Using Farmers’ Risk Tolerance to Explain Variations in Adoption of Improved Rice Varieties in Nepal

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Abstract

Rice is the leading cereal crop in Nepal and an important source of calories and plant protein. Despite the importance of rice, there are reports of widespread cultivation of older varieties with considerably large adoption lags. This warrants further investigation into the factors that influence rice farmers' adoption decisions. Risk attitude is reported to be an important determinant of farmers' decisions. However, in Nepal, evidence of the effect of risk attitude on adoption of improved crop varieties is limited because this important factor is not considered in adoption studies. This paper therefore connects field experiment, theoretical understanding of farmers' risk attitudes and empirical models with the aim of investigating determinants of farmers adoption of improved rice varieties in Nepal. The results show that majority of farmers currently grow old varieties. The top four varieties - Sona-Mansuli, Sarju-52, Samba-Mansuli and Radha-4 have an average varietal release age of 27 years. By estimating a binary response regression model, this paper show that risk attitude is a significant determinant of rice farmers' adoption decision. Specifically, the result show that risk tolerant farmers have the lowest propensity to adopt new improved rice varieties. This paper therefore highlights the importance of promoting holistic benefits over making risk-reducing attributes salient when new crop varieties are developed and disseminated to farmers.

Keywords

Rice, adoption, new improved varieties, risk attitude, risk tolerance, Nepal

1. Introduction

Farmers' low level of adoption of new technologies in developing countries has been a long running concern. Several studies have shown that adoption rates of new technologies in these countries do not meet expectations (Ugochukwu and Phillips 2018, pp. 373). Despite the importance of rice to Nepal, there are reports of widespread cultivation of older varieties with considerably large adoption lags of about 12 years (Thapa, Kumar & Joshi, 2019, pp 1-628). One explanation for this outcome is that there are uncertainties with the payoff of adopting such technologies. The implication is that a decision maker (hereafter DM) may have little motivation to adopt a technology if the risk the DM perceives to be associated with the new technology is greater than the perceived benefit.

Empirical evidence in the agricultural technology adoption literature supports the assertion that risk attitude is an important determinant of farmers' adoption decision. On one hand, studies show that the likelihood of technology adoption increases as risk aversion increases. On the other hand, there are findings that risk averse farmers are less likely to adopt a new technology thus uncovering heterogeneity in risk attitudes. Crucially, evidence of the effect of risk attitude on the adoption of improved crop varieties in Nepal and across South Asia is limited as this factor is not given considerable attention in adoption studies.

Farmers frequently make decisions within the confines of uncertainties and risks thus, understanding risk attitudes is crucial to predicting farmers' adoption behaviour. The justifications for examining farmers' risk attitude as a determinant of adoption decision in this paper is from two perspectives. First, the introduction of new crop varieties is not without uncertainties and risks given that external factors such as weather and soil affect their performance. The implication is that for agricultural technologies clouded by uncertainties and risks, farmers' risk attitude will be pivotal in such adoption decisions. Second, farmers choose to adopt a new rice variety depending on whether their needs are addressed by the attributes of the improved variety. In this regard, attributes that may be beneficial for one farmer may be perceived as a shortfall by another farmer. Making these choices usually involves a trade-off as no single improved variety can address all the needs of farmers. For instance, many new improved rice varieties are developed for their attributes to withstand abiotic stress. However, under normal conditions the grain yield and quality are similar to the older improved varieties. Thus, it can be hypothesised that risk attitudes would be one of the major drivers of adoption decision.

The summary of results in this paper is that most farmers currently grow old varieties with the top four cultivated varieties being Sona-Mansuli, Sarju-52, Samba-Mansuli and Radha-4. Majority of farmers reported that they have never changed their varieties since they began growing it. Crucially, the results show that risk attitude is a statistically significant determinant of adoption decision. Specifically, more risk tolerant farmers are less likely to adopt new improved rice varieties. This finding is attributed to the fact that during dissemination, the salience of the stress tolerant potential of new improved rice varieties possibly masks some other desirable attributes. Thus, farmers that can tolerate risk may have less incentive to adopt such varieties.

2. Literature Review

In order to understand the background and set the context for this paper, this section reviews and discusses determinants of adoption decision, risk attitude as a driver of adoption and highlights the importance of rice for Nepal.

2.1 Empirical evidence of factors affecting farmers adoption decision

Several studies have identified significant determinants of adoption to include age, farm tenure, farm-size, labour, access to credit, neighbourhood and membership of association, information constraints, risk, household assets, training, contact with extension agents, input supply (see Fadare et al., 2014, pp 45-54, Witcombe, Khadka, Puri, Khanal, Sapkota & Joshi, 2017 pp 512-527, Sánchez-Toledano, et al., 2018, pp. 1–22, Ghimire, Wen-chi & Shrestha, 2015, pp. 35-43). Broadly, these determinants could be classified as farmer characteristics, farm structure and management, knowledge and information, and resources availability.

[Table 1 here]

Table 1 summarises previous findings on adoption of rice in Nepal. Joshi and Bauer (2006) find a positive effect of education on adoption while Ghimire and Huang (2016) and Budhathoki and Bhatta (2016) in different studies find that farm size has a positive effect on adoption of new rice varieties. In addition, Subedi and Subedi (1999) observed a negative relationship between extension visits and adoption while Khanal and Maharjan (2014) show that membership to farmers association increases the likelihood of Nepalese farmers' adopting new rice varieties. Other factors found to influence adoption of new rice varieties in Nepal are the attributes of the varieties (in Joshi & Bauer 2006, pp. 120-138), input prices, sources and availability (e.g. Witcombe et al. 2017, pp 512-527 and Khanal & Maharjan 2014, pp. 49-64). Notably, none of these studies investigated the effect of risk attitude despite the distinct role risk play in the process of adopting new agricultural technologies. Ward and Singh (2014) argues that omitting attitudes to risk from studies examining technology adoption could be a potential source of bias in the estimation.

