CHAPTER 6

EMPIRICAL ANALYSES OF THE ADOPTION OF *TEF* AND WHEAT TECHNOLOGIES

6.1 Introduction

Improved technologies such as improved seeds, fertilizers and herbicides have played a great role in enabling farmers to increase their production and hence improve their standard of living. Therefore, the process of adoption of these improved technologies have been the interests of many economists. Essentially adoption is a dynamic process that involves learning about the improved technologies over time. Although the dynamic aspects of adoption have been recognized well in the literature, with the exception of a few, almost all previous studies used cross-sectional data to study adoption which do not allow proper modeling of the dynamics of the adoption process. Thus, these studies have not been able to explore the dynamic nature of the process of adoption. The present study attempts to model the dynamics of adoption by incorporating the importance of learning in the process of adopting *tef* and wheat technologies in Ethiopia using panel data. For the investigation of dynamic adoption of *tef* and wheat technologies, separate adoption models were estimated using panel data.

Tef and wheat are among the most important cereal grains in Ethiopia in terms of area coverage and production (CSA, 2001). Yields of these crops are low due to low adoption of improved technologies mainly improved seed and fertilizers. Northern and Western *Shewa* zones are medium and high potential growing areas, respectively, for the two crops. National Extension Programs (NEP) have been launched to enhance the food production in the two zones. *Tef* and wheat are among the major crops where NEP has been implemented. The new *tef* and wheat technologies require a new set of knowledge which farmers gain through learning (using the technologies). This study used profit differential between the improved and traditional technologies that have been grown by the farmer as a dynamic learning term. In this study panel data for 165 wheat farmers and

234 *tef* farmers were used to study the dynamic process of learning in the adoption of improved *tef* and wheat technologies.

6.2 Hypotheses

From the conceptual model discussed in Chapter 4, the following hypotheses were advanced to be tested:

a) With age, a farmer can become more or less risk averse to an improved technology. The older the farmer the lower is the probability to adopt and allocate area to improved *tef* and wheat technologies.
b) Exposure to education will increase a farmer's ability to obtain, process and use information relevant to the adoption of improved technologies. The less educated the farmer is the lower the probability he will adopt and allocate area to improved *tef* and wheat technologies.
c) The more family labour available in the household the more likely the family will adopt and allocate area to improved *tef* and wheat technologies.
d) Population pressure in the study area is causing a land shortage, and hence the scope for increasing land productivity depends on higher cropping intensity. This in turn will require farmers to allocate their limited land to improved technologies. Besides, farm size is an indicator of wealth and perhaps a proxy for social status and influence within a community and hence it is expected to be positively associated with the decision to adopt improved *tef* and wheat technologies.
e) Access to information through visit to development agent is hypothesized to positively influence farmers' decision to adopt and intensify use of improved *tef* and wheat technologies.
f) Closer distance to input and output markets and better road condition positively influences farmers' decision to adopt and allocate area to improved *tef* and wheat technologies.
g) Knowledge gained through own experience positively influences farmers' decision to continue adoption and area allocation to improved *tef* and wheat technologies.

h) Riskiness of improved technology discourages adoption and area allocation to improved *tef* and wheat technologies.

i) Ownership of livestock is hypothesized to be positively related to the adoption and intensity of improved *tef* and wheat technologies.

j) Farmers who have access to credit (in cash or in kind) are more relaxed in terms of financial constraints. Hence, access to credit will increase the probability that a farmer will adopt and allocate area to improved *tef* and wheat technologies.

6.3 Specification of the empirical adoption models

In this study panel data were used to study farmers' adoption decisions and intensity of use. Panel data, unlike cross-sectional data, can produce consistent estimates of parameters. The advantages of panel data over cross-section or time-series data are that panel data take into account heterogeneity by considering individual-specific variables; give more informative data, more variability, less collinearity among variables, more degrees of freedom and more efficiency; better suited to study dynamics of change; and better detect and measure effects that simply cannot be observed in pure cross-section or pure time-series data (Gujarati, 2003). Despite their substantial advantages, panel data pose several estimation and inference problems such as heteroscedasticity for cross-sectional data and autocorrelation for time-series data. There are also some additional problems, such as cross-correlation in individual units at the same point in time (Gujarati, 2003).

There are several estimation techniques to address the above problems. The two most important are the fixed effects model (FEM) and the random effects model (REM) or error components model (ECM). In FEM the intercept in the regression model is allowed to differ among individuals in recognition of the fact that each individual may have some special characteristics of its own. FEM is also appropriate in situations where the individual specific intercept may be correlated with one or more independent variables. An alternative to FEM is ECM. In ECM it is assumed that the intercept of an individual unit is random, drawn from a much larger population with a constant mean value. The individual intercept is then expressed as a deviation from this constant mean value. One advantage of ECM over FEM is that it is economical in degrees of freedom, as we do not have to estimate N cross-sectional intercepts. We need only to estimate the mean value of the intercept and its variance. ECM is appropriate in situations where the random intercept of each cross-sectional unit is uncorrelated with the independent variables (Gujarati, 2003). Therefore, this study used ECM in the analysis of adoption of improved *tef* and wheat technologies over time.

