
# Examining the Role of Spatially-Dependent Time Preference in Improved Rice Technology Adoption Decisions

by Omotuyole Isiaka Ambali, Francisco Jose Areal, Nikolaos Georgantzis, and Zainab Oyetunde-Usman

# Examining the Role of Spatially-Dependent Time Preference in Improved Rice Technology Adoption Decisions

Omotuyole Isiaka Ambali[1], Francisco Jose Areal[1,2], Nikolaos Georgantzis[1,3] and Zainab Oyetunde-Usman[4]

**Contributed paper accepted for presentation at the 31 st International Conference of Agricultural Economists (ICAE 2021) organised by International Association of Agricultural Economists (IAAE), themed "Agriculture under the 4 th Industrial Revolution"**

**August 17-31, 2021, Online**

## Abstract

Genetically improved agricultural technology enhances yield, food security and sustainable development but farmers do not usually embrace such innovation due to many factors. This study examined the role of spatially-dependent time preference in farmers' decisions to adopt high-yielding rice varieties (HYV) in Nigeria using experimental and survey data collected in the 2016 production season. We employ instrumental probit estimation method to examine the spatial heterogeneity in risk preference and adoption decisions. The results show household size, gender, neighbours significantly determine decisions to adopt HYV. In addition, farmers living in the rural agricultural zone have a high propensity to adopt HYV. Instrumented by spatial dependence, impatience negatively affects farmers' decisions to grow HYV. The finding suggests both personal and group attributes drive farmers' adoption decisions in addition to unobserved environmental factors. The degree of heterogeneity in farmers' adoption patterns indicates climatic factors deserve special attention in the adoption processes to accelerate sustainable development.

***Keywords:*** adoption decisions, agricultural technology, impatience, rice farmers, spatial dependence, time preference

**JEL classifications: O1, O2, O3**

[1]Department of Applied Economics and Marketing, School of Agriculture, Policy and Development, University of Reading, RG6 6AR, United Kingdom
[2]Centre for Rural Economy, School of Natural and Environmental Science, University of Newcastle, Newcastle Upon Tyne and Near, NE1 7RU, United Kingdom
[3]School of Wine and Spirits Business, Burgundy School of Business, Dijon, 21000, France
[4]Department of Agric, Food and Marketing Economics, Natural Resources Institute, University of Greenwich, Chatham Maritime, ME4 4TB, United Kingdom

Omotuyole Isiaka Ambali acknowledges the financial support and funding received for this project from the Tertiary Education Trust Fund (TETFund) of Nigeria.

## 1. Introduction

Food insecurity is the topical problems affecting humanity in history, especially in developing countries where over 80 per cent of the food insured and undernourished reside (FAO, 2020). FAO (2020) report on the state of food security and nutrition estimated the population of moderate and severe food insecure people globally at 2 billion, out of which 1.03 billion (51.5%) are located in Asia, 675 million (33.8%) in Africa, 205 million (10%) in Latin America and the Caribbean, 88 million (4.4%) in North America and Europe and 5.9 million (0.3%) in Oceania. The debate on the food insecurity problem gain popularity following the Word Food Summit in the early 1970s. The global challenges to food insecurity include population growth, climate change and technological gaps especially in the agricultural sector. Thus, agricultural productivity growth has been identified as one of the solutions to food insecurity problem especially in developing countries where many households actively engaged in and depend on agriculture for livelihood. In fact, it was estimated that the livelihood of over two-third of the sub-Saharan Africa (SSA hereafter) population depend on rain-fed Agriculture which results in low yield and income (Ludi, 2009); improved agricultural technologies have a significant positive impact on income and welfare in developing countries (Becerril & Abdulai, 2010; Kassie, et al, 2011, Awotide, et al, 2016, Ayenew, et al, 2020) while agricultural growth is a solution to food insecurity problem in SSA (Godfray, et al. 2010). Given the economic importance of rice in the diet of over half of the world population and employment opportunities along the rice value chain, self-sufficiency in rice production in SSA and in particular, Nigeria is important to addressing some of the food insecurity challenges. Policies at addressing food insecurity challenges should be holistic and include behavioural perspectives to agricultural technological innovation.

FAO (2014) highlighted the challenges confronting the Nigerian crop sector to include lack of irrigation, low access to credit, high cost of farm inputs and low use of improved farm technologies. The National rice yield was estimated at 1.81 tonne per hectare, which is attributed to many factors including lack of irrigation facilities (FAO, 2015). The rice land area which was estimated at 3.7 million hectares constitutes about 10.6 per cent of the total cultivated arable land (35 million hectares) in Nigeria[1]. It suggests rice is an important food security crop in the country, not only in terms of production but also consumption and income generation. An estimated one-half of the world's population depends on rice for calories needed for productive activities; most of whom are located in Asia and Africa. While rice is a popular staple food consumed among households in Nigeria, its output and yield have grossly lagged behind average Africa and World values (Figure 1) suggesting the need to increase rice productivity to achieve self-sufficiency in production and enhance food security.

Most of the past agricultural development policies and programmes aimed primarily at increasing agricultural productivity in Nigeria achieve little success partly due to lack of adequate attention to farmers' intrinsic behavioural as well as environmental factors in policy formulation. In addition, most past policies are top-down driven which limits their effectiveness. Thus, it is imperative to examine both the intrinsic and extrinsic factors which may correlate with farmers' adoption decisions. In the light of the above, we broadly examine the correlation between real-life decisions (adoption and inter-temporal decisions) as well as providing valuable insights into some important variables such as spatial dependence which may guide efforts at ensuring the acceptance of

[1]Rice provides employment to millions of small-holder farmers who sell about 80 percent of their produce. However, about 77 percent of Nigeria rice area is rain-fed out of which 47 percent is lowland, 30 percent is upland. (Monitoring African Food and Agricultural Policies (MAFAP, 2015). Analysis of Incentives and Disincentives for Rice in Nigeria , July 2013. Retrieved from http://www.fao.org/3/a-at581e.pdf. Accessed 12/08/ 2015.

improved farm (rice) technologies in the developing countries. This is in line with Streletskaya et al (2020) who buttress that linkages between behavioural economics and agricultural technology adoption will provide guidance on policy relating to farm production decisions including acceptance of improved agricultural technological innovation.

