Factors influencing adoption of improved bread wheat technologies in Ethiopia: empirical evidence from Meket district

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ABSTRACT
This study was conducted in Meket district of Amhara National Regional State in northern Ethiopia. Cross-sectional data was used for the study, which was collected from 214 randomly selected agricultural households using a structured interview protocol. With the help of the double hurdle model, factors were identified that influence the probability of adoption and the intensity of use of improved bread wheat varieties and associated technologies in the study area. The first hurdle of the model suggests that the number of oxen in the household, cell phone ownership, the level of education of the head of the household, and access to extension services significantly influenced the likelihood of improved adoption of bread wheat varieties. The first hurdle of the model suggests that the number of oxen in the household, cell phone ownership, the number of oxen in the household, cell of the household, that the number of oxen in the household, cell services significantly that the number of oxen in the household, cell bread wheat varieties. The intensity of the improved adoption of bread wheat varieties was significantly linked to ownership of the main plots, participation in farm demonstrations, awareness of the shattering problems of local bread wheat varieties, and the annual income of the household. The results of this study highlight the importance of economic (such as the number of oxen) and institutional (such as access to advice) factors in relation to agricultural advice and communication, participation of farmers in farm demonstrations, wealth creation and the recognition of the farmers' perception of improved attributes of bread wheat varieties. Development interventions should aim to target such economic, institutional and psychological factors in order to promote wider adoption of improved bread wheat technologies.

1. Introduction

Ethiopia's economy is largely depending on the agriculture sector where 34% of the gross domestic product (GDP) and 71% of the employment emanates from this sector. The Crop production sub sector accounts for 72% of total agricultural GDP, while the livestock sub sector emits around 20% and other sectors add 8.6%. Grains (such as wheat, corn, teff, sorghum, and millet) make up the bulk of crop production as the main staple food in the country (ATA, 2018).

The role of the any new technology in economic growth can only be acknowledged if the new technology is widely used and recognized by the beneficiaries mainly farmers. Otherwise, the production and transfer of agricultural technologies is not an end in itself. Unless the farmers apply improved agricultural technologies developed by research institutions, the goal of increasing the productivity and production of wheat will not be realized. The reasons for little or no introduction of new agricultural technologies can be categorized as technical, socio-economic and/or institutional in nature (Uaiene et al., 2009).

Public agricultural investment in Sub-Saharan Africa has recently shown renewed interest in package approaches with the aim to increase agricultural productivity by addressing problems related to market inefficiencies and limited information. The assumption of the package approach is that the provision of supplementary inputs and the extension ensure that the input mix and its application by the farmers correspond to the controlled agronomic experiment, which leads to optimal yield results. The package approach is a recently developed strategy that has been adopted by ministry of Agriculture (MoA) and Agricultural transformation Agency (ATA). Due to this, most of the adoption studies carried out to date are mainly based on a single attribute of the technology: improved variety, input application, and other agronomic practices (Tadesse et al., 2014).

Various studies have been carried out in the area of technology adoption and most importantly on agricultural technologies. According
to DSouza and Mishra (2018a, b), adoption of partial conservation is significantly influenced by years of education, access to credit, and membership in various clubs. Household heads with secondary and tertiary education are more likely to adopt partial conservation technologies compared to heads of households with primary education. Another study by Akinola et al. (2010) showed that adoption of balanced nutrient management is significantly affected by asset owner ship and off-farm income. According to studies by (Marco et al., 2012; Ghimire et al., 2015 and Abbas et al., 2018), the adoption of rice varieties is significantly associated with extension related variables.

According to Tesfaye Solomon et al. (2014), access to credit, sex of the household head, participation on field days, access to all weather roads, labor and distance to market as being key factors on the intensity and adoption of improved wheat varieties. Therefore, improving the status of the above variables should be carried out to increase adoption and intensity of use of wheat.

Similarly, a study by Manda et al. (2016) argues that the adoption of improved maize varieties is positively and significantly influenced by extension level of the household head and access to extension services. Adoption studies by (Bezu et al., 2014; Rahman and Haque, 2013; and Khonje et al., 2015) witnessed that adoption of a given agricultural technologies is positively and significantly affected by education level of the household head.

According to (Djana Babatime, 2011 and Gedefa, 2014), adoption decision of maize and Teff technologies were significantly influenced by farming experience and education level of the household head respectively. A study by Katengeza et al. (2012) showed that the probability of maize variety adoption is significantly affected by labor endowment, access to rural credit, livestock wealth, access to agricultural extension, farm size and access to off-farm employment while its intensity of adoption was found to be negatively associated to livestock wealth and fertilizer application. Findings of Arslan et al. (2014) indicated that the adoption intensity of conservation farming practices positively affected by age of the household head and education level.

Farming experience, age of the household head, number of oxen, annual income and distance to all weather roads significantly influence adoption intensity of barley varieties according to a study by Tufa and Teferra (2016). According to Abiro Tigabie et al. (2013), malt barley technology adoption was significantly and negatively associated with social participation and total farm size of the household.

