Risk induced farmers’ participation in agricultural innovations: evidence from a field experiment in eastern Ethiopia

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ABSTRACT
It is widely accepted that agricultural innovations are vital to ensure food security and economic development. While farmers are among the key sources of agricultural innovations, many studies conducted in the past conceived them as adopters of externally generated technologies. They regarded farmers only as adopters of induced technologies. This study is designed to analyze farmers’ participation in agricultural innovation activities using survey and experimental data. Both descriptive and econometric techniques were employed to analyze the data. It appears that risk attitudes and time preferences are variables that enhance farmers’ participation in agricultural innovation activities. Wealth and socioeconomic variables such as access to information and irrigation facilities, input usage and age of household head are significantly correlated with farmers’ participation in agricultural innovation activities. The findings comply with the induced innovation hypothesis, which recognizes the importance of threats and opportunities to triggering farmers’ participation in agricultural innovation activities.

1. Introduction
The development of the agricultural sector is one of the most powerful tools to end extreme poverty, raise incomes and improve food security for about 80% of the world’s rural poor whose occupation is mainly farming (McArthur and McCord 2017; Asravor 2018). According to the World Bank (WB) report of 2016, the growth in the agricultural sector is two-to-four folds more effective in raising incomes among the poorest than other sectors.

In spite of its prevailing contributions, the sector is still at risk due to climate change, land degradation, deforestation, soil erosion, frequent outbreak of disease, rural-urban migration, and other socioeconomic challenges (Chhetri et al. 2012; Tesfaye and Seifu 2016; Shikuku et al. 2017; Makate, Makate, and Mango 2018). In most Sub-Saharan African (SSA) countries, particularly Ethiopia, the agricultural sector is dominated by rain-fed, smallholder farmers and fragmented farms. The sector is threatened by several factors (Asravor 2018). These factors include, but are not limited to, low usage of improved seed varieties, as is the use of many other agricultural technologies (Spielman et al. 2011; Lemessa 2017); low rate of fertilizer application; poor extension service and other countless risk factors (Asravor 2018).

These multifaceted threats have serious implications on food security and poverty (Wheeler and Von Braun 2013).

Effective responses to such threats through different adaptation strategies in the sector can be part of the solution (Brooks and Loevinsohn 2011; Lybbert and Sumner 2012). One of these strategies is practicing agricultural innovations (Chhetri et al. 2012; Makate, Makate, and Mango 2018). Agricultural innovations are universally accepted to ensure food security and poverty reduction (WB 2011).

Agricultural innovation is mainly plied by smallholder farmers. They practice agricultural innovations to sustain food production and ensure rural food security under volatile production conditions, poor soil fertility, degraded land, proliferating agricultural risks, and high population pressure (Van der Veen 2010; Lybbert and Sumner 2012; Murray et al. 2016; Makate, Makate, and Mango 2018).

Nowadays, there is a growing interest in agricultural innovations though there is no clear definition of the concept in the literature. Different scholars and institutions have defined agricultural innovation in different ways. Most consider it to be a diffusion of externally-generated technologies and Research and Development (R&D) results. For instances, Kolade, Harpham, and
Kibreab (2014) stated that innovation is mainly conceived as new technological development and diffusion for improving agricultural production and productivity. In the view of Waters-Bayer and Bayer (2009), agricultural innovation involves the modification and adaptation of existing local and external practices that are new to a particular area but not to the entire world. In the same vein, Gebre-Michael (2001) noted agricultural innovations as an antediluvian practice started within the lifetime of the farmer. According to this author, agricultural innovation is not something inherited from parents or grandparents, but rather something that is learned through practice.

In the opinion of Hooli and Jauhiainen (2018), innovation emerges from local practices and is an evolutionary process. As also explicated by Korzun, Adekunle, and Filson (2014) and Mgumia, Mattee, and Kundi (2015), it is neither research nor science and technology. Instead, it has been developed over time within a social group incorporating both learning from experiences of earlier generations and accumulated knowledge from whatever sources. Agricultural innovation has been fully internalized within local ways of thinking and doing (Waters-Bayer et al. 2006). Agricultural innovation practices are, therefore, the dynamic interactions of many stakeholders such as: researchers, input suppliers, extension agents, farmers, traders, and processors engaged in the creation, diffusion, adaptation, and use of knowledge relevant to agricultural production and marketing (Hellin and Camacho 2017).

Akin to those studies that conceived farmers as practitioners of innovations and in contrast with those who consider farmers only as adopters of externally driven technologies, this study claims that risk attitudes and time preferences induce farmers to participate in agricultural innovations.

There is plenty of literature documented on the influences of smallholder farmers’ risk attitudes (e.g. Alem et al. 2010; Fafchamps 2010), time preferences (Tanaka, Camerer, and Nguyen 2010; Yesuf and Bluffstone 2008) and both risk attitudes and time preferences (Alemayehu, Beuving, and Ruben 2018) on adoption decisions of externally generated technology. Past empirical findings show that more risk averse and time impatient farmers are less likely to adopt externally-generated agricultural technologies compared to less risk averse and time patient farmers. This implies that farmers’ risk attitudes and time preferences are expected to have an influence on their innovations. However, we are not aware of any empirical studies that tested the influences of farmers risk attitudes and time preferences on their innovation capacities, which is the claim of this study.

