Risk Preference as an Endogenous Determinant of Improved Rice Technology Adoption Decisions: Evidence from Nigeria

Omotuyole Isiaka Ambali, Francisco Jose Areal and Nikolaos Geogantzis[1]

Abstract

Improved agricultural innovation is a panacea to economic development yet the level of adoption of the available improved agricultural technology is mixed in most developing countries. While attempts have been made to identify extrinsic factors in adoption decisions, less attention is given to the intrinsic variables. This study examines the roles of farmers' risk preferences and spatial dependence in the decisions to adopt higher yielding rice varieties. We utilize experimental and survey data from Nigeria and estimated instrumental probit model in two stages: risk model first, and adoption decisions model second. We account for the spatial heterogeneity in adoption and found the spatial lags of the risk attitude variables as significant instruments for unobserved variables like environmental factors. More importantly, risk preference is a significant endogenous determinant of adoption decisions. Correlation between spatial dependence and risk preference is an indication of the existence of social interaction and learning effects suggesting the diffusion of HYV may be enhanced through farmers' neighbours, because social interaction is an effective tool for information dissemination in the rural areas. Specific attention should not only be given to farmers' individual factors but also the group attributes like spatial aspects in decision making.

Key words: agricultural innovation, adoption decisions, endogenous variable, neighbourhood effects, risk attitudes, spatial dependence.

JEL classifications: O1, O2, O3

Contributed Paper prepared for presentation at the 93rd Annual Conference of the Agricultural Economics Society, University of Warwick, England. 15 – 17 April 2019

1. Introduction

Agricultural productivity growth is a panacea to economic development. However, slow agricultural productivity growth remains a bane to development in sub-Saharan Africa where agriculture is the main-stay of the economy. The low agricultural growth in SSA is attributed to factors like weak public institutions (extension services, finance and insurance markets), inconsistency in government policies, inadequate irrigation and low use of improved technological agricultural innovation (Development and Cooperation, 2012). Subsequently, most farmers are less productive and earn relatively low levels of income. Many developing countries witnessed productivity growth following the introduction of Green Revolution in the 1970s'. For instance, there are observed yield differences between the adopters and non-adopters of improved agricultural innovation in Asia (Abedullah, *et al.*, 2015; Villano *et al.*, 2015). Notwithstanding, it is not only unclear whether farmers increase adoption rates over ~~time in country like Nigeria~~ but also information on the intrinsic and extrinsic reasons for adoption, non-adoption and dis-adoption attitudes toward high yielding rice varieties (HYV hereafter) has not been well documented.

---

[1] Omotuyole Isiaka Ambali is a Lecturer in the Department of Agricultural Economics and Farm Management, Olabisi Onabanjo University, Ogun State, Nigeria. Email: tuyoleambali@gmail.com for correspondence. Francisco Jose Areal and Nikolaos Georgantzis are respectively Assistant Professor and Professor in the Department of Agrifood Economics and Social Sciences, University of Reading, UK. The authors express sincere appreciation to the Tertiary Education Trust Fund (TETFUND) of Nigeria for funding this research project.

Scholars have long sought to understand the drivers of technological changes among farmers. A major strand of this research has particularly focused on socio-economic characteristics and institutional factors including road, location, access to credit, market as well as extension services (Feder, *et al.*, 1985; Foster & Rosenzweig, 2010). The review of the literature suggests limited attention is paid to how individual and group characteristics influence decisions to adopt improved agricultural technologies. A valid example of the individual characteristics is farmers' risk attitudes or risk preferences (Marra, Pannell, & Abadi Ghadim, 2003; Liu, 2013; Ward & Singh, 2014; Barham, *et al.*, 2014; Barham, *et al.*, 2015; Ward & Singh, 2015), whereas geographical proximity and spatial dependence are examples of group characteristics. Evidence of social network or group effects are found in sickle adoption (Case, 1992), organic farming adoption (Läpple & Kelley, 2015) and conservation tillage adoption (Tessema *et al.*, 2016). Notwithstanding, these studies either examine the relationship between risk aversion and adoption decisions (Liu, 2013; Liu & Huang, 2013; Barham *et al.*, 2014; Barham *et al.*, 2015) or spatial dependence and adoption decisions (Läpple & Kelley, 2015; Tessema *et al.*, 2016). Both individual and group factors are considered in this study since many smallholder farmers have no control over many factors especially the production environment but exercise some level of control over their preferences including production decisions.

Adoption decisions are often made by farmers individually or in clusters under uncertainty. Such decisions have been modeled using different methods (Tambo & Abdoulaye, 2012; Anik & Salam, 2015). However, the potential endogenous nature of risk preferences has never attracted research attention. This study therefore contributes to the adoption literature in two ways. First, we test the hypothesis that risk preferences are endogenous determinant of farmer's HYV adoption decisions. Second, we accounts for unobserved heterogeneity within farmers' risk attitudes thereby minimizing estimating issues relating to latent variables in line with Tobler's (1970) principle on the role of geographical proximity in behaviour. In farming, social norms and cultural values constitute neighbourhood effects which reflect in farm decisions. Social and cultural values may be founded on conditions in the area such as climatic variability which may create a determined view on risk taking. Notably, farmers learn improved agricultural innovation from one another through interpersonal communication and social interaction (Bandiera & Rasul, 2006; Conley & Udry, 2010). Such social learning effects, along with unobserved spatial issues like local climatic and topographic conditions generally manifest in farmers' decision making processes.

Endogenous problem arrive from measurement errors in variables or omission of important variables. It is also a consequence of simultaneity problem or selection bias (Tambo & Abdoulaye, 2012; Anik & Salam, 2015). For instance, risk attitudes may not be accurately measured yet environmental, climatic, topographic and socio-economic factors may be unavoidably omitted in the adoption model. Moreover, spatial relationship is inherent in data collected from individual in points. Ignoring such spatial dependency tendency may produce a biased result and misleading inference (Benirschka & Binkley, 1994; Bockstael, 1996; Weiss, 1996). Put differently, farmer's adoption decisions may be influenced by spatially determined risk attitudes. Furthermore, information on the potential benefits of HYV is important for its acceptance. Such information is embedded in spatial relationships especially when farmers living closely rely on their friends and neighbours for information on improved farm practices. What is more, farmers living closely may behave in a similar way relative to distant ones suggesting similar adoption pattern among close farmers. In addition, farmers may emulate one another due to the influence of one or more of the spatial characteristics (local climate and socio-economic conditions). Thus, risk-taking ability of farmers and the spatial relationship associated with it may be a policy tool to understand the adoption and diffusion of improved agricultural innovation.

Improved agricultural technologies have many economic benefits. Some of these benefits include higher productivity, labour saving and mitigating effects on climatic shocks (Dar & Laxmipathi Gowda, 2013). Empirical evidences abound on the significant impact of improved agricultural technologies on farmers' income and poverty reduction in developing countries (Rahman, 1999; Mendola, 2007; Kijima, *et al.*, 2008; Udoh & Omonona, 2008; Becerril & Abdulai, 2010; Kassie, *et al.*, 2011). Agricultural growth has also been identified as a solution to food insecurity problems in developing countries (Mainuddin & Kirby, 2009; Barreett, 2010; Godfray, *et al.*, 2010; Rada, *et al.*, 2013). Specifically in Nigeria, Dontsop-Nguezet, *et al.,* 2011 report the positive impact of HYV on poverty and welfare while Awotide, *et al.,* 2015 show improved cassava varieties positively correlated with asset ownership and negatively related to asset poverty. Notwithstanding, productivity growth in rice production in many developing countries is constrained by extreme weather conditions such as drought and flood yet these shocks may be mitigated if farmers adopt improved agricultural innovation. Improved technologies are therefore essential for sustainable economic development because of the potential to increase yield without increasing farm size.