Extensive studies have been conducted on the adoption of agricultural technologies in different parts of the world as well as in our country Ethiopia, and most significantly on identifying factors affecting the adoption of agricultural technologies. However, most of the literatures were based on a single element of the technology (mostly improved variety) than the packages of the technology. Specifically in the study area where the current study was conducted, no empirical studies on the adoption of bread wheat has been conducted.

Thus, with the pursuit of filling the gaps identified in the above problem statements, the current study on “factors influencing adoption of bread wheat technologies” was conducted. Hence, the study seeks to identify both factors affecting adoption of improved bread wheat technology and intensity of its use.

2. Methods

2.1. Research design and study area

The study is based on the cross sectional data collected from smallholder wheat producer farmers. The empirical data comes from the farming households residing in the northern part of Ethiopia namely, Meket district. This district was selected primarily because of its presence mandate area of Sirinka Agricultural research center’s agricultural technology development, multiplication and dissemination activities. The study area, Meket is one of the districts in the Amhara Region of Ethiopia. Meket district consists of 34 rural kebeles* (Figure 1) (Meket District Office of Agriculture, 2018).

2.2. Sampling design and procedure

Meket district was one of the intervention sites where bread wheat technology generation, multiplication and promotion conducted. In relation to technology generation and promotion, Sirinka agricultural research center has released and promoted various bread and durum wheat varieties at large scale clustered farms in the district.

Multi stage sampling technique was employed to select sample households for this study. Meket district has 34 rural administrative kebeles (Meket District Agricultural Office, 2018). From these, 15 of them were identified as potential bread wheat producer kebeles for selecting sample kebeles. Then, four sample kebeles were randomly selected for the study. Finally, sample respondents were selected using systematic random sampling technique. The number of respondents in each kebele was determined by proportionate to size.

Bread wheat grower households in the selected kebeles were used as the sampling frame and the sampling units were the household heads. Hence, based on the type of sampling design, the sample size for this study was determined based on the following formula (equation 1) given by Yamane (1967) as follows:

\[ n = \frac{N}{1 + Ne^2} \]  

(1)

where \( n \) is the sample size for the study, \( N \) is the population of interest (wheat grower farmers in the production year 2017/18) which is 4022, \( e \) is the precision level which will be 0.07 in this study due to the fact that the population in the study area is relatively homogeneous in the socioeconomic set up. The formula is valid for 95% confidence level.

Based on the above formula (Eq. (1)) 194 sample respondents were selected randomly. According to Israel (2012), it is common to add 10% of the selected sample for compensating absentees of contact of respondents; hence, 214 samples were selected. The sample size for each kebele was determined based on their proportion to total share of households residing in each kebele (Table 1).

2.3. Data collection

Cross-sectional data were used for meeting the objective of this study. The data were collected both from primary and secondary sources. Primary data such as bread wheat production, input utilization and demographic characteristics of the household were collected from the sample farmers using structured questionnaire. Secondary data were collected from published documents as, books, proceedings and journals and unpublished documents like annual reports of different organizations. Before the formal data collection, the questionnaire was pretested for further fine-tuning. In addition, orientation was given for enumerators to have a common understanding regarding the data collection instrument. Finally, the questionnaire was administered by trained researchers of Sirinka agricultural research center in close supervision of the researcher.

2.4. Empirical strategy to data analysis

In order to describe the overall wheat production status with respect to the desired characteristics, descriptive statistics such as mean, standard deviation, percentages and graphs were used. Furthermore, test statistics such as t-test for continuous variables and chi-square \((\chi^2)\) test for dummy/discrete variables were employed to compare means of socioeconomic characteristics among improved bread wheat technology adopters and non-adopters. Spearman’s correlation was also used to test whether there is significant correlation between categorical variables.

2
and intensity of adoption. One way ANOVA was employed for testing the overall mean differences among bread wheat technology adoption categories.

Adoption status of improved bread wheat technologies: Various econometric models have been employed to analyze the adoption behavior of farmers and to identify the key factors of technology adoption. Based on the objectives of the study and the type of data available, the econometric model can be specified. Tobit model is one of the most utilized methods for modeling technology adoption behavior. The assumption of this model is that farmers demanding modern inputs have unconstrained access to the technology. However, in situations where input supply systems are not well strengthened, this is mostly unreliable, as farmers demanding to apply fertilizer or improved seeds often failed to access input. In addition, this model fails to differentiate households with a constrained positive demand for the new technology from those with unconstrained positive demand since it assumes that a household not adopting the technology is considered as a rational decision maker (Yu et al., 2011). Thus, in the cases where access to input is constrained, the Tobit model yields inconsistent parameter estimates (Croppenstedt et al., 2003).

The determinants of bread wheat technology adoption was estimated using double hurdle model assuming that the rate of adoption and intensity of adoption will be affected by different set of factors at different levels. Moreover, it is assumed that the two decisions will be made separately.

The double hurdle model was used to identify factors affecting the probability and intensity of use of an improved bread wheat technology. The double hurdle model is a model in which two separate stochastic processes determine the decision to adopt and the intensity of use of a technology.