In theory, there are rich arguments on how risk attitudes and time preferences drive farmers into poverty traps by preventing them from participating in innovative activities (Pennings and Garcia 2005). Yet, there have been very few empirical studies conducted to examine the impact of risk attitudes and time preferences on farmers’ participation in agricultural innovation activities. Even the literature that exists mainly focuses on the impact of farmers’ risk attitudes on their reluctance to adopt externally-generated improved agricultural technologies (Lamb 2003; Alem et al. 2010; Fafchamps 2010). Little attention has been paid to the identification of factors that induce farmers to participate in agricultural innovation activities so as to improve their livelihood, particularly, in eastern Ethiopia.

Given the paucity of identified literature on farmers’ participation in agricultural innovation activities, this study generally aims to analyze risk induced farmers’ participation in agricultural innovation activities in eastern Ethiopia. More specifically, it aims to: (i) examine factors that affect farmers’ participation in agricultural innovation activities; (ii) investigate the relationships between farmers’ participation in agricultural innovation activities, risk attitudes and time preferences; and (iii) compare the welfare status of participant and non-participant farmers in agricultural innovation activities.

While achieving the identified objectives, the study aims to answer the following research questions: (1) what are the determinants of farmers’ participation in agricultural innovation activities? (2) How significant is the difference between participant and non-participant farmers with respect to wealth variables? (3) Do farmers’ innovations contribute to household welfare? (4) Do farmers’ risk attitudes and time preferences significantly associate with their agricultural innovations behavior?

The remaining part of the paper is structured as follows. Section 2 presents the literature review. The empirical model specification, estimation and methodology of the study are presented in Section 3. Results and discussion are provided in Section 4. Finally, Section 5 concludes and presents policy implications.

2. Farmers innovations: pertinent literature review

Smallholder farmers’ participation in agricultural innovation activities is examined from two important perspectives: induced innovation hypothesis (IIH) and the innovation systems approach (ISA) (Sunding and Zilberman 2001; World Bank 2006; Liu and Shumway 2009).

The IIH, which was developed by Hicks in 1932 and empirically tested by Hayami and Ruttan (1985) and Liu
and Shumway (2007), considers threats and opportunities as key triggers of innovation (Olmstead and Rhode 1993). The constraints on economic growth imposed by resource scarcity are released by innovations that facilitate the conversion of scarce resources to productivity. Hayami and Ruttan (1971) argue that the search for new innovations is an economic activity that is significantly affected by economic conditions. According to this argument, new innovation is more likely to emerge and be practiced in response to socioeconomic threats and opportunities.

ISA, on the other hand, argues that innovations are gradually developed through actors’ networks and organizations. The ISA is evolved as a result of a transition from technology-oriented approaches to more systems-oriented approaches towards agricultural innovations. The ISA conceives innovation as a perceived process of combined technological (e.g. cultivars, fertilizer, agronomic practices) and non-technological (e.g. social practices such as labor organization or institutional settings such as land-tenure arrangements) changes (Schut et al. 2015).

Given the persistence of severe agricultural shocks, farming systems in eastern Ethiopia are generally consistent with the IIH than that of ISA. Accordingly, the threats and opportunities that urge farmers’ participation in innovation activities were analyzed in line with the IIH. Variables such as farmers’ risk attitudes and time preferences, plot fertility status, and frequency of occurrence of climate shocks were considered as elements of the induced innovation hypothesis. Apart from threats and opportunity variables, ISA variables such as cooperative membership, access to information, and frequency of extension contacts are also included in the analysis.

### 2.1. Importance of farmers’ innovations

Literature is replete on the importance of agricultural innovation practices by smallholder farmers. For example, agricultural innovations practices are meant for boosting the productivity of smallholder farmers and enhancing the quality of agricultural products (Van der Veen 2010; Gatzweiler and von Braun 2016; Läpple et al. 2016); it upholds how well farmers respond and adapt to climate changes (Makate, Makate, and Mango 2018); it is fundamental to the growth and development of the agriculture sector around the world (Chhetri et al. 2012); it is a basis for formal research and development (R&D) (Waters-Bayer et al. 2006); it assists smallholder farmers to share information through collective interactions among different stakeholders who are all influenced by diverse interests, values, norms, technologies, markets, institutions, and infrastructural resources (Lowitt et al. 2015); it helps smallholder farmers to diversify their agricultural systems (Lowitt et al. 2015); it increases profitability and competitiveness in the agricultural sector (Wang et al. 2012; Läpple et al. 2016); and it generally plays an important role in poverty reduction and economic growth (Mudombi and Muchie 2014; Swaans et al. 2014; Manyuchi 2018).

