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The impact of perception and other factors on the adoption of agricultural technology in the Moret and Jiru *Woreda* (district) of Ethiopia

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Abstract

The objectives of this study are to examine both the significance of the impact of farmers' perceptions regarding new technology for the adoption decision and how perceptions themselves are influenced by the decision to adopt new technology. The study is based on data from 96 wheat farms in the Moret and Jiru *woreda* (district) of Ethiopia. The probit approach is used to analyse the adoption decision, while the variables relevant to farmers' perceptions are modelled using the ordered probit methodology. A simultaneous equations model combining the probit and ordered probit approaches provides a useful approach to modelling the two-way relationship between perception and adoption. Variables such as farm size, farm income and soil type have a key role to play in the model. Perception is measured by eight different components and as there is a strong collinearity among these various measures, a principal components analysis is attempted to draw the best possible linear combination of variables.

Keywords: Principal components; Perception; Adoption; Ordered probit; Ethiopia

1. Introduction

Farmers' decisions to adopt a new agricultural technology in preference to other alternative (old) technologies depend on complex factors. One of the factors is farmers' perception of the characteristics of the new technology vis-à-vis that of the existing (old) technology. Other factors which influence farmers' adoption are the conventional (traditional) ones: resource endowments; socio-economic status; demographic characteristics; and access to institutional services (extension, input supply, markets, etc.). Studies on the effect of the conventional factors on adoption are extensive and numerous (Feder et al., 1985; Feder and Umali, 1993). The role of farmers' perception in adoption decisions is, however, scarcely studied (Adesina and Baidu-Forson, 1995). Recently, Adesina and Baidu-Forson (1995) and Adesina and Zinnah (1993) have demonstrated the impact that farmers' perceptions of the characteristics of different varieties (food quality, yield, tillering capacity, etc) have on the adoption of modern sorghum and rice

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varieties. This is a useful dimension to look for ways of facilitating farmers' gains in perception of the real characteristics of new technologies, and to identify factors that make differences in perception formation among farmers. Awareness of the factors that influence perceptions would also facilitate the enhancement of the development and transfer of appropriate technologies.

The objectives of this study are to examine the relative effects of perception and other factors on the adoption decision, to identify factors associated with perception and to investigate the interaction of perception and adoption. Econometric models using probit and ordered probit are used to estimate the adoption probability. The results then enable us to assess the effect that a change in an explanatory variable has on the probability of adoption. A simultaneous equations model is constructed and estimated to examine the interaction between perception and adoption.

The organisation of the paper is as follows. In Section 2, a brief review of the literature in the Ethiopian context is presented. In Section 3, the data and study area are described, while in Section 4, the theory and the econometric methods used are presented. In Section 5, the results of estimating various models are given. In Section 6, a simultaneous equations model between perception and adoption is presented, and the last section contains the summary and conclusions.

2. Research-improved crop varieties in Ethiopia

Formal public research and extension services in Ethiopia started around the end of the 1940s and early 1950s, with the establishment of Ambo Agricultural High School (1947), the Jimma Agricultural and Technical School (1953) and the Alemaya College of Agriculture (1956) (Roseboom et al., 1994). The Institute of Agricultural Research (IAR) was established under the Ministry of Agriculture in 1966. After its establishment, the IAR took over the role of leading agricultural research in the country from Alemaya College of Agriculture, but extension and training responsibilities remained with the latter. To date, the IAR and Alemaya University of Agriculture have been the major sources of modern wheat varieties and other complementary technologies.

The limited adoption of the recommended wheat production technologies and the poor progress in either increasing wheat productivity or easing constraints to wheat production were hinted at as early as the mid-1970s through IAR outreach activities and other related studies (Cohen, 1987, pp. 42–43). At the end of the 1980s, improved wheat seed was estimated to occupy only about 10% of the wheat area in the country. Inorganic fertiliser was used by <15% of the peasant farmers; fewer than 5% used herbicides and <1% used pesticides (Kidane and Abler, 1994, p. 180).

The fertiliser nutrient application rate in the country is estimated to be on average 7 kg/ha, well below the African average of 22 kg, while only 5% of farmers use improved seeds (Sasakawa-Global 2000, 1995). Moreover, there is significant differentiation among areas and regions of the country in the use-level of fertiliser and improved seeds. For instance, 10% of sample farmers in the Sinana area (in Bale Zone) and 100% in the Kulumsa area (in Arsi Zone) were found to use fertiliser in the 1988/1989 season. With regard to fertiliser rate, it was also reported that, on a sample basis, farmers in the Holetta area (West Shewa Zone) applied 40 kg of diammonium-phosphate (DAP) per hectare of wheat, while in Kulumsa the sample farmers applied on average 90 kg/ha (Beyene et al., 1992, pp. 205–206). In the Ada area (East Shewa Zone) of the Central Highlands >80% of the farmers grow improved wheat varieties (Negatu et al., 1994), while in the Aleltu area (North Shewa Zone) the proportion of improved wheat seed users is insignificant (Beyene et al., 1992).[1] Farming systems studies (e.g. Franzel and Van Hauten, 1992; DZARC, 1990; DZARC, 1992) have shed light on decisions by small farmers to adopt new technologies and on the major con-

