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Impact of Use of Chemical Fertiliser on Farm Households' Risk Behaviour and Food Security in Ethiopia

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Abstract

The paper explored the impact of chemical fertiliser on smallholder farmers' risk behaviour and food security. The findings show that the severity of food security is lower for farmers who adopted chemical fertiliser (15%) than those who didn't adopt (27%). Risk taking behaviour is predominantly associated with farmers who adopt chemical fertiliser. The number of food secure farmers was higher for risk taker farmers (54%) than that of risk averse farmers (46%). Use of chemical fertiliser significantly affected both farmers' risk behaviour and food security. Risk-averse farmers are less likely to adopt chemical fertiliser technology. There is need to improve farmers awareness through demonstration, teaching and public discussion.

Keywords: Chemical Fertilizer, Risk Behaviour, Food Security, Northern Ethiopia

Introduction

Smallholder farm households in the Sub-Saharan African countries are frequently exposed to multifaceted risks and hazards such as flooding, drought, climate change, diseases and pest, and other calamities (Todaro and Smith, 2011) and are unlikely to bear and undertake risky activities (Olarinde et al., 2007). A risk is a specific action where the potential outcome is known, measurable and quantifiable based on probabilities whereas risk behaviour is a state of mind with regard to the uncertainty of the specific action that could have an adverse impact on specified object (Bohm & Harris, 2010; Legesse & Drake, 2005). Risk can affect not only the behaviour of economic groups (consumers or farmers) but the economy as well (Holzmann et al., 2003).

Food insecurity has been the recurrent problem in Ethiopia. For instance, the percentage of the food insecure people in 2013 and 2012 were, respectively about 26% and 29% of the population. The corresponding figures were about 40% and 35% in the 1980s and 1990s, respectively, implying that agriculture failed to meet the food requirement of the country due

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to its low productivity, which could, in turn, result from high dependence on backward technologies, family labour and unpredictable natural factors (MoFED, 2015).

Adoption of technological innovations could increase farm yield, reduce risks and improve food security (Malhotra, 1991; Todaro and Smith, 2011; May and Fortunate, 2011). Household food security in Nigeria was influenced by farm size, farm income, educational level of the head, radio ownership, nonfarm income, technological innovation, landholding size and livestock, household size, improved seed varieties, years of formal education and access to extension services (Olarinde et al., 2007). In South Africa, access to credit, total income, marital status of the head, household size, soil conservation, chemical fertiliser, and employment status of the spouse were factors that determine food security (Sekhampu, 2013). Distance to markets, income, the number of adults, ethnicity, saving behaviour and nutrition awareness reported being the major influential factors for household food security in Kenya (Nyangwesoi et al., 2007).

William et al. (2014) found that age and sex of the head, landholding size and wealth status were significant variables that determining the risk behaviour and poverty status of cassava farmers in Ghana. Moscardi and de Janvry (1977) reported that age and sex of the head, household size, landholding size, minimum tillage, improved seed varieties, availability of infrastructure facilities and income were major factors that had statistically significant effect in influencing the risk behaviour of farmers in Brazil. In Nigeria, education, access to information, the frequency of contact for extension workers, asset holding, livestock, landholding size and age of the head were found to be the major factors that affect food security and risk aversion behaviour of smallholder farmers (Olagunju et al., 2012).

In Ethiopia, adoption rates of improved technologies have remained sluggish (Bacha et al., 2011; Prokopy et al., 2008) and they have consequently suffered from food insecurity. Since small farm households are less likely to adopt technological innovations without strong government push, the government of Ethiopia has introduced policies and strategies that focus on improved technological innovations, sustainable farming practices, and water harvesting schemes, for example, in the Sustainable Development and Poverty Reduction Programme (2000-2005), plan for accelerated and sustained development to end poverty (2006-2010), and growth and transformation plan (2011-2015) (MoFED, 2015). Farmers' training centres were established in each village to enhance awareness of farmers and distribute chemical fertiliser, pesticide and other biocide inputs to rural farmers. Non-governmental organisations were encouraged to participate in the construction of water harvesting schemes and distribution of improved technologies. Some microfinance institutions flourished in rural areas to provide loans for farmers.