6.4 Estimation procedures of empirical adoption models

There are three categories of farmers: farmers who have used only the new technology, farmers who have used only the old technology and farmers who have used the new and old technology simultaneously after the demonstration programs. Thus, only farmers who have used the new technology gain experience. For farmers who have used both the new and the old technologies simultaneously one can easily estimate the gains in profit. In this study, however, there are some farmers who have used only the new technology (improved seed with fertilizer, and improved seed with fertilizer and herbicide) after the demonstration programs. To estimate the gain in profit for farmers who have used only the new technology, average profits of farmers who have used the old technology were deducted from the profits of farmers who have used the new technology in their respective peasant association (PA). This follows the practice in another study by Cameron (1999), where average profit of farmers who have used the old technology in the village was subtracted from the profit of farmers who had used only the new technology.

In this study total profit from the production of *tef* or wheat (grain and straw) using the same input (improved seed, fertilizer, herbicide, improved seed with fertilizer, improved seed with fertilizer and herbicide) were considered for any year that the farmer had planted *tef* or wheat in Northern and Western Shewa zones. Equation (9) in Chapter 4 was used to estimate gains in profit from the *tef* or wheat technologies.

In this study, panel data regression models (Xtprobit and Xttobit) were employed to study farmers' decisions to adopt a new technology and resource allocation to the new technology. First, farmers' must make the initial choice of whether or not to use *tef* or wheat technologies for the first time in any one period. Second, conditional on choosing to adopt, farmers then must decide how much land to use. Third, the farmer has also to decide whether or not to try component(s) or the whole package conditional on choosing to use the new technology. Finally, following the adoption decision, each year the farmer has to decide whether or not to continue, which is influenced by gains in profit in previous years and risk faced in using the improved *tef* or wheat technologies. Farmers' knowledge (learning from own experience) improves as the farmers continue to use the new *tef* or wheat technologies.

Obviously, the above decisions are related and can be jointly determined or not. When decisions are not jointly determined farmers can adopt improved seed or fertilizer or herbicide. Thus, a panel data probit model (Xtprobit) was used to identify farmers who have used and not used the new technology over time (Equation 7 in Chapter 4). The dependent variable takes a value of one if the farmer has used the *tef* or wheat technologies, and zero otherwise for the specified period (1997-2001). Similarly, the independent variables will be year-specific to observation at the values taken in the year of adoption. On the other hand to capture the change in intensity of use of new technologies over time a panel data Tobit model (Xttobit) was used (Equation 8 in Chapter 4).

Accordingly explanatory variables were checked for problems of multicollinearity, endogenity and heteroscedasticiy. To detect the problem of multicollinearity among continuous explanatory variables, the variance inflation factor (VIF) was estimated. Values of VIF greater than 10 are often taken as signals that the data have collinearity problems. Likewise, contingency coefficients were used to check the degree of association among discrete variables. For endogeneity, an attempt was made not to include the dependent variables as explanatory variables to each and heteroscedasticiy is not a serious problem in panel and time series data.

6.5 Empirical results

This section presents comparison of the main features of wheat and *tef* growers, and models' estimation results using the computer Software Stata 7.0, which is appropriate to analyze panel data (Stata Corp., 2001). First, the main features of wheat and *tef* growers are compared. This is followed by results of farmer's adoption decisions over time, which involves two choices i.e., to use or not, and intensity of use of improved *tef* and wheat technologies over time using Xtprobit and Xttobit models, respectively. The results of *tef* and wheat technology adoption decisions are presented separately since the two crops have different farming systems and different samples were considered for the two crops in their respective production areas.

6.5.1 Comparison of the main features of wheat and *tef* farming systems

Farmers in the study area grow more than one crop to satisfy their needs. The major crops grown in the study areas include t*ef,* wheat, grass pea and chickpeas. Minor crops consist of barley, maize, lentils and faba-beans. Based on the major crop grown, the study area is divided into two farming systems: *tef*-based (*tef*, grass pea, lentil, chickpea, maize) and wheat-based (wheat, barley, faba bean, maize) farming systems where more than 95% of farmers grow *tef* or wheat in their respective areas.

