 2015; GEMS4, 2019; Shahbandeh, 2023).

Economic research findings like OECD (2021); Sarkar and Gosh (2023); Adeola and Oluwafemi (2024); Zhiyong (2015); Falkone and Rosenberg (2022), concluded that improved agricultural technology has been justified as an important vigor for boosting farming performance particularly yields, income and gross margin of farmers, as well as improving agriculture as a whole globally. Improved agricultural technology refers to the application of improved farm seeds, tractor service and information devices in the farming practice (Otchia, 2014). Friday (2022), disclosed that Nigerian rice farmers need to properly adopt agricultural technology particularly improved varieties, tractor service and information devices as strategy to attain self-sufficiency in rice farming. But rice farmers in Nigeria are dominantly small holders who are mostly conservative with limited adoption of the technologies (GEMS4, 2019). As a result, they are unable to produce the required rice yields, generate more income and make profits, therefore failing to uphold the frontier of the nation to reach sufficiency in the rice farming (Umeghalu, Okonkwo & Nwuba, 2012). GEMS4 (2019), reported further that only 13% of the North-Western Nigerian farmers are

applying improved technology with 32% of them utilizing irrigation. Against the above backdrop this study is carried out as an extract of Ph.D work to specifically to estimate the impact of HYVs adoption on yield and income of irrigated rice farmers and gross margin difference between adopters and non-adopters of tractor service. The study is organized in five parts; the remaining parts are literature clarification, methodology, results and discussion, and conclusion.

Literature Review

This section presents various reviews of literature covering conceptual clarification, theoretical framework and empirical literature in order to familiarize reader with relevant concepts, theoretical anchor and current position of empirical studies.

Conceptual Clarification

Farming performance as defined by Katz and Kahn (2016), is maximization of farm returns per a farming operation, usually measured using turnover, revenue, productivity and cost. In the word of Zhiyong (2015), farming performance means dependent representation of farming achievement or success in relation to the resources expended in the farming operation. In this study farming performance is operationalized as favourable rice farming outcome measured in kg of rice paddy yields, naira value of rice paddy income and gross margin. According to Falkone and Rosenberg (2022), yield is the quantity or amount of commodity produced. In the word of Otchia (2014), yield is the quantity of goods and services produced in a given time period by a firm, industry or country. Also, Gupta (2000) defined yield as the total quantity of goods and services that an individual, company, industry, city, region, or country or even the whole world produced. To Ayodele and Falokun (2003), yield as the amount of anything produced by a person, machine, factory, country, or world. Income is money received on regular basis from working or through investment (Otchia, 2014). In this study, yield is operationalized as the amount of paddy rice produced by an irrigated rice farmer. Income is defined by Kusz (2014), as money a person or an entity receives in exchange of their labour services or investment. Also, James (2022) defines income as the amount of money, property and other transfers of value received over a set period of time in exchange for services or products. Furthermore, Schmitt (2022) defined income as the cash received by an individual or organization in return for their services or goods. Here, income is the actual money received by an irrigated rice farmer from selling out of his rice produce at the end of his last irrigated rice season. Gross Margin on the other hand is defined as the difference between revenue and cost of goods sold, divided by revenue (James, 2022). Gross margin measures organizational gross profit compared to its revenues as a percentage (Schmitt, 2022). To Bloomenthal (2022), gross margin is the percentage of an individual(s) or firms' revenue that is kept after deducting expenditures involved like labour and materials. Gross margin in this study means the profit actualized by an irrigated rice farmer after subtracting all his costs of producing paddy rice yields from his sales. Agricultural technology in the word of Kusz (2014) means promoting farming system from conventional labour-based to technology-based. Improved agricultural technology is conceptualized as parcel of technology used to promote sensible farming, enlarge output, decrease losses in crop and enhance excellence of farm produce (Tewari et al., 2012). Here, improved technology means application of Higher Yielding rice seeds and tractor service by an irrigated rice farmer during last farming session.

Theoretical Framework

Expected Utility theory or Standard Rational Choice theory credited to the work of eighteenth-century mathematician, Daniel Bernoulli forms the foundation of this study (Chen, 2021). The theory hypothesized that under certain assumptions, an individual's preferences towards risks

can be represented as a linear function of the utility of each option multiplied by the probabilities of the option (Ogu, 2013). Therefore, adoption of improved agricultural technology is a linear of utility attach to the technology adoption, farmer's socio-economic characteristics, farm characteristics and technology based factors. The choice of this theory as a frame is based on the fact that farmer's decision making regarding the adoption of agricultural technology reflects choices under uncertainty or risk that necessitate for ranking their technology choice option according to their expected utility.

Review of Empirical Literature

In analyzing the link between improved agricultural technology and farming performance; Wu (2022), investigated adoption and income effects of new agricultural technology on family farms in China using Endogenous Switching Regression model and reveals that the impact is higher for non-adopters was greater but after controlling for selection bias positive and significant impact was found among the adopters. Also, Muhaimin et al. (2020), investigated the impact of technology adoption on income and food security using Propensity Score Matching and found heterogenous adoption effect and positive effect on income and diversity of household diets. Bidzakin et al. (2019) investigated the impact of contract farming on rice farm performance using Endogenous Switching Regression and Propensity Score Matching and found that contract farming significantly increases yield and gross margins. In another study, Adhikari, Mishra and Chintawar (2019) investigated adoption of technology and its impact on profitability of young and beginning farmers using 2004-2006 Agricultural Resource Management Survey (ARMS) data and Quantile regression model and found that adoption of improved crop (GM) among young beginning cotton farmers increased farm profitability but decreased farm profitability among corn farmers. Also, Bayene (2019) investigated impact of technology adoption on agricultural productivity and income in North Eastern Ethiopia using Multivariate regression was used and reveals that adopter farmers generated higher income than their non-adopters counterparts.