A number of studies on technology adoption in developing countries highlighting research gaps and proposed suggestions to improve future adoption studies. For instance, Olum et al. (2018) highlighted the lack of studies that include psychological factors into their adoption models and emphasised the importance of risk aversion, risk awareness and risk perceptions to adoption decisions while Foster and Rosenzweig (2010) opined that one method to address the limited literature examining the role of risk as a barrier to adoption of new technologies in developing countries is to determine whether risk differentially affects households in the face of similar endowment.

2.2 Risk attitude as a determinant of adoption

Understanding the risks farmers face is important to understanding risk attitudes as a factor influencing adoption. In the broader literature, the main risks in agriculture is classified into five main groups. First, farmers face production risks arising from uncertain natural growth processes of crops including weather related factors and susceptibility to pests and diseases. In south Asia, rice is particularly prone to climatic hazards prevalent in the deltas. This is either in the form of frequent floods, droughts, and storm surges (Gupta & Seth, 2007). Rice cropping is particularly susceptible to losses following climate hazards (Masutomi et al., 2009; Duncan et al. 2017). For instance, the growth duration and pattern of rice is found to be highly affected by temperature changes such that 1 °C rise in temperature can results in approximately 10% decrease in rice yield (ADB, 2009). Second, farmers face price or market risks due to unpredictable changes in prices of both inputs and outputs. Alliot and Fechner (2018) findings suggest that rice farmers in Nepal typically bear the consequences of price volatility. Farmers' position at the bottom of the rice value chain means their negotiating power is weak invariably forcing them to be price takers. The third and fourth risks are financial and institutional risks resulting from uncertainties surrounding credit and government actions respectively. In Nepal, several studies (e.g. Joshi, Maharjan & Piya, 2011; Devkota, et al. 2018) have identified constrained access to formal finance as a risk which farmers constantly face. Fifth, farmers face human or personal risks arising from problems with their health or personal relationships. According to Kaan (1998), the most significant of these uncertainties are prices and yield variabilities which makes farmers perceive farming as a "lottery" since at the onset of the farming season there is no certainty of how much their efforts will pay off. This paper however focuses on production risks as its relationship with adoption of new improved rice varieties is more defined in the context of this paper.

There is empirical evidence that risk attitudes influence farmers decision to adopt agricultural technologies. According to Shimamoto, Yamada and Wakano (2014) risk-averse crop farmers mostly adopted new technologies in Cambodia. Similarly, Asravor (2019) find that the decision to diversify cropping was significantly dependent on risk aversion. Liu (2013) provide empirical evidence that confirmed that compared to those that are risk-seeking, risk-averse farmers were more likely to adopt agricultural innovation while Canales, Bergtold, Williams and Peterson (2015) find that risk aversion delayed the adoption of cover crops. These studies all together provide confirmation that in addition to farmers' specific variables, risk attitude is a significant determinants of technology adoption.

Further, findings from different studies suggest that risk attitude as a determinant of adoption decision is context specific. Barham, Chavas, Fitz, Salas and Schechter (2014) investigated the impacts of risk and ambiguity aversion on the adoption of genetically modified (GM) corn and soy seeds and find that while ambiguity aversion encourages adoption of GM corn it had no impact on GM soy. This finding by Barham et al (2014) provides support for the fact that adoption decision is driven by the attributes of the technology. Holden and Quiggin (2016) find similar behaviour among maize farmers for drought tolerant maize. However, these same group of risk averse farmers were less likely to adopt other improved maize varieties. This evidence of context specificity draws attention to the need for further research.

2.2.1 Eliciting risk attitude

Due to difficulties in directly observing risk attitudes, many empirical studies have adopted experimental approaches. These experimental methods have provided the platform to build deeper understanding of risk attitudes and link the findings with farm decision making. In the applied economics literature, three methods widely employed to elicit DMs risk attitudes are either the choice list procedure, the ranking procedure, and the allocation procedure. For the choice list method (as employed in Freeman, Halevy & Kneeland, 2019, pp. 217-237; Eckel & Grossman, 2002, pp. 281-295) a DM is presented with a sequence of pairwise choices set out in a list from which the DM chooses. As for the ranking procedure a DM is presented with a set of options and is requested to rank the options. The allocation procedure (as applied in Loomes & Pogrebna, 2014, pp. 569-593) is different from the other two methods as the DM is given a fixed amount of money and asked to allocate it in any manner of their choosing between different possible states. Other non-experimental methods employed in the literature is asking DMs to rate their risk tolerance on a scale (Dohmen, Falk, Huffman, Sunde, Schupp & Wagner, 2005, pp 1-59).

Experimental studies relied on either (or both) real and hypothetical monetary lotteries to elicit risk attitude. However, the findings are mixed as to whether real or hypothetical monetary rewards modulate risk taking and decision making in a similar way. On one hand studies such as Xu, Pan, Wang, Spaeth, Qu and Rao (2016) and Barreda-Tarrazona, Jaramillo-Gutiérrez, Navarro-Martínez and Sabater-Grande (2010) find differences in risk attitudes between both methods, other studies such as Wiseman and Levin (1996) and Gneezy, Imas and List (2015) did not find difference in the estimated parameters between real and hypothetical lottery tasks. The consensus however is that simple hypothetical questions can provide some insights into a DM's risk attitude. Reynaud and Couture (2012) opined that if the experiment based on voluntary participation then participants would show enough interest such that their responses would effectively reflect their real preferences. Drawing on these arguments, this paper relies on data obtained from an incentivised single choice list procedure discussed in section 3.