Survey results suggest that, on average, wheat farmers are slightly younger (42 years) than *tef* farmers (45 years). On the other hand, education among wheat farmers is much higher (46%) than among *tef* farmers (29%). The age of a farmer is correlated with education. Younger farmers are more likely to have received some education than older farmers due to recent (late 1970s) expansion of formal education in the rural areas of Ethiopia (Wagayehu and Lars, 2003). Thus, wheat farmers are expected to have better capacity to understand improved technologies and learn faster than *tef* farmers. The average family size was slightly higher among wheat farmers than *tef* farmers (7.6 persons versus 7.0 persons). But wheat farmers had significantly higher family labour than *tef* farmers (3.6 persons versus 2.3 persons), which means wheat farmers can provide the additional labour required for adopting labour intensive improved technologies.

While average farm sizes were similar for wheat and *tef* growers (2.78 ha and 2.79 ha, respectively), *tef* farmers cultivated larger shares of their farmland to *tef* (60%) compared to the share of wheat (30%). This suggests that *tef* farmers are more specialized in *tef* production with some pulses (chickpea and lentil) in the rotation on 21% of the land. On the other hand, wheat farmers use more mixed cropping and diversify with barley and pulses on 22% and 19% of area, respectively. This may be attributed to the high risk associated with wheat production as improved wheat varieties grown in the area are introductions from outside (Hailu, 1992) mainly from the International Maize and Wheat Improvement Center (CIMMYT) and found to be susceptible to pests and diseases while *tef* varieties are local selections and hence better adapted (Seyfu, 1993).

Wheat farmers allocated most of the wheat area (90%) to improved varieties while *tef* farmers allocated only 20% of *tef* area to improved varieties from 1997 to 2001. More improved wheat varieties[1] (6 including the old ones) are distributed to farmers compared to only three improved *tef* varieties[2] supplied and grown at the time of the study. Most important is the fact that the zonal extension offices supplied much higher quantities of improved wheat seed (120.8 tons) than *tef* (10.8 tons) during 1999 and 2000 crop seasons. Improved seeds are supplied by the Ethiopian Seed Enterprise (ESE) depending on availability during the cropping season. This clearly is expected to lead to higher adoption of improved varieties by wheat farmers (86% of farmers) than *tef* farmers (42%) during the study period.

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[1] Wheat varieties included Dashen, Enkoy, ET-13, Kubsa, Wabe and Galema. Dashen and Enkoy are phased out of production by The National Variety Release Committee due to their susceptibility to disease and the seeds are no longer produced and supplied by ESE. However, farmers continued to grow these varieties and they are considered as local varieties in this study. Dashen and Enkoy are planted on 10% of total wheat area during the study period. ESE produced and supplied the seeds of the other varieties.

[2] Improved *tef* varieties supplied to farmers are DZ-354, DZ-196 and CR-7.

Wheat farmers showed a slightly higher demand for information about improved technologies than *tef* farmers as indicated by the number of visits they made to development agent (DA) office in 2001 (2.0 versus 1.3, respectively). This was in spite of the fact that both need same time to reach the DA office (1.4 hrs and 1.3 hrs for wheat and *tef* farmers, respectively). On the other hand, wheat farmers were closer to local markets (1.5 hrs versus 1.8 hrs) while *tef* farmers were much closer to major markets such as Addis Ababa (91 km versus 103 km from district capital to Addis Ababa). Moreover, 60% of wheat growers were located in districts where the capitals are connected to Addis Ababa by tarmac roads compared to *tef* farmers (36%). This suggests that proximity and access to information, input supply sources and markets are among the factors that contribute to higher adoption of improved technologies among wheat farmers.

Wheat was grown by 95% of farmers mainly for own consumption among those using local varieties (35% selling only) compared to those adopting improved varieties where 49% of the produce was sold. That means users of local wheat varieties appear to produce mainly for own consumption (65%). The opposite is true for *tef* where 69% of grain produced from improved *tef* was sold compared to only 40% of grain produced from local varieties. On aggregate, however, equal amounts of wheat and *tef* (48% and 46% of produce, respectively) were sold in the local market. This seems to suggest that although wheat farming appear to be more market oriented in terms of input use, both *tef* and wheat farmers sell half of their produce in the market (i.e., equally market oriented)

Similar levels of fertilizer and herbicide were used on wheat and *tef*. In terms of livestock ownership wheat and *tef* farmers were not different (6.0 TLU versus 6.1 TLU).

Five years after participating in the National Extension Package program, most wheat farmers (85%) continued adopting the new improved wheat varieties as compared to only 35% of *tef* farmers. Better education and longer experience together with better access to and availability of seed helped continued replacement of varieties among wheat farmers.