Furthermore, Michler et al. (2018) investigated the role of yields and profits in agricultural technology adoption in Ethiopia using survey data. ESR model was used and established positive link between adoption of technology and farmers' yields and profits. Sharma, Dupare and Patel (2018) investigated technology adoption, its impact and determinants among Soyabean farmers in Madhya Pradesh of India, using Tobit model. The result reveals that adoption of improved technologies improves yield and profit. Similarly, Owoeye (2017) investigated adoption of improved technologies in maize-based cropping systems on income of 160 Oyo maize-based farmers using multi-stage sampling and applied Tobit model for its analysis. The result disclosed that total revenue, gross margin and net farm income of adopters are significantly higher than for non-adopters. Houssou and Chapoto (2015) investigated the adoption of farm mechanization, Cropland expansion and intensification in Ghana using CRE models with alternative estimation method of Pooled OLS. It reveals existence of positive link between farm mechanization and expansion of cropland, a negative link between mechanization and farm strengthening. Mwangi and Kariuki (2015) investigated the determinants of new agricultural technology adoption by small scale farmers in developing economies using Content Review Analysis. It revealed that technological, economic, institutional and human are the major factors that determine the farm technology use.

From the reviewed literature, the study of Wu (2022) is concerned with adoption and income effect of new technology. Though the study applied ESR and established greater positive and significant impact among adopters but it only looked at one aspect of farming performance. Muhaimin et al. (2020) investigated technology adoption effect on income and food security.

Though it incorporated supply aspect of the farming but use of Propensity Score Matching alone cannot yield a robust result. Mwangi and Kariuki (2015) carried out a comprehensive study on the determinants of technology adoption. But a content analysis is deficient in many respects as regard to the impact analysis. The study of Houssou and Chapoto (2015) is concerned with effect of technology adoption on cropland expansion. Though, they also looked at supply aspect of farming as did by Muhaimin et al. (2020) but their use of CRE and OLS in the analysis of data could not help to address self-selectivity bias. Other similar studies, like Bidzakin et al. (2019), investigated contract farming on yield and gross margin using ESR and PSM; Adhikari et al. (2019) used Quantile regression to investigate technology adoption on profitability; the study of Bayene (2019) applied multivariate regression to measure the effect of adoption on productivity and income. Also, Michler et al. (2018) applied ESR to investigate the adoption effect on yields and profits. And the studies of Sharma et al. (2018) and Owofe (2017) used Tobit model to investigate the adoption effect on gross margin and income using same technology packages. Extant literature have made good effort to establish a link between improved technology adoption and farming performance among different farmers in Nigeria and beyond using varying techniques (Propensity Score Matching, Endogenous Switching Regression, Tobit model, OLS, Quantile regression and CRE). Using tractor service as a technology alternative in conjunction with HYVs is the uniqueness of this study. Therefore, this study applied ESR model to estimate the impact of HYVs adoption on the irrigated rice farmers' yields and income, and to estimate the gross margin difference between adopters and non-adopters of tractor service. Also, this study applied access to technology as instrumental variable based on the works of Chen et al. (2022), Zegeye et al. (2022) and Wu (2022).

Methodology

This section presents methodology of the study comprising the description of the study area, research design, data analytical techniques and model specification.

Description of the Study Area

North Western Nigeria is among the six geopolitical areas of the nation that make up the country (Accret, 2023). The North West is the largest zone in country, making about 59% of the entire landmass of Nigeria (Almu, Adesina & Kanmodi, 2019). It is located on Latitude 8°14'60"N to 14°30'0"N and Longitude 3°30'0"E to 10°24'0"E (Isaac, 2021; Bosola, 2020). The zone lies in the Sub-Saharan Sudan belt of the West Africa in zone of Savannah-type vegetation. Rainfall averaging about 30 inches annually occurs chiefly in a wet season which lasts from May to October, with a prolonged dry season extending from October to April usually dominated by dusty harmattan winds from the Northeast (USGS, 1973). Moreover, rice production in North Western part is dominated by **dry** farming (GEMS4, 2019).