[1]A major finding in the above studies is that recommendations of extension agencies are often not consistent with the farmers' objectives, strategies and decision criteria underlying their enterprise pattern and management practices, as these are usually related to their resource base. The studies showed that farmers, in their adoption decisions, take into account soil types and fertility, and seek dependable returns to their limited cash outlay; they also prioritise being food secure, and judge carefully the risks associated with unreliable rainfall patterns, availability of inputs, levels of input and output prices, and disease and insect incidence (ibid).

straints under which they operate. The constraints on adoption of the available technologies[2] can be categorised into three general sets: non-performance of the recommendations to the level of farmers' expectation and needs, when compared to their traditional methods; the problem of non-compatibility of the technologies with the ecological and other resource endowments of small farmers, which is often compounded by the risk-averse attitudes of farmers; and inadequacy of institutional support services.

3. Data and the study area

The data used for this study were collected in the 1994/1995 cropping year as part of the PhD study by the first author. The data were collected from 96 randomly selected farm households in the Moret and Jiru *woreda* (district) in central Ethiopia, using a formal survey questionnaire method. The Moret and Jiru *woreda* was chosen because of cereal based farming systems. The region is accessible by road and has varied socio-economic characteristics and resource endowments.

Moret and Jiru is located in the North Shewa Administrative Zone about 200 km north-west of Addis Ababa. The *woreda* has two distinct agro-ecological conditions: (i) a highland plateau with annual average rainfall of about 900 mm and soil dominated by the vertisol type; and (ii) gorge areas with rugged topography, non-vertisol dominated soil, a less reliable rainfall pattern and higher temperatures.

Ninety six farmers were randomly selected from 12 peasant associations (PA) stratified according to their locations (remote or near-middle distance from the town centre). A stratified two stage random sampling technique was employed to draw a sample of farm households. Since the distance of households from a town or from the main roads connecting towns within the *woreda* or a neighbouring *woreda* was assumed to be a possible important factor influencing farmers' access to information, inputs and markets, it was used as a stratifying criterion to categorise peasant associations into distance groups. Thus, all the PAs in the highlands of the *woreda* were defined in distance terms and then categorised into distance groups. Near-peasant associations were defined as those which were 1–6 km from the main road. Mid-peasant associations were located within a distance of 7–14 km and far peasant associations were >2 h walk away from the central locations. Four enumerators and one of the authors, who are employees of the DZARC, attended a one day training and discussion session on the aim and content of the survey questionnaire. For pre-testing, 20 farm households were interviewed, four farmers by each team member. Local development agents who were serving in the selected PAs assisted in locating and contacting the farm households. During the survey, time was allocated from each survey day for checking and clarifying the completed questionnaires, correcting any miscalculations or descriptions and converting local units of measurement while they were fresh in the memory. After testing a second meeting was held with the enumerators to discuss field experience, clarity of questions and language, unexpected responses and additional response options for questions. After incorporating corrections, the final version of the questionnaire was produced. Most of the questions in the survey were in relation to the traditional variety, however, frost and cold tolerance of the modern variety were in relation to that of local variety. These responses were tabulated as 1, 2, 3 and 4 where 1 indicated that the modern variety was less tolerant to cold; 2 implied that it was more tolerant to cold; 3 indicated that there was no significant difference to cold or frost levels between the traditional and modern variety, and 4 was used where the farmer had no idea. Similar ordinal scales prevailed for all other measures of perception indicators.

3.1. Cultivation of research-improved wheat varieties

Wheat is the dominant crop in the *woreda*, grown by 97% of the sample farm households on a sample mean

[2]Direct adoption studies which can further detail the influences of these and other constraints on the adoption of modern wheat and other crop innovations are, however, very few in Ethiopia. Adoption studies of agricultural technologies in Ethiopia started in the 1970s, about a decade after the initiation of the first comprehensive extension programme. Most of the studies dealt with the adoption of modern wheat varieties and fertiliser, and a considerable proportion of them were concentrated in the Arsi and Shewa regions, where most of the extension projects had been actively implemented. Almost all the studies dealt with the impact of conventional factors (Dadi, 1992, 1993, 1990)). Few considered the effect of farmers' perceptions of the characteristics of improved wheat variety on its adoption (e.g. Yirga, 1993; Dadi, 1992).

land area of 3.1 *kert*.[3] In the 1994/1995 cropping year it was grown on 40% of the cultivated land of the sample farm households.

Improved wheat varieties were introduced in the *woreda* for the first time in the mid-1980s. The improved wheat varieties under cultivation in the *woreda* were *Et-13*, *K-6295E* and *Enkoy*. All of them were released by the national research institute (IAR) of the country. These improved wheat varieties were grown by 74% of the sample farm households on 53% of the wheat area. The most widely grown improved variety was *Et-13* grown by 74% on 51% of the sample wheat area; there is, however, considerable variation within this average (coefficient of variation, CV = 78%).

4. Theories and models of adoption of agricultural technology in small-holder farming systems

Paradigms or conceptual models employed to explain the decision of small farmers to adopt new technology can be categorised into three groups: (i) the innovation–diffusion model; (ii) the economic constraints model; and (iii) the technology characteristics-user's context model.