Rice is a global food security and cultural crop, employing a large proportion of the population where it is grown. It is particularly important in Nigeria where both the poor and rich households rely largely on it as staple food. Rice is cultivated in virtually all the geo-political zones mostly by smallholder farmers. Indeed, its production is confronted with varying degrees of constraints ranging from the socio-economic to institutional factors (lack of access to credit, market and accessible roads). A cursory look at the rice sector in this country suggests more effort is required to bridge the demand-supply deficit. Nigeria is a leading rice producer in SSA. It is also a leading importer in the world attributable to population increase and low yield. Low rice productivity encourages importation to bridge the supply-demand gap with the country spending billions of dollars annually.

The quest to increase rice yield prompted the introduction of different improved varieties to Nigeria. The notable ones under cultivation in Ogun State Nigeria include the new rice for Africa (NERICA), FARO 44, FARO 50, FARO 52 ITA 150, WAB 189 and WITA 4 (Saka, *et al.*, 2005; Saka & Lawal, 2009). These authors reported significant yield difference between the adopters and non-adopters of HYV. Doubtless, many factors may explain the reasons for the low spread of improved agricultural innovation. Both group and individual attributes are particularly relevant in rice farming due to its global economic importance and the huge risk associated with adopting unproven varieties. The climatic and ecological environment required for rice production make its production to be confined and clustered among few farmers who understand its growing techniques. Thus, the decisions on the adoption of such innovative practices are very strategic one that needs careful and methodological approach.

This reminder of this paper is structured as follows. Existing literature on the adoption of improved agricultural technological innovation is covered in section 2 while Section 3 describes the data and estimation methods. Results and discussion are presented in section 4 while section 5 concludes the findings.

2. Literature on Adoption of Improved Agricultural Technologies

Adoption is a process of accepting innovation. In the context of divisible agricultural technology like HYV, adoption has been described as farmer's attitudes towards a new technology while diffusion is aggregate adoption (Sunding & Zilberman, 2001). However, Feder *et al.* (1985) has previously defined adoption as the "extent of the acceptance of innovation after farmers have full information about the technology and its potential benefits”. The later definition captures the intensity of adoption but poor record keeping in most developing countries constraint the assessment of the intensity of adoption of divisible technology. In fact, adoption is a process that takes place over space and time suggesting one theory may not adequately capture all the actions or processes involved. This suggests a conceptual structure on factors involved in adoption processes is necessary. Past studies identified factors extrinsic and intrinsic to adoption decisions. These variables are categorized here into farm and farmer specific characteristics, institution and community factors, perceptions of improved technology attributes, risk preferences and spatial dependence.

Risk Preferences and Spatial Dependence

Decisions to adopt improved agricultural innovation are linked with the risk and uncertainty associated with its potential benefits (Hiebert, 1974; Feder, 1982; Feder, 1980). Advances in the literature suggest that most farmers in developing countries are risk averse (Harrison, *et al.,* 2010; Tanaka, *et al.,* 2010); and that such risk aversion causes low adoption rates (Liu, 2013), Ward and Singh, 2015). Some notable findings include Knight, *et al.,* (2003) who reported a negative relationship between risk aversion and adoption rates in Ethiopia while Engle-Warnick, *et al.,* (2007) affirmed ambiguity aversion reduces the propensity of adoption in Peru. Equally important is the study by Liu (2013) which revealed risk averse and loss averse farmers were late Bt cotton adopters in China; Liu and Huang (2013) conclude risk aversion reduces the adoption of pesticides in China while Ward and Singh (2015) show risk and loss aversion decrease willingness to adopt new rice technology in India. Despite the global view on the important of risk aversion, most adoption studies in Nigeria ignore this variable in their analyses (Saka & Lawal, 2009; Tiamiyu, *et al.,*, 2009; Adedeji, *et al*., 2013; Dontsop-Nguezet, *et al.*, 2013; Awotide *et al.,* 2013; Awotide, *et al.*, 2015). In brief, while some studies considered intrinsic factor like risk aversion others concentrate on neighbourhood effects.

Spatial issues are broad with some studies using distance to characterize spatial factor. For instance, distance to information negatively relate to timing of adoption (Lindner *et al.*, 1982; Lindner *et al.*, 1979). Recent studies which used contiguity approach reveal neighbours behave in similar ways in sickle adoption (Case, 1992), HYV adoption decisions (Holloway *et al.*, 2002), maize seed and fertilizer adoption (Krishnan & Patnam, 2014), organic farming adoption (Läpple & Kelley, 2015) and conservation tillage adoption (Tessema *et al.*, 2016). Notwithstanding, both spatial relationship and risk aversion have received independent attention in the literature. Both aspects are considered here by examining the spatial dependency in experimental risky decision making and used same as instrumental variable for unobserved factors.

Institutional and Community Factors

Institutional and community factors such as access to information from both formal and informal sources are equally important in adopting HYV. For instance, access to information positively impacted improved legume technology adoption in Tanzania and Ethiopia (Asfaw, *et al.,* 2012) while Kebede, *et al.,* (1990) reported the role of information in technology adoption in Ethiopia. Extension contact is an indispensable formal variable in adoption decisions (Nkonya *et al.*, 1997; Anley *et al.*, 2007). Farmers may rely on the information provided by extension agents to make their farm decisions. Where such contact exists, it is expected to have a significant positive effect on farms' decisions. However, limited access to extension services imply less or low effect on farmers' decisions. Limited extension services in many developing countries encourage farmers to rely on social networks as an alternative source of information. For example, social networks and learning were reportedly positively correlated with the diffusion of improved farm practices (Foster & Rosenzweig, 1995; Bandiera & Rasul, 2006). Social learning effects sway farmers' adoption processes as revealed by Bandiera and Rasul (2006) who reported farmers rely on information from family and friends in adopting improved sunflower in Northern Mozambique. In addition, Foster and Rosenzweig (1995) showed propensity to adopt HYV increases when farmers learn from their neighbours in India. Similarly, Conley and Udry (2010) revealed pineapple farmers learn from their neighbours in Ghana. In summary, villagers may have late information about HYV due to low access to information, partly attributable to poor road networks.

Of equal important are accessible road networks which aid access to information and market. Poor accessible road networks may negatively affect the probability of adopting HYV. Equally important is the locations where farmers live. To capture the heterogeneity in adoption decisions and control for the effects of locations, three dummies representing agricultural zones are included in the adoption model. It is therefore hypothesized that farmers living in low rainfall or dried agricultural zones are more likely to adopt HYV.

Farm and Farmer Specific Factors

Farmers' socio-economic factors have been shown to be correlated with adoption decisions in different contexts. Farm size is like a universal factor in adoption model (Feder, 1982, 1980; Feder & O'Mara, 1981; Just & Zilberman, 1983). Many empirical studies reported the positive effects of farm size on the propensity to adopt improved HYV (Nkonya, *et al.*, 1997; Alene, *et al.*, 2000; Anley, *et al.*,, 2007; Dadi, *et al.*, 2001; Davey & Furtan, 2008). We also include education, age and gender as explanatory variables. Empirical studies have shown education increases the propensity to adopt improved agricultural technologies (Mendola, 2007; Läpple, *et al.*, 2015; Anik & Salam, 2015; Hossain, *et al.*, 2006; Nkonya *et al.*, 1997). In addition, age has been reported to have a negative effect on the adoption of HYV (Läpple *et al.*, 2015; Baidu-Forson, 1999; Anley *et al.*, 2007). In other words, older farmers are more likely to be reticent to adopting new technologies. Male and female may have different responsibilities at home and farm as well as differing in allocation and investment decisions. Thus, both gender are actively involved in rice farming.