Despite its high degree of importance, an agricultural innovation practice by smallholder farmers has received minimal attention in the literature. Many past studies on agricultural innovation activities and rural development, considered farmers as adopters of externally-generated technologies (Röling 2009; Reij and Waters-Bayer 2014; Letty et al. 2011). It is only in recent times that agricultural innovation practices and experimentation by smallholder farmers has gained scientific attention (Tambo 2015) though such activities were practiced even before the emergence of formal scientific enquiries (Biggs and Clay 1981).

In the view of Tambo (2015), for instance, farmers are not only adopters of recommended technologies but also key sources of innovation. Braun and Gatzweiler (2014) argue that many rural poor have remained poor, not only because they are unable to produce more products efficiently, but because they are marginalized. Other empirical studies also claim that some technologies were actually generated by researchers based on farmers’ ideas and practices (Chambers, Pacey, and Taylor 1994; Röling 2009). The recent increase in trends of environmental risks caused by climate change, population growth, urbanization, and land degradation has spurred agricultural innovation practices by smallholder farmers as mitigation strategies (Sangina et al. 2009; Wettasinha, Wongtschowski, and Waters-Bayer 2008; Chhetri et al. 2012). Moreover, smallholder farmers’ participation in agricultural innovation activities has recently attracted greater scientific attention (Wang et al. 2012; Läpple et al. 2016). Therefore, the inclusion of farmers’ ideas in problem solving and policy-oriented research is quite relevant.

Smallholder farmers in Africa, like those in other parts of the world, are good innovators (Letty et al. 2011). These farmers take the lead not only in local innovations but also in the dissemination of results thereof to other farmers. Similarly, farmers in Ethiopia are good at innovation practices and experimentation. For instance, farmers in the northern part of the country extracted a solution from the leaves of a plant that was introduced with grains imported from abroad to kill ticks on livestock (Letty et al. 2011). However, farmers’ participation in agricultural innovations suffered from decades of scientific and government negligence.
3. Research methodology

3.1. The study setting

This study was conducted in eastern Ethiopia, particularly in Haramaya district, where agricultural risks are more pronounced among farmers (Alemayehu, Beuving, and Ruben 2018). Haramaya is the worst affected district by climate change and is the most food insecure. The eastern Ethiopian highlands suffer from food production deficits and are exposed to high livelihoods vulnerability due to decreasing farm size, decline in soil fertility, severe land degradation, fragile ecosystems and recurrent weather-induced shocks like drought and flood (Setegn et al. 2011; Tesfaye and Seifu 2016). The climate of the district is sub-humid. March and April experience low rainfall and the principal rainy season occurs between mid-June and September (Setegn et al. 2011).

The major traditional crops grown in the area under irrigated conditions are chat, potato and vegetables (i.e. lettuce, carrot, onion, tomato and cabbage). Sorghum and maize are grown under rain-fed conditions. Chat, also spelled as qat, kat, cat, or ghat, is a leafy evergreen, mildly narcotic, stimulant perennial shrub widely grown in the district (Setegn et al. 2011).

3.2. Data types and collection methods

The study was carried out in six kebeles1 and eighty-two villages in Haramaya district, eastern Ethiopia. Haramaya district was purposively selected because of the following reasons: (i) high population pressure and exposure to different agricultural risks; and (ii) high level of farmers’ participation in innovation activities such as land use management, intercropping, adaptation to new crops and new irrigation practices.

We randomly selected 420 rural households from a population by using systematic sampling. The sample size was determined based on the nature of the analytical technique (maximum likelihood) which requires a relatively large sample size on the one hand, and the homogeneous nature of farmers within a specified agro-ecology, on the other hand, which requires a small sample size.

This study utilized primary data collected using both experimental games and direct survey method. The data on risk attitudes and time preferences were gathered by using experimental games. To measure risk attitudes and time preferences, respondents played two sequential games. First, they played a risk game with real payoffs (money). Second, they played a time preference experiment with a hypothetical game (see Appendices A and B for experimental structures, and Binswanger 1980; and Pender 1996, for more theoretical clarification). Data on other socioeconomic variables used in this study were collected using a structured survey questionnaire prepared and tested for this purpose.

3.2.1. The game procedure

In the risk game, respondents were provided with six choices having bad or good harvest outcomes with a probability of 50% each. For each alternative, the expected gain and range increase, which in turn increases the perceived payoffs of the game. The respondents were shown the good and bad outcomes of each of the six choices, and asked to make their choice, only one for each alternative. A coin is subsequently tossed to determine whether respondents receive the good or the bad outcome of their choices, and the reward is actually paid.