6.5.2 Results of wheat technology adoption analyses

This section presents parameter estimates of adoption and intensity of use of wheat technologies. Most adoption studies (Akinola and Young, 1985; Akinola, 1987; Jha et al., 1990; Hassan et al., 1998) used farmer's age at the time of the study. However, farmers may have made the decision to adopt earlier than the time of the study (Legesse, 1998). The present study considered the age of the farmer at the time of adoption[3] while other variables were measured at the time when the study is conducted.

Wheat farmers were classified into adopters and non-adopters. Non-adopters are farmers who use none of the new improved varieties or fertilizer or herbicide while adopters are farmers who used at least one of the new improved varieties or fertilizer or herbicide during the study period.

The parameter estimates of the Xtprobit model employed to identify factors influencing farmer's adoption of wheat technologies are presented in Table 6.1. Table 6.2 presents estimation results of the Xttobit model employed to examine factors influencing intensity of use of wheat technologies. In all analyses the likelihood ratio test statistics suggest the statistical significance of the fitted regressions. Results of the analyses also revealed that the adoption and intensity of use of wheat technologies are influenced by different factors and at different levels of significance for different factors.

Age of the farmer: The age of the farmer had different influences on adoption and intensity of use of improved wheat seed (Tables 6.1 and 6.2). The age of the farmer had negative influence on the adoption and intensity of improved seed and amount of herbicide applied on wheat. The influence was significant only for adoption of improved seed as older farmers are more conservative and avers to risk associated with new technologies. Studies by Legesse (1998) and Hassan *et al.* (1998) also obtained a negative relationship between technology adoption and the age of the decision maker. On the other hand, the age of the farmer had positive influence on the adoption and intensity of

[3] Also experience, livestock ownership and credit were measured at the time of adoption.

fertilizer and adoption of herbicide on wheat due to previous knowledge gained, as fertilizer and herbicides are earlier technologies introduced to the area.

Farmer's education level: Educated farmers are more interested in trying new technologies than non-educated. As expected, education had positive impact on adoption and intensity of use of wheat technologies, except for amount of fertilizer applied on wheat (Tables 6.1 and 6.2). This may be attributed to the fact that while educated farmers are more willing to adopt new innovation they have less access to cash and assets such as ownership of livestock. This limits their ability to purchase fertilizer and hence apply lower rates than the less wiling to adopt but wealthier farmers. The influence is significant only for likelihood and intensity of herbicide use on wheat. This is consistent with results of studies by Mafuru *et al.* (1999) and Shiyani *et al.* (2002).

Family labour: Larger households will be able to provide the labour that might be required by the improved technology. New wheat technologies promoted in the region appear to be labour intensive since partial and full adopters used significantly more labour than non-adopters in the production of wheat as indicated in Chapter 5 (Table 5.4). Adoption and intensity of use of improved seed and herbicide, and amount of fertilizer applied on wheat were positively and significantly influenced by family labour (Tables 6.1 and 6.2) suggesting farmers who have more family labour adopt improved seed and allocate more area, apply more fertilizer and herbicide since they can supply the required labour for different operations. This result is consistent with the findings of Getachew *et al*. (1995), who found positive and significant effect of family labour on adoption of coffee berry disease (CBD) resistant varieties. These results suggest that larger families will more likely adopt improved wheat technologies. The negative impact of family labour on the likelihood of adoption of fertilizer on wheat is hard to explain.

Farm size: As expected, farm size positively influenced the likelihood and intensity of adoption of improved wheat seed and fertilizer where only the likelihood of improved seed adoption was significant (Tables 6.1 and 6.2). On the other hand, farm size had negative and significant influence on the adoption and intensity of herbicide use on wheat. These negative impacts suggest that small farmers may be trying to utilize their limited resources (purchased inputs like fertilizer and herbicide) more efficiently to increase production while large farmers want to increase production by applying lower rates on larger areas. Small farmers used 0.505 l/ha herbicide and 136 kg/ha fertilizer on wheat while large farmers used 0.44 l/ha and 130 kg/ha of herbicide and fertilizer, respectively. Large farmers, however, applied those to larger land areas. Livestock ownership helps larger farmers use improved varieties with lesser rates of fertilizer and herbicide on larger areas. A study by Shiyani *et al. (*2002) provided a negative relationship between farm size and adoption of improved varieties and fertilizer. On the other hand, our results suggest that large farmers could increase their production by using improved seed with fertilizer but without herbicide.

Frequency of visit to Development Agent (DA) office: Agricultural extension services are the major sources of information for improved technologies. One can get access to information about new technologies through attending formal training, participate in package testing programs, visit demonstration fields, attending field days and visiting the development agent (DA) at his office. Of these, visit of farmers to the development agents' office was considered for this study. Farmers who frequently visit the DA's office are updated on the availability and arrival of improved technologies.