2.3 Adoption rate of rice varieties in Nepal

Due to agro-climatic variation across Nepal, there is very large diversity of both cultivated and wild relatives of rice. Past studies conjecture that there are over 2000 distinct landraces of cultivated rice, four wild Oryza species and two wild relatives spread across Nepal (Gupta, Upadhyay, & Katsumoto 1996; Rana, Garforth, Sthapit & Jarvis, 2007). According to Witcombe et al. (2017) the main varieties grown were Sona Mahsuri , Kanchhi Mansuli, Masuli, Radha-11, Sarjoo-52, Radha-4 and Sabitri most of which were released in 1970 and 1980's. Joshi (2003) cited by Joshi and Bauer (2006) reported that in Terai region 33 of the 48 new varieties are regarded as suitable for the growing under irrigated condition while five varieties were regarded as suitable for rainfed cultivation in Terai. This is closely followed by the hill where 18 new varieties have been adapted. However, for the upland ecosystem only a limited number (two varieties) have been developed and released.

Nepal's susceptibility to drought and flood also led the government and the Rice Research Institute (IRRI) to develop improved rice varieties as part of the Stress-Tolerant Rice for Africa and South Asia (STRASA). This resulted in the release of 11 stress-tolerant rice varieties (Gauchan et al., 2012). For instance, one of the varieties tolerant to various abiotic stresses, Swarna-Sub1 (IR05F102) possesses a single major quantitative trait locus (QTL) accountable for the crop's ability to tolerate submergence for up to 14 days. However, under normal conditions this variety does not outperform the older varieties in regard to agronomic attributes such as grain yield and quality (Sankar, Reddy, Sharma & Ismail, 2006; Septiningsih et al. 2008). Similarly, Malabayabas et al. (2015) also observed that while Swarna-Sub1 was more stress tolerant than the parent Swarna, however the average yield of Swarna-Sub1 was slightly lower than that of Swarna under normal conditions. The implication is that those farmers that adopt new varieties may lose the advantages they could otherwise derive from sticking to older improved varieties.

Further, Witcombe et al. (2017) findings suggest that rice diversity was low since only few rice varieties were predominant in large areas. For instance, they found that in in western districts as of 2011, nine varieties occupied a minimum of 75 per cent of the total rice area. Their finding also corroborated Gauchan et al. (2012) that most of the varieties were released *circa* 1990's confirming earlier studies of high average age of the predominant varieties irrespective of region or period considered.

Regarding varietal age, Gauchan et al. (2012) and Velasco et al. (2013) reported widespread cultivation of older varieties with considerably large adoption lags of about 12 year and varietal age of 18-20 years from recent studies in Nepal as well as other South Asian countries. The implication is that until approximately a decade after a variety is released will widespread adoption be observed. Older varieties also accounted for over 90 per cent of the seed sold (Gauchan et al. 2012). Despite the highlighted concerns, only a limited number of studies have investigated the reason for lags between varietal release and the initiation of adoption. One of few studies addressing such objectives is Witcombe et al. (2017). However, Witcombe et al. (2017) did not account for risk attitudes.

2.4 Importance of Rice for Nepal

From the perspective of area, production and livelihood, rice is the leading cereal crop in Nepal. It is grown in approximately 1.5 million hectares of land (MoADa, 2013). Approximately 40 per cent of Nepalese food calorie intake is obtained from rice (CDD, 2015) and it accounts for 20 per cent of protein from plant products in diet (Khanal & Maharjan, 2014, pp 49-64). Notably about two-thirds of agricultural households depend on rice for their livelihood (MoAD, 2013).

Although rice is grown across the different the ecological zones in Nepal, the share of rice area, production and yield varies by ecological zones as shown in Figure 1. The Terai (low land region) is by far the main rice producer with a production share of 73 per cent. The hills and mountain regions account for 24 per cent and 4 per cent respectively (Tripathi, Bhandari & Ladha, 2019). Regarding average yield potential by ecological zones, productivity in the mountains is about 1.7 to 2.0 t/ha, 1.6 to 2.3 t/ha in the hills and 1.6 - 2.9 t/ha in the Terai (Sharma, 2001).

[Figure 1 here]

The different agroecological zones have had varieties specifically adapted for them considering the major abiotic stresses that constrain rice production in Nepal (CDD, 2015). Approximately 15 and 30 per cent of the rice area are frequently liable to flash floods and drought respectively (ABPSD, 2012). In spite of some rice varieties superiority under stress, various reasons are adduced for not adopting newer varieties (see Gauchan et al., 2012). This paper postulates that should the unique trait be limited to risk-reducing traits such as stress tolerance then adoption will be determined mainly by the farmers' attitudes to risk.

3. Methodology

3.1 The Probit model

In order to determine the relationship between risk attitudes and decision to adopt new improved rice varieties, this paper estimates a probit regression model. This paper assumes an underlying economic theory that hinges on utility maximising framework. The postulation is that Nepalese rice farmers' act in a rational manner as such adopts new improved rice varieties when the anticipated utility from adopting is greater than that of not adopting.

Assuming U_a *and* U_b represent the level of utility a rice farmer derives from adopting new improved rice varieties and from not adopting new improved rice varieties respectively. The adoption decision is specified as:

$y_i = 1$ (farmer adopts new improved rice varieties)

$$if\ U_a > U_b$$

$y_i = 0$ (farmer does not adopt new improved rice varieties)

$$if\ U_a \leq U_b.$$

In this case, the utility function is specified as

$$U_{ij} = X_i\beta_j + \varepsilon_{ij} \qquad (1)$$

where U_{ij} refers to utility the farmer derives from adopting the new improved rice variety i.e. j=1, X is a vector of exogenous variables, β represents the coefficient of the vectors and ε the random error.