Following the seminal work of Binswanger (1980), households’ degree of risk-aversion was computed using a constant partial risk-aversion utility function of the form $U = 1 - \eta M^{1-\eta}$, where $\eta$ is the coefficient of risk-aversion and $M$ is the certainty equivalent of a prospect. The coefficient is estimated with the point that an individual is indifferent from two successive prospects (say A and B) provided that each prospect has equal probability of occurrence. Thus, we need to identify the value of the coefficient that equalizes the utility derived from the two prospects by a household that can be given as $E(U_A) = E(U_B)$, which can also be expressed as $1 - \eta M_A^{1-\eta} = 1 - \eta M_B^{1-\eta}$. This equation is solved using standard numerical analysis as it does not have an algebraic solution. The upper and lower limits of such a coefficient are computed for each prospect.

The details of the experiment and the upper and lower limits of the risk-aversion coefficient are similar with that of Yesuf and Bluffstone (2008) available online at Oxford Academic website. Thus, we measured risk preference values from the responses on risk experiment conducted to measure the degree of farmers’ risk-aversion computed from the above mentioned equation. We then grouped farmers into six risk-aversion levels (1 = extremely risk averse, 2 = severely risk averse, 3 = intermediate risk averse, 4 = moderately risk averse, 5 = slightly risk averse and 6 = risk seekers).

Regarding the time preferences experimental design, each farm household was offered a number of choices between receiving a specific amount of money at present and an alternative higher amount in the future. Respondents were asked to state their preferred choice of these alternatives (see Pender 1996 for a succinct summary). Each set of the experiment represents different magnitudes of hypothetical rewards in nominal monetary terms (100 and 250 Birr)$^2$. 

1. The term kebele refers to a rural administrative unit in Ethiopia.
2. Birr is the currency of Ethiopia.
different timeframes basically classified as 3, 6, and 12 months.

3.3. Methods of data analysis

The collected data were analyzed using both descriptive and econometric techniques. The descriptive analysis was carried out using frequency distribution, averages, ratios and pictorial presentations while the econometric analysis was carried out using a binary logistic regression model.

3.3.1. Econometric model (binary logit) specification

In this study, participation in agricultural innovation activities is taken as a dependent variable. It is a binary variable that takes the value 1 if a farmer participates either in product, process, or both innovation activities and 0 otherwise. Farmers were asked about their innovation practices by identifying six innovational activities (new crops adaptation, land management, new irrigation practice, intercropping, new animal fodder adaptation and tracing). These innovational practices belong to product, processes, or both. If farmers practice any one of the six innovational activities, we consider them a participant, and if they do not practice any one of the six activities, they are considered as non-participants during the survey time.

Participation in agricultural innovation activities, which is identified as a dependent variable is categorical. But, the distance between adjacent categories is not known well. For such categorical variable, a linear regression model that assumes equal distance between two adjacent data points throughout the dataset cannot be used. If used, it might produce biased and inconsistent estimates (Winship and Mare 1984). On the other hand, qualitative response models that involve two possible outcomes are binary and hence are studied using either binary logit or binary probit (Cameron and Trivedi 2005; Bucur et al. 2017). Qualitative choice models are suitable when respondents can choose only an outcome from the two mutually exclusive and collectively exhaustive choices (Bucur et al. 2017; Alemayehu, Beuving, and Ruben 2018). The binary categorical variable with two mutually exclusive categories can be expressed by numeric values of 1 and 0; whereby 1 signifies the occurrence of an event or represents the probability of an event to happen based on the values of the predictor variables (Greene 2012; Bucur et al. 2017). Our data set is binary and can, therefore, be analysed with either binary logit or binary probit econometric models. The two models generate comparable and equivalent results. Nonetheless, this study used the binary logistic regression model as it eases the computation of marginal-effects that are important for the subsequent interpretation.

To start with, suppose that there is a latent variable \( Y^* \) which measures the level of farmers’ participation in innovation activities of the \( i \)th farmer (a decision maker) as

\[
Y^*_i = X'_i \theta + U_i
\]

For \( \theta \) is an unknown parameter to be estimated, \( U_i \) is the stochastic term and \( X_S \) are vectors of the regressors. The latent variable \( Y^*_i \) is linked to the observed binary variable \( Y \) by the following measurement equation.

\[
Y_i = \begin{cases} 
1 & \text{if } Y^*_i > \tau \\
0 & \text{if } Y^*_i \leq \tau 
\end{cases}
\]

where \( \tau \) is a threshold or cut-off point that is assumed to be zero for identification purpose (Cameron and Trivedi 2005). The binary logistic regression model is given by the following mathematical expression.

\[
pr(y = 1|x) = \frac{exp(xB)}{1 + exp(xB)}
\]

It clearly ensures that the probability lies between 0 and 1 and the mathematical equation is estimated using a maximum likelihood estimation technique. The implied marginal effects for the logit model are given by the following equation, which is commonly known as the probability density function of the logistic distribution multiplied by the coefficient of the explanatory variable under consideration.

\[
\frac{dp_i}{dx_i} = \frac{exp(xB)}{(1 + exp(xB))^2} B_i
\]

4. Results and discussions

4.1. Descriptive analysis

As stated in the methodology section, data gathered on a range of relevant farm and household characteristics were analyzed using both descriptive and econometric (binary logit) techniques. The descriptive results are provided in Table 1.