Frequency of visit to DA's office positively influenced the likelihood and intensity of adoption of improved seed where the impact was significant to area allocated to improved wheat seed (Tables 6.1 and 6.2). Studies by Kaliba *et al.* (1998) and Mafuru *et al.* (1999) indicated that extension was a significant factor affecting land allocated to improved maize varieties in Tanzania.

Farmer's knowledge in using improved technologies: Farmers learning from their own experience in growing the improved technologies is an important factor in the promotion of improved technologies. In this study farmer's knowledge was defined as the profit differential between improved and traditional technologies assuming that farmers care more about profitability. Thus, farmers who participated in the demonstrations of improved wheat technologies have gained some knowledge and are therefore expected to use their knowledge in their future adoption decisions. As expected, farmers' knowledge had positive and non-significant impacts on adoption of wheat technologies. The non-significant effect of farmers' knowledge on improved seed adoption can be explained by the fact that non-adopting farmers are using some old improved varieties (Dashen and Enkoy) that were still productive on farmer's fields although the National Variety Release Committee banned these varieties due to their susceptibility to disease. The profit differential between the new and old varieties might be small to justify the cost of new seed purchases. A study by Chilot *et al.* (1996) also revealed that farmer's experience had no significant effect on the adoption of wheat varieties in Wolmera and Addis Alem *weredas* (districts).

Distance to Addis Ababa: Addis Ababa is considered as an external market for farmers' surplus output. Besides, farmers can buy inputs like herbicide from small shops in Addis Ababa and transport inputs like fertilizer at their own expense when there is delay in transporting fertilizers by the Ministry of Agriculture (MOA) to the district capital. Thus, closer distance of district capital to Addis Ababa enables traders to travel easily to purchase surplus produce from local assemblers and facilitate input delivery to farmers. The coefficients of distance to Addis Ababa had the expected negative signs and had significant effect on the adoption and intensity of fertilizer and herbicide use on wheat (Tables 6.1 and 6.2). The negative sign indicates the importance of proximity to regular sources of improved inputs and external markets leading to better access, lower transport cost, and timely delivery of inputs and disposal of outputs, and better output price for farmers.

Road condition: It is not only the proximity to local and external markets that influence adoption of improved technologies, but the road condition (tarmac) also matters. As expected, better road conditions from the district capital to Addis Ababa positively and significantly influenced the likelihood and intensity of adoption of improved seed and fertilizer on wheat (Tables 6.1 and 6.2) suggesting better roads are essential for timely input delivery and output disposal and less transport cost of inputs and outputs and hence investment in improved road infrastructure is crucial for promoting adoption and hence productivity gains.

Livestock: Generally livestock is considered as an asset that could be used either in the production process or be exchanged for cash (particularly small ruminants) for the purchase of inputs (fertilizer, herbicide, ete.) whenever the need arises. Besides, livestock is considered as a sign of wealth and increase availability of cash for adoption. Also livestock, particularly oxen, are used for draft for different farm operations. Ownership of livestock had positive and significant effects on the adoption of fertilizer and intensity of use of herbicide on wheat (Tables 6.1 and 6.2) due to availability of cash to adopt these technologies. Besides, livestock had positive and significant influence on allocating area to improved seed due to availability of oxen for farm operation. A study by Chilot *et al.* (1996) indicated similar positive and significant influences of livestock ownership on the intensity of fertilizer use on wheat.

Credit: The serious cash shortages faced by small farmers partly due to deteriorating output prices and increasing external input prices makes availability of credit to be an important determinant of farmer's adoption decisions. As expected, credit had positive and significant effect on adoption and intensity of fertilizers and herbicide use on wheat and adoption of improved varieties (Tables 6.1 and 6.2). The non-significant effect of credit on area allocated to improved varieties could be explained by farmer's use of improved seed from their previous harvest and credit was needed for the purchase of improved seed initially at the time of adoption. Other studies revealed a positive and significant association between access to credit and adoption of HYVs and intensity of use of fertilizer (Herath and Jayasuriya, 1996; Hassan *et al.,* 1998; Techane *et al.,* 2006).

Table 6.1. Parameter estimates of the Xtprobit model for adoption of wheat technologies in Northern and Western Shewa Zones, 1997-2001.