Household size and marital status are equally included as explanatory variables for adoption decisions. In most developing countries, farmers depend on family members for crop production. Thus more members mean more family labour. Large family size may constitute a push factor for a household head to taking risky investment decisions. Notwithstanding reported mixed results, farmers with large household size may show positive attitude towards the adoption of HYV in line with Ahmed (2015) and Alene *et al.* (2000). Moreover, married farmers may have more family members compared to single farmers suggesting married rice farmers are more likely to adopt HYV.

The practitioners of the two dominant religions, Christianity and Islam in the study area are not equally likely in decision making. Indeed, due to political influence, religion plays a significant role in the access to information and thus influences farm decisions. Limited studies however included religion in their study (Liu (2013). The type of rice production system (upland, lowland or both) engaged in by farmers is also hypothesized to have a significant effect on their adoption decisions. Put differently, the weather condition under which farmers produce rice may be a push factor for taking risky decisions. Therefore, farmers growing upland rice are expected to be more likely to adopt HYV.

Perceptions of Improved Technology Attributes

Farmers' perceptions of the attributes of HYV may significantly influence their adoption decisions (Kallas, Serra, & Gil, 2010). Typical examples are found in Mehar, *et al.*, (2015) who reported male farmers have strong preference for high yield and marketable traits in India. The attributes considered in our adoption model include high yield, short duration, long stem and good tiller in line with past studies who reported positive effects of these attributes on the propensity to adopt HYV (Adesina & Zinnah, 1993; Adesina & Baidu-Forson, 1995).

3. Data and Models

First in this session we present the source of data, followed by the analytical procedures.

3.1 Source of Data

This study utilizes experimental and survey data[2]. Rice farmers were sampled from over 46 rice growing locations across the 4 agricultural zones in Ogun State Agricultural Development Programme (OGADEP), Nigeria between March and May, 2016. We used two smart android phones with the aid of open data kit (ODK collect). This aids the recording of the GPS coordinates[3]. We employ the assistance of 3 post-graduate students, trained shortly before the commencement of the survey on how to use the ODK collect. Moreover, useful information on the main rice growing locations was collected from the OGADEP office. On some occasions, we were accompanied by extension agents who guided on rice growing locations. Farmers were individually interviewed at home and farms (homes are generally close to the farms due to the labour intensive nature of rice production). A total number of 329 rice farmers were interviewed but 328 fully completed the questionnaire.

The risk experiment was conducted first followed by questions on the socio-economic factors. Subjects were presented with the panel lotteries starting from panel 1 to panel 4 of SG1. Each subject was shown with a bag containing 10 mixed blue and red balls which respectively represent the winning and losing probability in the experiment. Other sequence follows the presentation of panels 1 to 4 of SG2, LG1, LG2, respectively.

3.2 The Empirical Models

Adoption decisions have been previously modeled using different approaches. The choice of the model is motivated by data and context. A good number of studies apply two stage models such as Tobit (Nkonya *et al.*, 1997; Alene *et al.*, 2000; Fufa & Hassan, 2006), Heckman selection model (Dadi *et al.*, 2001) and double hurdle model (Tambo & Abdoulaye, 2012; Anik & Salam, 2015). Survival/duration model (Fuglie & Kascak, 2001; Liu, 2013), multivariate probit (Ahmed, 2015), bivariate probit (Neill & Lee, 2001) and three-stage

---

[2] The panel lotteries used are presented in the appendix. The panel lotteries have 4 treatments each with the nomenclature small gain one (SG1), small gain two (SG2), large gain one (LG1) and large gain two (LG2). Each treatment has 4 panels each, thus the name panel lotteries. These panel lotteries capture the heterogeneity in risk attitudes.

[3] Notwithstanding the poor or absence of mobile networks in most visited villages, the locations of each sampled farmer were manually recorded. This record was later used to obtain the coordinates from the website: http://www.mapcoordinates.net/en.

estimation method (Saha, *et al.,* 1994) have also been adopted. Whereas a binary model is an appropriate approach when a decision maker faces a situation of two technology options, two-stage procedure is preferred when one or more variable(s) is suspected endogenous in a model. We test this assumption of endogenous risk preferences in adoption decisions. Hence, an instrumental variable probit (IV probit hereafter) model is applied. Rice farmers with greater social networks may be well informed showing positive or negative attitudes towards adopting HYV. Since such spatially determined conditions are typically unobserved, we incorporate spatial dependency in the analysis to account for unobserved heterogeneity in the data. This heterogeneity is defined in the spatial weights matrix.

3.2.1 The Spatial Weights Matrix

The distance between rice farmers was estimated from the GPS coordinates. This distance in kilometres is used in the power weights matrix (Equation 1)[4]. Most studies standardized the row of the weights matrix, $\boldsymbol{W}$ for easy interpretation by first converting the diagonal elements of the weights matrix to zero, then the matrix with zero diagonal elements is divided by the vector matrix, the sum of each row (Case, 1992; Holloway *et al.*, 2002; Läpple & Kelley, 2015). Row standardization may increase the links between observations especially those with few neighbours. However, this practice is useful for binary weights matrix. Here, only the diagonal elements of the weights matrix are set to zero to prevent self-neighbour.

$$\boldsymbol{W}_{ij} = exp\left(-{d_{ij}}^2/s^2\right) \tag{1}$$

Where $d_{ij}$is the distance between farmers in locations i and j, s is the cut-off distance that tests the dependency limit between farmers. The cut-off distances tested include 10km, 20km, 30km, 40km and 60km.

3.2.2 Probit Model with a Continuous Endogenous Covariate

The risk variable may not be accurately measured yet some variables (environmental, climatic, topographic and socio-economic) may not be adequately accounted for in the adoption model. To address this endogenous problem, we incorporate the spatial lag of the risk attitudes as instrument for latent variables in the adoption model (Equations 2 and 3). The model specification is adapted from Wooldridge (2002).