The descriptive results show that more than half (52%) of the respondents have access to information sources such as radio, tape recorder, television, or combinations of these sources. Concerning irrigation, about 57% of the respondents reported that they have access to such facilities. Surveyed households are economically in an active age group, with an average age of 38 years, with the age range of between 18 and 80 years, which makes the research area similar to other remote rural parts of Ethiopia.
The average landholding in the study area is very small (0.4 ha) compared to the national average of 0.96 ha. This fact makes the selected district suitable for our study that focuses on smallholder farmers and their participation in agricultural innovation activities. Given the small land-holding, these farmers commonly produce vegetables such as potato, beetroot, sweet potato, onion, garlic, and others. More than four-fifths (87%) of the respondents earn at least part of their income from the sale of these vegetables. However, vegetable production is a risk prone farming which calls for a high level of participation in innovation activities.

There is a limited credit service coverage whereby only 5% of the respondents have access to the services on average with an exception of affluent farmers with better access. However, farmers in the study area do compensate the limited access to loans through savings (56%) at formal financial institutions like banks and microfinance institutions which is higher than the national average (30%). Nevertheless, poverty in the study area remains prevalent as about 66% of the sampled households live below the poverty line, earning less than $1.25 a day per adult equivalent. The responses of the participant and non-participant farmers in agricultural innovation activities were also compared with regard to some selected wealth variables, and the results thereof are presented in Table 2.

The average income of participant farmers is higher than that of non-participants, and the difference is statistically significant. This difference even widens when it comes to income from vegetable farming. The average income received by participant farmers is 30% higher than that of non-participants whereas the average income received by participant farmers from vegetable farming is 65% higher than that of non-participants. On the other hand, the average size of farm land owned by participant farmers is about 10% lower than that of non-participants. This implies that farmers are more motivated to innovate when challenged by farm land scarcity. This finding concurs with the IIH stated earlier.

The descriptive statistics results also show that farmers’ innovation plays an integral role in wealth building processes. Higher average income and consumption expenditure imply that participant farmers have better welfare than that of non-participants. As the average income may not be an appropriate tool to measure the welfare of the two groups, adult equivalent per capita income for both groups of farmers in innovational activities is used as a measurement, see Table 3. Welfare is usually measured by the access of each adult household member to income and not by the average income of a household.

As it can be seen from Table 3, participant farmers have higher per-capita income and consumption than non-participants. The average per-capita consumption expenditure for participant farmers is 55% higher than that of non-participants. On the other hand, the average income earned by participant farmers in per-

### Table 1. Descriptive statistics results (N = 420).

| Variable                  | Unit       | Mean    | Std. Dev. | Min | Max |
|---------------------------|------------|---------|-----------|-----|-----|
| Age                       | years      | 37.56   | 11.43     | 18  | 80  |
| Saving                    | 000 Birr   | 9.21    | 36.43     | 0   | 600 |
| Time preference           | Percent    | 43      | 5.24      | 12  | 101 |
| Value of domestic animals | 000 Birr   | 16.08   | 12.76     | 0   | 74.7|
| Farm size                 | Ha         | 0.41    | 0.26      | 0   | 1.75|
| Cooperative membership    |            | 0.5     | 0.5       | 0   | 1   |
| Household income          | 000 Birr   | 20.62   | 19.47     | 0   | 195 |
| Vegetable income          | 000 Birr   | 10.54   | 14.87     | 0   | 187 |
| Access to off-farm income |            | 0.18    | 0.39      | 0   | 1   |
| Frequency of shocks       | Number of occurrence | 1.71 | 0.53  | 0 | 3 |
| Farm implements           | 000 Birr   | 4.5     | 4.75      | 0   | 18.56|
| Access to information     |            | 0.52    | 0.5       | 0   | 1   |
| Plot fertility            |            | 1.32    | 0.49      | 0   | 3   |
| Access to irrigation      |            | 0.57    | 0.50      | 0   | 1   |
| Access to improved seed   |            | 0.55    | 0.50      | 0   | 1   |
| Manure use                | Kg         | 138.31  | 124.23    | 0   | 900 |
| Frequency of extension use| Number of visits | 3.31 | 1.94  | 0 | 12 |
| Risk preferences          |            | 3.65    | 1.82      | 1   | 6   |
| Consumption expenditure   | 000 Birr   | 12.27   | 8.30      | 1   | 64.90|
| Access to credit          |            | 0.055   | 0.23      | 0   | 1   |

Source: Own computation from survey data, 2017.