Other factors limiting agricultural productivity growth in SSA include low extension services, imperfect financial markets, and low use of modern agricultural technology. Adoption of improved agricultural innovation is reportedly determined by social networks, risk and uncertainty (Foster and Rosenzweig, 2010, Maertens and Barrett, 2013). Socio-economic factors such as technology attributes, institutional and community factors, and preferences for a time also militate against the adoption of technological innovation. This study specifically focused on the effect of time preference and spatial variation in temporal decisions on rice farmers' adoption decisions as previous studies pay little or no attention to how intrinsic factors such as attitudes toward risk, ambiguity, and time affect adoption (Barham et al., 2014). Recent evidence from Ghana suggests risk preference, ambiguity aversion and liquidity constraints play important roles in smallholder farmers' insurance participation decisions (Ali et al., 2021), affirming both extrinsic and intrinsic factors are important for policy relating to economic decisions. Impatience and spatial dependence play an important role in the adoption of high-yielding rice varieties (HYV thereafter) and thus necessary for agricultural policy in Nigeria. Therefore, it is hypothesized that impatience or time preference spatially determined rice farmers' adoption decisions.

Time preference explains the tendency for an individual to prefer the present outcome over the delayed outcome (Frederick et al., 2002). It can also be viewed as a trade-off between short-time gain and long-time pain. Thus, an individual rice farmer may either be described as being patient or not. In other words, the decisions between two or more payoffs at different points in time determine the level of impatience. Such decisions have implications on different aspects of life including savings, investment, and health. For example, farmers may decide to grow HYV today based on the perceived future benefits or continue growing traditional varieties. Moreover, most farmers in developing countries lack access to productive resources like credit. Poor access to important productive inputs may cause temptation for immediate consumption or result in high subjective discount rates (Shively, 2001). Therefore, impatience may explain decisions to grow improved agricultural technology and subsequently determines farmers' level of income.

Behavioural studies in developing countries found farmers to be risk-averse and impatient (Tanaka et al., 2010; Liebenehm and Waibel, 2014). Poor farmers are equally reported to be risk averse and have high discount rates (Wik et al., 2004; Yesuf and Bluffstone, 2009). These attitudes may affect farmers' resource allocation behaviour, consumption, and utility function. A farmer who wishes to maximize expected utility should not only care about present income but also how to increase future income. How do farmers weigh future events that are associated with economic values? While future consumption optimizers may be more willing to adopt HYV, the *laissez-faire* and impatient farmers may be laggard. Moreover, since farming generally involves committing resources today with the expectation of reaping future benefits, risky production decisions, or uncertain decisions made today may be profitable in the future. In short, strong preferences for traditional seed varieties or status quo bias may imply less interest in HYV with a negative consequence on farmer's future income.

Measurement issues partly explain the reason for the omission of preferences for risk, time, and spatial dependence effects in the adoption model. Moreover, spatial factors like social and cultural norms, social networks, soil type, climatic and topographic conditions are often omitted in the adoption models due to difficulty in measurement (Ward and Pede, 2015). The omission of important variables constitutes an endogeneity problem. Farmers' adoption patterns may be a reflection of spatial dependency just like subjective discount rates may be spatially correlated. Thus, this study seeks to examine the heterogeneity in time preferences and adoption of improved agricultural technology to facilitate policy formulation in adoption decisions.

## 2. Research Methods

Decisions to adopt HYV may depend on farmers' level of awareness and unobserved variables suggesting the need to account for sample selection bias and endogeneity problems. An instrumental probit (IV probit hereafter) is considered in this study to test the hypotheses of endogenous time preference in adoption decisions. Given that most sampled rice farmers either grow HYV or traditional variety, the decision to adopt HYV is expressed in the framework of the discrete choice model. Hence, the spatial autoregressive model (SAR) is estimated in the first stage while the second stage involves estimation of the adoption decisions model. The instrumental variable (IV) method has long been used to address the potential endogenous problem in economic models. It is suspected that the unobserved adoption variables may be correlated with the time preference. It is therefore important to obtain the exogenous variation in farmers' adoption decisions. IV model requires an instrument to obtain a consistent estimate. Such an instrument must be significantly correlated with the endogenous variable but not with the error term. Thus, the spatial lag of the time preference is used as an instrument in the adoption model.

Rice farmers' subjective discount rate was estimated using a continuous exponential function, $F = Pe^{rt}$, $r = \left[log\left({}^{F}/_{P}\right)\right]/t$. $r$ is the subjective discount rate, $F$ is the future amount, $P$ is the payoff offers at present while $t$ is the time horizon. IV probit is then estimated as shown in equations 1 and 2. The spatial lag of the subjective discount rates is assumed proxies for social network, climatic and topographical conditions, as well as other unobserved socio-economic variables. The IV probit specification is adapted from Wooldridge (2002).

$$\mathbf{S}_1 = \boldsymbol{X}\alpha + \theta\boldsymbol{W}\boldsymbol{S}_1 + \mu \tag{1}$$

$$p_2^* = \boldsymbol{S}_1\omega + \boldsymbol{X}\gamma + \varepsilon \tag{2}$$

Where $\boldsymbol{S_1}$ is the $N\ X$ 1 vector of the subjective discount rates. $\boldsymbol{X}$ is the $N\ X\ K$ vector of exogenous variables hypothesize to explain adoption decisions, $\boldsymbol{WS_1}$ is the $N\ X$ 1 vector of the spatial lag of subjective discount rate. This is the weighted average of subjective discount rates in the neighbourhood locations. $\theta$ is a scalar parameter that determines the spatial dependency between the subjective discount rate of a rice farmer and the adjusted-by-distance mean discount rates of his neighbours. $\boldsymbol{W}$ is the $N\ X\ N$ weights matrix defined in Equation (4). $\theta\boldsymbol{WS}_1$ assumes that the utility of a farmer in the temporal decisions is related due to neighbourhood effect.