---

[4] Distance based power weights matrix has many advantages. First, unlike the binary contiguity method, neighbours may have different weights. Second, more weights are attached to shorter distance implying the closer the neighbours the more the influence.

$$\boldsymbol{Y_1} = \boldsymbol{X}\alpha + \rho \boldsymbol{W}\boldsymbol{Y}_1 + \nu \tag{2}$$

$$y_2^* = \boldsymbol{Y}_1\beta + \boldsymbol{X}\gamma + \varepsilon \tag{3}$$

Where $\boldsymbol{Y}_1 = N\ X\ 1$ vector of endogenous variable, an index of willingness to risk taking (risk avoidance)[5] defined as the average probability values corresponding to farmers' choices in each treatment of the panel lotteries. This ranges between 0.1 and 1. An index of 1 indicates highly risk avoidance. $\boldsymbol{X} = N\ X\ K$ is a vector of exogenous variables in the adoption decisions model. $\boldsymbol{W}\boldsymbol{Y_1} = N\ X\ 1$,is the vector of the instrumental variable (spatial lag of the risk variable). This represents the weighted average of the risk attitudes in the neighbourhood locations. The ρ is a scalar parameter that determines the correlation between willingness to risk taking by a rice farmer and the adjusted-by-distance mean risk willingness of his neighbours. $\boldsymbol{W}$ is the $N \times N$ weights matrix defined in Equation 1. Lastly, $\rho\boldsymbol{W}\boldsymbol{Y}$ suggests the utility derived by rice farmer from the risk experiment is related to that derived by his neighbours'. y_2^* represents adoption decisions. Since y_2^* is not observed, Equation 4 applies:

$$y_2 = \begin{cases} 0, & y_2^* < 0 \\ 1, & y_2^* \geq 0 \end{cases} \tag{4}$$

The error terms are assumed to be jointly and normally distributed, $(\varepsilon, \nu) \sim N(0, \boldsymbol{\delta_i})$ with the first element of the error matrix normalized to one to identify the model. $\beta = N\ X\ 1$ is a vector of parameter corresponding to the predicted value of the first stage model. γ is the vector of structural parameters in the second stage model while α is the vector of the parameters of the first stage model. A significant correlation between the disturbance errors of the two models suggests relationship. The order condition for the identification of the structural parameters is that the number of variables in the risk model is greater than or equal to that of the adoption model. In addition to the spatial lag as instrumental variable, other variables in the adoption model are treated as being exogenous and instruments to exactly identifies the model. Table 1 summarizes the statistics of the variables considered in the adoption model.

---

[5] Risk avoidance is preferred in this study in place of risk aversion because the parameter of the utility function is not estimated, given the nature of our risk lotteries. Willingness to risk taking is equally used interchangeably with risk avoidance because risk preference may be viewed as the extent to which individuals are willing to take risk.

Table 1Table 2

Definitions of the Variables used in the Adoption Decisions Model

Variables	Definition	Min	Max	Mean	SD
Adoption	1 if rice farmer grows HYV, 0 otherwise	0.00	1.00	0.09	
Age	Years	20.00	80.00	47.00	12.50
Education	Years of formal schooling	0.00	16.00	4.60	4.50
Religion	1 for Christians, 0 otherwise	0.00	1.00	0.56	
Household size	Numbers of current household members	1.00	21.00	6.00	3.00
Farm size	Size of land cultivated to rice in hectares	0.20	16.00	1.90	1.50
Male	1 if male, 0 otherwise	0.00	1.00	0.68	
Married	1 if married, 0 otherwise	0.00	1.00	0.94	
Upland	1 if upland production system, 0 otherwise	0.00	1.00	0.87	
High yield	Perception of importance of high yield	1.00	5.00	4.20	1.00
Long stem	Perception of importance of long stem	1.00	5.00	3.60	1.00
Short duration	Perception of importance of short production cycle	1.00	5.00	3.80	1.00
Good tiller	Perception of importance of good tiller	1.00	5.00	3.40	1.00
Friends	1 If rice farmers rely on friends and neighbours for information, 0 otherwise	0.00	1.00	0.68	
Extension contact	Number of contact with extension agents per year	0.00	7.00	2.30	1.00
Bad road	1 if rice farmers reside in less accessible road network areas, 0 otherwise.	0.00	1.00	0.37	
Ikenne	1 for Ikenne zone, 0 otherwise	0.00	1.00	0.26	
Ilaro	1 for Ilaro zone, 0 otherwise	0.00	1.00	0.19	
Ijebu-Ode	1 for Ijebu-Ode zone, 0 otherwise.	0.00	1.00	0.27	
Abeokuta	Reference zone	0.00	1.00	0.28	
SG1	Small gain one probability index	0.10	1.00	0.80	0.15
SG2	Small gain two probability index	0.10	1.00	0.60	0.13
LG1	Large gain one probability index	0.10	1.00	0.70	0.15
LG2	Large gain two probability index	0.10	1.00	0.60	0.16

Note: perception questions are measured on 5 scales ranging from not at all important (1), somewhat important (2), important (3), very important (4) and extremely important (5)

4. Results and Discussion

Four models were estimated with respect to the four risk treatments since the inclusion of the spatial lag prevents pooled estimations. The results corresponding to the limit of spatial dependence (60 km) are presented in Table 2. We accept the hypothesis of endogenous risk preferences. Significant correlation between the standard errors of the risk and adoption models confirms dependency. Thus the models are better estimated in two stages. The key finding is presented first.

Table 2:
Effect of Risk Preference on Adoption Decisions

Variables	1	2	3	4
Risk Preference				
Risk avoidance	-7.6850***	-8.3689***	-7.9113***	-9.0092***
	(0.6742)	(0.6266)	(0.5321)	(0.6605)
Farmers Specific Factors				
Age	-0.0015	-0.0059	-0.0076	-0.0001
	(0.0096)	(0.0065)	(0.0072)	(0.0072)
Education	0.0617	0.0167	0.0204	0.0389
	(0.0432)	(0.0328)	(0.0292)	(0.0277)
Christian	-0.0746	0.0159	-0.4742***	0.0152
	(0.1685)	(0.1477)	(0.1468)	(0.1568)
Household size	-0.0215	0.0013	-0.0098	-0.0253
	(0.0378)	(0.0303)	(0.0308)	(0.0396)
Farm size	0.0154	0.0537	-0.0317	0.0527
	(0.0854)	(0.0649)	(0.0560)	(0.0702)
Male	-0.7156*	-0.4016	-0.4286*	-0.4332
	(0.3951)	(0.2916)	(0.2588)	(0.2734)
Married	0.1114	-0.0237	0.3880	0.1929
	(0.4254)	(0.3691)	(0.4050)	(0.3540)
Upland rice	0.0700	0.2017	-0.1145	0.0170
	(0.2838)	(0.2531)	(0.3192)	(0.3305)
Agricultural Zones				
Ikenne	-0.6433	-0.5309	-0.3852	-0.6016
	(0.8489)	(0.7992)	(0.6478)	(0.6505)
Ijebu-Ode	-0.0702	-0.3789	-0.2292	-0.6240**
	(0.5618)	(0.4570)	(0.3383)	(0.2923)
Ilaro	0.9992***	0.6164***	1.0188***	1.7128***
	(0.2994)	(0.2256)	(0.2461)	(0.2237)
Community and Institutional Factors				
Extension contact	0.0360	-0.0098	0.0593***	0.0265
	(0.0277)	(0.0244)	(0.0221)	(0.0249)
Friends	-0.2479	-0.2209	0.1403	0.2188
	(0.2298)	(0.1869)	(0.1752)	(0.1805)
Perceptions about Technology attributes				
High yield	0.3092***	0.1341	0.2633**	0.0714
	(0.1119)	(0.0973)	(0.1095)	(0.1056)
Long stem	-0.1595	-0.1697	-0.1347	0.0572
	(0.1562)	(0.1213)	(0.1230)	(0.1211)
Short duration	-0.4060	-0.2981	-0.2999*	-0.5558***
	(0.2685)	(0.2051)	(0.1571)	(0.1564)
Good tiller	-0.3940*	-0.2468	-0.2823*	-0.3040**
	(0.2315)	(0.1832)	(0.1510)	(0.1497)
Constant	6.7752***	6.5916***	6.5119***	6.0872***
	(1.8807)	(1.6713)	(1.4339)	(1.5361)
Tests of Correlation of Errors				
Corr. (SE2 and SE1)	0.9626***	0.9877**	0.9878***	0.9922***
Sigma (SE1)	0.1275***	0.1219***	0.1313***	0.1281***