### Table 2. Distribution of average wealth variables by innovation participants (N = 420).

| Wealth variable          | Unit       | Participants | Non-participants | Difference | Percentage | Test statistic |
|--------------------------|------------|--------------|------------------|------------|------------|----------------|
| Household income         | Birr       | 23,555       | 18,120           | 5435       | 30         | 2.88***        |
| Vegetable income         | Birr       | 13,390       | 8109             | 5281       | 65         | 3.68***        |
| Saving                   | Birr       | 12,581       | 6274             | 6307       | 101        | 1.77***        |
| Expenditure              | Birr       | 15,092       | 9876             | 5216       | 53         | 6.75***        |
| Value of farm implements | Birr       | 5670         | 3504             | 2166       | 62         | 4.78***        |
| Farm land                | Ha         | 0.38         | 0.42             | −0.04      | 10         | −1.29*         |
| Value of domestic animals| Birr       | 17,306       | 15,034           | 2272       | 15         | 1.82**         |
| Irrigated land           | Ha         | 0.17         | 0.12             | 0.05       | 42         | 2.41***        |

Source: Own computation from survey data, 2017.

***, ** and * indicate the tests are significant at 1%, 5% and 10% probability levels, respectively.
capita household income and agricultural income are 33% and 47% higher than that of non-participants, respectively. This implies that participant farmers have created relatively better welfare than non-participants.

4.2. Econometric results

This paper examined the relationship between the dependent variable (farmers’ participation in agricultural innovation activities) and the independent variables (risk attitudes, time preferences and other socioeconomic variables).

In the previous section, some determinants of farmers’ participation in agricultural innovation activities such as household income, land size and other variables were identified and explained. In this section, the influence of the identified variables on farmers’ participation in agricultural innovation activities are statistically tested using an econometric model. The regression results are given in Table 4.

A negative sign of a parameter estimate shows a decrease in the tendency of farmers’ participation in agricultural innovation activities whereas a positive sign shows an increase in the propensity of participation in agricultural innovation activities. The regression results show that socioeconomic variables such as age, cooperative membership, access to information, frequency of shocks occurrence, and farmers’ risk attitudes have significant positive effects on farmers’ participation in agricultural innovation activities. On the other hand, variables such as farm size, access to off-farm income, and plot fertility status have significant negative effects on farmers’ participation in agricultural innovation activities.

As indicated earlier, the tendency to participate in agricultural innovation activities increases with the age of farmers. Contrary to the findings of Läpple, Renwick, and Thorne (2015), the positive influence of age on agricultural innovations is due to the fact that an increase in the age of farmers helps them to develop innovation behavior from accumulated past experiences. In the same vein, after citing several past studies, Kolade and Harpham (2014) stated that farmers’ entrepreneurial experience improves with age, which in turn improves their participation in agricultural innovation activities. In general, older farmers have higher social and physical capital, which makes them more likely to be risk takers and to participate in innovative activities than younger farmers.

In developing countries like Ethiopia where information is asymmetric and costly, cooperative membership can increase farmers’ propensity to participate in agricultural innovation activities. This is because cooperatives provide services like product and market information that can create awareness about the importance of innovation and encourage them to innovate. The result of this study corroborates the findings of Hermans, Klerkx, and Roep (2015) who state that innovations take place through social interactions and, in the process, build a social network where individuals can learn from each other and strategically adapt to new tools and techniques to suit their particular circumstances.

Similarly, variables such as access to information, irrigation and improved seeds, manure usage, and frequency of extension visits have significant positive effects on farmers’ participation in agricultural innovation activities. The results of this study are in line with the findings of Chindime et al. (2017) who found positive relationships between access to inputs and farmers’ innovation practices.

Environmental challenges, particularly frequency of shocks occurrence induces farmers to participate in agricultural innovation activities as risk mitigation strategies.

### Table 3. Distribution of average income and consumption per-capita by innovation participants (N = 420).

| Variable                          | Unit  | Participants | Non-participants | Difference | Percentage | Test statistic |
|-----------------------------------|-------|--------------|------------------|------------|------------|----------------|
| Per-capita household income       | Birr  | 9478         | 7136             | 2342       | 33         | 3.21***        |
| Per-capita consumption expenditure| Birr  | 6111         | 3940             | 2171       | 55         | 6.58***        |
| Per-capita agricultural income    | Birr  | 8981         | 6120             | 2861       | 47         | 4.09***        |

Source: Own computation for survey data, 2017. *** , ** and * indicate the tests are significant at 1%, 5% and 10% probability level, respectively.

### Table 4. Determinants of farmers’ participation in agricultural innovations (N = 420).

| Variables                  | Parameter estimates | Test statistics |
|----------------------------|---------------------|-----------------|
| Constant                   | −2.437              | −1.73*          |
| Age                        | 0.025               | 1.98**          |
| Farm size                  | −1.176              | −1.74**         |
| Cooperative membership     | 1.194               | 3.88***         |
| Access to off-farm income  | −0.791              | −1.86*          |
| Rates of time preference   | −1.277              | −2.41**         |
| Access to information      | 1.381               | 4.28***         |
| Plot fertility status      | −2.506              | −5.63***        |
| Access to irrigation       | 1.470               | 4.77***         |
| Access to improved seed    | 0.052               | 2.84***         |
| Manure use                 | 0.003               | 2.35**          |
| Frequency of extension visits | 0.451              | 4.53***         |
| Frequency of shocks occurrence | 1.249             | 4.36***         |
| Risk preferences           | 0.198               | 2.34**          |

Source: Own computation from survey data, 2017. *** , ** and * indicate the tests are significant at 1%, 5% and 10% probability level, respectively.
This finding also concurs with the induced innovation hypothesis. On the other hand, the positive effect of farmers’ risk attitudes implies that risk neutral farmers dare to participate in agricultural innovation activities than risk-averse farmers. This implies that the tendency of farmers’ participation in innovation activities decreases with increasing risk-aversion levels. Such a negative correlation between farmers’ participation in agricultural innovation activities and risk-aversion is common, when farmers’ participation, especially in the agricultural sector, involves risk and uncertainty (Weeks 1970).