With respect to the choices the *ith* farmers face on whether or not to adopt the new improved rice varieties, the probit model is specified as

$$Y = F(\omega + \beta X_i) = Fz_i \qquad (2)$$

where Y and F represents the discrete adoption choice and the cumulative probability distribution function respectively. z is the z-score of the βX area under the normal curve. The expected value of the Y conditional on the independent variables in equation (2), is specified as

$$E[Y|X] = 0[1 - F(\beta'\text{X})] + [F(\beta'\text{X})] = F(\beta'\text{X}) \qquad (3)$$

where the marginal effect of the respective predictor variable on the probability that the *ith* farmer adopts the new improved rice varieties is specified as

$$\frac{\partial E[Y|X]}{\partial X} = \phi(\beta\text{X})\beta \qquad (4)$$

with the standard normal density function denoted by $\phi(\cdot)$ (Thuo et al. 2011; Fufa & Hassan, 2006). The choice of explanatory variables included in the estimated Probit model presented in Table 2 is guided by previous findings that have been discussed in section 2. The dependent variable was whether farmer currently adopts at least one new improved rice variety. This definition of adoption is adapted from Gebre et al. (2019) where farmers are referred to as adopters if they cultivate new improved varieties in all or some of their plots, which they grow either as a stand-alone crop or mixed with other varieties and regardless of the other crops these farmers grow in addition.

[Table 2 here]

3.2 Data

The analysis in this paper depends on data from the 2014 IRRI South Asia Rice Monitoring Survey (RMS-SA) household survey data implemented with support from the Bill and Melinda Gates Foundation (BMGF). The objective of collecting this data was to keep track of rice system that captures varietal turnovers over time. The sample comprised Nepalese 1471 farming households. The participant in the risk experiment were farm decision makers ranging from household head to spouse or parent. The field experiment used to obtain risk tolerance[3] involved offering farmers a choice between various payment options. Among the five choices presented to farmers, they were allowed to choose only one option in Table 3. Although the choices were hypothetical, the experiment was incentivised.

Farmers were informed that they would get actual payment in terms of mobile phone credit, so were advised to think carefully about their choice. At the end of the experiment, payment was determined by throwing a dice. Odd numbers in the dice resulted in the lower payoff while even numbers meant the larger payoff was given to the farmer. For example, if either 1, 3 or 5 showed on the face of the dice, a farmer that chose option 2 will be get Rs. 48 otherwise the farmer will get Rs. 64 worth of mobile phone credit.

The ‘lotteries’ were low-stake with the sure option approximately half of the daily agricultural wage. Considering that there is evidence (see Binswanger, 1980; Yesuf and Bluffstone, 2009) that DMs become increasingly risk averse with larger stakes, these small stakes will provide better reflection of real world financial decisions and a more realistic measure of risk aversion of Nepalese farmers.

The reliability of the modified Eckel and Grossman (2002) experiment used in this paper has been tested in developing country context. Compared to other popular experiments e.g. Holt, and Laury (2002) the procedure is easily understood by respondents with low numeracy skills. The predictive accuracy is also found to be good as it generates less noisy behaviour (see Dave, Eckel, Johnson and Rojas, 2010).

[Table 3 here]

4. Result and discussion

4.1 Farmer and farm characteristics

The result summarizing the socio-economic characteristics of farmers are presented in Table 4. Rice farmers in the sample are predominantly male. The results showed that the average household size is 8. The average age was 45 with respondents over the age of 40 accounting for the largest proportion i.e. approximately 60 per cent.

[Table 4 here]

With respect to farm tenure, those farmers that own their plots constituted 87 per cent of the sample. The proportion of farmers with some form of formal education (at least primary level education) was about 65 per cent. During previous growing seasons, respondents experienced some abiotic stress with 67 per cent reporting that they experienced drought compared to 23 per cent that experienced flooding. The number of days farmers had access to extension services in the previous 12 months varied between 0 and 35. The main source of seed for the season was either from open market or seed traders accounting for 50 per cent and 21 per cent respectively. The reasons adduced for patronizing the different seed sources was good quality by 43 per cent, trust by 27 per cent and convenience by 12 per cent of farmers.

Table 5 summarizes old and new improved of rice varieties[1, 2] in Nepal. This paper categorised new improved rice varieties as those varieties developed and released by research institutions after 1990.

[Table 5 here]

Within the categories of improved rice varieties, the oldest variety still grown by farmers in Nepal is Mansuli. On the other hand, Swarna Sub1 and Lalka Basmati were among the new improved varieties grown by farmers in the sample. Majority of farmers (52 percent) currently grow old-improved varieties. The top four varieties grown consist of two old-improved rice varieties i.e. Sona-Mansuli and Sarju-52 and two new improved rice varieties namely Samba-Mansuli and Radha 4) which jointly had an average varietal release age of 27 years.

[Figure 2 here]

Regarding adoption on new improved rice varieties, Figure 2 shows that 13 per cent are partial adopters as they jointly grow at least one new improved rice varieties in combination with old improved rice varieties, 4 per cent are combined adopters (they adopted more than one improved rice varieties) while 31 per cent are single adopters. However, 8 percent are dis-adopters as they had previously grown at least one improved rice varieties but replaced all of it with older rice varieties. The proportion of farmers that never changed their varieties irrespective of whether it is old or new improved rice was 66 per cent. Of the 34 per cent that changed their varieties, the main reasons reported for changing older varieties were ‘not satisfied with yield’, ‘wanted to try something new’ and ‘inconsistent production’.

In terms of desirable attributes, 47 per cent and 23 per cent of farmers identified ‘high yield’ and ‘good for cooking’ respectively as the main attributes that made them grow their current varieties. Regarding seed source, most farmers obtained their seeds from either seed traders which accounted for 21 per cent, market (48 per cent) and fellow farmer (23 per cent). The reasons for patronizing these different sources was reported as quality, trust and convenience accounting for 40, 39 and 14 per cent respectively.

[Figure 3 here]

Figure 3 presents the distribution of farmers risk tolerance based on their payment choices. The distribution shows the heterogeneity in risk tolerance of Nepalese rice farmers. 39 per cent picked option one suggesting that not all farmers are willing to take risk. 17 per cent chose option five which involved the highest risk. Overall, these statistics suggest that majority of farmers accounting for 61 per cent will tolerate some level of risk i.e. chose the 50:50 possibility of a lower or higher payoff over option one which have a fixed assured payoff. The expected values[4] of the choice tasks was 64, 72, 80, 88 and 96 for options one to five respectively. The implication is that despite having a chance of a higher payoff, extremely risk averse farmers will have higher preference for the assured payoff over the options with higher expected value.