1, 2, 3 and 4 relates to models SG1, SG2, SG3 and SG4, respectively

Diagnostic statistics: Model 1: Wald test of exogeneity (correlation = 0): Chi squares (1) = 10.60, Prob > chi2 = 0.0011
Wald Chi2 (18) =219.59, Prob > chi2 = 0.000
Model 2: Wald test of exogeneity (correlation = 0): Chi squares (1) = 12.00Prob > chi2 = 0.0003
Wald Chi2 (18) = 258.41, Prob > chi2 = 0.0000
Model 3: Wald test of exogeneity (correlation = 0): Chi squares (1) = 18.60, Prob > chi2 = 0.0000
Wald Chi2 (18) = 375.74, Prob > chi2 = 0.0000
Model 4: Wald test of exogeneity (correlation = 0): Chi squares (1) = 21.42, Prob > chi2 = 0.0000
Wald Chi2 (18) = 386.02, Prob > Chi2 = 0.0000

Note: SE2 = standard error of the adoption model, SE1 = standard error of the risk model, Sigma = standard error of risk model, SE = Standard Error, Corr. = correlation, Figures in the parentheses are the SE. *, **, *** implies coefficients are significant at 10%, 5%, and 1%, respectively. Number of Observations (N=328)

The results presented in Table 2 reveal that risk avoidance decreases the propensity to adopt HYV. This result evidently supports the relationship between real-life decisions (adoption and experimental risk). On one hand, it agrees with the previously expressed views that neighbours influence one another in the adoption processes (Case, 1992; Holloway *et al.*, 2002; Holloway, *et al.,* 2007; Läpple & Kelley, 2015). On the other hand, it affirms the negative effects of risk aversion in adopting improved agricultural technology (Marra *et al.*, 2003; Liu, 2013; Ward & Singh, 2014; Barham *et al.*, 2014; Barham *et al.*, 2015; Ward & Singh, 2015). Farmers who are strongly unwilling to take risky decisions are less likely to adopt HYV relative to those with strong willingness to risk taking.

A highly risky technology may offer more yield and income to farmers yet aversion to risk may reduce adoption propensity. Thus, risk loving farmers are likely to be early adopters or allocate larger proportion of their farm size to improved farm technologies while those who avoid risk are likely to lag behind. Nonetheless, acceptance of innovation is not a direct process as they may be complicated with many factors. Risk aversion has been identified as one of such factors. In brief, risk avoidant farmers may base their decisions on the yield evidence of innovation in the field of others suggesting spatial heterogeneity.

The result suggests adoption decisions are not only influenced by risky decisions of a farmer but also his neighbours' confirming the existence of social networks and other unobserved spatially correlated conditions such as climatic and environmental variables. Indeed, rice farmers living very closely interact with one another. Such interaction effects may manifest in adoption decisions and patterns. Put differently, farmers living closely may influence one another while making risky investment decisions. Social interaction effects, in addition to other spatial factors are proxy by spatial dependence implying similar patterns of adoption are observed among rice farmers.

As shown in Table 2, Christians are less likely to adopt HYV relative to the practitioners of other religions which may align with previously expressed views that religious farmers are risk averse (Liu, 2013; Liebenehm & Waibel, 2014). Since religion relates to belief, it may affect individuals' perceptions as well as resource allocation or production and investment decisions. Thus it provides information on the risk taking ability inherent in the norms, values and politics.

The analysis of the economic policy is not complete if gender issues are ignored. In our result, the probability of adopting HYV decreases for males relative to females. Although it is contrary to the previously expressed views but agrees with Davey & Furtan (2008). Many reasons may be adduce to this finding. First, male farmers, on average, cultivate more land and earn more income from rice production than female farmers. Again, higher tendency to diversify income generating activities may reduce the propensity of adopting HYV as research suggests wealthy individuals are less averse to risk taking (Wik, *et al.*, 2004; Yesuf, 2004; Yesuf & Bluffstone, 2009; Tanaka *et al.*, 2010; Liu, 2013; Liebenehm & Waibel, 2014). Second it could be linked to the peculiarity of the rice production enterprise which is labour intensive. Third, female headed households may be under financial pressure and thus more innovative and willing to undertake new investment relative to their male counterparts. Furthermore, male farmers may be strongly bias towards status quo relative to their female counterparts. Lastly, males may be cautious of losing the 'sure' output or yield from the traditional varieties than their female counterparts. Therefore, the desire to increase farm income by female farmers may constitute push factor for the adoption of risky innovation.

The results indicate rice farmers located in Ikenne and Ijebu-Ode agricultural zones are less likely to adopt HYV while farmers living in Ilaro agricultural zone are more likely to adopt HYV relative to farmers living in Abeokuta zone. Variability in climatic environment is one possibility for this pattern of behaviour. Farmers living in the drier Ilaro zone have higher propensity to adopt HYV due largely to the stress-tolerance and drought resistant nature of HYV. As shown in the significant coefficients, the trend propensity for adoption follows Ilaro, Abeokuta, Ikenne and Ijebu-Ode zones, respectively. It also reveals farmers residing in the low rainfall zone prefer HYV suitable for their climate as those in the low land areas (Ijebu-Ode zone) are least likely to adopt HYV. Overall, geographical proximity explains the observed adoption patterns among farmers.

Access to information and infrastructure is another reason farmers may behave heterogeneously across locations. In line with Kebede *et al.* (1990), rice farmers living in the rural agricultural zones or remote areas may have less access to information compared to urban dwellers. Rural areas generally lack access to infrastructural facilities such as accessible roads and schools which limit access to information. This is in agreement with previous findings that farmers in rural areas are resource poor and often less willing to take risky decisions (Wik *et al.*, 2004; Yesuf & Bluffstone, 2009; Lawrance, 1991). In summary, access to information may influence the decisions to adopt or otherwise.

As shown in Table 2, access to extension services has positive and significant effect on the adoption of HYV. This is consistent with previous findings which reported a positive and significant effect of extension contact on the adoption of improved agricultural technology (Moser & Barrett, 2006; Polson & Spencer, 1991; Oladele, 2006; Alene *et al.*, 2000). Farmers often rely on the information provided by extension agents to make informed farm production and investment decisions. However, low extension service is one of the major challenges confronting farmers in developing countries. This limits access to information and subsequently investment in improved agricultural innovation.

The characteristics of improved rice seeds such as high yield, long stem and short duration have been previously reported as one of the key factors influencing farmers' adoption decisions. With the exception of high yield, the results indicate that rice farmers who highly ranked HYV attributes such as long stem, shorter growing cycle and good tiller important are less likely to adopt HYV. This is contrary to previous findings (Adesina & Zinnah, 1993; Adesina & Baidu-Forson, 1995; Kallas, *et al.*, 2010). It however, agrees with Mehar, *et al.*, (2015) who found strong preference for high yield and marketable traits. One plausible reason is the fact that even though these attributes were perceived important, a sizeable proportion of rice farmers did not grow HYV partly because of high preference for a local delicacy, OFADA rice. However, rice farmers perceived high yield as important attribute in their choice of HYV as shown in the coefficient of this variable. It could be argued that among various attributes, yield is perceived most important which is not surprising since higher yield implies more income. Again, most agricultural technologies are developed central to producing more output per hectare of land to appeal to farmers' judgment and acceptance. It can therefore be submitted that farmers attached more importance to high yield relative to other attributes due largely to the desire to obtaining higher yield and subsequently more income without increasing farm land.