The double hurdle (DH) model (Cragg, 1971) is a useful and appropriate approach to analyze technology adoption under constrained access to agricultural inputs. Many Ethiopian farmers faced constraints in accessing inputs like fertilizer and improved seed varieties in this case the DH model is suitable for analyzing technology adoption. The DH model examines technology adoption in two steps. In the first step, the farmer decides whether to participate in the fertilizer or other input market. If he/she chooses to participate, then the next step is to decide how much to purchase (Yu et al., 2011). In this model, the zero values in the dependent variable signifying non adoption of the technology could be resulted either from households that decided not to adopt the technology or households that have the willingness to adopt but are unable to do so due to reasons not embodied in the Tobit framework (for example, the unavailability of inputs discussed above). In other words, we can separate farming households into three categories using DH model; households applying fertilizer (or improved seed), households wanting to adopt but reporting no positive application, and households choosing not to adopt. Hence, using the DH model to include this additional information enables us to obtain more efficient and consistent estimates of technology (Amemiya and Powell, 1981; Arabmazar and Schmidt 1981, 1982).

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\[
D_{hi} = 1 \quad \text{if } d_{hi}^* > 0 \tag{2}
\]

\[
D_{hi} = 0 \quad \text{if } d_{hi}^* \leq 0 \tag{3}
\]
where: $d_{hi}^*$ is a latent variable and $D_H$ takes the value 1 if a farmer adopts improved bread wheat technology and zero otherwise, $Z_i$ is a vector of household socioeconomic and institutional characteristics and $\alpha$ is a vector of parameters. The level of adoption ($Y_i$) decision has an equation (Eq. (5)):

$$Y_i = Y_i^*— \text{ if } Y_i^* > 0 — \text{ and } ——D_{hi}^* > 0$$

(5)

where $Y_i$ is the observed amount of agricultural technologies, $X_i$ is a vector of household socioeconomic and institutional characteristics and $\beta_i$ is a vector of parameter.

The log-likelihood function for the double hurdle model is:

$$\log L = \sum \ln \left[ 1 - \Phi \left( \frac{\alpha_i Z_i}{\sigma} \right) \right] + \sum \ln \left[ \Phi \left( \frac{Y_i^* - \beta_i X_i}{\sigma} \right) \right]$$

(7)

Under the assumption of the independency between the error terms $V_i$ and $U_i$, the double hurdle model is equivalent to amalgamation of Probit model (1) and the truncated regression model (2) (Greene, 2003). Whether estimations are obtained simultaneously or one regression at a time, the results will be identical because of the separability of Craig’s likelihood function. That is, while using craggit makes estimation more coherent, it will not alter results. Moreover, it is possible to facilitate post estimation analysis and interpretation of results using craggit command (Burke, 2009). Hence, in this paper both the probability and intensity of adoption were estimated via a single command i.e. craggit.

Double-hurdle model comprises two separate decisions: the participation decision (whether to adopt wheat technologies) and the level of participation (the extent of use of bread wheat technologies). The type of association between these decisions and the specifications of the error terms determine the likelihood function to be estimated. Hence, the two decisions are modeled independently if an individual makes both decisions separately, modeled jointly if both decisions are made simultaneously, or modeled sequentially if one decision is made first and affects the other one, they are (Martínez-Espineira, 2006). Thus three models namely the independence, the dependence and the dominance can be resulted respectively from the estimation.

**Levels of adoption of improved bread wheat technology:** In order to estimate the level of adoption of improved bread wheat technology (improved variety, row planting, recommended chemical fertilizer application and herbicide/insecticide), adoption index was employed using the following formula (Eq. (8)).

$$A_i = \sum \left[ \frac{AH_i + FAUi + FANi + RP_i + CAi}{CR} \right] / NP$$

(8)

where: $A_i$ = Adoption index

$AH_i$ = Area under improved variety of bread wheat of the $i^{th}$ farmer
$AT_i$ = Total area allocated for bread wheat production by the $i^{th}$ farmer
$FWi$ = Recommended amount of Urea fertilizer for bread wheat (100 kg/ha)
$FRi$ = Recommended amount of NPS fertilizer bread wheat (100 kg/ha)
$FANi$ = Amount of NPS fertilizer applied per unit area of land by $i^{th}$ farmer
$FAUi$ = Amount of urea fertilizer applied per unit area of land by $i^{th}$ farmer
$RP_i$ = Area under row planting of bread wheat in hectare
$ARBi$ = Total area of bread wheat planted both through row planting and broadcasting

$CR = \text{Recommended amount of chemical (herbicide) for wheat (lit/ha)}$

$CAi = \text{Amount of chemical (herbicide) applied for bread wheat (lit/ha)}$

$NP = \text{Number of practices}$

**2.5. Definition of variables and working hypothesis**

**2.5.1. Dependent variables**

The first equation of double hurdle model deals with adoption decision. Then dependent variable of the first hurdle takes dichotomous value depending on the farmers’ decision either to adopt or not to adopt the improved bread wheat technology. Thus, the household using at least one of the production packages will have the value of one otherwise, zero. However, the truncated regression model will have a continuous value, which is the intensity, measured using adoption index Table 2.