4.2 Probit Regression Results

The Wald test was employed to test the hypothesis that at least one of the regression coefficients of the predictors is not equal to zero. The test indicates the overall significance of the probit model. Thus, the conclusions drawn in respect to the determinants of adoption are based on models of good statistical fit ($\chi^2 = 267.8$; df = 21; $p < .000$). As discussed in section 3 and presented in Table 2, the dependent variable in the Probit model estimated in this paper is whether or not the farmer adopted a new improved rice variety. In the Probit estimation presented in Table 6, risk attitudes, gender, and level of education are most strongly related with famers adoption decision.

[Table 6 here]

Specifically, risk attitude is found to be an important determinant of rice farmers' adoption decision. Being risk tolerant decreases the predicted probability of adopting new improved rice varieties. Compared to risk averse farmers, risk tolerant farmers are at least 17 per cent less likely to adopt new improved rice varieties. This finding is similar to Shimamoto, Yamada and Wakano (2018) that find that in Cambodia, risk averse rice farmers are more likely to adopt post-harvest agricultural technologies. The Wald tests performed to test the equality of various risk tolerance categories against each other show statistically significant difference. Thus, the equality hypothesis is rejected (at 10 per cent level for *Risk tolerance1 = Risk tolerance2* $\chi^2(1) = 2.99$, $p = 0.084$, 1 per cent for *Risk tolerance2 = Risk tolerance3* $\chi^2(1) = 14.10$, $p = 0.000$ and 1 per cent for *Risk tolerance3 = Risk tolerance4* $\chi^2(1) = 7.15$, $p = 0.008$).

The results also indicate that males were more likely to adopt new improved rice varieties than females. Findings that highlights gender differences in in management of farm resources and farm decision making are reported in previous research. There is consonance between this result and Ngokkuen and Grote (2012) that found significant difference between gender in the adoption of improved technologies among Thai farm households. Regarding household size, the results also indicate that larger households are less likely to adopt new improved rice variety. This corroborates Chandio and Jiang (2018) that found that the number of persons in a farming household is strongly associated with adoption decisions.

Age has a significantly *albeit* marginally positive effect on adoption decision. The positive sign on the coefficient of age indicates that the predicted probability of adoption of a new improved rice variety is greater among older farmers. This finding contradicts Ghimire, Wen-chi & Shrestha (2015) and Gauchan et al. (2012) that find no effect of age on adoption among rice farmers in Nepal. Regarding education, the results indicate that compared to farmers without formal education, those farmers that have some formal education are more likely to adopt new improved rice varieties. This may be attributed to the role of formal education in increasing ability to receive and understand technical information. This corroborates the findings of Chandio and Yuansheng (2018) on adoption of modern varieties and rice varietal diversity in Pakistan.

Land type has effect of adoption decision as the coefficient to upland rice growers is statistically significant. This indicates that compared to lowlands rice farmers, upland rice farmers are more likely to adopt new improved rice varieties. This may be explained by the limited number of varieties that have been developed and released for the upland. Relying on rain-fed farming also increases the probability of adopting new improved rice varieties. This may be due to the fact that some improved varieties are early maturing which make them ideally suited to rainfed regions. The results also show that experience of recent abiotic stresses decreases the likelihood of adopting new improved rice variety. This finding does not conform to *a priori* expectation. Holden and Quiggin (2016) provide evidence that is contrary i.e. experience of previous natural hazard motivated adoption of DT maize. However, Kuehne et el. (2017) postulates that recent disaster such as flood or drought can constrain resources in the short term thereby limiting adoption.

4.3. Discussion

This paper investigated the linkage between risk attitude and adoption of improved rice varieties in Nepal. By employing a field experiment approach offering farmers a choice between various monetary payment options, rice growers risk attitude was elicited. Probit regression model was estimated to address the important question of whether risk tolerance affects adoption of improved rice varieties.

Risk tolerance tends to matter in the decision to adopt new improved rice varieties as heterogeneity in risk attitudes lent a hand in explaining variations in adoption of improved rice varieties in Nepal. The finding that some farmers are partial adopters i.e. combine old and new improved rice varieties could be explained using their risk tolerance. Farmers may prefer to maintain some status quo due to the uncertainty associated with new improved varieties. Thus, partial adoption may have been used as a 'risk minimization' strategy. From a different perspective, framing effect during dissemination could also have impacted on risk attitudes. Farmers portray risk-seeking tendencies to avoid losses particularly for options that are uncertain and negatively framed.

Another credible argument to why risk tolerant farmers are less likely to adopt new improved rice variety is that during dissemination, stress tolerant potentials (which is mainly beneficial in the event of abiotic stress) could have been the most salient attributes of some of the new improved rice varieties which sometimes mask other important attributes (such as high yield and cooking quality desired by 70 per cent of farmers). Thus, farmers that can tolerate risk may have less incentive to adopt such varieties. Thus, one solution would be to promote holistic benefits over making risk-reducing attributes salient as this is likely to have an impact on risk attitude and consequently adoption levels. Crucially, in employing risk attitude to explain adoption decisions, consideration should be given to context specific factors as the pattern of behaviour will differ across context.

In general, the findings of the present study provide empirical evidence that corroborates previous findings there is significant adoption lag of new improved rice varieties in Nepal. This is also in consonance with findings across South Asia. One reason for slow adoption is that for many low-income rice farmers, vulnerability to risk is a dominant feature of their livelihoods. This may reduce the ability and willingness to take on additional risks regardless of the potential benefit.

The observation that age, gender, household size and education affects the adoption of new improved rice varieties brings to the fore heterogeneity in farmer related characteristics associated with adoption and the need for a tailored approach in disseminating new improved rice varieties. Future rice research and development processes should make effort to align attributes of the new improved rice varieties to predominant farm and farmers characteristics since preferences for certain attributes are determined by these contextual characteristics. This will encourage adoption and reduce adoption lag overall.