Equation 1 is structural with the dependent variable being continuous while Equation 2 is a reduced form, having a binary dependent variable. Therefore, $p_2^*$ represents unobserved HYV adoption decisions. The observed adoption decisions ($p_2$) are defined in Equation 3.

$$p_2 = \begin{cases} 0, \ and\ p_2^* < 0 \\ 1, \ and\ p_2^* \geq 0 \end{cases} \tag{3}$$

ω is $N\,X\,1$ vector of parameter corresponding to the predicted value of the first stage Equation, $\gamma$ is the vector of structural parameters in the second stage adoption model while $\alpha$ is the vector of the parameters of Equation 1. The error terms $(\varepsilon, \mu) \sim N(0, \boldsymbol{\delta_i})$. A significant correlation between the disturbance errors of the two models suggests that a strong relationship exists between Equations 1 and 2.

The distance between rice farmers is estimated from the latitude and longitude. This distance is used in the weights matrix defined using a power function of Equation (4)[2]. Row-standardized of $\boldsymbol{W}$ is more useful for binary contiguity. Thus, only the diagonal elements of the weights matrix are converted to zero to prevent self-neighbour.

$$\boldsymbol{W}_{ij} = exp\left(-{d_{ij}}^{2}/s^{2}\right) \qquad (4)$$

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 rice farmers.

***Source of Data***

The study applied primary data collected from rice farmers in over 46 rice growing locations across the 4 agricultural zones in Ogun State, Nigeria. The map of the study area is shown in **Figure 2**, showing the selected Local Government Areas where three hundred and twenty-nine (329) rice were sampled between March and May, 2016.

We adopted similar method to Tanaka and Munro (2014) to elicit farmers' time preferences. They were presented with two monetary plans (A and B) shown in **Table 1**:

The switching point in choices aids the estimation of the subjective discount rates for individual subject. The minimum and maximum payoffs in the time task are 2,000 and

[2]The advantages of distance based power weights matrix include different weights for neighbours and attachment of more weights to shorter distance. In addition, using equal number of neighbours may not be appropriate since the number of sampled rice farmers is not equal across locations.

18,000 (Naira), respectively. The minimum payoff is approximately equivalent to the labour wage rage in Nigeria at the time the experiment was conducted. The maximum payoff was presented to farmers to examine their level of impatience and test attitudes toward the future. This task was hypothetical due largely to logistics. It also prevented non-rice farmers from participating in the experiment.

The record sheet shown to farmers is depicted in **Figure 3**. This was shown to compliment the technology used in the survey to facilitate rice farmers in making their choices.

A total number of 329 rice farmers were interviewed during the survey with the assistance of three post-graduate students. Data were electronically recorded using an open data kit (ODK collect) with the aid of two smart android phones[3]. Extension agents accompanied the research team and provided useful information on rice growing locations. The variables included in the analyses are summarized in **Table 2**. Farmers growing any improved rice varieties are categorized as adopters. Most of the sampled farmers are impatient, young with a low level of formal education. The majority of the sampled farmers cultivated less than 2 hectares of land but perceived improved rice technology attributes important for adoption.

## 3. Results

The test of difference of mean in the subjective discount rate between adopters and non-adopters are presented in **Table 3**. The results indicate that the mean subjective discount rate of adopters is 18 per cent point lower and significantly different from than that of non-adopters. In other words, the variation is statistically difference from zero at one

[3]This technology aids the recording of the Geographical Point System (GPS) coordinates (latitude and longitude) of the rice farmers' locations and where bad network prevents recording of GPS, farmers' locations were used to obtain such information later.

per cent level. It suggests non-adopters are more impatient than their adopters' counterparts. The results of the test of difference of mean in the subjective discount rate between male and female farmers were also examined and revealed the subjective discount rates between the gender groups are significantly different from zero at one per cent level of significant. Put differently, the subjective discount rates of male farmers are 8 per cent point lower than that of their female farmers' counterparts. Given the gender representation in the sample, it can be concluded that male rice farmers are more patient than their female counterparts.

The descriptive statistics of the variables included in IV probit model are summarized in **Table 4**. Farmers growing improved rice varieties are categorized as adopters. Most of the sampled farmers are impatient (high discount rate), young (average age of 47 years) with low level of formal education (most of the sampled farmers did not complete primary school). In addition, the majority of the sampled farmers cultivated less than 2 hectares of land but perceived most of improved rice technology attributes important for adoption. The t-test and Chi-squared test show there is a degree of variation in some of the socio-economic variables between adopters and non-adopters of HYV.

The results of the IV probit model are presented in **Table 5**. The reported results relate to the limit of spatial dependence (60 km). The Wald statistics with a Chi-square value of 9.28 ($p < 0.023$) suggests the decision to reject the null hypothesis of no endogeneity. In other words, it confirms time preference is an endogenous determinant of rice farmers' adoption decisions. The correlation coefficient of 0.99 ($p < 0.016$) shows that the standard errors of the first-stage (time preference) and second-stage (adoption decision) models are significantly related. This suggests a binary probit might produce an inconsistent estimate.

Information on the degree of impatience or attitude towards inter-temporal decisions among individual rice farmers is important in economic because uncertainty is a time-variant. The results statistically show impatience (time preference) decreases the propensity to adopt HYV. This agrees with Le Cotty et al. (2017) who reported that impatience has negative effect on the adoption of fertilizer in Burkina Faso. It is also in line with Yesuf (2004) whose study showed the rate of time preference decreases the likelihood of adoption of land management technology. The result is also consistent with savings' and investments' studies (Ashraf et al., 2006; Bauer et al., 2012; Dupas and Robinsona, 2013). Additionally, spatial dependence is instrumental in the adoption of HYV confirming the importance of neighbourhood effects in the adoption of improved agricultural technological innovation.