5. Conclusions

We provide insight into the correlation between real life decisions (experimental risk and adoption). Spatial heterogeneity is an attribute of socio-economic, geographical, ecological and climatic characteristics inherent in farmers' locations. These attributes may extend beyond the boundaries of the existing land divisions suggesting wrong policy may be applied if the existence of spatial dependence or the endogenous problem in adoption model is ignored. Evidence of spatial dependency in risk taking suggests some unobservable factors within farmers' locations may constitute a driving force for risky decisions among farmers. Identifying such factors will aid policy at ensuring the acceptance of agricultural technological innovation. The following policy options emerged from the finding.

First, heterogeneity in adoption decisions indicates rural farmers deserve specific research attention. Since farmers located in the low rainfall zone are more willing to take risky decisions relative to those residing in urban agricultural zone, provision of infrastructural facilities like accessible roads will not only aid farming practices in the rural areas but also encourage the diffusion of technological innovation. Second, correlation between the spatial dependence and risk preferences points to social learning effects. Since farmers do not live in isolation, policy on HYV adoption and diffusion could be targeted at farmers' neighbours in addition to identifying the unobservable factors that drive their decisions. It follows that interpersonal communication and social interaction could be used as effective tool for the diffusion of agricultural innovation especially in the rural areas which lack educational facilities. Third, risk aversion is an important driver of farmers' adoption decisions. Thus, farmers' ability to taking risky decisions could be a useful tool for managing background risk. In conclusion, in developing agricultural technological innovation for farmers' acceptance, specific attention should not only be given to farmers' individual factors but also group attributes. Further research should focus on the identification of the unobservable factors that influence farmers' decision making processes.

References

Abedullah, Kouser, S., & Qaim, M. 'Bt Cotton, Pesticide Use and Environmental Efficiency in Pakistan', *Journal of Agricultural Economics,* Vol. 66, (2015) pp. 66-86.

Adedeji, T., Nosiru, M., Akinsulu, A., Ewebiyi, I., Abiona, B., & Jimoh, T. 'Adoption of New Rice for Africa (NERICA) technology in Ogun State, Nigeria', *Journal of Development and Agricultural Economics,* Vol. 5, (2013) pp. 365-371.

Adesina, A. A., & Baidu-Forson, J. 'Farmers' perceptions and adoption of new agricultural technology: evidence from analysis in Burkina Faso and Guinea, West Africa', *Agricultural Economics,* Vol. 13, (1995) pp. 1-9.

Adesina, A. A., & Zinnah, M. M. 'Technology characteristics, farmers' perceptions and adoption decisions: A Tobit model application in Sierra Leone', *Agricultural Economics,* Vol. 9, (1993) pp. 297-311.

Ahmed, M. H. 'Adoption of multiple agricultural technologies in maize production of the Central Rift Valley of Ethiopia', *Studies in Agricultural Economics,* Vol. 117, (2015) pp. 162-168.

Alene, A. D., Poonyth, D., & Hassan, R. M. 'Determinants of adoption and intensity of use of improved maize varieties in the Central Highlands of Ethiopia: A Tobit analysis', *Agrekon,* Vol. 39, (2000) pp. 633-643.

Anik, A. R., & Salam, M. A. 'Determinants of adoption of improved onion variety in Bangladesh', *Journal of Agriculture and Environment for International Development (JAEID),* Vol. 109, (2015) pp. 71-88.

Anley, Y., Bogale, A., & Haile-Gabriel, A. 'Adoption decision and use intensity of soil and water conservation measures by smallholder subsistence farmers in Dedo district, Western Ethiopia', *Land Degradation & Development,* Vol. 18, (2007) pp. 289-302.

Asfaw, S., Shiferaw, B., Simtowe, F., & Lipper, L. 'Impact of modern agricultural technologies on smallholder welfare: Evidence from Tanzania and Ethiopia', *Food Policy,* Vol. 37, (2012) pp. 283-295.

Awotide, B. A., Awoyemi, T. T., Salman, K. K. and Alene, A. D. 'Impact of seed voucher system on income inequality and income per hectare among rural households in Nigeria: A randomized control trial (RCT) approach', *Quarterly Journal of International Agriculture,* Vol. 52, (2013) pp. 95-117.

Awotide, B. A., Alene, A. D., Abdoulaye, T., & Manyong, V. M. 'Impact of agricultural technology adoption on asset ownership: the case of improved cassava varieties in Nigeria, *Food Security,* Vol. 7, (2015) pp. 1239-1258.

Baidu-Forson, J. 'Factors influencing adoption of land-enhancing technology in the Sahel: lessons from a case study in Niger', *Agricultural Economics,* Vol. 20, (1999) pp. 231-239.

Bandiera, O., & Rasul, I. 'Social networks and technology adoption in northern Mozambique', *The Economic Journal,* Vol. 116, (2006) pp. 869-902.

Barham, B. L., Chavas, J.-P., Fitz, D., Ríos-Salas, V., & Schechter, L. 'Risk, learning, and technology adoption', *Agricultural Economics,* Vol. 46, (2015) pp. 11-24.

Barham, B. L., Chavas, J.-P., Fitz, D., Salas, V. R., & Schechter, L. 'The roles of risk and ambiguity in technology adoption', *Journal of Economic Behavior & Organization,* Vol. 97, (2014) pp. 204-218.

Barrett, C. B. (2010). Measuring food insecurity. *Science, 327*(5967), 825-828.

Becerril, J., & Abdulai, A. 'The impact of improved maize varieties on poverty in Mexico: a propensity score-matching approach', *World Development,* Vol. 38, (2010) pp. 1024-1035.

Benirschka, M., & Binkley, J. K. 'Land price volatility in a geographically dispersed market', *American Journal of Agricultural Economics,* Vol.76, (1994) pp. 185-195.

Bockstael, N. E. Modeling economics and ecology: the importance of a spatial perspective', *American Journal of Agricultural Economics,* Vol. 78, (1996) pp. 1168-1180.

Case, A. 'Neighborhood influence and technological change', *Regional Science and Urban Economics,*Vol. 22, (1992) pp. 491-508.

Conley, T. G., & Udry, C. R. 'Learning about a new technology: Pineapple in Ghana', *The American Economic Review,* Vol. 100, (2010) pp. 35-69.

Dadi, L., Burton, M., & Ozanne, A. 'Adoption and intensity of fertiliser and herbicide use in the Central Highlands of Ethiopia' *Agrekon,* Vol. 40, (2001) pp. 316-333.

Dar, W. D., & Laxmipathi Gowda, C. L. 'Declining agricultural productivity and global food security' *Journal of Crop Improvement,* Vol. 27, (2013) pp. 242-254.

Davey, K. A., & Furtan, W. H. 'Factors that affect the adoption decision of conservation tillage in the prairie region of Canada' *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie,* Vol. 56, (2008) pp. 257-275.

Development and Cooperation. 'Food Security: Productivity Boost, 2012. Available at: https://www.dandc.eu/en/article/africas-agricultural-productivity-must-rise (Last accessed 12 November 2017)

Dontsop Nguezet, P. M., Diagne, A., Okoruwa, O. V., Ojehomon, V., & Manyong, V. 'Estimating the actual and potential adoption rates and determinants of NERICA Rice Varieties in Nigeria', *Journal of Crop Improvement*, Vol. 27, (2013) pp. 561-585.