(i) The innovation–diffusion model, also called transfer-of-technology (TOT), follows from the initial work of Rogers (1962). According to this model, a technology is transferred from its source (research systems) to final users through agent-medium (extension systems) and its diffusion in potential user-communities depends mainly on the personal characteristics of the potential individual user. What is assumed by this model is that the technology is appropriate for use unless hindered by the lack of effective communication.

(ii) The economic constraints model. The central assumption of this model, also known as the factor endowment model, is that the distribution of resource endowments among the potential users in a country/region determines the pattern of adoption of a technological innovation. The model assumes that market prices (or surrogate prices induced by policy and institutional interventions) reflect the relative scarcity of the factors, implying the existence of (or need for) well-performing markets and the importance of price policies (Hayami and Ruttan, 1971; Hayami and Ruttan, 1985).

(iii) The technology characteristics—user's context model. This model integrates approaches which assume that characteristics of a technology underlying users' agro-ecological, socioeconomic and institutional contexts play the central role in the adoption decision and diffusion process (Biggs, 1990; Scoones and Thomson, 1994). This model can also consider the perceptions of potential adopters regarding the characteristics of a technology as a component affecting adoption decisions and hence the diffusion of the technology (Gould et al., 1989). The model implies the importance of the involvement of farmers in the technology development process with the aim of generating technologies with appropriate and acceptable characteristics. The model also implies the importance of institutionalisation of research policies and strategies that facilitate the participation of farmers and other relevant stakeholders in the technology development process. Our study is generally based on the assumptions of this model.

4.1. Econometric approach to adoption–perception issues

Adesina and Zinnah (1993) present a conceptual model based on Rahm and Huffman (1984) for the farmers' adoption decisions. According to these authors, the decision is based on the assumption of utility maximization which remains unobserved. The decision whether to grow a modern variety in relation to a traditional variety is based on a comparison of marginal net benefits of one against the other. Define the modern and traditional variety by the symbols *m* and *o*. The preference of the *i*th farmer for the adoption Y_i^* is given by the difference between the marginal net benefits of the modern against the traditional variety which is unobserved. $Y_i^* > 0$ corresponds to the net benefit of the modern variety exceeding that of the traditional variety while $Y_i^* \leq 0$ refers to the net benefits of the traditional variety being no smaller than that of the modern variety. We may write the following equation in the

[3] 1 kert = 0.25 ha.

unobserved variable Y_i^*

$$Y_i^* = \sum_{j=1}^{m} \beta_j X_{ij} + U_i, \quad i = 1,2,3 \ldots n \qquad (4.1)$$

where X_{ij}s are explanatory variables and U_i is the error term. The observed variables are $Y_i = 1$ when $Y_i^* > 0$; $Y_i = 0$ when $Y_i^* \leq 0$ for the ith farmer. In this formulation, $\sum \beta_j X_{ij}$ is known as an index function.

It is not necessary that the function be linear. The ith farmer will select the modern variety if $U_i > -\sum \beta_j X_{ij}$. The model can be cast as a probit model where P_i is the probability of adopting the modern variety.

$$P_i = \text{Prob}(Y_i = 1) = \text{Prob}(\sum \beta_j X_{ij} + U_i > 0) \qquad (4.2)$$

$$P_i = \text{Prob}(Y_i = 1) = \text{Prob}(U_i > -\sum \beta_j X_{ij}) \qquad (4.3)$$

If the distribution is symmetric as are the normal and logistic,

$$\text{Prob}(Y_i^* > 0) = \text{Prob}(U_i < \sum \beta_j X_{ij}) = F(\sum \beta_j X_{ij}) \qquad (4.4)$$

$F(\sum \beta_j X_{ij})$ is the cumulative distribution function for U_i evaluated at $\sum \beta_j X_{ij}$. The above model is a probit model for the analysis of observed probabilities (1,0) where the information on the latent variable is only observed through the index function. The probability that a farmer will adopt the modern variety is a function of the vector of explanatory variables and the unobserved error term. As the form of F is not known, we assume F to have a cumulative normal distribution on the assumption that U_i has a normal distribution.

4.2. Ordered probit approach for perception

The decision to adopt a modern variety is based on the perception that farmers have about the new variety. A farmer's perception may be determined by his/her experience of growing the new variety, extension visits, his/her knowledge about the modern variety and other conditions. Perception may be with respect to the straw quality, grain yield and/or marketability of the new variety. These measures are ordinal and as a result the perception variable is treated as an ordered probit. The model for perception is similar to a latent regression model except that we have information recorded with increasing preference intensities of perception. Let

$$Y_{2i}^* = \sum \gamma_j Z_{ji} + \epsilon_i \quad i = 1,2 \ldots n \qquad (4.5)$$

Y_{2i}^* is unobserved. What we observe is

$$Y_{2i} = 0 \text{ if } Y_{2i}^* \leq 0 \qquad (4.6)$$

$$Y_{2i} = 1 \text{ if } 0 < Y_{2i}^* \leq \mu_1 \qquad (4.7)$$

$$Y_{2i} = 2 \text{ if } \mu_1 < Y_{2i}^* \leq \mu_2 \qquad (4.8)$$

$$Y_{2i} = 3 \text{ if } \mu_2 < Y_{2i}^* \leq \mu_3 \qquad (4.9)$$

This is a kind of censoring where the μs are unknown parameters and are to be estimated along with γ_j. Indeed, the perception of farmers depends upon certain measurable variables, namely socio-economic, demographic and environmental and unobservable stochastic factors ϵ_i. We assume that ϵ_i is normally distributed across observations. ϵ_i is normalised with mean zero and standard deviation one. In order for all probabilities to be positive, we must have $0 < \mu_1 < \mu_2 < \mu_3$.