However, there was some opposition to the distribution of chemical fertiliser and other biocide inputs by the government because first, farmers were forced to purchase recommended amount of chemical fertiliser regardless of their financial ability or interest or despite the soil assessment. Consequently, farmers sold the inputs that they have already bought from the government at the black market at a lower price. Some had to sell their permanent assets and animal for the loan repayment. Second, they are less likely to accept the assumption of the government that small farmers have risk-averse behaviour in technology adoption. In most case, smallholder farm households are often considered as risk averse and

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resistant to newly introduced technological innovations. Thus, they accused the government of importing and distributing biocide inputs.

Finally, the government fail to realise that adoption of chemical fertiliser improves food security and reduce risks. Studies show situations, where adoption of improved technologies can reduce risks and improves food security (Bard and Barry 2001) and it can also increase risks thereby inducing food insecurity (Torkamani et al., 2001; Nyangwesoi et al., 2007; Sekhampu, 2013). The situation calls for an investigation to understand the behaviour of farmers.

The main purpose of this study was to investigate the impact of adoption of chemical fertiliser on smallholder farmers' risk behaviour and food security. Specifically, the study: explored the status of risk behaviour and food security of smallholder farm households: explained the interrelationship between risk behaviour and food security: and identified factors influencing farmers' risk behaviour and food security.

Methodology

Area description

This study was conducted in the Tigray region, Northern Ethiopia. It is located between 12^0 to 15^0 north latitude and 36^0 30' to 41^0 30' east longitude. The region is classified into sixteen livelihood zones, namely, Adiyabo Lowland, Alaje-Ofla Highland, Atsbi Wonberta Highland, Central-Mixed Crop, Eastern Plateau, Enderta Dry Midland, Gesho and Wheat Highland, Humera Sesame and Sorghum, Irob Mountain, Mereb Basin, Middle Tekeze, Raya Valley Sorghum and Teff, Tsirare Catchment, West Central Teff, Werie Catchment, and Western Cereal and Sesame livelihood zones. 36 districts and 360 villages are found in the Tigray region (MoFED 2015).

Sampling Framework

The study used four-stage sampling strategy. First, six livelihood zones were randomly selected, namely, Atsbi Wonberta highland, Enderta dry midland, Alaje-Ofla highland, Humera Sesame and Sorghum, Central-Mixed Crop, and Western Cereal and Sesame. Second, one district was randomly selected from each selected livelihood zone. Third, two villages were randomly selected from each target district. Finally, 600 sample farmers were randomly selected from the sampling frame of each village using proportionate and random sampling techniques.

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Table 1: Distribution of sample size of farm households by livelihood zone and district

Livelihood zone	Sample district	Population	Household head	Samples
Atsbi Wonberta Highland	Saesi Tsaeda Emba	175381	38007	108
Enderta Dry Midland	Enderta	144014	31019	84
Alaje-Ofla Highland	Alaje	136045	31228	105
Humera Sesame and Sorghum	Tsegedie	130854	29006	105
Central Mixed Crop	Ahferom	218862	49057	99
Western Cereal and Sesame	Welkait	175047	38273	99

Variable Specification

Approaches to risk behaviour: There are several approaches that have frequently applied for measuring risk behaviour, example, the certainty equivalence techniques, choice experiments, and Von Neumann and Morgenstern, and psychometric approach (Bohm & Harris, 2010).

The Von Neumann and Morgenstern model (Torkamani et al., 2001) was used to understand and estimate risk behaviour of smallholder farm households in the study areas. We reviewed the highest and the lowest income that rural farmers in the region received only from rain-fed crop production for the last four years (2008-2012). The certain income (Birr 2580) was determined by the equal probabilities between the highest and the lowest average income earned.

The selected farmers were requested to specify a preference of two options (a) that would need to be indifferent between adopting chemical fertiliser in rain-fed crop production in 2013 and get uncertain income from the sale of what they would produce (b) not use chemical fertiliser in 2013 and get certain offer income. Farmers who preferred the certain offer income are considered as risk averse while farmers who preferred to use chemical fertiliser and accrue profit from the sale of produce are treated as risk takers.