Only the family size and gender significantly explained HYV adoption decisions among the farm and farmers' specific factors. The result suggests rice farmers with fewer household members are more likely to adopt HYV. This is contrary to previously reported findings (Ahmed, 2015; Alene et al., 2000). The reason may be attributed to the fact that most improved technologies are labour-saving. Furthermore, Male rice farmers are less likely to adopt HYV compared to females. This result supports the view expressed by Mehar et al., (2015) that female farmers based their decisions on cooking quality and stress-tolerance while males favoured high yielding and marketable traits.

Farmers who relied on information from friends and neighbours in social networks are less likely to adopt HYV. It can be deduced that most farmers are not currently growing improved rice varieties due partly to the fact that their neighbours are not growing them. This is evident by the reported low adoption rates in the study area. Lastly, farmers located in Ilaro agricultural zone are significantly more likely to adopt HYV compared to farmers living in the Abeokuta zone probably due to the low rainfall pattern of this agricultural zone.

## 4. Discussion

Rice farmers' adoption decisions are associated with some degree of uncertainty. Our results show that the propensity to adopt HYV reduces among impatient farmers compared to patient farmers which further confirm the level of uncertainty in the adoption of agricultural technological innovation. Uncertainty about the future and bias for the present may encourage present consumption among small-scale farmers especially in the developing countries where poverty and food insecurity are more prevalent. Moreover, most small-scale rice farmers largely depend on nature for production which makes their faith to hang in balance. Therefore, obtaining high yield and income is predicated on timely investment decisions as well as perception about the future benefit associated with present decisions. In this respect, patient rice farmers may be early adopters, with higher potential to cultivate more land compared to impatient farmers. Patient rice farmers may equally serve as a contact group for other farmers for emulation during development programme.

The spatial lag time preference is used an instrumental variable in our adoption model. This suggests a significant correlation between individual rice farmers' subjective discount rate and his neighbour's subjective discount rates adjusted by distance is a pointer to the existence of neighbourhood or social network effects which have direct consequences on rice farmers' HYV adoption decisions. It also implies farmers living closely influence the decisions of one another. Therefore, our result agree with many previous studies which reported significant neighbourhood influence in the adoption of improved agricultural technology (Wollni and Andersson, 2014; Tessema et al., 2016). It specifically aligned with Ward and Pede (2015) who observed neighbourhood effect in hybrid rice adoption decisions among Bangladesh farmers. Indeed, our results indicate neighbourhood effects are as important as interpersonal communication which may be used to facilitate the adoption of improved agricultural innovation.

The propensity to adopt HYV reduced with higher family numbers. Farmers often rely on family labour as a cheap source of production input, especially in the rural communities. Moreover, increasing awareness about the importance of formal education encourages most farmers to enrol their children in schools. It suggests rice production activities may be left in the hands of adult family members as well as engagement of rotatory and hire labour. Where farmers lack access to farm machinery as in the case in most developing countries, their overall farm output and farm productivity may not guarantee them the level of income required for subsistence. Hence, labour is an important factor of rice production which should attract the attention of policy makers.

Our result shows that the likelihood of adopting HYV reduced among males compared to females. Given the representative nature of our data, this result is robust and therefore important for rice production policy. Farmers' attitudes in agricultural production depend largely on the circumstances as well as their gender orientation. Gender determines the choice of occupation, educational attainment, business, and many more. Therefore, the observed gender differences in adoption decisions are rules rather than exceptions. In summary, rice farmers' decisions may be influenced by gender as well as other unobserved variables inherent in their respective farm locations.

The result indicates rice farmers' relying on information from friends and neighbours are less likely to adopt HYV. This result is contrary to expectation and past findings which reported the positive effects of social networks on adoption decisions (Conley and Udry, 2010; Maertens and Barrett, 2013). It is however plausible since the effects of social network on others may be positive or negative. The roles of social networking in the adoption process cannot be over-emphasized. For example, it is not uncommon to find farmers negatively influencing themselves on the adoption and diffusion of technological innovation. A typical example is the experimental trial approach or the use of contact farmers to experiment the yield advantage of improved seeds in seed programme. If the outcome proves to be better, other farmers will emulate and adopt such technology, otherwise, such technology would be completely rejected. In other words, farmers emulate good things from their peers. This means we can take advantage of positive networks where proven improved agricultural technology may be enhanced through farmers' friends and neighbours in many development programmes.

The propensity to adopt HYV is higher among farmers residing in Ilaro zone compared to those in Abeokuta zone. There are many possibilities for farmers in Ilaro zone to express more willingness to adopt improved rice varieties compared to those living in Abeokuta zone. First, the result may confirm the variation in the attitude to time and adoption among farmers residing in the rural and urban agricultural zones. Rural areas generally lack access to infrastructural facilities such as schools, accessible roads, hospitals, financial institutions, among other important formal institutions. This limits the economic potential of the rural dwellers since remoteness affects access to information and awareness. Second, agricultural zones may not only reflect access to information but also access to city markets. For instance, Neill and Lee (2001) reported that the probability of adopting cover crop technique reduces with distance from the road in Honduras. Furthermore, the result may reflect the climatic conditions of the existing agricultural zones. For example, Ilaro is the driest zone attributed to lower rainfall, followed by Abeokuta, Ikenne, and Ijebu-Ode, respectively. It suggests the importance of climatic conditions in the adoption process. Thus, variation in the weather and climate is not only important in the adoption of improved agricultural technological innovation but also key to mitigation effects of climate change.

## 5. Conclusion

HYV adoption rates are usually at a slower pace because farmers take time to adopt and diffuse new technology. This behaviour is attributable to many factors including risk and uncertainty. Uncertainty is a time-variant that affects investment decisions including the adoption of HYV. Farmers' attitude to time is however often omitted in many adoption studies. This study, therefore, tests the endogenous hypothesis of rice farmers' time preference in the adoption of HYV using experimental and survey data from Nigeria.