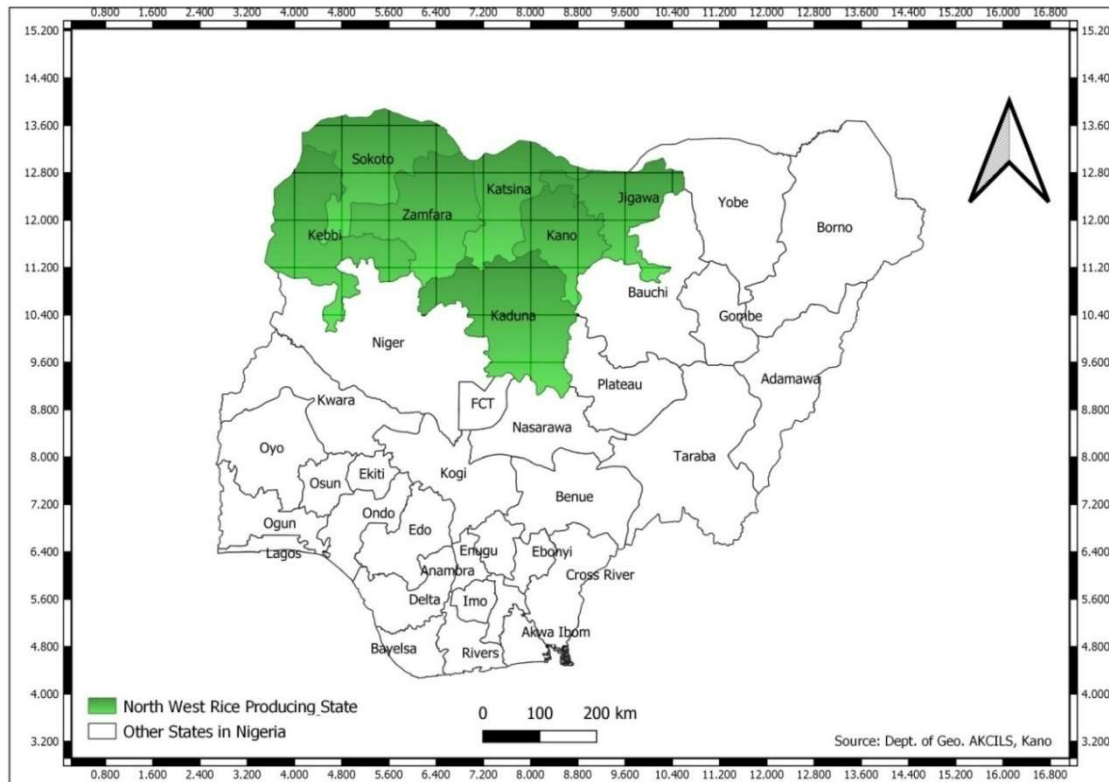


Figure 1: North Western Rice Producing State in Nigeria

Research Design

This study is survey focuses on the responses of irrigated rice farmers in North Western Nigeria. The population of the study comprises all registered irrigated rice farmers across Kaduna, Jigawa and Kano States. The sample size for this study is determined based on Yamane (1967). Thus;

$$\text{Hence, } n = \frac{N}{1 + N(e)^2} = \frac{542,206}{1 + 542,206(0.05)^2} = 400 \dots \dots \dots (3.1)$$

Additionally, non-response error/bias is taken care with using the formula of Fox, Hunn and Mathers (2009), who suggested for dividing the earlier sample size by the response rate of respondents for better representative sample elements. Thus;

$$\therefore n_2 = \frac{400}{0.7} = 571 \text{ irrigated rice farmers.}$$

With respect to the sampling technique, multi-stage sampling was used in order to avail individual irrigated rice farmers that spread across all the rice producing clusters and units equal chances of being part of the study (Wu, 2022). In the first stage, the 7 rice producing states were stratified into high, medium and low size of land mass from which Kaduna (among high); Jigawa (among medium) and Kano (among the low) were selected. In the second stage, in order to give equal chance to the bigger and smaller rice producing local governments, the local governments were stratified according to high, medium and low number of irrigated rice farmers. Therefore, Makarfi, Ringim and Kura (among the high); Soba, Hadejia and Doguwa (among the medium) and Kudan, Gwiwa and Bunkure (among the low) were chosen from Kaduna, Jigawa and Kano States respectively. In the third stage, enumeration of villages/clusters in each of the local government selected was carried out systematically by taking 1 as a common random start across the local governments and determined 3, 5 and 3 as the skip intervals for Kaduna, Jigawa and Kano

respectively. Therefore, Makarfi, Soba and Hunkuyi were selected from Makarfi, Soba and Kudan Local Governments of Kaduna State; Gujaba, S/Garu and Wailare were selected from Ringim, Hadejia and Gwiwa Local Governments of Jigawa State; and Kura and Bagau, Doka Sati and Zangon Buhari were selected from Kura, Doguwa and Bunkure Local Governments of Kano State. Lastly, in the fourth stage sampling of 571 individual irrigated rice farmers from the list of enumerated villages is based on the farmers' availability in each village as did by Obayelu et al. (2017). The distribution of the sample farmers can be seen in Table 3.1 below:

Table 1. Distribution of the Research Sample Irrigated Rice Farmers

S/N	Name of Strata	Local Government	Selected Villages (Clusters)		Number of Respondents
			Tech. Adopters	Tech. Non-Adopters	
1	Kaduna	Makarfi L.G.A.	Makarfi (49)	Makarfi (30)	79
		Soba L.G.A.	Soba (35)	Soba (20)	55
		Kudan L.G.A.	Hunkuyi (55)	Hunkuyi (35)	90
		Sub-total			224
2	Jigawa	Ringim L.G.A.	Gujaba (24)	Gujaba (24)	48
		Hadejia L.G.A.	Sabon Garu (29)	Sabon Garu (28)	57
		Gwiwa L.G.A.	Wailare (10)	Wailare 7)	17
		Sub-total			122
3	Kano	Kura L.G.A.	Kura (63)	Kura (42)	105
			Bagau 10)	Bagau (4)	14
		Doguwa L.G.A.	Doka Sati (37)	Doka Sati (18)	55
		Bunkure L.G.A.	Z/Buhari (35)	Z/Buhari (16)	51
		Sub-total			225
4	Grand Total				571

Source: Researcher's Computation, 2024

Note: Figure in parenthesis represents the number of sampled irrigated rice farmers

Techniques of Data Analysis

This section covers all the techniques utilized in data analysis comprising Endogenous Switching Regression model, the model specification and description of variables.

Endogenous Switching Regression (ESR)

Irrigated rice farmers' decision to adopt an improved agricultural technology may be self-selected which may result into a potential self-selectivity bias (Zegeye et al., 2022; Chen et al., 2022). In order to address this bias, the Endogenous Switching Regression consisting of treatment equation and two outcome equation are widely used in economic literature (Chen et al., 2022) and this study will adapt Chen et al. (2022) with possible modifications.