The regression results show that farm size has a significant negative effect on the farmers’ participation in agricultural innovation activities. This implies that farmers with relatively smaller land-holdings are induced to participate in agricultural innovation activities to generate the required return to maintain the welfare of their families. To put it differently, farmers with relatively larger land-holdings are less induced to participate in agricultural innovation activities as they can maintain the welfare of their family without being innovative. This result is in line with Van der Veen (2010) who noted that innovation can be applied on small plots of land and in contrast with Läpple, Renwick, and Thorne (2015) who found a positive association between farm size and innovation. Plot fertility status has a similar effect whereby the decrease in fertility leads to a high tendency of farmers’ participation in agricultural innovation activities.

On the other hand, the parameter estimate of time preferences has a significant inverse relationship with farmers’ participation in agricultural innovation activities. This implies that farmers who are time impatient have a lower tendency to participate in agricultural innovation and vice-versa. Farmers who have higher time preferences prefer to use their income for immediate consumptions than for investment on agricultural innovations that can generate benefits in the long-run.

Generally, the model results reveal that farmers show more tendencies to participate in agricultural innovation activities under challenging situations, which complies more with the induced innovation hypothesis than with the innovation systems approach.

The binary logistic coefficients show the direction of changes in farmers’ propensity for participation in agricultural innovation activities when independent variables change by one unit though they do not show the magnitude of changes. Rather, the magnitude of the changes in the probability of farmers’ participation in agricultural innovation activities is measured by the marginal function of the logistic model and such values are presented in Table 5.

| Variables                | Rate of change | Test statistics |
|--------------------------|----------------|-----------------|
| Age                      | 0.006          | 1.86*           |
| Farm size                | −0.289         | −1.83           |
| Cooperative membership   | 0.276          | 4.10***         |
| Access to off-farm income| −0.176         | −2.16**         |
| Rate of time preferences  | −0.155         | −1.92***        |
| Access to information    | 0.305          | 4.51***         |
| Plot fertility status     | −0.591         | −5.87***        |
| Access to irrigation     | 0.323          | 5.26***         |
| Access to improved seed  | 0.225          | 3.08***         |
| Manure use               | 0.007          | 2.27**          |
| Frequency of extension visit | 0.107      | 4.59***         |
| Frequency of shocks occurred | 0.301     | 4.49***         |
| Risk preferences         | 0.045          | 2.20**          |

Source: Own computation from survey data, 2017. ***, ** and * indicate the tests are significant at 1%, 5% and 10% probability level, respectively.

As it can be seen from Table 5, an increase in farmer’s age by one year increases the probability of farmer’s participation in agricultural innovation activities by 0.6% when other independent variables are kept at their mean value. On the other hand, being a member of cooperatives and having access to information increase the probability of farmer’s participation in agricultural innovation activities by 28% and 31%, respectively. The study conducted by Kolade and Harpham (2014) also affirmed a positive correlation between cooperative membership of the farmers and their participation in agricultural innovation activities.

Other socioeconomic variables such as access to irrigation and improved seeds, manure usage and frequency of extension visits have positive marginal effects. The positive marginal effect of risk attitudes, an important variable in this study, shows that risk-averse farmers have lower tendencies to participate in agricultural innovations (i.e. 5%) than risk-neutral farmers. This finding concurs with the study by Van der Veen (2010) which noted that innovative farmers are intelligent, willing and able to take risks. However, Gatzweiler and von Braun (2016) argue that adverse agro-ecological conditions and associated perceived risks discourage smallholder farmers from participating in agricultural innovation activities.

On the other hand, independent variables such as farm land, time preferences and plot fertility status have negative marginal effects. For instance, an additional hectare of plot size, on average, lowers farmers’ tendency to participate in agricultural innovation activities by about 29%. Likewise, a decrease in plot fertility status and an increase in farmer’s time impatience lower farmers’ probability for participation in agricultural innovation activities by 59% and 16%, respectively. Farmers’ access to off-farm income also lowers their probability of participation in agricultural
innovation activities by about 18%, which implies the importance of other livelihood sources to sustain family welfare without active participation in agricultural innovation activities.