**Adopters:** farmers who were growing improved bread wheat variety with some of the recommended agronomic practices during the survey year (2017/2018 production season).

**Non-adopters:** farmers who were not growing improved variety of bread wheat in the last crop production (study) year (2017/18).

**Adoption index:** Measures the extent of adoption at the time of the survey. It is used in the case of study of multiple practices to measure adoption and intensity of adoption. Adoption studies by (Giziew, 2008; Mulugeta, 2011 and Ketema and Kebede, 2017) employed adoption index to measure intensity of adoption. Therefore, for this study, adoption intensity of improved bread wheat production was measured using adoption index.

**2.6. Selection of explanatory variables**

Based on literature review, the following explanatory variables were hypothesized that influence adoption and level of adopting bread wheat technology Table 3.

**i. Farmers’ characteristics**

Age of the household head: This variable is supposed to affect adoption positively (Lambrecht et al., 2014; Kinyangi, 2014; Kebede et al., 2017; Chandio and Yuansheng, 2018).

Household’s education level: According to (Obuobisa-Darko, 2015; D’Souza and Mishra, 2018a, b), education is supposed to affect adoption positively.

**ii. Economic factors**

**Number of plots:** According to (Beshir, 2014; Ketema and Kebede, 2017), Number of plot affects adoption positively.

**Livestock holding:** Total Livestock owned by the household is supposed to affect adoption positively (Njane, 2007; Simtowe et al., 2011; Bekele et al., 2000).

**Access to cell phone:** According to (Gumataw et al., 2013) ownership of mobile affects adoption positively.

**Table 2. Definition of dependent variables.**

| No | Variable | Operational Definition of the Variables |
|----|----------|----------------------------------------|
| 1  | Adoption status | Improved bread wheat technology adoption, takes the value 1 if the household uses improved bread wheat variety in 2017/18 otherwise, 0 |
| 2  | Intensity of adoption | Measured using adoption index (between 0 and 1) and the value is calculated from composite list of improved practices (indicated in equation 8 above) |

Source: own operational definition.
Annual income: According to (Kinyangi, 2014; Ketema and Kebebe, 2017), annual income of the household affects adoption positively.

Ownership of main plots: The household having a land is supposed to affect intensity of adoption positively.

Fertility status of main plot: According to (Mengistu and Bauer, 2012) fertility status of plots affects adoption of agricultural technologies.

Participation on off farm activity: Households participation on off farm activities in the last 12 months. This variable is supposed to affect adoption positively.

Number of oxen: This variable is expected to positively affect adoption (Teshome and Abate, 2013; Tafese, 2016; Mentirie and Gecho, 2017).

Ox plough set: Number of ox plough set is supposed to affect adoption positively (Solomon et al., 2014; Fenta, 2017).

Corrugated iron sheet house: this variable is expected to affect adoption positively (Shiferaw et al., 2008; Kassie et al., 2013).

iii. Institutional factors

Market information: This variable is expected to affect adoption positively (D’Souza and Mishra, 2018a and 2018b).

Credit utilization: whether the household has taken credit 1 otherwise 0. According to (Tura et al., 2010; Solomon et al., 2014; Diro et al., 2016).

Participation on on-farm Demonstration events: Households participation on on-farm demonstration if yes 1 otherwise 0 in the last 12 months. According to (Mariano et al., 2012; Ghimire et al., 2015).

Extension contact: Households frequency of contact with extension workers in the last 12 months. According to (Simtowe et al., 2011; Bezabih, 2012; Awotide et al., 2016; Nigussie et al., 2016).

iv. Psychological factors

Farmer’s perception about technology attributes: Measured using Likert scale (1–5). 1 stands for the negative response i.e. strongly disagree and 5 for positive response i.e. strongly agree. According to (Duvel 1969; Idowu, 2005; Ghiziew, 2008; Tesfaye, 2013; Fenta, 2017).

v. Social capital: Measured in number of people the household rely for critical support. According to (Kassie et al., 2013; Beyene and Kassie, 2015; Hunecke et al., 2017; Fenta, 2017).

2.7 Model specification test

Wooldridge (2002) indicates that the second stage of the DHM is defined by a truncated normal distribution that provides the nesting of the Tobit Model in it. This implies that we can test whether the Tobit model or the DHM best fits the data. DHM can be tested against the Tobit model using a standard likelihood ratio test.

The LR test of the DHM against the Tobit model rejects the use of Tobit model. This is an indication for the existence of two separate decision making stages in which individuals make independent decisions regarding the adoption decision and level of adoption of bread wheat. In addition, the test statistics of inverse mills ratio lambda was used to check the existence sample selection bias for further consideration of heckman selection model (Appendix 4). Thus, the model specification tests against three competing econometric models indicate that Cragg’s independent double hurdle model is appropriate for this study.