3.3.2 Model Specification

In this study, expected utility framework will be adopted to analyse the irrigated farmer's decision to adopt improve agricultural technology based on the work of Chen et al. (2022) with little modifications. Here, D_i^* indicates the difference in the utility between adoption of improved agricultural technology and non-adoption. An irrigated rice farmer would adopt the technology if $D_i^* > 0$, and not adopt the technology when $D_i^* \leq 0$. Hence, the irrigated rice farmers' decision to adopt HYVs and tractor service (measured in the cost of tractor service) is modeled as:

$$D_i^* = X_i\beta + \varepsilon_i, D_i = \begin{cases} 1 & \text{if } D_i^* > 0 \\ 0 & \text{if } D_i^* \leq 0 \end{cases} \dots \dots \dots (iv)$$

Where D_i is a dummy variable that is equal to one if an irrigated rice farmer adopts improved agricultural technology and zero otherwise; X_i are factors influencing the farmers' decision to adopts improved agricultural technology (age, household's size, year of formal education, access to credit, farm size, farming experience, frequency of extension of contact, year of cooperative membership); β s are coefficients to be estimated; and ε_i is a random error term with a zero mean. The ESR will help to compare the expected yield, income and gross margin of the irrigated rice farmers that adopted improved agricultural technology alternatives and those who did not adopt the technology.

$$\text{Empirically; } D_i^* = AGE_i\beta_1 + HSZ_i\beta_2 + YEDU_i\beta_3 + AOL_i\beta_4 + FSZ_i\beta_5 + FEX_i\beta_6 + FEC_i\beta_7 + COM_i\beta_8 + \varepsilon_i \dots \dots \dots (v)$$

Table 2. Variables of the Model and Their Hypothesized Relationships

Variable Label	Description	Unit	Expected Signs (Endogenous Switching Regression Model)			
1.	Characteristics of Irrigated Rice Farmers		Yield	Income	Gross Margin	Tech. Adoption
AGE	Age of the farmer	Years	-	-	-	-
HSZ	Numbers of family	Number	+	-	-	-
EDU	Education level	Years	+	+	+	+
AOL	Access to credit access=1, 0=No access)	Dummy	+	+	+	+
2.	Inputs					
FSZ	Size of farmland	Hectare (ha)	+	+	+	+
HYVs	Quantity of rice seeds	Kilogram (kg)	+	+	+	+
TSER	Service of tractor used	Hour (hr)	+	+	+	+
FERT	Quantity of fertilizers	Kilogram (kg)	+	+	+	+
PEST	Quantity of pesticides	Liter (L)	+	+	+	+
HERB	Quantity of herbicides	Liter (L)	+	+	+	+
HLAB	Quantity of labour	Number	+	+	+	+
3.	Inputs' Prices					
CHYVs	Price of rice seeds	Naira (₦)	-	-	-	-
CTSER	Price of tractor service	Naira (₦)	-	-	-	-
CFERT	Price of fertilizers	Naira (₦)	-	-	-	-
CPEST	Price of pesticides	Naira (₦)	-	-	-	-
CHERB	Price of herbicides	Naira (₦)	-	-	-	-
CHLAB	Labour wages	Naira (₦)	-	-	-	-
4.	Output					
Yield	Yield/ha	Kilogram (kg)				
Income	Income/kg	Naira (₦)				
GMargi n	Gross Margin/ha	Naira (₦)				

Source: Researcher's Computation, 2023.

Note: Robust standard error are in parenthesis; *, **, and *** represent level of significance at 10%, 5% and 1%.

Table 1, presents the description and explanation of the variables used in the study as well as their respective Apriori expectations.

Results and Discussion

This section covers presentation of estimated results, interpretation and discussion of their major findings.

Table 3. Irrigated Rice Farmers' Socio-Economic Characteristics

Variables	Non-adoption of Technology (0)	Adoption of HYVs Only (1)	Adoption of tractor service Only(2)	Combined adoption of HYVs & tractor service(3)
	Mean	Mean	Mean	Mean
AGE	(40.304)	38.048	30.600	43.229
HSZ	(9.870)	4.619**	1.600	13.571
YED	(1.255)	3.381**	2.700*	3.400
AOL	(0.503)	0.119	0.050*	0.629**
FSZ	(7.593)	6.167**	1.000**	10.743***
FXC	(3.915)	6.081***	6.000***	4.267**
GEN	(0.863)	0.762**	0.900*	0.914**
DIS	(5.590)	5.667**	3.000**	9.000**

Source: Researcher's Estimation Using Stata 14.

Note: The Mean Comparison of t-test is used to compare the mean of explanatory variables between non-adopters and adopters of the agricultural technology packages (here, adoption of HYVs only; adoption of tractor service only & combined adoption of HYVs and tractor service); and the signs *, ** and *** represents level of significance @ 10%, 5% and 1% respectively.

The results as reported in Table 2 show that average comparison indicates some levels of heterogeneity between adopters and non-adopters as well as across the adopters of improved agricultural technology. The mean age of non-adopters of improved technology is about 40.304 years, while the mean age difference between adopters of HYVs, tractor service and their combined adoption, and non-adopters are statistically the same. The mean household size of non-adopters of improved technology is about 9.870 persons that of adopters of HYVs is 4.619 and found statistically and significantly different at 5% level. While the mean household size difference between adopters of tractor service and combined adoption of HYVs and tractor service, and non-adopters are statistically the same. The mean year of formal education for non-adopters of improved technology is about 1.255 years that of adopters of HYVs is 3.381, found statistically and significantly different at 5% level; that of adopters of tractor service is 2.700, found statistically and significantly different at 10% levels. While the mean year of formal education difference between adopters of combined adoption of HYVs and tractor service and non-adopters are statistically the same. The mean access to credit of non-adopters of improved technology is about 0.503 that of adopters of tractor service is 0.050, found statistically and significantly different all at 10% level that of combined adopters of HYVs and tractor service is 0.629, found statistically and significantly different at 5% level. While the mean access to credit difference between adopters of HYVs only and non-adopters are statistically the same.