Approaches to food security*:* The United Nations Food and Agriculture Organization defined the term 'food security' in 2001 as 'a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life' (FAO, 2001).

There are several approaches that are used to measure and estimate food (in) security, for example, food insecurity access scale, supply approach (yield or livestock density), demand approach (expenditure, income, health and nutrition), anthropometric method, and household coping strategies. The main difference for those approaches is only nature of the data (Castell et al., 2015 and Knueppel et al., 2010)

In this paper, adult equivalent[1] expenditure approach was used to determine and estimate food security status across farm households. It is less sensitive than other approaches. It also

[1]. Adult equivalence scale captures the age and sex-based difference in earning and consuming capacities of the household members, and computed as an adult male and female (15-60 years) is assigned 1; male above 60 years is 0.67; female above 60 years 0.60; child (10-14 years) is 0.50; child (4-9 years) is 0.30 and children below 3 years is economically insignificant (Randela et al. 2000).

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considers and captures both food supply and food access. Further, this approach accounts for farmers' behaviour, for example, farmers may not remember the exact amount they have earned. Finally, it assumes the presence of unequal consuming capacities among the members of the household head (Randela et al., 2000).

Two-thirds of mean per adult equivalent expenditure can serve as a vicinity of estimated food insecurity line, which helps to categorise farm households into food secure and food insecure groups. A farmer whose adult equivalent expenditure fall below the estimated food insecurity line is considered as food insecure while a farmer whose adult equivalent expenditure equals or greater than threshold line is tagged as food secure.

Data collection methods

The study was based on a cross-sectional survey where a structured questionnaire was used to collect qualitative and quantitative data. In general, based on the conceptual frameworks, prior significant studies and the objectives, the study established expected signs (Table 2).

Table 2: Specification of variables and establishment of prior hypothesis of the variables

Variables and definition	Unit of measurement	Expected signs		
		Food security	Risk aversion	Adoption decision
Sex of household head	1 for male otherwise 0	?	?	?
Age of household head (year)	Continuous	?	+	?
Primary occupation	1 for farming otherwise 0	-	+	?
Household size	Continuous	-	+	?
Dummy of head education	1 for literate otherwise 0	+	-	+
Family members in school	Continuous	?	+	+
Livestock resources	TLU[2]	+	+	-
Landholding size	*Tsimad*[3]	+	-	+
Membership in association	1 for members otherwise 0	?	-	?
Access to rural credit	1 for easy access otherwise 0	+	+	+
Distance to rural function[4]	Minute	+	-	+
Frequency of extension contact[5]	1 for contacts more than 20 times	+	-	+
Access to information	1 for easy access otherwise 0	+	-	+
Distance to all-weather roads	Minute	+	-	+
Distance to district markets	Minute	-	-	-
Mean per capita asset	Birr	+	-	+

[2].*1 TLU equals 1 camel, 0.7 cows, 0.8 oxen, 0.1 sheep/goat, 0.5 donkeys, 0.45 heifer/bull, 0.7 mule/ horse, 0.2 bee colonies or 0.01 chickens (Randela et al. 2000).*

[3]. *Tsimad is a measurement unit for farmland in Ethiopia. In customary, four tsimad equals to one hectare but there is no standard conversion factor.*

[4]. *The average distance from home of the household head to various social and physical rural services such as primary schools, health centre, veterinary clinics, bank offices, post office, and telephone booths.*

[5]. *It is assigned 1 when farm households contacted the extension workers or development agents for more than 20 times in a year otherwise assigned 0.*

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The questionnaire was pre-tested with 25 randomly selected farmers to check the local language discourse, test the ability of the farmers in answering the questions and evaluate the adequacy of the questions.

Analytical Framework

The independent two-sample t-test was used to compare adopter and non-adopters on access to rural functions, district markets and all-weather rural roads. The chi-square independent test was used to differences between adopters and non-adopter in receiving frequent extension services and having information access. Farmers' food security and risk behaviour were analysed using the severity food security index and Von Neumann-Morgenstern risk model. The distribution of resources such as livestock, income, asset holding and food consumption across farm household is assessed and estimated using the *Ginni* coefficient inequality method. The impact of the use of chemical fertiliser on food security and risk behaviour was investigated using the bivariate probit model.