Stata version 14 was used to estimate both the probability and intensity of smallholder farmers’ adoption of bread wheat technology. The user written command, ‗craggit‘ by Burke (2009) was used for the estimation. This command estimates the first and second hurdles of the DHM simultaneously. Before the estimation, diagnostic test for Multicollinearity was conducted based on variance inflation factor (VIF) to identify any potential misspecification problems that may exist in the estimated model. As shown in the Appendix Table 6, the test indicated that the mean VIF value of 1.19. This value is well below the maximum value of 10 that is used as a rule of thumb to indicate the presence of Multicollinearity. This implies that Multicollinearity is not a problem in the estimated model. The established procedure for the correction of Heteroscedasticity is to estimate the models using robust standard errors. Therefore, the model is estimated using robust standard errors to correct for Heteroscedasticity. The Ramsey RESET test of omitted variable suggests no evidence of functional form misspecification in the model (Appendix Table 3).

2.8 Ethical approval

This work was approved by the ethical committee of Bahir Dar University i.e. Major and co advisors, chairman of graduate council and coordinator of graduate council in the college of Agriculture and environmental sciences. Finally, informed consent was obtained from the respondents of the questionnaire at the beginning of data collection.

3. Results and discussions

3.1 Descriptive statistics of variables used for econometric model

The survey results reveal that 88.78% of the sample respondents adopted the improved bread wheat technologies. As shown in (Table 4), adopters are slightly younger, more educated and own more resources (mainly livestock, corrugated iron houses and oxen-plough set) than the non-adopters. Moreover, there was a significant difference between adopters and non-adopters with regard to TLU, education level, number of oxen, extension contact and ownership to corrugated iron houses.
The decision to adopt improved bread wheat technology is significantly determined by five of the 12 explanatory variables. The result of the first hurdle (Probib Model) indicates that, number of oxen owned by household, mobile phone ownership, livestock ownership (measured in TLU Appendix Table1), Education level of the household head (measured in years of schooling) and number of extension contact significantly determined it. Significant variables determining the decision to adopt bread wheat technologies are well distributed over four categories; household characteristics (education level), asset ownership (number of oxen, livestock ownership and mobile phone ownership), institutional variables (extension contact) and varietal perception. Oxen based farming is commonly practiced in the study area so that oxen (the number of oxen owned) is included as a separate explanatory variable in the model. The coefficient of this variable is statistically significant at 5 % significance level and has a positive effect on the probability to adopt improved bread wheat technologies by 3.9%. This result is consistent with the findings of (Yirga et al., 2013; Tufa and Tefera, 2016) who found out positive and significant effect of number of oxen on adoption.

Access to information was expected to positively affect the likelihood of adopting improved agricultural technologies. In this study, the effect is captured by ownership of mobile phone. As expected mobile phone ownership has a positive effect for bread wheat technology adoption and statistically significant at 1% significance level. The marginal effect also reveals that possessing mobile phone increases the probability of bread

### 3.2. Determinants of bread wheat technology adoption

The results for the determinants of bread wheat technology has a binary nature and hence estimated by the Probit model (the first hurdle or tier one) is displayed in Table 7. The Wald chi-square value of 30.68 is statistically significant at 1% indicating that the explanatory variables in model jointly explain both the probability of adoption and intensity of adoption. There is no theoretical guidance as to which variable to include in each hurdle, hence an attempt was made to include a number of economic and perception variables in both hurdles.

Turning to the estimation results, coefficients in the first hurdle (tier 1) indicate how a given decision variable affects the likelihood (probability) to adopt improved bread wheat technology. Those in the second hurdle (tier 2) indicate how decision variables influence the intensity of bread wheat technology adoption. In the estimation process, 24 explanatory variables were included in the two hurdles (Tier 1 and Tier 2) (Table 7).

### Table 4. Independent T test for continuous explanatory variables.

| Variables | Non-Agri Adopters (n = 24) | Adopters (n = 190) | Mean | Standard error | t-value |
|-----------|-----------------------------|--------------------|------|----------------|--------|
| Age       | 48.91                       | 49.14              | 2.69 | -0.13 ns       |        |
| Education level | 0.709                     | 1.69               | 0.585 | -1.7**       |        |
| Extension contact (#) | 2.125                 | 2.81               | 0.481 | -1.4**       |        |
| Annual income (ETB) | 12392.08                  | 19700.03           | 5223.70 | -1.4**     |        |
| Social (#) | 8.334                      | 12.01              | 2.57  | -1.45**       |        |
| Number plots (#) | 3.083                   | 3.02               | 0.26  | 0.25 ns       |        |
| TLU       | 1.482                       | 2.29               | 0.34  | -2.35***      |        |
| Number Oxen (#) | 0.709                     | 0.96               | 0.15  | -1.65**       |        |
| Ox plough set owned (#) | 1.125                  | 1.19               | 0.16  | -0.4 ns       |        |
| Corrugated iron sheet house (#) | 1.00                   | 1.14               | 0.13  | -1.1**        |        |

Where # indicates number.

Source: Own survey data, 2019, *, **, and *** = significant at 10 %, 5 % and 1 %.