The findings on recent experience of climatic stress (flooding and drought) appears counterintuitive at first glance. To explain such findings, one might argue that perhaps the recent climatic stress resulted in affected farmers being 'locked' into the use of older improved rice varieties as they may be constrained due to the losses incurred during any recent drought or flooding. This constrain may limit their ability to purchase seeds of new improved rice varieties. Repeated exposure to climate hazards has been reported in other studies to undermine farmers current and future capacity. If this is the case, input support such in form of seeds may encourage adoption among affected groups.

5. Conclusion

This paper brings to the fore the important role of risk attitude in adoption decisions. The adoption literature in Nepal and across South Asia so far has not paid as much attention to farmers' attitudes to risk as a determinant of technology adoption. This study serves as an example of how field experiments targeted at eliciting attitude and behaviour can be employed in understanding real world agricultural decisions with economic consequences. By incorporating risk attitudes in the probit model the paper explains Nepalese rice farmers decision to adopt new improved rice varieties. This paper confirms previous findings that in Nepal, the adoption of new improved rice varieties is at a rather slow pace.

Given the importance of rice to Nepal, understanding the drivers and barriers to adoption of new improved varieties is imperative. Specifically, before new varieties are to be developed and released it is important to understand which categories of farmers are likely to adopt and how to frame the varietal attributes. Considering risk attitude in technology design and dissemination would result in efforts targeted as increasing adoption becoming more successful. More so, collaborative efforts between researchers and farmers could enhance the acceptance of improved varieties. This could be made possible by providing a platform for farmers to discuss their preferences and expectations about a new variety. This will ensure it is in concordance with the attributes targeted by rice research and development institutions. Finally, to enhance the adoption of new improved rice varieties, there is a need to improve farmer education as this has the potential to increase capacity to receive and understand technical information.

Notes

1. Within the agricultural economics literature, improved rice is used interchangeably with modern rice varieties.
2. This broad categorisation of rice varieties in this paper is adopted from CDD (2015), Gauchan et al. (2012) and Ghimire, Wen-chi & Shrestha (2015). In line with these papers, new improved rice varieties constitute varieties developed and released after 1990 by research institutions. Old-improved varieties include rice developed and released prior to 1990. This distinguishes old-improved varieties from traditional rice varieties.
3. Similar to the categorisation method employed in Sohn (2017) this paper refers to farmers that preferred the sure payoff over the lotteries as risk averse while those farmers that chose the lotteries are regarded as (having various levels of) risk tolerant.

4. The context in which this paper refers to expected value of a random variable is the weighted average of the all the possible values that the variable can take.

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Table 1: Studies examining determinants of improved/modern rice varieties adoption in Nepal

Author	**Region**	**Sample size**	**Method**	**Main results (significant variables)**
Budhathoki and Bhatta (2016)	Terai and hills	3350	Logit regression	Gender, household size, plot, remittance, livestock, land sharecropped, region
Gauchan, Panta, Gautam and Nepali (2012)	Terai and hills	300	Tobit and probit	Awareness, training, land type
Ghimire, Wen-Chi and Shrestha (2015)	Hill and Tropical plains Terai	416	Probit regression	Education, farm size, animal power, extension service, seed access, land type, animal owned, acceptability, yield potential
Joshi and Bauer (2006b)	Terai region	222	Multinomial logit regression	Education, experience, seed source, threshing, maturity, maturity, education, irrigation, other uses
Khanal and Maharjan (2014)	Terai	180	Logistic regression	Irrigation, price of seed, membership, location
Subedi and Subedi (1999)	Low, middle and high hills	424	Logistic regression, Multivariate analysis	food grain production, fodder supply, extension
Upadhyaya, Thapa, David and Otsuka (1993)	Terai	55	Tobit regression	Irrigation

Table 2: Variables included in the probit model

Variables	Description
Dependent	
Adopt	Adopted new improved rice varieties (1=Yes, 0 =No)
	(New improved rice varieties refer to those released after 1990)
Independent	
Age	Age of farmer (years)
Gender	Gender of farmer (1 = male, 0 = otherwise)
No education	No formal education (1 = No education, 0 = otherwise)
Primary	Primary education (1 = Primary, 0 = otherwise)
Secondary	Secondary education (1 = Secondary, 0 = otherwise)
Higher education	Tertiary education (1 = Tertiary, 0 = otherwise)
Others	Other education (1 = Other education, 0 = otherwise)
Household size	Size of household (Number of persons)
Training	Training received (1 = Training, 0 = otherwise)
Extension	Extension visits (Number of extension contact)
Non-irrigated land	Water source (1 = Farmland is rainfed, 0 = otherwise)
Lowland	Land type (1 = Farmland is lowland, 0 = otherwise)
Medium land	Land type (1 = Farmland is medium land, 0 = otherwise)
Upland	Land type (1 = Farmland is upland, 0 = otherwise)
Region	Development Region (1 = Eastern, 2 = Central, 3 = Western 4= Mid-Western)
Drought	Abiotic stress (number of years experienced drought in the past 5)
Flooding	Abiotic stress (number of years experienced flooding in the past 5)
Risk attitude	Attitude (1 = Risk averse, 0 = otherwise)

Attitude (1 = Risk tolerance 1, 0 = otherwise)

Attitude (1 = Risk tolerance 2, 0 = otherwise)

Attitude (1 = Risk tolerance 3, 0 = otherwise)

Attitude (1 = Risk tolerance 4, 0 = otherwise)

Source: Author's compilation using data from Yamano (2017) IRRI South Asia Rice Monitoring Survey