In addition to the socio-demographic variables, intrinsic factors are important in explaining the reasons for the adoption of HYV. It is empirically proven that a significant relationship exists between the level of impatience of a rice farmer and his neighbours. Furthermore, farmers living in the drier agricultural zone are more willing to adopt HYV compared to those living in the more climatically favourable zone. More importantly, impatience instrumented by spatial dependence reduces the propensity to adopt HYV. Thus, the misleading inference is eminence if spatial dependence is not controlled for in the adoption model. Spatial dependence effects are consequences of socio-economic, geographical, ecological, and climatic conditions of any location. These attributes may extend beyond the existing agricultural zones suggesting inappropriate policy may be applied if spatial dependence effects and time preference are ignored in the adoption model. The policy options from the findings include.

First, farmers located in the drier agricultural zone should be targeted and encouraged to adopt HYV to increase their productivity and income. Construction of access roads would not only aid farming practices in the rural areas but also encourage the diffusion of technological agricultural innovation. Second, policy intervention that will encourage the adoption and diffusion of HYV should not only be targeted at progressive farmers but also their neighbours. In other words, interpersonal communication and social networks can serve as effective tools for the diffusion of agricultural innovation.

Furthermore, identifying patient farmers and encouraging them to accept improved agricultural technology may partly solve the problems of low income and food insecurity in the agrarian economies like Nigeria. In conclusion, the evidence of spatial dependency in time preference *viz-a-viz* adoption suggests certain unobserved factors drive farmers' temporal and adoption decisions. Such drivers of farmers' decisions may aid policy in ensuring the acceptance of agricultural technological innovation. Are these factors climatic, social or economic, or combinations of many variables? Further research should focus on the identification and modelling of these unobserved factors.

**References**

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

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

Ali, W., Abdulai, A., Goetz, R., and Owusu, V. (2021). Risk, ambiguity and willingness to participate in crop insurance programs: Evidence from a field experiment. *Australian Journal of Agricultural and Resource Economics*, (Early View), https://doi.org/10.1111/1467-8489.12434.

Ashraf, N., Karlan, D., and Yin, W. (2006). Tying Odysseus to the mast: Evidence from a commitment savings product in the Philippines. *The Quarterly Journal of Economics* 121: 635-672.

Awotide, B. A., Karimov, A. A., and Diagne, A. (2016). Agricultural technology adoption, commercialization and smallholder rice farmers' welfare in rural Nigeria. *Agricultural and Food Economics,* 4: 1-24

Ayenew, W., Lakew, T., and Kristos, E. H. (2020). Agricultural technology adoption and its impact on smallholder farmers welfare in Ethiopia. *African Journal of Agricultural Research,* 15: 431-445.

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

Bauer, M., Chytilová, J., and Morduch, J. (2012). Behavioral foundations of microcredit: Experimental and survey evidence from rural India. *The American Economic Review* 102: 1118-1139.

Becerril, J., and Abdulai, A. (2010). The impact of improved maize varieties on poverty in Mexico: a propensity score-matching approach. *World Development, 38*(7), 1024-1035.

Conley, T. G., and Udry, C. R. (2010). Learning about a new technology: Pineapple in Ghana. *The American Economic Review* 100: 35-69.

Dupas, P., and Robinsona, J. (2013). Why don't the poor save more? Evidence from health savings experiments. *The American Economic Review* 103: 1138-1171.

FAO (2020). The State of Food Security and Nutrition in the World 2020: Transforming Food Systems for Affordable Healthy Diets. Assessed at www.fao.org, 31/01/ 2021.

FAO (2015). Rice Yield. Food and Agriculture Organisation of the United Nations, assessed at http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor, 13/04/2015.

FAO (2014). Nigeria at a Glance. Food and Agriculture Organisation of the United Nations, assessed at http://www.fao.org/nigeria/fao-in-nigeria/nigeria-at-a-glance/en/, 04/12/2017.

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

Frederick, S., Loewenstein, G., and O'donoghue, T. (2002). Time discounting and time preference: A critical review. *Journal of economic literature* 40: 351-401.

Godfray, H. C. J., Beddington, J. R., Crute, l., Haddad, L., Lawrence, D., Muir, J. F., . . . Toulmin, C. (2010). Food Security: The Challenge of Feeding 9 Billion People. *Science*, 327 (5967): 812-818.

Kassie, M., Shiferaw, B., & Muricho, G. (2011). Agricultural technology, crop income, and poverty alleviation in Uganda. *World Development*, 39 (10): 1784-1795.

Le Cotty, T., Maître d'Hôtel, E., Soubeyran, R., and Subervie, J. (2018). Linking risk aversion, time preference and fertiliser use in Burkina Faso. *The Journal of Development Studies* 54: 1991-2006.

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

Ludi, E. (2009). Climate Change, Water and Food Security. Overseas Development Institute (ODI), *Background Note*, March 2009.

Maertens, A., and Barrett, C. B. (2013). Measuring social networks' effects on agricultural technology adoption. *American Journal of Agricultural Economics* 95: 353-359.

Mehar, M., Yamano, T., and Panda, A. (2015). The role of gender, risk, and time preferences in farmers' rice variety selection in eastern India. *Asian Journal of Agriculture and Development* 14: 17-36.

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

Shively, G. E. (2001). Poverty, consumption risk, and soil conservation. *Journal of Development Economics* 65: 267-290.

Streletskaya, N. A., Bell, S. D., Kecinski, M., Li, T., Banerjee, S., Palm-Forster, L. H., and Pannell, D. (2020). Agricultural adoption and behavioural economics: Bridging the gap. Applied Economic Perspectives and Policy, 42: 54-66.

Tanaka, T., Camerer, C. F., and Nguyen, Q. (2010). Risk and time preferences: linking experimental and household survey data from Vietnam. *The American Economic Review,* 100: 557-571.

Tanaka, Y., and Munro, A. (2014). Regional Variation in Risk and Time Preferences: Evidence from a Large-scale Field Experiment in Rural Uganda. *Journal of African Economies* 23: 151-187.