Variable name	**Estimated coefficients for**		
	Seed (n =165)	**Fertilizer (n = 165)**	**Herbicide (n = 165)**
Constant	0.6526	0.6475	-2.4835
	(0.4998)	*(1.1586)*	*(10959)*
Age of farmer	-0.0334**	0.0266	0.0203
	(0.0121)	*(0.0197)*	*(0.0169)*
Farmer's education	0.2357	0.04227	0.8197**
	(0.2098)	*(0.2658*	*(0.2803)*
Family labour	0.2408**	-0.0891	0.7927***
	(0.0938)	*(0.0995)*	*(0.2803)*
Farm size	0.3568**	0.2587	-0.5195***
	(0.1184)	*(0.1973)*	*(0.1343)*
Frequency of DA visit	0.1659	NR	NR
	(0.1042)		
Knowledge gained	0.0002	0.0002	0.0003
	(0.0001)	*(0.0002)*	*(0.0002)*
Distance to Addis	NR	-0.0333**	-0.3868***
		(0.0130)	*(0.0065)*
Road condition	2.4240***	1.5540*	NR
	(0.4177)	*(0.8945)*	
Livestock owned	0.0309	0.2251**	0.0391
	(0.0393)	*(0.0973)*	*(0.0489)*
Credit	0.0038**	0.0225***	0.0098***
	(0.0017)	*(0.0015)*	*(0018)*
Log-likelihood	-190.30	-81.42	-183.61
Likelihood-ratio	218.13***	15.45***	164.76***
Wald	54.56***	30.93	58.51***

Note: NR means not relevant; **, and *** indicates significance at 5% and 1% level, respectively

Figures in parentheses are standard errors

Table 6.2. Parameter estimates of the Xttobit analysis of intensity of wheat technology adoption in Northern and Western Shewa Zones, 1997-2001.

Variable name	Estimated coefficients for		
	Seed (n =165)	Fertilizer (n = 165)	Herbicide (n = 165)
Constant	0.0871	1.3218***	0.3616***
	(0.2193)	*(0.1725)*	*(0.0506)*
Age of farmer	-0.0061	0.0004	-0.0002
	(0.0048)	*(0.00257)*	*(0.0010)*
Farmer's education	0.0239	-0.0353	0.0498***
	(0.1022)	*(0.0130)*	*(0.0114)*
Family labour	0.1633**	0.0395**	0.0368***
	(0.0524)	*(0.0130)*	*(0.0043)*
Farm size	0.0658	-0.0263	-0.0327***
	(0.0448)	*(0.0214)*	*(0.0060)*
Frequency of DA visits	0.5525***	NR	NR
	(0.0754)		
Knowledge gained	0.00005	0.0001	0.00001
	(0.00005)	*(0.00001)*	*(0.00001)*
Distance to Addis	NR	-0.0062**	-0.0007**
		(0.0018)	*(0.0003)*
Road condition	2.1960***	0.5766***	NR
	(0.2812)	*(0.1243)*	
Livestock owned	0.0502**	0.0084	0.0036*
	(0.0156)	*(0.0068)*	*(0.0020)*
Credit	0.0004	0.0012***	0.0002**
	(0.0004)	*(0.0002)*	*(0.0001)*
Log-likelihood	-305.08	-490.63	227.12
Wald	86.56***	144.52***	176.95***

Note: NR means not relevant; *, **, and *** indicates significance at 10%, 5% and 1% level, respectively.

Figures in parentheses are standard errors

6.5.3 Results of *tef* technology adoption analyses

In this section, parameter estimates on determinants of adoption and intensity of *tef* technologies are presented. This study considered the age of the farmer at the time of adoption[4] while other variables were measured at the time when the study was conducted.

Tef farmers were classified into adopters and non-adopters. Non-adopters are farmers who used none of the new improved *tef* varieties or fertilizer or herbicide while adopters are farmers who used at least one of the improved *tef* technologies between 1997 and 2001.

The parameter estimates of the Xtprobit and Xttobit models employed to examine factors influencing adoption and intensity of *tef* technologies are presented in Tables 6.3 and 6.4, respectively. Results of the analyses also revealed that the adoption and intensity of adoption of *tef* technologies are influenced by different factors and at different levels of significance for different factors.

Age of the farmer: The age of the farmer had different influences on adoption and intensity of *tef* technologies (Tables 6.3 and 6.4). The age of the farmer had positive effect on adoption and intensity of fertilizer and herbicide use on *tef*. However, the impact was significant on adoption and intensity of herbicide use on *tef*. It is important to note that these inputs were introduced earlier than improved varieties and hence farmers had more experience in using these inputs. Older farmers apply more fertilizer and herbicide to *tef* than younger farmers due to their better financial status given the wealth differential between the two groups. On the other hand, the age of the farmer had negative and significant influence on the likelihood and intensity of adopting improved *tef* seed. Younger farmers appear to be more eager to test new technologies than older farmers. A study by Techane *et al.* (2006) had similar non-significant relationships between the age of the household head and the adoption and intensity of fertilizer use.

[4] Also experience, risk, livestock ownership and credit were measured at the time of adoption.