Also, the mean farm size of non-adopters of improved technology is about 7.593ha, that of adopters of HYVs and tractor service are 6.167 and 1.000 respectively, found statistically and significantly different each at 5% level and the mean farm size of combined adoption of HYVs & tractor service is 10.743, found statistically and significantly different at 1% level. The mean frequency of extension contacts for non-adopters of improved technology is about 3.915 days,

that of adopters of HYVs and tractor service are 6.081 and 6.000 respectively, found statistically and significantly different at 1% level, and mean frequency of extension contacts of combined adopters of HYVs and tractor service is 4.267, found statistically and significantly different at 5% level. The mean gender of non-adopters of improved technology is about 0.863, that of adopters of HYVs is 0.762 found statistically and significantly different each at 5% level, the mean gender of adopters of tractor service and that of combined adopters of HYVs & tractor service 0.900 and 0.914 respectively, found statistically and significantly different each at 10% level. The mean distance to market for non-adopters of improved technology is about 5.590 km, that of adopters of HYVs, tractor service and combined adopters of HYVs & tractor service are 5.667, 3.000 and 9.000 respectively; found statistically and significantly different each at 5% level.

Table 4. Endogenous Switching Regression Results for Adoption of HYVs and Its Impact on Yields of Irrigated Rice Farmers

Higher Yielding Variety seeds (HYVs)				Treatment Effects	
Variable	Adoption of HYVs	Farmers Adopting HYVs	Farmers Not Adopting HYVs	ATT	ATU
SEEDS		0.204 (28.09) ***	0.189 (0.01)	1.654 (1.018) ***	0.391 (0.142) ***
FSZ	0.059 (1.22) *	0.368 (57.62)	0.524 (0.02)		
FERT	-0.058 (1.43)	0.476 (2.86) *	0.132 (0.001)		
PEST	0.086 (0.10)	0.154 (86.52)	0.158 (0.02) ***		
HERB	-1.077 (1.74)	0.336 (159.19)	0.982 (0.03)		
HLAB	0.084 (4.94)	0.441 (57.87)	-0.540 (0.01)		
AOL	1.061 (2.12)	0.047 (489.20) **	-0.093 (0.18)		
HSZ	0.297(12.82) ***	0.201 (84.84)	0.202 (0.02) ***		
YED	0.086 (0.10)	0.256 (1.43)	0.201 (1.43)		
AGE	-0.051 (1.50)	-0.122 (7.79)	-0.168 (2.40)		
Instr. Var.	0.003 (0.08) ***				
Con.	0.566 (57.60)	14.4.71(128.25)	-4.00 (114.256)		
/Ins0			5.401(0.09) ***		
/Ins1		5.218(0.06) ***			
/r0			-2.788 (0.43) ***		
/r1		3.493(0.51) ***			
Sigma_0			221.722 (20.05) ***		
Sigma_1		184.612 (10.654) ***			
rho_0			-0.992 (0.01) ***		
rho_1		0.998 (0.002) ***			
Log Likelihood	-4712.697				
Indep. Eqs. (χ^2)	107.62 ***				
N	564	226	338		

Source: Researcher's Estimation Using Stata 14.

Note: Robust standard error are in parenthesis; *, **, and *** represent level of significance at 10%, 5% and 1%.

Table 3 reports the estimates of the impact of HYVs adoption on yield of the irrigated rice farmers in the study area. From the results, the Wald test is found highly signed (107.62) showing the goodness of fit of the Endogenous Switching Regression model and presence of endogeneity which justifies the use of the ESR model. From the likelihood ratio test results of independence of the selection and the two outcome equations, the results also justify the rejection of the null hypothesis. The validity of the instrument used (access to technological information) was verified using the falsification test and the result also indicated a significant and positive correlation with adoption of HYVs and ESR is effectively identified. The negative correlation of ρ_0/ρ_1 indicates the negative selection deviation. From the ESR first stage result, it can be seen that farm size, household size and instrument variable (access to technology) significantly determined the adoption of HYVs among the irrigated rice farmers. The results of the second ESR stage show significant difference in coefficient estimates of adopters and non-adopters of HYVs. It reveals that adoption of HYVs is likely to increase the yield of irrigated rice farmer by 0.204 percentage points higher than that of non-adopters of the HYVs (0.188), implying that adoption of HYVs has strong positive correlation with yield of irrigated rice farmers that adopted the seeds the variable is found significant at 1% level. All things being equal, with 1 kg increase of HYVs, an irrigated rice farmer's kg of paddy yield is likely to increase by 0.204 percentage points. This is because planting HYVs with proper observation of its instructional guide lines will surely help in achieving higher rice turn out. This result is found similar to that of Zegeye (2022) and Bidzakin et al. (2019).

Use of fertilizers is likely to increase the yield of HYVs adopters by 0.476 percentage points higher than that of non-adopters of the HYVs (0.132), the variable is found significant at 10% level. All thing beings equal, with 1 kg increase of fertilizers, HYVs adopters' kg of paddy yield is likely to increase by 0.476 percentage points. This is because fertilizers improves the soil HP and helps it to regain its lost fertility thereby promoting the efficiency of HYVs. This finding is similar to that of Bidzakin et al. (2019). Use of pesticides is likely to increase the yield of HYVs non-adopters by 0.158 percentage points slightly higher than that of adopters of the HYVs (0.154), the variable is found significant at 1% level. All things being equal, with 1 liter increase of pesticides, an irrigated rice farmer's kg of paddy yield is likely to increase by 0.158 percentage points. This may be due to the fact that use of pesticides to kill yield-destroying insects has been a long practice among the rice farmers. This result supports the finding of Michler et al. (2018). Also access to credit is likely to increase the yield of HYVs adopters by 0.047 percentage points lower than that of non-adopters of the HYVs (0.093), the variable is found significant at 5% level. All things being equal, with ₦1000 increase in the access to credit, an irrigated rice farmer's kg of paddy yield is likely to increase by 0.047 percentage points. This is because credit serves as capital avails the financial capability of the farmers to adopt desired technology. This result is in line to the conclusion of Sharma et al. (2018) but contradicts finding of Owoye (2017). Household size is likely to increase the yield of HYVs non-adopters by 0.202 percentage points slightly higher than that of adopters of the HYVs (0.201), the variable is found significant at 1% level. All things being equal, with one person increase in the number of family members, a non-adopter irrigated rice farmer's kg of paddy yield is likely to increase by 0.202 percentage points. This is because technology resisting farmers rely heavily on the use of large farm labour particularly house based in order to achieve higher yields. This result is similar to the finding of Sharma et al. (2018) but contradicts the finding of Bidzakin et al. (2019) but affirms the conclusion of Wu (2022). Lastly, the instrumental variable (access to technological information) is found and positive determinant of irrigated rice farmers' yield.