5. Conclusions and practical implications

Unlike past studies, this study claims that farmers are not only adopters of externally-generated technologies, but that they have the capacity to experiment, adapt and innovate themselves. To this end, this study aims to analyze the nature of farmers’ participation in agricultural innovation activities, and its relationship with risk attitudes, time preferences and socioeconomic variables such as age, access to information and irrigation, extension visits and others.

The overall findings of this study show that risk-averse and time impatient farmers are less likely to participate in agricultural innovation activities. The study also uncovered the existence of a varying tendency of farmers’ participation in agricultural innovation activities with wealth and household characteristics. The main epilogue of this study is that environmental risks such as the occurrence of shocks, small farm size, and low plot fertility are the main driving factors for farmers’ participation in agricultural innovation activities.

The following practical implications can be set from the findings of this study. Firstly, although farmers applied agricultural innovations can be an entry points into a process of further development of the technology through participatory experimentation (Katanga et al. 2007), their innovation practices were not given recognition. Therefore, attention should be paid by different stakeholders including researchers, policy makers and government bodies to boost and underpin their participation in agricultural innovation activities. Secondly, smallholder farmers who are operating in a risky environment should be fortified to participate in agricultural innovation activities to adapt risky factors which recede agricultural development. Thus, fostering an innovative spirit promotes local capital accumulation, in turn and over time serves as a springboard to overcome rural poverty. Thirdly, as also recommended by Mudombi and Muchie (2014) and Tambo (2015), government and other stakeholders should aim to develop and enforce strong and facilitative institutions such as future markets, insurance programs, and credit institutions to enhance farmers’ participation in agricultural innovations. They should also appreciate farmers’ knowledge and creative capacities and be prepared to work together with farmers in their fields on questions that farmers are trying to investigate themselves.

Further research directions can also be made from this study: Firstly, the sources of smallholder’s agricultural innovations should be studied in detail. Secondly, this study focuses on the eastern Ethiopia region; other studies should be carried out in other parts of the county for comprehensive and comparative purposes. Thirdly, this study overlooked the role of gender in agricultural innovations; hence future studies should take into account gender-based agricultural innovations.

Notes

1. Kebele is the smallest administrative unit in Ethiopia.
2. The conversion rate was, 1$ = 22.50 Ethiopian Birr during the survey time.

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Appendices

Appendix A

Table A1. The basic structure of risk experiment.

| Experimental sets | Bad harvest | Good harvest | expected gain | Spread | CPRA coefficients (γ) | Risk-aversion classification |
|-------------------|-------------|--------------|---------------|--------|------------------------|-------------------------------|
| 1                 | 20          | 20           | 20            | 0      | >7.47                  | Extreme                       |
| 2                 | 18          | 36           | 27            | 9      | 7.47 to 2.00           | Severe                        |
| 3                 | 16          | 48           | 32            | 16     | 2.00 to 0.85           | Intermediate                  |
| 4                 | 12          | 60           | 36            | 24     | 0.85 to 0.32           | Moderate                      |
| 5                 | 4           | 76           | 40            | 36     | 0.32 to 0              | Slight to neutral            |
| 6                 | 0           | 80           | 40            | 40     | <0                     | Neutral to risk-seeking       |

Appendix B

Table B1. Time preference experimental choice sets.

Set one: Time frame = 3 months, reference date July 2017, and Nominal magnitude = 100

| Options | Choice |
|---------|--------|
| 100 Birr today or 128 Birr after 3 months |
| 100 Birr today or 159 birr after 3 months |
| 100 Birr today or 192 Birr after 3 months |
| 100 Birr today or 228 Birr after 3 months |
| 100 Birr today or 265 Birr after 3 months |

Set two: Time frame = 6 months, reference date July 2017, and Nominal magnitude = 100

| Options | Choice |
|---------|--------|
| 100 Birr today or 128 Birr after 6 months |
| 100 Birr today or 159 birr after 6 months |
| 100 Birr today or 192 Birr after 6 months |
| 100 Birr today or 228 Birr after 6 months |
| 100 Birr today or 265 Birr after 6 months |

Set three: Time frame = 6 months, reference date July 2017, and Nominal magnitude = 250

| Options | Choice |
|---------|--------|
| 250 Birr today or 276 Birr after 6 months |
| 250 Birr today or 305 birr after 6 months |
| 250 Birr today or 351 Birr after 6 months |
| 250 Birr today or 385 Birr after 6 months |
| 250 Birr today or 463 Birr after 6 months |
| 250 Birr today or 530 Birr after 6 months |
| 250 Birr today or 686 Birr after 6 months |

Set four: Time frame = 12 months, reference date July 2017, and Nominal magnitude = 250

| Options | Choice |
|---------|--------|
| 250 Birr today or 276 Birr after 12 months |
| 250 Birr today or 305 birr after 12 months |
| 250 Birr today or 351 Birr after 12 months |
| 250 Birr today or 385 Birr after 12 months |
| 250 Birr today or 463 Birr after 12 months |
| 250 Birr today or 530 Birr after 12 months |
| 250 Birr today or 686 Birr after 12 months |