Farmer's education level: As would be expected, education had positive and significant effect on adoption of herbicide on *tef* (Table 6.3) as exposure to education increases farmer's ability to obtain, process and use information about improved technologies. On the other hand, education had negative and significant influence on intensity of herbicide use on *tef* (Table 6.4). This may suggest that factors other than education have stronger power in influencing intensity of herbicide use on *tef* as education among *tef* farmers was similar.

Family labour: As shown in Tables 6.3 and 6.4, family labour had positive influence on adoption and intensity of improved *tef* seed, adoption of fertilizer and herbicide on *tef* indicating the importance of large active family members in the adoption of improved technologies by supplying the required farm labour for different operations. Family labour had significant influence on intensity of improved seed adoption as *tef* is labour intensive crop. Family labour also had negative and significant effect on amount of herbicide applied on *tef.* The negative impact of family labour on intensity of herbicide use on *tef* indicates that herbicide is a substitute for weeding labour.

Farm size: Farm size negatively and significantly influenced amount of fertilizer use on *tef* (Table 6.4) indicating small farmers can increase their production by using more fertilizer. A study by Endrias *et al*. (2006) also found similar negative and significant influence of farm size on adoption of improved sweet potato varieties. On the other hand, farm size had positive and significant effect on intensity of herbicide use on *tef.* This may be due to the fact that large farm areas would require significantly higher labour efforts in weeding and hence herbicide is the cheaper option and also affordable for large farmers due to their better financial ability compared to small farmers.

Frequency of visit to DA office: As expected, frequency of visit to DA's office positively influenced the likelihood and intensity of adoption of improved *tef* seed and fertilizer and adoption of herbicide on *tef* although the results were not significant (Tables 6.3 and 6.4). The positive signs indicate that farmers who visited the DA office continued growing the improved varieties with fertilizer and allocated more area to improved varieties and applied more fertilizer and herbicide to increase their production. The negative sign on herbicide adoption is hard to explain. Studies by Kaliba *et al*. (1998) and Mafuru *et al.* (1999) indicated that extension contact was a significant factor affecting land allocated to improved maize varieties in Tanzania.

Farmer's knowledge in using improved technologies: As expected, farmer's knowledge gained in previous years had positive impact on adoption and intensity of improved *tef* technologies (Tables 6.3 and 6.4). However, knowledge gained had significant influence only on area allocated to improved varieties indicating that farmers who continued using the improved *tef* technologies over time have benefited from higher yield they provide than the local varieties. Most farmers did not like the improved varieties because of their colour and discontinued planting them a year after the demonstration.

Risk: Risk is an important explanatory variable in the adoption of improved technologies since yield loss due to the use of improved technology discourages farmers from adopting improved technologies. In this study risk is defined as yield variance. Risk had negative significant influence on the likelihood and intensity of adoption of improved *tef* seed (Tables 6.3 and 6.4) suggesting the new improved varieties are less riskier than local varieties. That could be one major reason why some farmers had continued using the new improved varieties as risky technologies discourage farmers not to use these technologies.

Livestock: Livestock ownership had positive influence only on the adoption of fertilizer on *tef* (Tables 6.3 and 6.4). On the other hand livestock ownership had unexpected negative effect on the likelihood and intensity of improved seed and herbicide adoption and amount of fertilizer applied on *tef.* As livestock provides the required draft power for different farm operations and cash for the purchase of improved inputs like fertilizer and herbicide, and *tef* needs fine seedbeds and adequate weed control, the result is strange and hard to explain. Livestock also supply manure, which is mostly used for fuel and some for garden crops around homestead.

Credit: As expected, availability of credit had positive and significant influence on adoption and intensity of improved *tef* technologies (Tables 6.3 and 6.4) as serious cash shortages faced by small farmers is a constraint to farmers ability to purchase and use improved inputs and affect optimal applications. A study by Techane *et al.* (2006) reported similar positive and significant influence of credit on the adoption and intensity of fertilizer use on cereals.

Table 6.3. Parameter estimates of the Xtprobit model for adoption of *tef* technologies in Northern and Western Shewa Zones, 1997-2001.