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### Table 5. Chi-square and spearman's test for categorical variables.

| Variables | Response | Non-Agri Adopters Total | Adoption Wald (χ²) test | Intensity of Adoption Spearman's rho |
|-----------|----------|--------------------------|-------------------------|--------------------------------------|
| Credit    | Yes      | 13                       | 12.03 95 108 100        | 0.148 0.03 ns                         |
|           | No       | 11                       | 10.37 95 106 100        | (0.70) (0.63)                         |
| Off farm  | Yes      | 17                       | 12.98 114 87 02 131 100 | 1.05 0.06 ns                         |
|           | No       | 7                        | 8.43 76 91 57 83 100    | (0.30) (0.33)                         |
| Mobile    | Yes      | 12                       | 23.53 39 76 47 51 100   | 10.19*** 0.13**                      |
|           | No       | 12                       | 7.36 151 92 64 163 100  | (0.001) (0.05)                       |
| Demon     | Yes      | 11                       | 9.48 105 90 52 116 100  | 0.76 0.17***                         |
|           | No       | 13                       | 13.27 85 86 73 98 100   | (0.38) (0.01)                        |
| Land      | Own      | 20                       | 11.05 161 88 95 181 100 | 0.032 -0.08 ns                       |
|           | Other    | 4                        | 12.12 29 87 88 33 100   | (0.85) (0.19)                        |
| Market    | Yes      | 11                       | 10.89 90 89 11 113 100  | 0.02 0.01 ns                         |
|           | No       | 13                       | 11.50 100 88 50 101 100 | (0.88) (0.79)                        |
| Total     | 24       | 24                       | 11.21 190 88 79 214 100 | (0.70) (0.33)                        |

Source: Own survey data, 2019: P***significant at %, p**significant at 10%, ns = not significant.
wheat technology adoption by 12.5%. Along with the development of information communication technology and the needs, mobile phone as an instrument or medium of information communication is widely used by farmers. Hence, farmers with cell phones can support the extension communication channel and access information easily. Thus, communication via mobile phone might contribute for facilitating advisory services with development agents. This result is consistent with the study by Solomon et al. (2011) who find out that ownership of mobile phone positively and significantly affected agricultural technology adoption.

Livestock wealth also positively influences the adoption of bread wheat technologies. The coefficient of livestock ownership is statistically significant at 5 % level of significance and has positive effect on the probability to adopt improved bread wheat technologies. An increase in livestock ownership by one TLU increases the likelihood of adopting improved bread wheat technologies by 5.5%. This might be due to the reason that in Ethiopia farm machineries are not yet widely used by smallholder farmers (except large-scale investment farms) in this case livestock are the major source of drafting and traction power. Moreover, livestock are indicators of wealth in the farming community. This result is consistent with various adoption studies such as Njane (2007) and Katengeza et al. (2012).

The probability of improved bread wheat adoption was influenced positively and significantly by education level of household head at 10% significance level. The result implied that educated household heads were more likely to adopt improved bread wheat technology. More specifically an increase in years of schooling increases the probability of bread wheat adoption by 1.1%. This result is in agreement with Tariku Bezabih (2012) who find out a positive and significant effect of education and wheat variety adoption. Education level was included in both hurdles of the model. While the coefficient of this variable was significant in the first hurdle (probability equation), it was not significant in the second hurdle (intensity) of adoption. The result might be an indication that the two

| Table 6. Chi-square (χ^2) test for perception explanatory variables. |
|----------------------------------------------------------------------------------------------------------|
| | Variables | Category | Non Adopters | Adopters | Total | (χ^2) | Intensity of adoption |
| | | N | % | N | % | N | % |
| Marketability | Disagree | 1 | 33.33 | 2 | 66.66 | 3 | 100 |
| | Agree | 22 | 10.83 | 181 | 89.16 | 203 | 100 |
| | ND | 1 | 12.5 | 7 | 87.5 | 8 | 100 |
| | Total | 24 | 11.21 | 190 | 88.79 | 214 | 100 |
| Shattering problem | Disagree | 1 | 33.33 | 2 | 66.66 | 3 | 100 |
| | Agree | 22 | 10.83 | 181 | 89.16 | 203 | 100 |
| | ND | 1 | 12.5 | 7 | 87.5 | 8 | 100 |
| | Total | 24 | 11.21 | 190 | 88.79 | 214 | 100 |
| Yield | Disagree | 0 | 0 | 3 | 100 | 3 | 100 |
| | ND | 0 | 0 | 2 | 100 | 2 | 100 |
| | Agree | 24 | 11.21 | 185 | 88.51 | 209 | 100 |
| | Total | 24 | 11.21 | 190 | 88.78 | 214 | 100 |

Source: Own survey data, 2019.