The estimates of ATT and ATU account for the selection bias that arises from the fact that adoption and non-adoption of the HYVs may be systematically different. The results indicate that adoption of HYVs significantly increases the yield of the adopters with potential of increasing that of the

non-adopters if they adopt. Specifically, the causal effect (yield-increasing effect) of adopting HYVs for the adopters is about 1.654 representing 6.91% increase in the kg of paddy yields of the adopters if they adopt the HYVs. Also, the causal effect of adopting the HYVs for non-adopters is about 0.391 representing 12.61% decrease in their kg of paddy yields for not adopting the HYVs. Therefore, adoption of HYVs has a positive and significant effect on yield of irrigated rice farmers and irrigated rice farmers that did not adopt HYVs will experience a more significant increase in their yield if they adopt the HYVs because ATU is higher than ATT. This result contradicts the finding of Wu (2022).

Table 5. Endogenous Switching Regression Results for Adoption of HYVs and Its Impact on Income of Irrigated Rice Farmers

Higher Yielding Variety seeds (HYVs)				Treatment Effects	
Variable	Adoption of HYVs	Farmers Adopting HYVs	Farmers Not Adopting HYVs	ATT	ATU
SEEDS		0.284 (57.619)*	0.144 (0.018)	2.097 (0.085)*	0.642 (0.019)***
FSZ	0.081 (10.827)	-0.042 (38.092)	0.389 (0.008)		
FERT	0.719 (-3.480)	0.477 (2.855)*	0.320 (0.01)		
PEST	0.304 (2.323)	0.597 (86.516)	0.158 (0.018)*		
HERB	0.374 (-33.03)	-0.365 (159.188)	-0.398 (0.031)		
HLAB	-0.632 (11.002)	-0.414 (57.866)	-0.054 (0.011)		
AOL	0.497 (310.87)***	0.484 (489.204)	-0.593 (0.177)		
HSZ	0.091 (-26.604)	-0.437 (84.835)*	0.202 (0.021)		
YED	0.179 (-3.480)	0.175 (33.72)***	0.181 (420.78)		
AGE	-0.632 (11.002)	-0.325 (804.51)	-0.312 (19150.2)*		
Instr. Var.	0.004 (0.008)**				
Con.	0.258 (0.077)***	14.594(1281.25)	-40.006 (143.26)***		
/Ins0			14.61 (0.05)***		
/Ins1		14.43 (0.08)***			
/r0			-2.797 (0.360)***		
/r1		8.481 (0.663)***			
Sigma_0			22516(167.69)***		
Sigma_1		18593(141.94)***			
rho_0			-0.993 (0.005)***		
rho_1		0.998 (0.002)***			
Log Likelihood	-4712.6985				
Indep. Eqs. (χ^2)	107.62***				
N	564	226	338		

Source: Researcher's Estimation Using Stata 14.

Note: Robust standard error are in parenthesis; *, **, and *** represent level of significance at 10%, 5% and 1%.

Table 4 reports the estimates of the impact of HYVs adoption on income of the irrigated rice farmers in the study area. From the results, the Wald test is found highly signed showing the goodness of fit of the Endogenous Switching Regression model and presence of endogeneity which justifies the use of the ESR model. From the likelihood ratio test results of independence of the selection and the two outcome equations, the results also justifies the rejection of the null hypothesis of no correlation between the adoption of HYVs and irrigated rice farmers' income, meaning that adoption of HYVs is positively correlated with the income of the irrigated rice farmers. The validity of the instrument used (access to technological information) was verified using the falsification test and the result also indicated a significant and positive correlation with adoption of HYVs and ESR is effectively identified. The negative correlation of ρ_0/ρ_1 indicates the negative selection deviation. From the ESR first stage result, it can be seen that access to credit and instrument variable are significantly related to the adoption HYVs among irrigated rice farmers. The results of the second stage of ESR show significant difference in coefficient estimates of adopters and non-adopters of HYVs. It reveals that adoption of HYVs is likely to increase the income of irrigated rice farmer by 0.284 percentage points higher than that of non-adopter of the HYVs (0.144), the variable is found significant at 10% level, implying that adoption of HYVs has strong positive correlation with income of irrigated rice farmers that adopted the seeds. All thing being equal, with 1 kg increase of HYVs, an irrigated rice farmer's income is likely to increase by about 0.284 percentage points. This finding concurs that of Ajewole et al. (2015).

Use of fertilizers is likely to increase the income of HYVs adopters by 0.477 percentage points higher than that of non-adopters of the HYVs (0.320), the variable is found significant at 10% level. All thing beings equal, with 1 kg increase in fertilizers, HYVs adopters' income is likely to increase by 0.477 percentage points. This is because fertilizers improve the quality and fertility of soil, thereby promoting the yield and income. This finding is similar to that of Wu (2022). Use of pesticides is likely to increase the income of HYVs non-adopters by 0.158 percentage points lower than that of adopters of the HYVs (0.597), the variable is found significant at 5% level. All thing beings equal, with 1 liter increase in pesticides, HYVs non-adopters' income is likely to increase by 0.158 percentage points. This is because insect-destroying chemicals help to reduces farm loss, promoting the yield and income. This finding is similar to that of Bayene (2021). Also, year of formal education is likely to increase the income of HYVs adopters by 0.437 percentage points far higher than that of adopters of the HYVs (0.202), the variable is found significant at 1% level. All thing beings equal, with 1 year increase in formal education, HYVs adopters' income is likely to increase by 0.437 percentage points. This is because formally more educated irrigated rice farmers can have better access to information concerning technology, its instructions and bargaining skills in its purchasing. This finding is similar to that of Wu (2022) and Bayene (2021).