Dontsop Nguezet, P. M., Diagne, A., Okoruwa, O. V., Ojehomon, V. 'Impact of improved rice technology adoption (NERICA varieties) on income and poverty among rice farming households in Nigeria: a local average treatment effect (LATE) approach', *Quarterly Journal of International Agriculture*, Vol. 50 (2011) pp. 267-291.

Engle-Warnick, J., Escobal, J., & Laszlo, S. 'Ambiguity aversion as a predictor of technology choice: Experimental evidence from Peru, *Scientific Series.* Centre interuniversitaire de recherche (CIRANO)-Scientific Publications, January, 2007. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1077656 (Last accessed 23 January 2019).

Feder, G. 'Farm size, risk aversion and the adoption of new technology under uncertainty', *Oxford Economic Papers*, Vol. 32, (1980) pp. 263-283.

Feder, G. 'Adoption of interrelated agricultural innovations: Complementarity and the impacts of risk, scale, and credit', *American Journal of Agricultural Economics,* Vol. 64, (1982) pp. 94-101.

Feder, G., Just, R. E., & Zilberman, D. 'Adoption of agricultural innovations in developing countries: A survey', *Economic development and cultural change,* Vol. 33, (1985) pp. 255-298.

Feder, G., & O'Mara, G. T. 'Farm size and the diffusion of green revolution technology. *Economic development and cultural change,* Vol. 30, (1981) pp. 59-76.

Foster, A. D., & Rosenzweig, M. R. 'Learning by doing and learning from others: Human capital and technical change in agriculture', *Journal of Political economy,* Vol. 103, (1995) pp. 1176-1209.

Foster, A. D., & Rosenzweig, M. R. Microeconomics of technology adoption. *Annual Review of Economics,* Vol. 2, (2010) pp. 395-424.

Fufa, B., & Hassan, R. M. 'Determinants of fertilizer use on maize in Eastern Ethiopia: A weighted endogenous sampling analysis of the extent and intensity of adoption', *Agrekon,* Vol. 45, (2006) pp. 38-49.

Fuglie, K. O., & Kascak, C. A. 'Adoption and diffusion of natural-resource-conserving agricultural technology', *Review of Agricultural Economics*, Vol. 23, (2001) pp. 386-403.

Godfray, H. C. J., Beddington, J. R., Crute, l., Haddad, L., Lawrence, D., Muir, J. F., . . . Toulmin, C. Food Security: The Challenge of Feeding 9 Billion People', *Science,* Vol. 327, (2010) pp. 812-818.

Harrison, G. W., Humphrey, S. J., & Verschoor, A. 'Choice under uncertainty: evidence from Ethiopia, India and Uganda', *The Economic Journal,* Vol. 120, (2010) pp. 80-104.

Hiebert, L. D. 'Risk, learning, and the adoption of fertilizer responsive seed varieties', *American Journal of Agricultural Economics,* Vol. 56, (1974) pp. 764-768.

Holloway, G., Lapar, M., & Lucila, A. 'How big is your neighbourhood? Spatial implications of market participation among Filipino smallholders', *Journal of Agricultural Economics,* Vol. 58, (2007) pp. 37-60.

Holloway, G., Shankar, B., & Rahmanb, S. 'Bayesian spatial probit estimation: a primer and an application to HYV rice adoption', *Agricultural Economics,* Vol. 27, (2002) pp. 383-402.

Hossain, M., Bose, M. L., & Mustafi, B. A. 'Adoption and productivity impact of modern rice varieties in Bangladesh', *The Developing Economies*, Vol. 44, (2006) pp. 149-166.

Just, R. E., & Zilberman, D. 'Stochastic structure, farm size and technology adoption in developing agriculture', *Oxford Economic Papers,* Vol. 35, (1983) pp. 307-328.

Kallas, Z., Serra, T., & Gil, J. M. 'Farmers' objectives as determinants of organic farming adoption: the case of Catalonian vineyard production', *Agricultural Economics,* Vol. 41, (2010) pp. 409-423.

Kassie, M., Shiferaw, B., & Muricho, G. 'Agricultural technology, crop income, and poverty alleviation in Uganda', *World Development*, Vol. 39, (2011) pp. 1784-1795.

Kebede, Y., Gunjal, K., & Coffin, G. 'Adoption of new technologies in Ethiopian agriculture: the case of Tegulet-Bulga district Shoa province', *Agricultural Economics,* Vol. 4, (1990) pp. 27-43.

Kijima, Y., Otsuka, K., & Sserunkuuma, D. 'Assessing the impact of NERICA on income and poverty in central and western Uganda', *Agricultural Economics,* Vol. 38, (2008) pp. 327-337.

Knight, J., Weir, S., & Woldehanna, T. 'The role of education in facilitating risk-taking and innovation in agriculture', *The Journal of Development Studies,* Vol. 39, (2003) pp. 1-22.

Krishnan, P., & Patnam, M. 'Neighbors and Extension Agents in Ethiopia: Who Matters More for Technology Adoption? *American Journal of Agricultural Economics,* Vol. 96, (2014) pp. 308-327.

Läpple, D., & Kelley, H. 'Spatial dependence in the adoption of organic drystock farming in Ireland', *European Review of Agricultural Economics,* Vol. 42, (2015) pp. 315-337.

Läpple, D., Renwick, A., & Thorne, F. 'Measuring and understanding the drivers of agricultural innovation: Evidence from Ireland', *Food policy,* Vol. 51, (2015) pp. 1-8.

Lawrance, E. C. 'Poverty and the rate of time preference: evidence from panel data', *Journal of Political economy,* Vol. 99, (1991) pp. 54-77.

Liebenehm, S., & Waibel, H. 'Simultaneous Estimation of Risk and Time Preferences among Small-scale Cattle Farmers in West Africa', *American Journal of Agricultural Economics,* Vol. 96, (2014) pp. 1420-1438.

Lindner, R., Fischer, A., & Pardey, P. 'The time to adoption', *Economics Letters*, Vol. 2, (1979) pp. 187-190.

Lindner, R. K., Pardey, P. G., & Jarrett, F. G. 'Distance to information source and the time lag to early adoption of trace element fertilisers', *Australian Journal of Agricultural Economics*, Vol. 26, (1982) pp. 98-113.

Liu, E. M. 'Time to change what to sow: Risk preferences and technology adoption decisions of cotton farmers in China', *Review of Economics and Statistics,* Vol. 95, (2013) pp. 1386-1403.

Liu, E. M., & Huang, J. 'Risk preferences and pesticide use by cotton farmers in China', *Journal of Development Economics,* Vol. 103, (2013) pp. 202-215.

Mainuddin, M., & Kirby, M. 'Agricultural productivity in the lower Mekong Basin: trends and future prospects for food security', *Food Security,* Vol. 1, (2009) pp. 71-82.

Marra, M., Pannell, D. J., & Abadi Ghadim, A. K. 'The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: where are we on the learning curve? *Agricultural Systems,* Vol. 75, (2003) pp. 215-234.

Mehar, M., Yamano, T., & Panda, A. 'Role of gender, risk and time preference in influencing rice variety selection decision in eastern India', Research Gate, Uploaded August 11, 2015.

Mendola, M. 'Agricultural technology adoption and poverty reduction: A propensity-score matching analysis for rural Bangladesh', *Food policy,* Vol. 32, (2007) pp. 372-393.