| Table 7. Estimates of double hurdle model for adoption of bread wheat technologies. |
|----------------------------------------------------------------------------------------------------------|
| | Variables | Double Hurdle |  |  |  |  |  |  |
| | | First hurdle (Tier 1) |  |  |  |  |  |  |
| | | Coefficient | Marginal Effect | Variable | Coefficient |  |  |  |
| Fertilstat | 0.1547 (0.3679) | 0.0178 | Fertilstat | 0.06234 (0.04057) |  |  |  |
| Ownership | -0.0659 (0.3628) | -0.0080 | Ownership | -0.07059 * (0.040) |  |  |  |
| Gorisonsheet | 0.2383 (0.2182) | 0.0300 | Gorisonsheet | 0.00306 (0.00557) |  |  |  |
| Marketino | 0.1912 (0.2538) | 0.0239 | Marketino | 0.00810 (0.00929) |  |  |  |
| Oxen_no | 0.3123 **(0.1585) | 0.0394 | Oxen_no | 0.00005 (0.00008) |  |  |  |
| Oxplsetowned | 0.1368 (0.1935) | 0.0172 | Oxplsetowned | 0.01899 (0.01314) |  |  |  |
| Mobileowned | 0.7387 ****(0.2767) | 0.1247 | Mobileowned | 0.06727** (0.03058) |  |  |  |
| Offfarm | -0.4377 (0.2756) | -0.0518 | Offfarm | -0.02957 (0.02369) |  |  |  |
| TLU | 0.4323 ** (0.1940) | 0.0545 | TLU | 0.00902 (0.02971) |  |  |  |
| Eduelevel | 0.0868 ** (0.0505) | 0.0109 | Eduelevel | 0.01612 (0.02199) |  |  |  |
| Social | 0.0693 (0.0738) | 0.0087 | Social | 0.00533 **(0.00298) |  |  |  |
| EXTENSION | 0.3935 ** (0.1633) | 0.0496 | EXTENSION | 0.02494* (0.01473) |  |  |  |
| Constant | -1.0275 (0.5924) | 0.29730 (0.36122) | Constant |  |  |  |  |

**p < 0.01, *p < 0.05 and ‘p < 0.10
Wald chi2 (12) = 30.68.
Log pseudolikelihood = -22.882145; Prob > chi2 = 0.0022.
Numbers in the parenthesis are robust standard errors.
decisions (Adoption and intensity of adoption) can be affected by different set of explanatory variables. Once the education affects the decision to adopt, the decision on the intensity might not be influenced by education level.

Frequency of extension contact positively affects household's probability of bread wheat technology adoption at 5% level of significance. In addition, the marginal effect of this variable reveals that an increase in frequency of extension contact increases the probability of adoption by 4.96%. The result indicates that farmers with frequent extension visit are more likely to adopt improved bread wheat technologies. This result is in agreement with (Simtowe et al., 2011; Sodjinou et al., 2011; Teshome and Abate, 2013; and Chando and Yuansheng, 2018).

3.3. Determinants of intensity of adoption of bread wheat technologies

The decision to adopt improved bread wheat technology is significantly determined by four of the 12 explanatory variables. As shown in column 1 of Table 7 below, the result of the second hurdle (Tier 2) indicates that the variables such as, ownership of main plots (Ownership), participation on on-farm demonstrations (Partondemon), perception towards shattering problem of bread wheat varieties (Shateringproblem) and annual income (logAnnualincome) are the significant determinants for adoption intensity of bread wheat technologies.

Ownership of land by title (Ownership) negatively influenced adoption intensity of bread wheat technologies and this variable was statistically significant at 10%. Ownership of land decreases intensity of adoption by 4%, indicating that farmers cultivating bread wheat on rented land are reluctant to use improved bread wheat technologies than those possessing land. The implication of the result might be related to the fact that farmers renting land for bread wheat have to use intensive technologies to cover production costs related to land rent, labor and fertilizer. Since farmers are expected to reap significant benefits in the short run from bread wheat technology adoption, they tend to invest on agricultural intensification.

Participation on on-farm demonstration (proxy for access to agricultural extension services) positively and significantly affects intensity of bread wheat technology adoption at 5% level of significance. Participation of farmers on on-farm demonstration increases the level of adoption by 6.72%. The result suggests that, on farm demonstrations are means of learning by doing which enable farmers to develop confidence on the given technology. In addition, demonstration plots will create the opportunity for experience sharing among invited and host farmers of the demonstration plots. This result is consistent with Yigezu Annaf et al. (2018) who find out that both hosting and involvement on-farm demonstration trials decreases the duration to adoption by 36.5%.

Farmers’ perception towards shattering problem negatively affected intensity of bread wheat adoption at 5% significance level. The result implying that, farmers perceiving negative advantage about the improved variety towards shattering problem would allocate lower parcel of land for bread wheat production. This result is consistent with the theory of diffusion of innovation by Rogers (1983). According Rogers (1983), “The greater the perceived relative advantage of an invention, the more rapid its rate of adoption will be.” The degree to which the farmer perceives the technology as important matters how much to allocate his/her land for the introduced technology.

As expected, the coefficient of annual income is positive and significant at 10% significance level. Accordingly, an increase in household annual income by one Birr would lead to an increase in the intensity of bread wheat technology adoption by 2.49%. This could happen because a household with necessary annual income could not be financially constrained and prohibited from the timely use of improved bread wheat technology packages. This result is consistent with the findings of (Beshir et al., 2012; Tufa and Tefera, 2016; Kebede et al., 2017).