Table 3: Hypothetical monetary task

Option 1	Option 2	Option 3	Option 4	Option 5
Rs.64 for sure	50 per cent chance of Rs.48 50 per cent chance of Rs.96	50 per cent chance of Rs.32 50 per cent chance of Rs.128	50 per cent chance of Rs.16 50 per cent chance of Rs.160	50 per cent chance of Rs.0 50 per cent chance of Rs.192

Source: Author's compilation using data from Yamano (2017) IRRI South Asia Rice Monitoring Survey

Table 4: Farmer and farm characteristics

Characteristics	**Mean**	**Standard deviation**	**Minimum**	**Maximum**
Age	45.5	13.04	18	87
Gender	0.82	0.38	0	1
No education	0.12	0.33	0	1
Primary	0.35	0.48	0	1
Secondary	0.32	0.47	0	1
Higher education	0.20	0.40	0	1
Household size	8.73	4.91	0	53
Extension	0.49	2.47	0	35
Rain-fed	0.27	0.45	0	1
Drought	1.45	1.38	0	5
Flooding	0.61	1.36	0	5
Risk aversion	0.42	0.49	0	1
Risk tolerance 1	0.15	0.36	0	1
Risk tolerance 2	0.14	0.35	0	1
Risk tolerance 3	0.11	0.31	0	1
Risk tolerance 4	0.18	0.38	0	1
Adopt NIRV	0.49	0.50	0	1

Source: Authors' compilation using data from Yamano (2017) IRRI South Asia Rice Monitoring Survey

Table 5: Old and New Improved Rice Varieties in Nepal

New-improved varieties	**Yield (MT/ha)**	**Age**	**HH growing the variety (per cent)**	**Old-improved varieties**	**Yield (MT/ha)**	**Age**	**HH growing the variety (per cent)**
Basmati	3.9	26	2.18	Bindheswari	4.0	33	3.55
Hardinath 1	4.0	10	5.69	Mansuli	3.5	41	1.18
Hybrid	4.9-9.1	11	2.98	Sarju-52	5.0	32	18.38
Kanchi mansuli		23	5.46	Sona Mansuli	5.0[d]	32	30.49
Radha 4	3.2	21	7.99	Sabitri	4.0	35	1.30
Lalka Basmati	2.5-3.5	3	0.65	Swarna		32	2.10
Ram Dhan	4.9	8	1.22				
Ranjit	3.0-3.6	21	4.97[f]				
Samba Mansuli	3.5-4	25	11.23[f]				
Swarna Sub1	4-5	3	0.57[f]				

f and d represent flood and drought tolerant varieties respectively. HH is household

Source: Author's compilation using data from Yamano (2017) IRRI South Asia Rice Monitoring Survey, CDD (2015) and Witcombe et al. (2017).

Table 6: Probit regression results of determinants of adoption of new improved rice varieties

Characteristics	**Coeff.**	**dy/dx**		**Coeff.**	**dy/dx**	
Risk attitudes						
Risk aversion	Ref.	Ref.		Ref.	Ref.	
Risk tolerance 1	-0.469	-0.187	***	-0.435	-0.1734	***
	(0.069)	(0.027)		(0.063)	(0.025)	
Risk tolerance 2	-0.330	-0.132	***	-0.250	-0.100	***
	(0.070)	(0.028)		(0.065)	(.026)	
Risk tolerance 3	-0.659	-0.263	***	-0.591	-0.236	***
	(0.078)	(0.031)		(0.073)	(0.029)	
Risk tolerance 4	-0.750	-0.170	***	-0.454	-0.181	***
	(0.271)	(0.026)		(0.060)	(0.023)	
Age	0.004	0.002	*			
	(0.001)	(0.001)				
Gender	0.333	0.132	***			
	(0.066)	(0.026)				
Education						
No education	Ref.	Ref.				
Primary	0.337	0.134	***			
	(0.078)	(0.031)				
Secondary	0.236	0.094	***			
	(0.058)	(0.023)				
Higher education	0. 127	0.050	*			
	(0.063)	(0.025)				

Others	0. 308	0.123	
	(0.392)	(0.156)	
Household size	-0. 014	-0.006	**
	(0.004)	(0.002)	
Training	0.275	0.110	
	(0.182)	(0.073)	
Awareness	0.058	0.023	
	(0.063)	(0.025)	
Extension	0.003	0.001	
	(0.011)	(0.004)	
Farm tenure	0.114	0.045	
	(0.067)	(0.027)	
Land type			
Lowland (terai)	Ref.	Ref.	
Medium land (hills)	0.126	0.050	
	(0.084)	(0.033)	
Upland (mountain)	0.525	0.209	***
	(0.152)	(0.061)	
Region	-0.049	-0.019	*
	(0.023	(0.009)	
Rain-fed	0.277	0.110	***
	(0.052)	(0.021)	
Stress Experienced			
Drought	-0.039	-0.016	*
	(0.016)	(0.007)	

Flooding	-0.136	-.054	***		
	(0.019)	(.008)			
Intercept	-0.750		**	0.212	***
	(0.271)			(0.032)	
Wald chi2	267.83	***		113.45	***

legend: * p<.05; ** p<.01; *** p<.001 Standard error in parenthesis

Source: Author’s compilation using data from Yamano (2017) IRRI South Asia Rice Monitoring Survey