As the eight different indicators used to measure perception are highly interrelated, alternative measures are attempted. Principal components analysis on the eight perception indicators extracted two components to represent perception. Grain yield, marketability, straw yield and straw quality of the new variety are found to be the most important ingredients of perception underlying the extracted perception factors. Grain yield and marketability are also used directly as perception variables in one of the regressions to explain adoption. This was attempted because many farmers believed that their perception about grain yield and marketability determined their adoption.

5. Principal components and single equation models of adoption

In the study, 33 explanatory variables are considered for their potential role in accounting for the adoption incidence of the new improved wheat variety (*Et-13*). The names, symbols, units of measurement and means and standard deviations of the variables used in the study are given in Appendix A. Two principal components were derived from a set of eight perception variables, 12 from the categorised variables and 11 from the whole set of 33 variables. Before extracting principal components, all variables were standardised.

When there is collinearity among explanatory variables there exists a possibility of replacing these variables by a smaller number of variables that can account for most or all of the variation in explanatory variables. Thus, we categorised the 33 variables into five groups (perception, socio-economic, institutional, demographic and environmental factors) and obtained one or more principal components for each group of variables. If the linear function is

$$\mathbf{Z}_1 = \mathbf{X}c_1 \tag{5.1}$$

then c_1, the vector of coefficients, is the characteristic vector of $X'X$ associated with λ_1, the largest characteristic root. The proportion of the variation in $X'X$ explained by this variable is

$$W_1 = \lambda_1 / \sum \lambda_k \tag{5.2}$$

One can seek a second principal component to represent a second linear combination of **X** subject to the condition that the second such variable is orthogonal to the first. If there are K variables, they can be replaced by K principal components, corresponding to K characteristic roots. However, the objective of reducing multicollinearity requires us to replace K variables by less than K principal components. The principal component estimator is a biased estimator but it can be more precise than OLS, since the latter has higher variance compared to the former when faced with the ill-conditioned data (Judge et al., 1985). When choosing the model or estimator, one may be willing to give up a bit of bias for increased sampling precision. There exists a trade-off between bias and sample precision and this can be attained by minimizing the mean squared error rather than the variance of the estimator. The principal component estimator does not normally use all the information available in the set of explanatory variables when it replaces the set of K variables by less than K variables. It is similar to the restricted least-squares estimator and unless restrictions are true, the PC estimator remains a biased estimator. The trade-off between the reduced sampling variances against the bias exists and the investigator has to make a choice between the two. Firstly, we derived two principal components from a set of eight perception variables and then they were used in the adoption equations of Table 3.

Using principal component (PC) analysis a total of 12 factors with eigenvalues of one and above were extracted from the categorised variables: three from perception variables, three from socio-economic variables, and two from each of the environmental, demographic and institutional groups of variables. Different combinations of these factors were used to estimate adoption employing a binomial probit model. None of the extracted factors was significant. Both models with and without heteroscedasticity were estimated and the likelihood-ratio test supported the homoscedasticity assumption.

The PC analysis on all the 33 variables provided 11 factors with eigenvalues one or above. Table 1 shows the estimation with the best (goodness of fit) combinations of factors. The first extracted factor with the highest eigenvalue (ALL1) is found to be the most

Table 1
Binomial probit regression coefficients, t-ratios and count R^2 for models of adoption based on factor analysis of all explanatory variables

Model	ALL1	ALL3	ALL4	ALL7	ALL8	Constant	Count-R^2
Homo-scedastic	2.2909[a]	0.4494	0.6102[b]	0.2645	−0.1742	2.1170[a]	0.975
	(2.505)	(1.092)	(1.646)	(0.670)	(−0.445)	(3.312)	
	[0.0952]	[0.0187]	[0.0253]	[0.0109]	[−0.0072]	[0.0884]	
Hetero-scedastic	3.2274	0.9599	0.6947	0.3234	−0.4449	2.7883	0.975
	(0.499)	(0.899)	(0.639)	(0.184)	(−0.404)	(0.897)	
	[0.0264]	[0.0079]	[0.0057]	[0.0027]	[−0.0036]	[0.0228]	

Note: The hypothesis of homoscedasticity was supported; figures in curved (first) parentheses are t-ratios, while those in the rectangular parentheses (second) are marginal effects.
[a] Significant at 1% probability.
[b] Significant at 10% probability.

significant factor ($p < 0.05$) and ALL4 is significant at 10% probability. The variables with the highest component weight underlying ALL1 are farmers' perceptions of straw quality, marketability and grain yield of the *Et-13 variety* compared with the traditional variety (*Enat-Sindea*). These variables are also found to have the highest weight in the extracted component from perception variables. This shows the important role of farmers' perception of the agronomic, economic and food quality traits of the new variety in the adoption decision.