4. Conclusions and recommendations

The study examined the adoption and intensity of improved bread wheat technologies in the study area. Descriptive results of the study revealed that, there exists a significant variation among adopters and non-adopters in relation to education level, age, livestock ownership, mobile phone ownership and number of oxen owned. The first tier of double hurdle model analysis indicated that number of oxen, mobile phone ownership, livestock ownership, education level of the household head and extension contact significantly determine the adoption of bread wheat. The second tier of double hurdle model indicates that, ownership of wheat plots, participation on on-farm demonstrations, perception towards shattering problem of bread wheat varieties and annual income significantly determine adoption intensity of bread wheat technology.

Based on the findings of cragg’s double hurdle model, it is suggested that the adoption of improved bread wheat technologies could be increased by raising farm household asset formation, providing frequent extension visit, improving agricultural information system like farm radio, enhancing participation of farmers on agricultural events such as on farm demonstrations, trainings and field days. Moreover, bread wheat variety development strategies should be directed in alignment with farmers’ perception. More importantly, participation of beneficiaries especially farmers in crop variety development should be enhanced to increase adoption rate of improved technologies.

Declarations

Author contribution statement

Negussie Siyum: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.
Almaz Giziew: Conceived and designed the experiments; Performed the experiments; Contributed reagents, materials, analysis tools or data.
Azanaw Abebe: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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Appendices

1. Appendix Tables

### Appendix Table 1. Conversion factor used to compute man equivalent.

| Age group year | Male | Female |
|----------------|------|--------|
| Less than 10   | 0    | 0      |
| 10–13          | 0.2  | 0.2    |
| 14–16          | 0.5  | 0.4    |
| 17–50          | 1    | 0.8    |
| Greater than 50| 0.7  | 0.5    |

Source: Storck et al., 1991.

### Appendix Table 2. Tropical livestock unit conversion factor (TLU).

| Animal category | TLU | Animal category | TLU |
|-----------------|-----|-----------------|-----|
| Calf            | 0.34| Donkey          | 0.35|
| Bull            | 0.75| Camel           | 1.25|
| Heifer          | 0.75| Sheep/Goat      | 0.06|
| Cow             | 1   | Chicken         | 0.013|
| Ox              | 1   |                 |     |
| Horse/Mule      | 1.1 |                 |     |

Source: Storck et al., 1991.

### Appendix Table 3. Omitted variable test using Ramsey RESET.

Ho: model has no omitted variables  
F (3, 198) = 1.96  
Prob > F = 0.1218

### Appendix Table 4. Model Specification Test.

| Model Test value | Decision |
|------------------|----------|
| Standard Tobit vs. independent double hurdle | 138.51*** (12) [0.05] | Reject Tobit |
| Heckman vs. Double hurdle | (1) [mills]lambda = 0 chi2 (1) = 1.37, 13 | Prob > chi2 = 0.2424 | Reject heckman |

### Appendix Table 5. Multicollinearity Test using VIF.

| Variables | VIF | 1/VIF |
|-----------|-----|-------|
| Annual income | 1.482 | .675  |
| Involve off farm | 1.341 | .746  |
| TLU          | 1.326 | .754  |
| Education level | 1.318 | .759  |
| Household age | 1.318 | .759  |
| Corrugated iron sheet | 1.28 | .781  |
| Social rely on | 1.233 | .811  |
| Oxen plough set owned | 1.232 | .812  |
| Extension contact | 1.164 | .859  |
| Market info | 1.145 | .873  |
| Participation on demonstration | 1.145 | .873  |
| Mobile owned | 1.122 | .891  |
| Credit use | 1.111 | .9    |
| Number Oxen | 1.106 | .904  |
| Number plots | 1.103 | .907  |
| Perception on Shattering problem | 1.083 | .923  |
| Fertility status main plots | 1.076 | .929  |
| Perception on grain yield | 1.072 | .933  |
| Perception on Marketability | 1.072 | .933  |
| Tenure type | 1.072 | .933  |
| Mean VIF | 1.19 | .581  |
Appendix Table 6. Collinearity statistics for categorical variables.

| Variables       | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|-----------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| (1) Credit use  | 1.00|     |     |     |     |     |     |     |     |      |
| (2) Involve,offfarm | 0.036| 1.00|     |     |     |     |     |     |     |      |
| (3) Mobileowned  | -0.028| 0.072| 1.00|     |     |     |     |     |     |      |
| (4) Partoncemon  | -0.048| 0.038| 0.014| 1.00|     |     |     |     |     |      |
| (5) Ferti,status | 0.098| -0.009| -0.104| 0.013| 1.00|     |     |     |     |      |
| (6) Early maturing | 0.066| 0.041| 0.049| -0.005| 0.038| 1.00|     |     |     |      |
| (7) Grain yield  | 0.078| 0.133| -0.001| 0.008| -0.054| 0.395| 1.00|     |     |      |
| (8) Shatterproof  | -0.035| -0.094| 0.010| 0.068| -0.044| -0.027| -0.051| 1.00|     |      |
| (9) Marketability | 0.045| -0.026| 0.012| 0.039| 0.100| 0.180| -0.002| 0.025| 1.00|      |
| (10) Ownership   | 0.069| -0.127| 0.034| -0.003| 0.075| -0.085| -0.085| 0.039| -0.020| 1.00|

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