In many low-income countries, decisions for adopting technological innovations are made under the imperfect market structure, incomplete property right regimes and missing institutions. Such decisions can be explained by and derived from the maximisation of discounted expected utility of wealth subjected to several constraints. Also in Ethiopia, farmers' decisions to use chemical fertiliser in rain-fed crop production rely on the value of the expected utility of wealth; decide to adopt only when the expected utility of wealth from adoption $(U_{i1}(W))$ exceeds the expected utility of wealth from non-adoption $(U_{i0}(W))$. The model for the expected utility of wealth is given as follows:

$$U_{ji}(W) = X_{ji}\partial + \varpi D_{ji} + \varepsilon_{ji} \qquad i = 1,2,...n \qquad j = 0,1 \tag{1}$$

Where, $U(W)$ is the expected utility of wealth (food security and risk behaviour) for farm household i where the expected utility of wealth, X_i is the vector of explanatory variables, D_j is adoption decision for chemical fertilizer (D_j =1 if a farmer adopted chemical fertilizer and D_j = 0 otherwise); ϖ is the effect of adoption decision on the expected utility of wealth; and ε_i is an error term with mean zero and variance δ_ε^2 that captures the measurement errors and unobserved factors that concurrently influence the adoption decision and its outcomes.

The dependent variables was food security (Y_{i1}) and risk behaviour (Y_{i2}) and assigned 1 for food secure farmers and 0 for food insecure farmers. Similarly, 1 was assigned for farmers who preferred the certain offer income and 0 for the counterpart farmers. Risk behaviour and food security can be potentially interrelated. To deal with this simultaneity or selection bias, a bivariate model associated with probit model was used and given by:

$$\begin{aligned} Y_{i1}^* &= X_{i1}\beta + \varepsilon_{i1} \qquad Y_{i1} = 1, if \quad Y_{i1}^* > 0, otherwise, 0 \\ Y_{i2}^* &= X_{i2}\beta + \varepsilon_{i2} \qquad Y_{i2} = 1, if\ Y_{i2}^* > 0, otherwise, 0 \end{aligned} \tag{2}$$

Where, the dependent variables Y_{i1} and Y_{i2} are conditional on a set of observed characteristics X_i and unobserved random error variables (ε_{i1} and ε_{i2}), where they are dependent and normally distributed with $E[\varepsilon_{i1}] = E[\varepsilon_{i2}] = 0; \mathrm{var}(\varepsilon_{i1}) = \mathrm{var}(\varepsilon_{i2}); \mathrm{cov}(\varepsilon_{i1}, \varepsilon_{i2}) = \rho.$

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If a Wald test shows ρ is statistically insignificant, then no endogeneity bias is present and the two equations can be estimated separately. If ρ is statistically significant, indeed (Y_1) and (Y_2) are endogenous and are not estimated independently.

The log-likelihood for the bivariate probit is given as in eq.3 where Φ is the standard univariate normal cumulative distribution and Φ_2 is the standard bivariate normal cumulative distribution with correlation ρ. Eq.3 is simultaneously estimated using maximum likelihood, producing unbiased estimates of coefficients β and ρ.

$$L = \prod_{Y_1=0} \Phi(-X_{Y_{i1}}\beta_{Y_1}) \prod_{Y_1=1,Y_2=1} \Phi_2(X_{Y_{i1}}\beta_{Y_1}, X_{Y_{i2}}\beta_{Y_2}, \rho) \prod_{Y_1=1,Y_2=0} \Phi_2(X_{Y_{i1}}\beta_{Y_1}, -X_{Y_{i2}}\beta_{Y_2}, -\rho) \quad (3)$$