Table 1 supports the hypothesis of homoscedastic disturbances and we therefore present the results of the homoscedastic model in terms of original variables in Table 2. Table 1 uses five factors but these factors are related to the 33 variables of the original regression and our interpretation will be based on *t*-ratios pertaining to the original variables. These estimates are minimum mean square error estimates. The results of Table 2 indicate that the lower the demand for fertilisers the greater would be the adoption rate *ceteris paribus*. Straw quality and straw yield variables have opposite signs. The poorer the quality of the straw yield, the lower should be the adoption rate. This did not turn out to be the case because the new variety has lower quality of straw but higher yield. Farmers looking for higher quantity of straw yield compromise on quality and hence we find that the adoption rate is positively related to quantity. The higher the labour-land ratio and the greater the consuming unit, the lower would be the adoption rate as these farmers probably tend to be more risk averse than others. With all other variables, the expected signs are positive and they are borne out although not all are significant. If a farmer's frequency of visits to local market is high then the adoption rate tends to be lower as the local information might not favour adoption.

Table 2
Regression coefficients, *T*-ratios of the homoscedastic model

Name of the variable	Regression coefficient	*t*-Ratio
Fertdmnd (high to low)	−0.8754	−2.82[a]
Frosttol	1.4133	2.68[a]
Grainyld	1.8046	2.66[a]
Marketbl	1.9175	2.79[a]
Strawqul (poor to better)	−1.9119	−2.72[a]
Strawyld	1.6913	2.62[a]
Watertol	0.4921	1.71
Coldtol	1.4099	2.69[a]
Foodqul	0.0135	0.12
Bushlar	0.0733	0.46
Cheberar	0.0061	0.02
Mererara	1.1492	1.97[a]
Padist	1.4108	2.44[a]
Prpvert	1.0733	2.14[a]
Cityvist	0.8417	2.60[a]
Creditak	−0.1174	−0.51
Demovist	0.7534	2.64[a]
Educat3	0.0249	0.09
Extfreq	0.1143	0.59
Fertdist	0.9958	2.33[a]
Marktfrq	−0.4931	−1.54
Cashland	1.1294	2.98[a]
Cultvata	0.9756	1.87
Incmland	0.9538	2.47[a]
Lablandr	−0.5853	−1.33
Ownlandr	1.0705	1.96[a]
Oxlandr	−0.0863	−0.28
Totlu	0.9798	2.09[a]
Adult	0.2787	1.14
Chldren	−0.0127	0.06
Consunit	0.2146	1.66
Prpconla	−1.1294	0.53
Age	0.2261	0.63

[a] Critical value at 5% = 1.96.

5.1. *Sequential model of perception and adoption*

Marketability and grain yield perceptions were selected as the index of perception,[4] and used in the estimation of adoption along with other socio-economic and agroecological factors (Table 3). Perception as indexed by PC-extracted factors was also used to estimate adoption (Table 4).

Case 1: The first adoption model which employed perception as measured by the direct subjective perception of the two characteristics of the variety showed that both perception variables (marketability and grain yield) are the most significant factors. Farm size (CULTVATA) and farm income (INCMLAND) are significant only at 10% probability.

Table 3 also shows factors that influence the formation of the two perception variables. Perception of

[4] Straw yield and quality perceptions also have the highest weight in the extracted perception factors. They are not, however, used to approximate perception, for almost all farmers agree that the new variety provides higher straw yield, but of worse quality (constant perceptions).

Table 3
Regression coefficients, *t*-ratios and count R^2 for models of perception and adoption: sequential approach—Case 1

Explanatory variable	Perception of marketability: Ordered probit	Perception of grain yield: Ordered probit	Adoption with actual perception and other variables: Binomial probit
CULTVATA	—	0.1136 (1.088)	0.4221* (1.732) [0.0060]
INCMLAND	0.0018* (1.821)	0.0017 (1.404)	0.0079* (2.019) [0.0001]
PRPVERT	−0.0362 (−0.076)	2.0079*** (4.398)	0.7849 (0.854) [0.0112]
PADIST	0.5908** (2.298)	—	0.1327 (0.346) [0.0019]
MARKTFRQ	−0.2964* (−0.833)	−0.4876** (−1.981)	—
CITYVIST	0.9140** (2.155)	—	—
MARKETBL	Dependent variable	—	0.8417** (2.535) [0.0120]
GRAINYLD	—	Dependent variable	1.0301** (2.535) [0.0147]
CONSTANT	0.6696 (0.828)	2.2251 (1.322)	−9.2393*** (−3.5560) [−0.132]
MU (1)	1.1656 (4.231)	1.9255 (3.017)	—
MU (2)	1.6478 (5.979)	2.3495 (3.959)	—
COUNT-R^2/χ^2	0.79	0.79	0.94
Degrees of freeedom	29.4691 (5)	33.5954 (4)	58.73 (6)