Tessema, Y. M., Asafu-Adjaye, J., Kassie, M., and Mallawaarachchi, T. (2016). Do neighbours matter in technology adoption? The case of conservation tillage in northwest Ethiopia. *African Journal of Agricultural and Resource Economics-Afjare* 11: 211-225.

Ward, P. S., and Pede, V. O. (2015). Capturing social network effects in technology adoption: the spatial diffusion of hybrid rice in Bangladesh. *Australian Journal of Agricultural and Resource Economics* 59: 225-241.

Wik, M., Aragie Kebede, T., Bergland, O., and Holden, S. T. (2004). On the measurement of risk aversion from experimental data. *Applied Economics* 36: 2443-2451.

Wollni, M., and Andersson, C. (2014). Spatial patterns of organic agriculture adoption: Evidence from Honduras. *Ecological Economics* 97: 120-128.

Wooldridge, J. M. (ed.) (2002). Econometric analysis of cross-section and panel data. MIT press, Cambridge, London, England.

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

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

**Table 1: Time Preference Elicitation Payoffs**

| Row | Plan A | Plan B |
|---|---|---|
| **Series 1** | | |
| 1 | Receive 10,000 today | Receive 12,000 in 2 months |
| 2 | Receive 10,000 today | Receive 14,000 in 2 months |
| 3 | Receive 10,000 today | Receive 16,000 in 2 months |
| 4 | Receive 10,000 today | Receive 18,000 in 2 months |
| **Series 2** | | |
| 1 | Receive 8,000 today | Receive 18,000 in 2 months |
| 2 | Receive 6,000 today | Receive 18,000 in 2 months |
| 3 | Receive 4,000 today | Receive 18,000 in 2 months |
| 4 | Receive 2,000 today | Receive 18,000 in 2 months |
| **Series 3** | | |
| 1 | Receive 10,000 in 4 months | Receive 12,000 in 6 months |
| 2 | Receive 10,000 in 4 months | Receive 14,000 in 6 months |
| 3 | Receive 10,000 in 4 months | Receive 16,000 in 6 months |
| 4 | Receive 10,000 in 4 months | Receive 18,000 in 6 months |
| **Series 4** | | |
| 1 | Receive 8,000 in 4 months | Receive 18,000 in 6 months |
| 2 | Receive 6,000 in 4 months | Receive 18,000 in 6 months |
| 3 | Receive 4,000 in 4 months | Receive 18,000 in 6 months |
| 4 | Receive 2,000 in 4 months | Receive 18,000 in 6 months |
| **Series 5** | | |
| 1 | Receive 10,000 today | Receive 11,000 in 1 month |
| 2 | Receive 10,000 today | Receive 12,000 in 1 month |
| 3 | Receive 10,000 today | Receive 13,000 in 1 month |
| 4 | Receive 10,000 today | Receive 14,000 in 1 month |
| **Series 6** | | |
| 1 | Receive 9,000 today | Receive 14,000 in 1 month |
| 2 | Receive 8,000 today | Receive 14,000 in 1 month |
| 3 | Receive 7,000 today | Receive 14,000 in 1 month |
| 4 | Receive 5,000 today | Receive 14,000 in 1 month |
| **Series 7** | | |
| 1 | Receive 10,000 in 5 months | Receive 11,000 in 6 months |
| 2 | Receive 10,000 in 5 months | Receive 12,000 in 6 months |
| 3 | Receive 10,000 in 5 months | Receive 13,000 in 6 months |
| 4 | Receive 10,000 in 5 months | Receive 14,000 in 6 months |
| **Series 8** | | |
| 1 | Receive 9,000 in 5 months | Receive 14,000 in 6 months |
| 2 | Receive 8,000 in 5 months | Receive 14,000 in 6 months |
| 3 | Receive 7,000 in 5 months | Receive 14,000 in 6 months |
| 4 | Receive 5,000 in 5 months | Receive 14,000 in 6 months |

Source: Authors' Compilation

Note: Figures are in Naira

**Table 2: Definition of Variables and Descriptive Statistics**

| Variables | Definition |
|---|---|
| Adoption | 1= adopters of HYV, 0 otherwise |
| Impatience | High subjective discount rates (> = 0.49) |
| Age | Years |
| Education | Years of formal schooling |
| Religion | 1 = Christians, 0 otherwise |
| Household size | Numbers of current household members |
| Farm size | Size of land cultivated to rice in hectares |
| Male | 1 if male, 0 otherwise |
| Married | 1 if married, 0 otherwise |
| Upland | 1 if upland production system, 0 otherwise |
| High yield | Perceived importance of high yield |
| Long stem | Perceived importance of long stem |
| Short duration | Perceived importance of short production cycle |
| Good tiller | Perceived importance of good tiller |
| Friends | 1= reliance on friends and neighbours for information, 0 otherwise |
| Extension contact | Number of contact with extension agents per year |
| Bad road | 1 = those residing in less accessible road network areas, 0 otherwise. |
| Ikenne | 1 = Ikenne zone, 0 otherwise |
| Ilaro | 1= Ilaro zone, 0 otherwise |
| Ijebu-Ode | 1 = Ijebu-Ode zone, 0 otherwise. |
| Abeokuta | Reference zone |

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). N = 329

Source: Authors' Data Analysis

**Table 3: Subjective Discount Rates across Adoption Groups and Gender**

| Groups | Frequency | Mean | SD | Z-value | Degree of Freedom |
|---|---|---|---|---|---|
| Adopter | 30 | 0.41 | 0.038 | 5.6*** | 327 |
| Non-adopter | 299 | 0.50 | 0.083 | | |
| Male | 222 | 0.48 | 0.089 | 3.8*** | 327 |
| Female | 107 | 0.52 | 0.064 | | |