Moser, C. M., & Barrett, C. B. 'The complex dynamics of smallholder technology adoption: the case of SRI in Madagascar', *Agricultural Economics,* Vol. 35, (2006) pp. 373-388.

Neill, S. P., & Lee, D. R. 'Explaining the adoption and disadoption of sustainable agriculture: the case of cover crops in northern Honduras. *Economic development and cultural change,* Vol. 49, (2001) pp. 793-820.

Nkonya, E., Schroeder, T., & Norman, D. 'Factors affecting adoption of improved maize seed and fertiliser in northern Tanzania', *Journal of Agricultural Economics,* Vol. 48, (1997) pp. 1-12.

Oladele, O. 'A Tobit analysis of propensity to discontinue adoption of agricultural technology among farmers in Southwestern Nigeria. *Journal of Central European Agriculture,* Vol. 6, (2006) pp. 249-254.

Polson, R. A., & Spencer, D. S. 'The technology adoption process in subsistence agriculture: The case of cassava in Southwestern Nigeria', *Agricultural Systems,* Vol. 36, (1991) pp. 65-78.

Rahman, S. (1999) 'Impact of technological change on income distribution and poverty in Bangladesh agriculture: an empirical analysis', *Journal of International Development,* Vol. 11, (1991) pp. 935-955.

Saha, A., Shumway, C. R., & Talpaz, H. 'Joint estimation of risk preference structure and technology using expo-power utility', *American Journal of Agricultural Economics,* Vol. 76, (1994) pp. 173-184.

Saka, J., & Lawal, B. 'Determinants of adoption and productivity of improved rice varieties in southwestern Nigeria', *African Journal of Biotechnology,* Vol. 8, (2009) pp. 4923-4932.

Saka, J., Okoruwa, V., Lawal, B., & Ajijola, S. 'Adoption of improved rice varieties among small-holder farmers in south-western Nigeria', *World Journal of Agricultural Sciences,* Vol. 1, (2005) pp. 42-49.

Sunding, D., & Zilberman, D. 'The agricultural innovation process: research and technology adoption in a changing agricultural sector', *Handbook of Agricultural Economics,* Vol. 1, (2001) pp. 207-261.

Tambo, J. A., & Abdoulaye, T. 'Climate change and agricultural technology adoption: the case of drought tolerant maize in rural Nigeria', *Mitigation and Adaptation Strategies for Global Change,* Vol. 17, (2012) pp. 277-292.

Tanaka, T., Camerer, C. F., & Nguyen, Q. 'Risk and time preferences: linking experimental and household survey data from Vietnam', *The American Economic Review,* Vol. 100, (2010) pp. 557-571.

Tessema, Y. M., Asafu-Adjaye, J., Kassie, M., & Mallawaarachchi, T. 'Do neighbours matter in technology adoption? The case of conservation tillage in northwest Ethiopia. *African Journal of Agricultural and Resource Economics-Afjare,* Vol. 11, (2016) pp. 211-225.

Tiamiyu, S., Akintola, J., & Rahji, M. 'Technology adoption and productivity difference among growers of new rice for Africa in Savanna Zone of Nigeria', *Tropicultura,* Vol. 27, (2009) pp. 193-197.

Tobler, W. R. 'A computer movie simulating urban growth in the Detroit region', *Economic Geography,* Vol. 46, (1970) pp. 234-240.

Udoh, J. E., & Omonona, T. B. 'Improved rice variety adoption and its welfare impact on rural farming households in Akwa Ibom State of Nigeria. *Journal of New Seeds,* Vol. 9, (2008) pp. 156-173.

Villano, R., Bravo-Ureta, B., Solis, D., & Fleming, E. 'Modern Rice Technologies and Productivity in the Philippines: Disentangling Technology from Managerial Gaps', *Journal of Agricultural Economics*, Vol. 66, (2015) pp. 129-154.

Ward, P. S., & Singh, V. 'Risk and Ambiguity Preferences and the Adoption of New Agricultural Technologies: Evidence from Field Experiment in Rural India', *Environmental and Production Technology Devision, International Food Policy Research Institute (IFPRI) Discussion Paper 01324* (February 2014).

Ward, P. S., & Singh, V. 'Using Field Experiments to Elicit Risk and Ambiguity Preferences: Behavioural Factors and the Adoption of New Agricultural Technologies in Rural India', *Journal of Development Studies,* Vol. 51, (2015) pp. 707-724.

Weiss, M. D. 'Precision farming and spatial economic analysis: Research challenges and opportunities', *American Journal of Agricultural Economics,* Vol. 78, (1996) pp. 1275-1280.

Wik, M., Aragie Kebede, T., Bergland, O., & Holden, S. T. 'On the measurement of risk aversion from experimental data', *Applied Economics,* Vol. 36, (2004) pp. 2443-2451.

Wooldridge, J. M. 'Econometric analysis of cross section and panel data', MIT Press, Cambridge, Massachusetts, London, England, (2002) pp 1-450.

Yesuf, M. 'Risk, time and land management under market imperfections: Applications to Ethiopia', *Economic Studies,* Department of Economics, School of Economics and Commercial Law, Goteborg University, Series 139, (2004) pp 111.

Yesuf, M., & Bluffstone, R. A. 'Poverty, risk aversion, and path dependence in low-income countries: Experimental evidence from Ethiopia', *American Journal of Agricultural Economics,* Vol. 91, (2009) pp. 1022-1037.

Appendix[6]

Table 3: Risk Panel Lotteries’ Payoffs

Panel Lotteries for Four Treatments (currency in Nigerian naira)

P	1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
					$Payoffs\ for\ SG1$					
Panel 1	225	251	282	322	376	451	563	751	1,126	2,251
Panel 2	225	251	282	322	376	451	564	753	1,129	2,259
Panel 3	225	251	283	324	379	455	570	762	1,145	2,295
Panel 4	225	252	284	326	382	460	578	774	1,165	2,340
					$Payoffs\ for\ SG2$					
Panel 1	0	26	57	97	151	226	338	526	901	2,026
Panel 2	0	26	57	97	151	226	339	528	904	2,034
Panel 3	0	26	58	99	154	230	345	537	920	2,070
Panel 4	0	27	59	101	157	235	353	549	940	2,115
					$Payoffs\ for\ LG1$					
Panel 1	22,500	25,002	28,128	32,148	37,507	45,010	56,265	75,024	112,540	225,090
Panel 2	22,500	25,012	28,150	32,186	37,567	45,100	56,400	75,234	112,900	225,900
Panel 3	22,500	25,056	28,250	32,358	37,834	45,500	57,000	76,167	114,500	229,500
Panel 4	22,500	25,112	28,375	32,572	38,167	46,000	57,750	77,334	116,500	234,000
					$Payoffs\ for\ LG2$					
Panel 1	0	2,502	5,628	9,648	15,007	22,510	33,765	52,524	90,040	202,590
Panel 2	0	2,512	5,650	9,686	15,067	22,600	33,900	52,734	90,400	203,400
Panel 3	0	2,556	5,750	9,858	15,334	23,000	34,500	53,667	92,000	207,000
Panel 4	0	2,612	5,875	10,072	15,667	23,500	35,250	54,834	94,000	211,500

Source: Authors’ Compilation, 2015

---

[6] These lotteries are presented to farmers using blue and red balls which explain the probabilities (p). Although the information in the above table is electronically coded as explained in the method, record sheets were shown to farmers to complement the technology and to guide subjects in making choices.