Lastly, age of irrigated rice farmer is likely to decrease the income of HYVs non-adopters by 0.312 percentage points slightly higher than that of adopters of the HYVs (0.325), the variable is found significant at 10% level. All thing beings equal, with 1 year increase in the age of irrigated rice farmer, HYVs adopters' income is likely to decrease by 0.312 percentage points. This is because aged farmers are at their diminishing operation rate, producing lower yields and make lower income. This result is supports the finding of Michler et al. (2018) and Sharma et al. (2018). Other determinants with positive but insignificant effect on adoption of HYVs are access to credit, farm

size and household size while herbicides and hired labour indicated negative and insignificant effect on the adoption of HYVs.

The ESR estimates of ATT and ATU account for the selection bias that arises from the fact that adoption and non-adoption of the HYVs may be systematically different. The results indicate that adoption of HYVs significantly increases the income of the adopters with potential of increasing that of the non-adopters if they adopt. Specifically, the causal effect (income-increasing effect) of adopting HYVs for the adopters is about 2.097 representing 9.48% increase in the income of the adopters for adopting the HYVs. Also, the causal effect (income-increasing effect) of adopting the HYVs for non-adopters is about 0.642 representing 6.60% decrease in their income for not adopting the HYVs. Therefore, adoption of HYVs has a positive and significant effect on income of irrigated rice farmers and irrigated rice farmers that did not adopt HYVs will experience a less significant decrease in their income for not adopting the HYVs. The finding of this study supports the conclusion of Wu (2022) and Zegeye et al. (2022).

Table 6. Endogenous Switching Regression Results for Adoption of Tractor Service and Its Impact on Gross Margin Difference of Irrigated Rice Farmers

Variable	Tractor Service (Tserv)			Treatment Effects	
	Adoption of Tractor Service	Farmers Adopting Tractor Service	Farmers Not Adopting Tractor Service	ATT	ATU
CTSERV		-0.447(12.320)**	-0.589 (29.036)	2.048 (1.761)**	1.004 (0.178) ***
CSEED	-0.604 (19.901)	-0.238 (35.006)	-0.178 (33.170)		
CFERT	-0.050 (0.197) ¹	-0.302(0.194) ***	-0.247(0.276) ***		
CPEST	-0.480 (11.719)	-0.234 (15.016)	-0.357 (24.396)		
CHERB	-1.002(21.632)	-0.266 (31.958)	-0.107 (40.703)		
AOL	0.110 (712.12)	0.224 (272.4)	0.117 (300.2)		
HSZ	0.269 (129.12) ***	0.127(277.8)	0.267 (145.8)		
YED	0.865 (7089.43)	0.368 (1357.61)**	0.047(2023.9)		
AGE	-0.551(460.50)	-0.149 (129.62)	-0.459(209.85)**		
Instr.	0.006 (0.004) ***				
Con.	165.5(414.56)	250 (6324.1)	150 (7194.4)		
/Ins0			14.095 (0.001) ***		
/Ins1		14.510 (0.06) ***			
/r0			-0.092 (0.627) ***		
/r1		2.781 (0.380) ***			
Sigma_0			13225 (1147.4) ***		
Sigma_1		20030(2062.604) ***			
rho_0			-0.097 (0.621) ***		
rho_1		0.092 (0.006)***			
Log Likelihood	-4525.4457				
Indep. Eqs. (χ^2)	5015169.93***				
N	564	188	376		

Source: Researcher's Estimation Using Stata 14.

Note: Robust standard error are in parenthesis; *, **, and *** represent level of significance at 10%, 5% and 1%.

Table 5 reports the estimates of the impact of tractor service adoption on yield of the irrigated rice farmers in the study area. From the results, the Wald test is found highly signed showing the goodness of fit of the Endogenous Switching Regression model and presence of endogeneity which justifies the use of the ESR model. From the likelihood ratio test results of independence of

the selection and the two outcome equations, the results also justifies the rejection of the null hypothesis of no correlation between the adoption of tractor service and irrigated rice farmers' yield, meaning that adoption of tractor service is positively correlated with the yield of irrigated rice farmers. The validity of the instrument used (access to technological information) was verified using the falsification test and the result also indicated a significant and positive correlation with adoption of tractor service and ESR is effectively identified. The negative correlation of ρ_0/ρ_1 indicates the negative selection deviation. From the ESR first stage result, it can be seen that cost of fertilizers, household size and instrument variable (access to technology) are significant determinants of irrigated rice farmers' gross margin.

The results of the ESR second stage show significant difference in coefficient estimates between adopters and non-adopters of tractor service. It reveals that cost of adopting tractor service is likely to decrease the gross margin of irrigated rice farmer by 0.447 percentage points lower than that of non-adopter of the tractor service (0.589), implying that adoption of cost of tractor service has strong negative correlation with gross margin of irrigated rice farmers that adopted the tractor service. The variable is found significant at 5% level. All things being equal, with ₦1 additional expenditure on hiring tractor service, an irrigated rice farmer's gross margin is likely to decrease by about 0.447 percentage points. This finding is similar to the conclusion of Owoeye (2017). Cost of fertilizers is likely to decrease the gross margin of irrigated rice farmers that adopted tractor service by about 0.302 percentage points higher than non-adopters (0.247). The variable is found significant at 1% level. All things being equal, with ₦1 additional expenditure on kg of fertilizers, an irrigated rice farmer's gross margin is likely to decrease by about 0.302 percentage points. This result supports the finding of Bidzakin et al. (2019). Results of costs of tractor service and fertilizers conform to the a priori expectation. According to the theory cost is inversely related to the gross margin (Bidzakin et al. 2019).