*** implies the z-values are statistically different from zero at one per cent level

Source: Authors' Data Analysis

**Table 4: Tests of Variation in Socio-economic Variables between Adopters and Non-adopters**

| Variables (Defined) | Total sample (Mean/Prop) | Adopters (Mean/Prop) | Non-adopters (Mean/Prop) | Mean difference | T/Chi-square Test |
|---|---|---|---|---|---|
| Adoption | | 30 (0.09) | 299 (0.91) | | |
| Impatience | 0.49 | 0.41 (0.07) | 0.50 (0.05) | -0.09 | -5.64*** |
| Age | 47 | 44.47 (1.81) | 47.21 (0.74) | -2.74 | -1.15 |
| Education | 4.6 | 5.73 (0.89) | 4.51 (0.26) | 1.22 | 1.43 |
| Religion | 0.56 | 16 (0.05) | 167 (0.51) | | 0.07 |
| Household size | 6.00 | 5.50 (0.51) | 5.94 (0.17) | -0.44 | -0.77 |
| Farm size | 1.90 | 2.25 (0.27) | 1.90 (0.09) | 0.35 | 1.21 |
| Male | 0.68 | 22 (0.07) | 200 (0.61) | | 0.52 |
| Married | 0.94 | 27 (0.08) | 282 (0.86) | | 0.89 |
| Upland | 0.87 | 19 (0.06) | 266 (0.81) | | 15.46*** |
| High yield | 4.20 | 2.40 (0.16) | 4.41 (0.04) | -2.01 | -13.44*** |
| Long stem | 3.60 | 2.03 (0.01) | 3.70 (0.06) | -1.67 | -8.69*** |
| Short duration | 3.80 | 1.80 (0.12) | 3.98 (0.06) | -2.18 | -11.99*** |
| Good tiller | 3.40 | 1.70 (0.13) | 3.59 (0.06) | -1.89 | -10.42*** |
| Friends | 0.68 | 23 (0.07) | 199 (0.61) | | 1.27 |
| Extension contact | 2.30 | 2.90 (0.60) | 2.30 (0.18) | 0.60 | 1.02 |
| Ikenne | 0.26 | 4 (0.01) | 83 (0.25) | | 2.92* |
| Ilaro | 0.19 | 9 (0.03) | 54 (0.16) | | 2.5 |
| Ijebu-Ode | 0.27 | 12 (0.04) | 76 (0.23) | | 2.96* |
| Abeokuta | 0.28 | 5 (0.02) | 86 (0.26) | | 1.99 |

Note: Figures in parentheses are standard errors for continuous variables. The frequencies and proportions are presented for categorical variables under adopters and non-adopters.

Source: Authors' Data Analysis

**Table 5: Effects of Impatience on Rice Farmers' HYV Adoption Decisions**

| Variables | Coefficients | SE | Z-value | P-value |
|---|---|---|---|---|
| **Time preference** | | | | |
| Impatience | -15.0322*** | 1.2664 | -11.87 | 0.000 |
| **Farm and Farmers' specific factors** | | | | |
| Age | 0.0081 | 0.0067 | 1.21 | 0.225 |
| Education | 0.0270 | 0.0309 | 0.87 | 0.382 |
| Christian | 0.1004 | 0.1489 | 0.67 | 0.5 |
| Household size | -0.0581* | 0.0340 | -1.71 | 0.088 |
| Farm size | 0.0023 | 0.0760 | 0.03 | 0.976 |
| Male | -0.6009** | 0.3014 | -1.99 | 0.046 |
| Married | 0.2571 | 0.3709 | 0.69 | 0.488 |
| Upland rice | 0.1553 | 0.2120 | 0.73 | 0.464 |
| **Locations/Agricultural zones** | | | | |
| Ikenne | -0.2302 | 0.5964 | -0.39 | 0.700 |
| Ijebu-Ode | 0.1711 | 0.3347 | 0.51 | 0.609 |
| Ilaro | 0.4138* | 0.2433 | 1.7 | 0.089 |
| **Institutional and Community Factors** | | | | |
| Extension contact | -0.0168 | 0.0223 | -0.75 | 0.450 |
| Friends and Neighbours | -0.5654*** | 0.2062 | -2.74 | 0.006 |
| **Perceptions about HYV attributes** | | | | |
| High yield | 0.0087 | 0.0840 | 0.1 | 0.918 |
| Long stem | -0.1244 | 0.1223 | -1.02 | 0.309 |
| Short duration | -0.0511 | 0.1965 | -0.26 | 0.795 |
| Good tiller | -0.0032 | 0.1926 | -0.02 | 0.987 |
| Constant | 7.1817 | 1.8378 | 3.91 | 0.000 |

Correlation between SE. of time preference and adoption model = 0.99 (sig=0.016), SE of time model = 0.072 (sig. = 0.004)
Wald Chi 2 (13) =306 (p< 0.38). Wald test of exogeneity (correlation = 0): Chi 2 (1) = 9.28 (p< 0.023)
Note: SE = standard error, ***, **, * implies coefficients are significantly different from zero at 1 percent, 5 percent, and 10 percent , respectively. Number of Observation (N = 329)