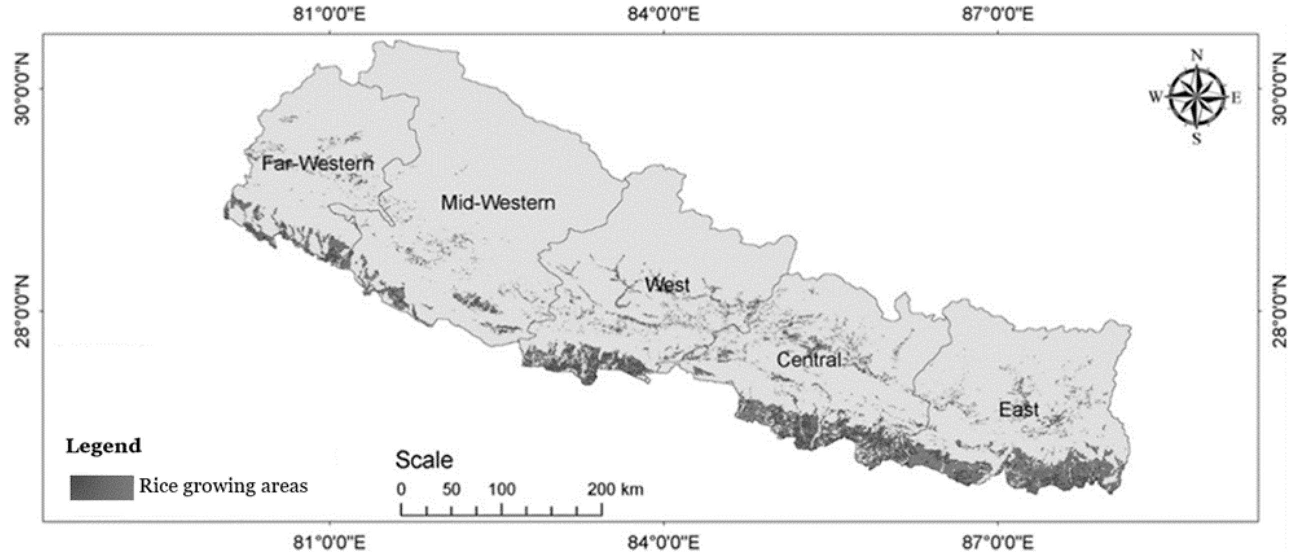

Figure 1. Map showing rice growing areas in Nepal (reprinted with permission from Gumma et al. 2011)

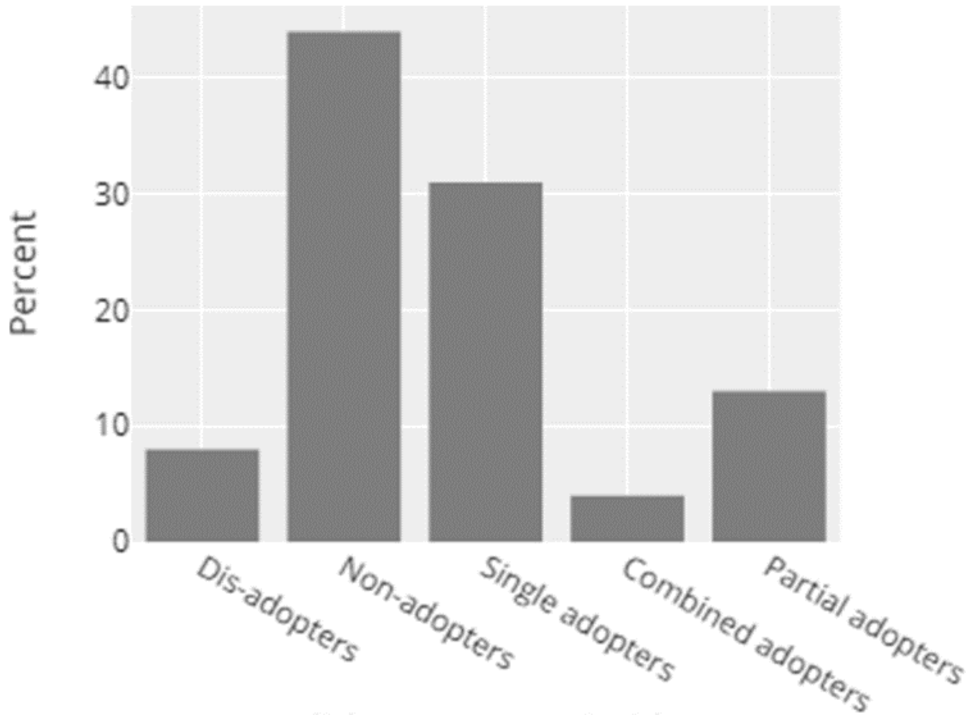

Figure 2. Farmer classification based on adoption categories

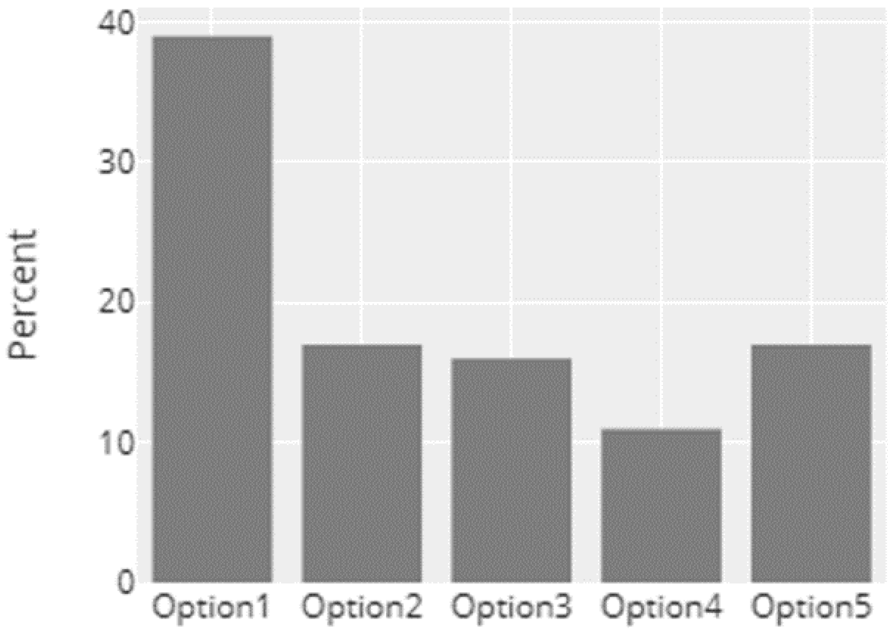

Figure 3. Distribution of farmers risk tolerance based on payment choice