Note: Figures in curved parentheses are *t*-ratios, while those in rectangular brackets are marginal effects. In the last row, figures in parentheses are degrees of freedom. The critical value for χ^2 at 5% level is 9.488 for 4 df, 11.07 for 5 df and 12.592 for 6 df.

marketability is significantly ($p < 0.05$) related to proximity of PAs to town (PADIST) and frequency of visits to the nearby zone city (CITYVIST). Those who are nearer to town and those who go to the zone city frequently are more likely to have a positive perception for the marketability of the variety than others who are far away from the city and do not often visit the city. Higher income farmers are also more likely to have a positive perception for marketability of the new wheat variety than low income farmers. In the formation of the perception of the grain yield of the variety, the proportion of vertisol soil type (relatively fertile compared to light soils) is found to be a significant positive variable. Farmers endowed with a higher vertisol proportion than the average are likely to possess information regarding the better yielding characteristics of the variety either through direct adoption experience or indirectly from other sources. This relation could be related to the fact that wheat cultivation in the area is preferred on vertisol. Higher marketing frequency seems rather to be negatively related with the perception of marketability and grain yield of the variety. This relation could be due to the higher frequency of market-goings by farmers in the

Table 4
Regression coefficients, *t*-ratios and R^2 for models of perception and adoption: sequential approach—Case 2

Explanatory variable	Extracted perception factor (PERC1) OLS-estimation	Extracted perception factor (PERC2): OLS-estimation	Adoption with extracted perception variables: Binomial probit
CULTVATA	0.0675* (1.852)	−0.1319*** (−2.809)	0.2985 (1.017) [0.0001]
INCMLAND	0.0015*** (2.884)	0.0007 (1.108)	0.0089 (1.515) [0.000003]
PRPVERT	0.6231** (2.250)	0.3792 (1.063)	1.3741 (1.028) [0.0005]
PADIST	0.3148** (2.412)	−0.1669 (−0.992)	0.2709 (0.464) [0.0001]
MARKTFRQ	−0.1466* (−1.904)	−0.0412 (−0.415)	—
CITYVIST	0.3268** (2.406)	−0.1080 (−0.617)	—
PERC1	Dependent variable	—	2.7720** (2.003) [0.0009]
PERC2	—	Dependent variable	0.1285 (0.293) [0.00004]
CONSTANT	−1.8494*** (−3.677)	0.9442 (1.457)	−3.5247 (−1.160) [−0.0011]
R^2/χ^2	0.43	0.15	0.854/34.93(6)

Note: R^2 for the probit model is count-R^2; figures in curved brackets are *t*-ratios, while those in rectangular brackets are marginal effects. Perc1 and Perc2 are continuous variables and they are linear combinations of eight characteristics. In the χ^2 row, the degrees of freedom is six in parenthesis.

far PA (gorges) of the *woreda* to local markets (to sell fruits and firewood), but who are less frequent adopters of the new variety.

Case 2: The two principal-component-extracted perception factors (PERC1 and PERC2) with the highest eigenvalues were used in the estimation of adoption (Table 4). As Table 4 shows, the first extracted perception factor (PERC1) is the only significant factor affecting adoption decision. The same table shows the factors underlying the formation of this and the second extracted perception factor. The first perception index (PERC1) in which lie marketability, straw quality and grain yield (with the highest weight in the principal component analysis) is significantly and positively affected by the frequency of visits to the zone city (CITYVIST), proximity of PAs (villages) to town (PADIST), proportion of vertisol (PRPVERT) and farm income per *kert* of cultivated land (INCMLAND). The second perception factor (PERC2) in which lie cold tolerance and food quality (as the variables with maximum weights) is negatively and significantly related to farm size (CULTVATA). This is nearly equivalent to saying that holders of larger farms are more likely to have negative perception of cold tolerance and food quality. This perception could be as a result of direct observation of the traits of the new variety by these large farmers who are the likely adopters of the variety (Table 4). Dependent variables, namely perception index 1 and perception index 2, are linear combinations of eight variables measuring perception. The right-hand side variables are all exogenous variables in the model and they are not principal components. All *t*-ratios refer to the coefficient of original variables of the regression model.

6. Simultaneous estimation models of perception and adoption

As indicated above, perception is measured in two alternative ways —direct subjective evaluation of the major characteristics (MARKETBL) and the perception factor extracted from the eight perception variables (PERC1). They can play an important role in the adoption decisions. Our data is only for one year and contained both farmers who have and farmers who have not adopted the new variety in the past. As a result, the farmers who are conversant with the use of the new variety have already perceived the advantages or disadvantages. The follow-up argument or hypothesis is that it is not only that perception affects adoption, but also adoption in turn influences the formation of perception. Thus, as we have only one year data, we assume that both perception and adoption are endogenous and jointly dependent. This hypothesis can be tested with a general simultaneous equations model.