As stated in eq.1 the expected utility of wealth is affected by the adoption of chemical fertiliser, which can also be explained by factors, such as demographic variables, socioeconomic factors, infrastructure services, village factors and institutional factors. We assumed that non-technology variables that affected the adoption decision of chemical fertiliser were exogenous. Adoption of chemical fertiliser is endogenous. The adoption decision is given by probit model as follows:

$$D_i = \sum_{i=1}^{n} \varpi M_i + e_i \Rightarrow \lambda = \frac{\phi(\varpi, M_i)}{\Phi(\varpi, M_i)} = \frac{\phi(-\varpi M_i)}{1-\Phi(-\varpi M_i))} \quad (4)$$

Where D_i represents adoption decision of farm households to use chemical fertiliser in rain-fed crop production; M_i captures the main factors that influence farm households to use chemical fertiliser; ϖ estimates the effect of chemical fertiliser on food security and risk behaviour; ϕ is the normal probability density function; and Φ is the normal cumulative distribution.

Based on this, we constructed the Inverse Mills Ratio or selectivity effect (λ) that captures the correlation between the unobserved factors in the selection and outcome equations and measures the average effect of chemical fertiliser. λ is included in the bivariate probit models (see eq.5) to measure the impact of the use of chemical fertiliser on food security and risk behaviour.

$$Y_{i1} = 1 \text{ if } Y_{i1}^* + X_{i1}\beta + \varpi\lambda_{i1} > 0 \text{ otherwise } 0 \quad (5)$$
$$Y_{i2} = 1 \text{ if } Y_{i2}^* + X_{i2}\beta + \varpi\lambda_{i2} > 0 \text{ otherwise } 0$$

Results and Discussion

Socio-Economic Characteristics of Respondents

Table 3 shows that about 55% of the respondents adopted chemical fertiliser, 64% of the adopters and 76.9% of non-adopters were male-headed. The average age of the household head was about 45 years. About 56% of adopters and 50% of the non-adopters were literate at different educational levels, including religious schools, literacy campaigns, and formal school. The mean household size was below 6, which was like the regional average family size in 2012. There were differences in the number of family members in school and

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membership in rural associations between adopters and non-adopters. The agricultural sector was a primary occupation for about 53% of the adopters and 61% of the non-adopters.

There was a little or no difference in accessing to rural functions, district markets and all-weather rural roads between adopters and non-adopters, although the mean distance to rural functions, district markets and all-weather roads was more than one hour. There were differences in receiving frequent extension services and having information access between adopters and non-adopters.

The average livestock asset and landholding size were respectively about 2.7 TLU and 2.4 *tsimad* for adopters, and 2.5 TLU and 2.7 *tsimad* for non-adopters. The mean per capita expenditure, income and asset of the respondents were about Birr 967, 1640 and 2340 for adopters; and Birr 695, 1220 and 1910 for non-adopters. We find differences in per capita income, per capita asset and per capita expenditure between adopters and non-adopters.

Table 3: Demographic and socioeconomic characteristics of respondents

Variables	Adopters	Non-adopters	Difference
Sex of the household head (%)	64	69	-5
Agriculture as primary occupation (%)	53	61	-8
Literacy rate of household head (%)	56	50	6
Household age (in years)	46	44	2
Household size	5	6	-1
Livestock asset	2.7	2.5	0.2
Landholding size	2.4	2.6	-0.2
Family members in school	4.0	2.0	2***
Membership in rural association (%)	73	61	12***
Access to rural credit (%)	81	89	-8
Frequency of extension contacts (%)	84	72	12**
Access to information media (%)	56	47	9***
Distance to all-weather roads	47	50	-3
Distance to district markets	86	85	1
Distance to rural function	80	85	-5
Mean per capita income	1640	1220	420***
Mean per capita expenditure	967	695	272**
Mean per capita asset	2340	1910	430***

**** for P≤0.01; ** for P≤0.05*

Food Security between Adopters and Non-Adopters

The food insecurity line in the study areas was Birr 750. Accordingly, about 47% of the respondents were food secure while the figure for the food insecure was about 53%. About 46% of adopters were food insecure while the corresponding figure for non-adopters was about 62%, suggesting the number of food secure were significantly higher for adopters (54%) than that of non-adopters (38%). On average, the food insecure farmers fell below the food insecurity line by about 26% for adopters and 29% for non-adopters.