Year of formal education of an irrigated rice farmer is likely to increase the gross margin of irrigated rice farmers that adopted tractor service by about 0.368 percentage points far higher than non-adopters (0.047). The variable is found significant at 5% level. All things being equal, with 1 year increase in formal education, an irrigated rice farmer's gross margin is likely to increase by about 0.368 percentage points. This is because formally more educated irrigated rice farmers are at better position to adopt agricultural technology, produce more yields, make higher income and realize better gross margin. This result supports the finding of Adhikari et al. (2019). Lastly, age of an irrigated rice farmer is likely to decrease the gross margin of non-adopter of tractor service by about 0.459 percentage points far higher than adopters (0.149). The variable is found significant at 5% level. All things being equal, with 1 year increase in the age of an irrigated rice farmer that did not adopt the tractor service; gross margin is likely to decrease by about 0.459 percentage points. This is because aged farmers are at their diminishing operation rate, producing lower yields and make lower income and end up with least gross margin. This result is similar the finding of Bidzakin et al. (2019). Also, other determinants of gross margin with negative and insignificant effect are cost of seeds, cost of pests, and cost of hired labour while access to credit and household size are found positive but insignificant determinants of the gross margin.

The ESR estimates of ATT and ATU account for the selection bias that arises from the fact that adoption and non-adoption of the tractor service may be systematically different. The results indicate that adoption of tractor service significantly increases the yield of the adopters with potential of increasing that of the non-adopters if they adopt. Specifically, the causal effect (gross margin-increasing effect) of adopting tractor service for the adopters is about 2.048 representing 62.50% increase in the gross income of the adopters with adoption of the tractor service. Also,

the causal effect (gross margin-increasing effect) of adopting the tractor service for non-adopters is about 1.004 representing 41.47% increase in their gross margin if they adopt the tractor service. Therefore, adoption of tractor service has a positive and significant impact on gross margin of irrigated rice farmers and irrigated rice farmers that did not adopt the tractor service will experience a less significant increase in their gross margin if they adopt the tractor service. This result is in line to the finding of Zegeye et al. (2022); Adhikari et al. (2019).

Table 7. Gross Margin Difference between Adopters and Non-adopters of Tractor Service

Farm Outcomes	Adoption Status	Predictions		Treatment Effect	Gross Margin Difference
		Adopters	Non-adopters		
Gross Margin/ha	ATT (Adopters)	82.051	80.003	2.048(1.761)***	1.044***
	ATU (Non-adopters)	69.091	68.087	1.004(0.178)***	
	Heterogeneity Effect	12.96	11.916		

Source: Researcher's Estimation Using Stata 14.

Note: Robust standard error are in parenthesis; *, **, and *** represent level of significance at 10%, 5% and 1%.

From Table 6, the gross margin difference between adopters and non-adopters of tractor service among the irrigated rice farmers is determined using the prediction different effect of the predictive values of the adopters and non-adopters of tractor service (Heterogeneity Effect) which is statistically and significantly determined at about 1.044. Therefore, irrigated rice farmer that adopted tractor service has a gross margin difference of 1.044 gross margin differences from their non-adopters. This finding is similar with the result of Owoeye (2017), who found positive and significant profit difference between maize farming adopters and non-adopter counterparts.

5. Conclusion and Summary

Higher yields, income and gross margin are the key indicators of farming performance used to measure the adoptability of improved agricultural technology. The combined use of yields, income and gross margin is informed by intention of measuring the farming performance in both nominal and real forms. This study intends to estimate the impact of Higher Yielding Variety seeds (HYVs) on irrigated rice farmers' yields and income, and the gross margin difference between adopters and non-adopters of tractor service. The data used in this study were collected using structured questionnaire administered among 571 irrigated rice farmers across Kaduna, Jigawa and Kano States, out of which 564 were successfully retrieved with 98% return rate which is enough to carry out the main estimation and analysis. Endogenous Switching Regression model is used as a main analytical tool and access to improved technology was adopted from the work of Bidzakin et al. (2019); Chen et al. (2022); Wu (2022); Zegeye et al. (2022); and used as instrumental variable. From objective one, the results of the Endogenous Switching Regression model reveal that adoption of HYVs has positive impact on yields and income of irrigated rice farmers, pointing strong and positive correlation with irrigated rice farmers' yield and income but the effect on non-adopters due to the existence of self-selectivity is lower. The yield-increasing effects and income-increasing effects of adopting HYVs for the adopters are higher. Also, from objective 2, the results reveal that cost of adopting tractor service has negative and significant impact on gross margin of irrigated rice farmers, pointing negative correlation with the irrigated rice farmers' gross margin but the negative effect on non-adopters dues to self-selectivity as indicated from the estimates

of treatment effects is lower. Also, the gross margin-increasing effect for adopters of tractor service is higher and the gross margin difference between adopters and non-adopters of tractor service is about 1.044. Therefore, the empirical results of this study support the view that adoption of improved agricultural technology will help to improve farm performance of irrigated rice farmers.

Given the statistical significance of the coefficient of HYVs in Table 3, 4 and 5, there is the need for redirecting policy aimed at promoting the adoption of improved technology particularly HYVs and tractor service among the irrigated rice farmers by making the technology accessible and affordable in appropriate time. Also, higher causal effect of adoption of HYVs and tractor service on non-adopters and positive and significant difference between the gross margin of tractor service adopters and non-adopters, there is need for encouraging the adoption the technologies among non-adopter irrigated rice farmers through effective communication and extension services, enlightenments and easing the hiring of tractor service so that they will enjoy the possible causal effect of its adoption. Also, other studies should classify the non-adopters into different category and look at the categorical non-adoption differences.

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