$$Y_{1i}^{*} = \sum \beta_j X_{ij} + \gamma y_{2i}^{*} + U_i \quad (6.1)$$

$$Y_{2i}^{*} = \sum \lambda_j X_{ij} + \alpha Y_{1i}^{*} + \epsilon_i \quad (6.2)$$

where Y_{1i}^{*} and Y_{2i}^{*} are unobserved variables in which

$$Y_{1i} = 1 \text{ if } Y_{1i}^{*} > 0 \quad (6.3)$$

and

$$Y_{1i} = 0 \text{ if } Y_{1i}^{*} \leq 0 \quad (6.4)$$

and

$$Y_{2i} = 0 \text{ when } Y_{2i}^{*} \leq 0; \quad (6.5)$$

$$Y_{2i} = 1 \text{ when } 0 < Y_{2i}^{*} \leq \mu_1 \quad (6.6)$$

$$Y_{2i} = 2 \text{ when } \mu_1 < Y_{2i}^{*} \leq \mu_2 \quad (6.7)$$

$$Y_{2i} = 3 \text{ when } \mu_2 < Y_{2i}^{*} \leq \mu_3 \quad (6.8)$$

Both these equations are identified as there is at least one distinguishing variable in each of the equations. A set of X_j variables is not the same in Eq. (6.2). Some experiments were conducted with single equation models before excluding variables from each of the regression equations. The reduced-form equations are probit for Eq. (6.1) and ordered probit for Eq. (6.2). The second stage of two step estimation substitutes the estimated or predicted probabilities in each of the structural equations and two stage least-squares estimates are derived. These are shown in Table 5.

The estimation is done in two stages—estimation of perception and estimation of adoption using instrumental variables or reduced-form least squares using probit or ordered probit methodology. In the simultaneous equations estimation procedure, the predicted perception and adoption variables are included as explanatory variables in the appropriate estimating equations. Perceptions as measured by marketability/grain yield are estimated using ordered probit model. Adoption is estimated using a binomial probit

Table 5
Estimation of perception and adoption using two-stage ordered probit and binomial probit models: simultaneous equations—Case 1

Explanatory variable	Perception of marketability with predicted adoption and other variables: Ordered probit	Perception of grain yield with predicted adoption and other variables: Ordered probit	Adoption with predicted marketability and other variables: Binomial probit	Adoption with predicted grain yield and other variables: Binomial probit
CULTVATA	—	—	0.2255* (1.758) [0.0339]	0.2154* (1.719) [0.0291]
INCMLAND	0.021** (2.124)	0.0009 (0.704)	0.0031* (1.710) [0.0005]	0.0044** (2.276) [0.0006]
PRPVERT	—	1.7587** (3.766)	1.4620* (1.907) [0.2202]	0.7496 (0.871) [0.1012]
PADIST	0.6824** (2.098)	0.2323 (0.744)	0.0484 (0.122) [0.0073]	0.4566 (1.315) [0.0617]
MARKTFRQ	−0.3134* (−1.851)	−0.4640** (−2.136)	—	—
CITYVIST	0.9575** (2.359)	—	—	—
ADOPEST	−0.3079 (−0.466)	0.4788 (0.801)	—	—
MARKTEST	—	—	0.9630** (2.261) [0.1451]	—
GRAINYES	—	—	—	0.3986 (1.115) [0.0538]
MU (1)	1.1739 (3.865)	2.0290 (3.843)	—	—
MU (2)	1.6556 (5.413)	2.4608 (4.877)	—	—
CONSTANT	0.5927 (0.762)	2.5802** (2.009)	−4.9623 (−3.593) [−0.7474]	−4.4496 (−3.219) [−0.6009]
COUNT-R^2	0.79	0.79	0.94	0.94
χ^2	29.79	34.45	34.72	39.14

Note: Figures in the curved brackets are *t*-ratios, while those in rectangular brackets are marginal effects. Standard errors are obtained using the adjustment factors based on Lee et al. (1980). χ^2 value at 95% confidence level for 5 degrees of freedom is 11.07.

model (Table 5). Standard errors of the parameters are adjusted using the corrected standard error of the error term.

The predicted perception of marketability (MARKTEST) is found to be significantly related to the adoption decision. Farm size (CULTVATA), farm income per *kert* of cultivated land (INCMLAND) and proportion of vertisol-area owned (PRPVERT) are also significant but at 10% probability. In the same case, however, no significant impact was observed of adoption on the formation of perception of both traits (MARKETBL and GRAINYLD). Here, INCMLAND, PADIST and CITYVIST are positive factors affecting perception of marketability significantly. For grain yield perception, PRPVERT is the sole significant positive factor. MARKTFRQ is negatively related to marketability and grain yield perceptions, as also shown in the prediction of perception with the explanatory variables (Table 3), where adoption is not one of the explanatory variables.

7. Summary and conclusions

Our study on a sample of Ethiopian farmers suggests that perception about the modern variety has a highly significant effect on adoption. This conclusion is embedded in models using principal components, sequential estimation and simultaneous models where perception and adoption interact. The most robust result is the role of perception in influencing adoption; farmers' perceptions about grain yield and marketability of product are the two most important ingredients affecting the adoption decision. It is, however, the case that most farmers suspect the quality of straw with the new variety to be poor and hence there is less variability among adopters and non-adopters regarding this component of perception variable. Thus, this variable has not been used in the empirical models employed. When the principal components are extracted from the perception variables, they show significance in both sequential and simultaneous equations estimation. In a simultaneous equations model, the farm size, income per *kert* of cultivated land and proportion of vertisol owned area are significant explanatory variables in determining adoption, while income per *kert* of cultivated land and proximity to town (PADIST) and mode of visits to the zone city centre (CITYVIST) are most important explanatory variables affecting the perception of marketability and grain yield of the modern variety. The results in general supported the reciprocal interaction of adoption and perception of technology characteristics.