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The severity of food insecurity also varied from 15% for adopters to 27% for non-adopters. A significant difference was found in asset holding and income between adopters and non-adopters while an insignificant difference in livestock assets, landholding size and food consumption, suggesting income and asset were equally distributed among adopters than among non-adopters. We conclude that the depth and severity of food insecurity were higher for non-adopters than adopters.

A similar finding was also reported in Nigeria by Olagunju et al. (2012), who studied food security between farmers who participated and not participated in improved agricultural technologies. Given the estimated food insecurity line of $367, about 49% of the farmers who adopted improved technologies were found food insecure whereas 61% of farmers who didn’t adopt the technologies were found food insecure.

In Zimbabwe, about 67% of the farm households who adopted gardening vegetable using artificial fertiliser were found to be food secure and the figure for the farmers who didn’t adopt was about 45% (May and Fortunate, 2011). Related findings were also found in Kenya by Nyangwesoi et al. (2007), and in South Africa by Sekhampu (2013).

Table 4: The food security and inequality status of the respondents

Variables	Adopters	Non-adopters	Difference
Independent two-sample t-test			
Food insecurity incidence	46	62	16**
Food insecurity gap (depth) index	26	29	3
Food insecurity gap (severity) square	15	27	12***
Gini coefficient inequality			
Livestock asset	0.37	0.36	0.01
Landholding size	0.16	0.13	0.03
Household income	0.30	0.44	0.14**
Food consumption	0.40	0.42	0.02
Overall asset holding	0.29	0.40	0.11**

*** for P≤0.01; ** for P≤0.05 *P≤0.10

Risk Behaviour between Adopters and Non-Adopters

Table 5 presents risk behaviour between adopters and non-adopters. About 58% of the respondents had risk averse behaviour for chemical fertiliser 42% had risk-taking behaviour. Of the risk-averse respondents, about 41% were adopters and 59% for non-adopters. In a similar way, 67% of the risk seekers were adopters and 33% for non-adopters. The chi-square test $(P(\chi^2(0.000)))$ indicates a significant difference in risk behaviour between adopters and non-adopters.

Related results were found in Brazil, Ghana, India and Nigeria while exploring risk attitudes between farm households who adopted and didn’t adopt improved agricultural technologies. The percentage of farm households who adopted agricultural technologies was significantly higher for risk seeker farm households than that of risk-averse households (Dillon and Scandizzo 1978; Binswanger, 1980; Lamb, 2003; Olarinde et al., 2007; William 2014).

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In the study area, the percentage of risk-averse farmers is significantly higher for non-adopters than adopters while the percent of risk seekers is higher for adopters compared with non-adopters. Risk-averse farmers are, thus seemed less willing to use chemical fertiliser.

Table 5: Risk behaviour in adopting chemical fertiliser

Households	Adopters %	Non-adopters %	Total %
Risk averse	41	59	56
Risk taker	67	33	44

Interrelationships between Farmers' Risk Behaviour and Food Security

This section examines the interconnectedness between risk behaviour and food security using chi-square independence test. Table 6 presents the results and about 54% of the food secure respondents were risk takers, and about 69% of the food insecure was risk-averse farmers.

The number of food secure was relatively higher for risk seeker farmers (54%) compared to that of the risk-averse farmers (46%). The chi-square test $(P(\chi^2(0.000)))$ shows that there was a statistically significant difference in risk behaviour between food secure and food insecure respondents.

Similar findings were also reported in other countries; in Brazil, about 70% and 90% of farmers who adopted improved agricultural technologies were respectively found to be non-poor and risk takers. About 81% of non-poor households in Nigeria were deemed to be risk lovers while the remaining were risk-averse farmers. About 73% of the poor households had risk averse behaviour while 27% had risk taking behaviour (Moscardi and De Janvry, 1977; Dillon and Scadizzo, 1978; Binswanger, 1980; Bard and Barry, 2001; Torkamani et al., 2001; Olarinde et al., 2007).

This justifies that the behaviour of food insecure farmers was highly skewed towards risk aversion while towards risk preference for food secure farmers. Thus, it is more likely to conclude that food insecure farmers are risk averse while food secure farmers are more of risk seekers.