Source: Authors' Data Analysis

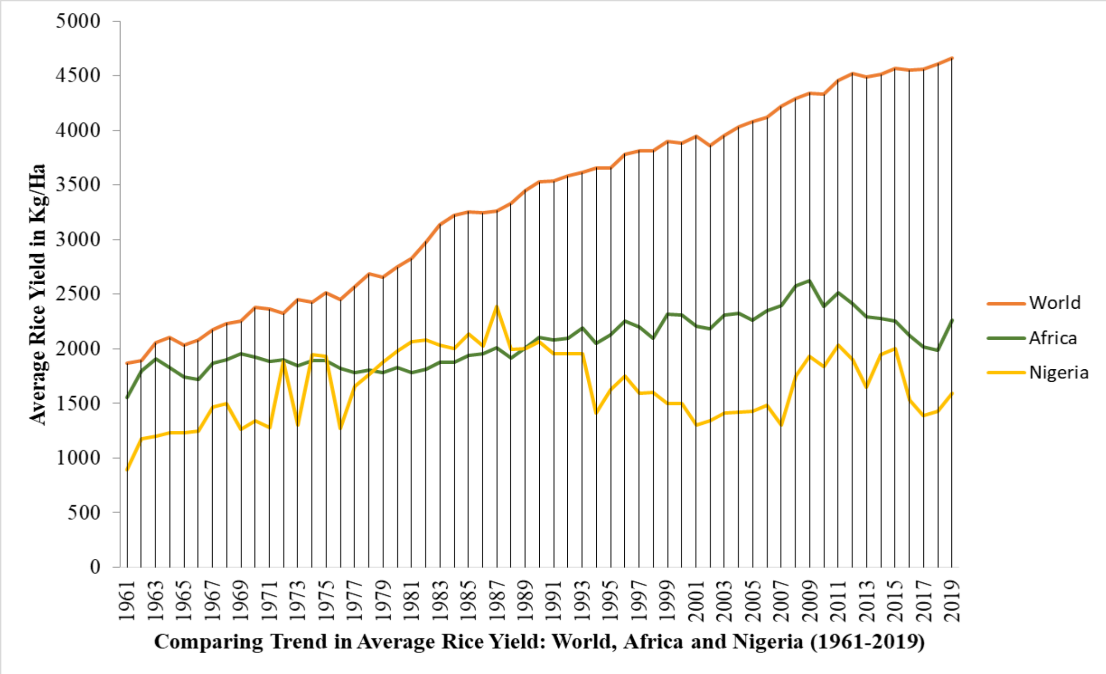


**Figure 1: Comparison of Rice Yield (Kg/ha) from 1961-2019**

Source: FAOSTAT

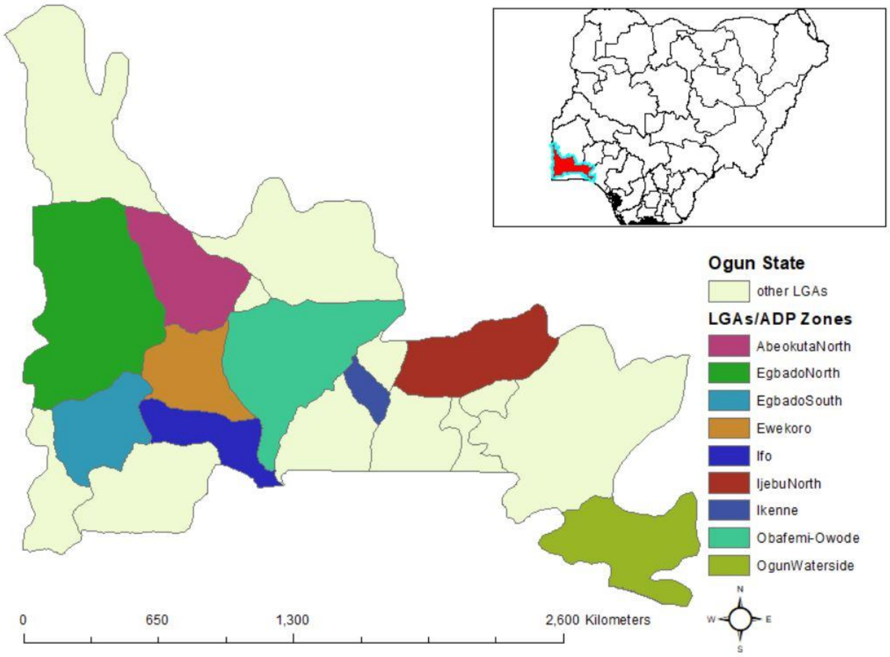


**Figure 2: Map of the Study Area**

Source: Authors' Design

SERIES 1

Row 1

| PLAN A (₦10,000 TODAY) | | | PLAN B (₦12,000 in 2 MONTHS) | | |
|---|---|---|---|---|---|
| x10 Today | 1 Month | 2 Months | Today | 1 Month | x12 2 Months |
| 3 Months | 4 Months | 5 Months | 3 Months | 4 Months | 5 Months |
| 6 Months | 7 Months | 8 Months | 6 Months | 7 Months | 8 Months |
| 9 Months | 10 Months | 11 Months | 9 Months | 10 Months | 11 Months |

TICK A ☐ OR TICK B ☐

Row 2

| PLAN A (₦10,000 TODAY) | | | PLAN B (₦14,000 in 2 MONTHS) | | |
|---|---|---|---|---|---|
| x10 Today | 1 Month | 2 Months | Today | 1 Month | x14 2 Months |
| 3 Months | 4 Months | 5 Months | 3 Months | 4 Months | 5 Months |
| 6 Months | 7 Months | 8 Months | 6 Months | 7 Months | 8 Months |
| 9 Months | 10 Months | 11 Months | 9 Months | 10 Months | 11 Months |

TICK A ☐ OR TICK B ☐

Row 3

| PLAN A (₦10,000 TODAY) | | | PLAN B (₦16,000 in 2 MONTHS) | | |
|---|---|---|---|---|---|
| x10 Today | 1 Month | 2 Months | Today | 1 Month | x16 2 Months |
| 3 Months | 4 Months | 5 Months | 3 Months | 4 Months | 5 Months |
| 6 Months | 7 Months | 8 Months | 6 Months | 7 Months | 8 Months |
| 9 Months | 10 Months | 11 Months | 9 Months | 10 Months | 11 Months |

TICK A ☐ OR TICK B ☐

Row 4

| PLAN A (₦10,000 TODAY) | | | PLAN B (₦18,000 in 2 MONTHS) | | |
|---|---|---|---|---|---|
| x10 Today | 1 Month | 2 Months | Today | 1 Month | x18 2 Months |
| 3 Months | 4 Months | 5 Months | 3 Months | 4 Months | 5 Months |
| 6 Months | 7 Months | 8 Months | 6 Months | 7 Months | 8 Months |
| 9 Months | 10 Months | 11 Months | 9 Months | 10 Months | 11 Months |

TICK A ☐ OR TICK B ☐

**Figure 3: Record Sheet for Series 1 of the Time Preference Experiment**

Source: Authors' Design