The limitation of the study is that the number of the sample farms is small and that the data are only for one year, thus making it difficult to generalise the conclusions of the study to Ethiopia as a whole. However, our contribution is towards the construction of appropriate models such as probit for adoption decisions and ordered probit for perception measures. Moreover, since in many cases socio-economic, demographic, environmental and institutional variables are highly correlated, we suggest the extraction of principal components from each of the categories and the use of such components in a standard regression analysis. The policy recommendation from such a study is that perception comes from experience of adoption and that earlier introduction and contact with information sources (city visiting, proximity to towns, etc.) of modern technology will induce farmers to use or not to use such a technology. Adoption of a modern

Table 6
Names, symbols and descriptive statistics of variables in the study

Name of variable/units of measurement	Symbol	Mean/SD
(a)		
Comparative straw quality of Et-13 (0,1,2,3) (P)	STRAWQUL	0.19 (0.43)
Oxen number per *kert* of farm land owned	OXLANDR	0.20 (0.12)
Comparative fertiliser demand of Et-13 [0(more), 1, 2, 3(less)] (P)	FERTDMND	0.39 (0.75)
Labour per *kert* of farm land	LABLANDR	0.41 (0.21)
Proportion of vertisol soil type	PRPVERT	0.43 (0.32)
Frequency of visits to nearby zone city (0,1,2,3)	CITYVIST	0.50 (0.68)
Adoption incidence of Et-13 (0,1)	ET13ADOP	0.74 (0.40)
Consuming units per *kert* of landholding	PRPCONLA	0.81 (40)
Chebere (light) soil area in *kert*	CHEBERAR	0.94 (1.58)
Borrower/non-borrower of cash since last harvest (1,2)	CREDITAK	1.17 (0.37)
Comparative food quality of Et-13 (0,1,2,3) (P)	FOODQUL	1.18 (1.24)
Comparative water-tolerance of Et-13 (0,1,2,3) (P)	WATERTOL	1.23 (1.32)
Visit to demonstration fields (1,2)	DEMOVIST	1.49 (0.50)
Educational status of household head	EDUCAT3	1.72 (0.71)
Contact rate by extension agents per year, 1994/95 (1,2,3)	EXTFREQ	1.80 (0.76)
Comparative frost tolerance of Et-13 (0,1,2,3) (P)	FROSTTOL	1.83 (1.12)
(b)		
Proximity of PA-villages to town (1,2,3)	PADIST	2.17 (0.80)
Comparative marketability of Et-13 (0,1,2,3) (P)	MARKETBL	2.45 (0.90)
Comparative grain yield of Et-13 (0,1,2,3)(P)	GRAINYLD	2.47 (0.88)
Comparative straw yield of Et-13 (0,1,2,3)(P)	STRAWYLD	2.48 (0.95)
Proximity to input supply store (1,2,3)	FERTDIST	2.51 (0.79)
Area of *Bushla* (medium light) soil in *kert*	BUSHLAR	2.64 (2.69)
Total livestock in tropical livestock units	TOTLU	2.99 (1.60)
Frequency of visits to local markets (0,1,2,3,4)	MARKTFRQ	3.03 (1.23)
Number of children (age <15) in the household	CHLDREN	3.08 (1.83)
Area of *Merere* (vertisol) soil type in *kert*	MERERAR	3.14 (2.59)
Number of adults (15 years of age and above) in the household	ADULT	3.47 (1.60)
Family size in consuming units (adult-equivalent)	CONSUNIT	5.13 (1.87)
Area of landholding in *kert*	OWNLNDAR	7.18 (3.60)
Area of cultivated land in *kert*	CULTVATA	7.49 (3.54)
Age of household head	AGE	46.04 (13.17)
Farm cash outlay per *kert* of cultivated land in Birr	CASHLAND	52.10 (34.20)
Cold Tolerance (0,1,2,3)	COLDTOL	2.11 (1.14)
Farm gross margin per *kert* of cultivated land in *Birr*	INCMLAND	437.25 (178.63)

Figures in parentheses in the Mean column are SD (=standard deviations), while in the first column are values for discrete variables; 1 *kert* = 0.25 ha; one US$ = 7.00 *Birr*; comparisons (perceptions) of the traits of *Et-13* are relative to the popular traditional wheat variety (*Enat-Sindea*); P in parenthesis refers to perception variable.

variety depends positively on the net benefits proxied by an index measure of perception and other variables, such as farm size, income and soil type (vertisol proportion). The use of income (INCMLAND) as an exogenous variable may be criticised but as we do not have any other source of data for these groups of farmers, we were left with no choice. Instruments for income were not available to remove the endogeneity problem of farm income per cultivated land area.

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Appendix A

Names, symbols and descriptive statistics of variables in the study

Table 6

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