Table 6: Cross-tabulation of risk behaviour and food security of farmers

Farm households	Risk averse (%)	Risk seeker (%)	Total (%)
Food insecure	69	31	53
Food secure	46	54	47

Factors Influencing Farmers' Risk Behaviour and Food Security

The result of the bivariate model is presented in Table 7. The Wald test (98.48; P≤0.05) shows that the overall model is statistically significant. The independent variables in each equation are important for predicting the probability of farmers' food security and risk behaviour. Hosmer-Lemeshow test shows that there is no sound evidence that the goodness-of-fit for both risk behaviour and food security equations has a deficiency to reject.

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The correlation of the error terms of the two equations is statistically significant (rho=0.57, P≤0.05). They are strongly associated, which suggest food security and risk behaviour equations are interrelated and thereof are not estimated independently. The decision to use chemical fertiliser could also affect both equations jointly and therefore unlikely for independent decisions.

Table 7: Marginal effects of food security and risk behaviour index

Variables	Food security model Coefficient	Risk aversion model Coefficient
Age of the household head	0.3437	0.0546**
Sex of household head	0.1551*	0.0546
Farming primary occupation	-0.0129	0.4144**
Household size	-0.2984***	-0.1276*
Education of household head	0.3687**	-0.1992**
Livestock resources	0.1569**	0.0318**
Landholding size	0.0983**	-0.0600
Membership in rural association	0.2896	-0.3808***
Access to rural credits	-0.2918**	-0.5286*
Frequency of extension contact	0.1307**	-0.1307**
Access to information	0.3783*	-0.1805***
Distance to all-weather roads	0.1836	0.0446***
Distance to district markets	-0.0500*	-0.0879*
Mean per capita asset	0.3265***	-0.1546**
Inverse Mills ratio	0.401**	0.274**
Food security (1=food secure)		0.523*
Risk behaviour (1=aversion)	-0.463**	
Hosmer-Lemeshow chi-square	0.0270**	0.0281**

***≤ 0.05**

Adjusting food security and risk behaviour equations for adoption selection correction or Inverse Mills Ratio clearly improves the overall significance of the bivariate model compared to logit model, for example, it affects some parameters such as access to rural credits and removes an upward bias for some variables, such as agricultural dependency and frequency of contact with extension workers.

The bivariate probit model shows that farmers' food security is positively affected by education, livestock, landholding size, extension services, use of chemical fertiliser, and asset holding while it is negatively affected by household size, rural credits and risk aversion. Livestock, agricultural dependency, household size, distance to all-weather rural roads, and age of the head are also factors that positively influence farmers' risk behaviour although it is negatively affected by education, membership in rural associations, extension services, and access to information.

A decision to adopt chemical fertiliser, which is indicated in the adoption selection correction, is a significant positive for food security but a significant negative for risk

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behaviour, implying farm households who use chemical fertiliser are more likely to be food secure and to have risk-taking behaviour than farmers who do not use chemical fertiliser.

The probability of achieving food security was 40% higher for adopters than non-adopters. The likelihood to use chemical fertiliser in rain-fed crop production was about 27% higher for risk seekers than risk-averse farmers. Since adoption decision to chemical fertiliser significantly affects both food security and risk behaviour, it can be concluded that uncontrolled adoption selection biases with observed covariate effects would have led to false inferences on the outcomes.

The household asset has a significant positive effect on farmers' food security but a significant negative effect on farmers' risk aversion. Farmers who have more livestock assets and whose livelihood primarily depends on agriculture are more likely to have risk averse behaviour because agriculture is exposed to many hazards and the people are therefore vulnerable to various risks.

Farmers were literate, who had frequent contact with extension workers, who were member of rural associations, who had information access from radio/television, and who had access to credits were found to be more of risk takers because these rural services are sources of awareness and knowledge especially associated with risks and hazards (Prokopy et al. 2008, Sekhampu 2013).

Access to rural roads and markets have direct and indirect implications with transport cost, other transaction costs and awareness issues. For example, the longer the distance to get the rural roads or main markets, the lower would be the information that farmers have about agricultural practices, the more would be the transaction costs that farmers incur for searching information, the higher would be the risks that the farmers attached with. Thus, proximity to district markets has a significant positive impact on food security and risk aversion.

In parallel, the univariate logit model is used to identify the determinant factors because the coefficient of the rho is at vicinity to accept and reject (5%).Both models produced closely related estimated coefficients for some variables. (Table 7 and Appendix 1) The odds ratio for household size indicates that every unit increase in household size was associated with a 3% decreased in the odds of being food secure while the remaining variables were held constant. This might be due to the higher number of consumers than that of producers in the family cell. This could also be linked to the existing socioeconomic situation in the economy.

The odds ratio to be food secure was increased by about 45% for literate households than illiterate households. The odds ratio to ensure food security were increased by about 17%, 10% and 41% with an increasing of livestock asset by 1TLU, landholding size by 1 *tsimad* and overall asset by Birr 1000, respectively.

The odds ratio for the risk averse farmers increased by about 7, 3 and 4% when the age of the household head increased by 1 year, livestock assets increased by 1TLU, and the farmer away from the all-weather rural road by 1km, respectively. Compared with an odds ratio of risk seekers, the odds ratio for risk-averse farmers decreased by about 17, 12, 41 and 18% for farmers who have access to information, who have frequently contact with extension workers, who have access to rural credits and who are members of rural associations.

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Similar findings were reported by other studies, for example, Moscardi and De Janvry (1977), Binswanger (1980), Olagunju et al. (2001), Lamb (2003), Bard and Barry (2007), Nyangwesoi et al. (2007), Olarinde et al. (2007), Prokopy et al. (2008), May and Fortunate (2011), Sekhampu (2013) and William et al. (2014). However, some results are contradicting, for example, Olagunju et al. (2001) in Nigeria, Nyangwesoi et al. (2007) in Kenya, and May and Fortunate (2011) in Zimbabwe found a positive effect of access to rural credit on food security.

The negative impact of rural credit on food security might be associated with several reasons such as the high rate of interest, and crop failure due to the frequent drought, which can lead to high debt burden and sale of permanent assets for loan repayment.

Binswanger (1980) and Bard and Barry (2007) also found contradict finding; sex and age of household head, family members in school, and distance to rural roads were found to be statistically significant factors in explaining risk behaviour and food security of farm households.

Conclusion and Recommendations

Adopters were more food secure and risk seekers than non-adopters. Use of chemical fertiliser in rain-fed crop production has a significant effect on food security (positive) and risk aversion (negative). Risk aversion negatively influences food security but not vice versa. There is a need for further investigation through advance approaches that incorporate all the limitations to get a clear picture on the adoption decision, food security and risk behaviour nexus. Infrastructure facilities and local institutions that can enhance awareness of farmers should be prioritised in the development strategies and programs of the country to reduce risk aversion and improve the food security of smallholder farm households.

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Appendix 1: Marginal effect and odd ratio of Logit model for adoption decisions

Variables	Adoption Logit model	Logit model Odds ratio (%)[6]	
	Coefficient	Food security	Risk aversion
Age of household head	0.079*	16.8	5.6
Sex of household head	0.366	16.8	5.6
Farming primary occupation	-0.026	-25.8	51.3
Household size	-0.013	-1.3	12.0
Dummy for education of the head	0.057	44.6	18.1
Livestock assets	0.319*	17.0	3.2
Landholding size	0.027*	10.3	5.8
Membership in rural association	0.067*	33.6	31.7
Access to rural credits	-0.033	-25.3	41.1
Frequency of extension contact	0.394*	20.2	12.3
Access to information	0.143*	-4.9	16.5
Distance to all-weather roads	-0.091*	70.1	4.4
Distance to district markets	-0.089*	16.8	8.4
Mean per capita asset	0.172*	41.0	5.6
Risk aversion	-0.375	31.4	23.7
Log likelihood = -269.5	Pseudo R2 = 0.7696	Prob>chi2= 0.0218	

*P≤0.05

[6]. *The percentage of odd ratio of a variable is computed by subtracting 1 from the odd ratio of the explanatory variable.*