Variable name	Estimated coefficients for Seed (n =234)	Fertilizer (n = 234)	Herbicide (n = 234)
Constant	1.1343**	1.4022	-1.3144*
	(0.4296)	*(0.8954)*	*(0.6767)*
Age of farmer	-0.0096*	0.0056	0.0222**
	(0.0059)	*(0.0133)*	*(0.0084)*
Farmer's education	-0.0882	-0.0749	0.5167**
	(0.1152)	*(0.2548)*	*(0.2122)*
Family labour	0.0173	0.0194	0.0183
	(0.0345)	*(0.0762)*	*(0.0447)*
Farm size	-0.0533	-0.1186	0.8656***
	(0.0570)	*(0.1627)*	*(0.1323)*
Frequency of DA visit	0.0147	0.0413	-0.0184
	(0.0640)	*(0.1067)*	*(0.0536)*
Knowledge gained	0.00015	0.00006	0.00012
	(0.00011)	*(0.0001)*	*(0.00009)*
Risk	-0.0570***	NR	NR
	(0.0098)		
Livestock owned	- 0.01208	0.0486	-0.0153
	(0.0187)	*(0.0491)*	*(0.0254)*
Credit	0.0037***	0.0085**	0.0028***
	(0.0006)	*(0.0031)*	*(0.0008)*
Log-likelihood	-521.87	-139.65	-325.52
Likelihood-ratio	439.12***	31.56***	631.30***
Wald	87.49***	10.89	85.86***

Note: NR means not relevant; *, **, and *** indicates significance at 10%, 5% and 1% level, respectively.

Figures in parentheses are standard errors

Table 6.4. Parameter estimates of the Xttobit analysis for intensity of *tef* technology adoption in Northern and Western Shewa Zones, 1997-2001

Variable name	Estimated coefficients for Seed (n =234)	Fertilizer (n = 234)	Herbicide (n = 234)
Constant	0.2215	1.6944***	0.4256***
	(0.1488)	*(0.1653)*	*(0.0192)*
Age of farmer	-0.0039**	0.0010	0.0007**
	(0.0019)	*(0.0028)*	*(0.0003)*
Farmer's education	-0.0077	-0.0441	-0.0045***
	(0.0471)	*(0.0493)*	*(0.0062)*
Family labour	0.0129**	-0.0023	-0.0022*
	(0.0053)	*(0.0082)*	*(0.0013)*
Farm size	-0.0354	-0.1374***	0.0073
	(0.0263)	*(0.0261)*	*(0.0029)*
Frequency of DA visit	0.0015	0.0006	0.0048
	(0.0149)	*(0.0202)*	*(0.0026)*
Knowledge gained	0.00004**	0.00001	0.000003
	(0.00001)	*(0.00001)*	*(0. 000003)*
Risk	-0.0078***	NR	NR
	(0.0013)		
Livestock owned	-0.0038	-0.0022	-0.0035***
	(0.0063)	*(0.0057)*	*(0.0010)*
Credit	0.0005**	0.0009***	0.00004*
	(0.0001)	*(0.0001)*	*(0.00003)*
Log-likelihood	-6370.04	-812.56	540.96
Wald	57.58***	78.28***	35.14***

Note: NR means not relevant; *, **, and *** indicates significance at 10%, 5% and 1% level, respectively.

Figures in parentheses are standard errors

6.6 Summary of key empirical results

Comparison of the main features of *tef* and wheat farmers revealed that wheat farmers are slightly younger and more educated than *tef* farmers. The average family size was slightly higher among wheat farmers than *tef* farmers. But wheat farmers had significantly higher family labour than *tef* farmers. While average farm size is similar for wheat and *tef* farmers, *tef* farmers cultivated larger shares of their land to *tef* (60%) compared to the share of wheat farmers (30%). This suggests that *tef* farmers are more specialized in *tef* production while wheat farmers use more mixed cropping and diversify with barley and pulses due to higher risk associated with wheat production as improved wheat varieties grown in the area are introduction from outside and found susceptible to pests and diseases while *tef* varieties are local selections and hence better adapted. In terms of livestock ownership wheat and *tef* farmers were not different.

Wheat and *tef* farmers allocated 90% and 20% of wheat and *tef* area, respectively, to improved varieties from 1997 to 2001. More improved wheat varieties (6 including the old ones) are distributed to farmers compared to only three improved *tef* varieties. Besides, the zonal extension office supplied much higher quantities of improved wheat seed than *tef* based on farmer's demand in 1999 and 2000 crop seasons. This clearly is expected to lead to higher adoption of improved varieties by wheat farmers (86% of farmers) than *tef* farmers (42%) during the study. Similar levels of fertilizer and herbicide were used on *tef* and wheat.

Wheat farmers showed slightly higher demand for information about improved technologies than *tef* farmers as indicated by the number of visits they made to DA office in 2001. On the other hand, wheat farmers were closer to local markets while *tef* farmers were much closer to major markets such as Addis Ababa. Moreover, 60% of wheat farmers were located in districts where the capitals are connected to Addis Ababa by tarmac roads compared to *tef* farmers (36%). This suggests that proximity and access to information, input supply sources and markets are among the factors that contribute to higher adoption of improved technologies among wheat farmers.

Wheat was grown by 95% of farmers mainly for own consumption. Among those using local and improved varieties 35% and 49%, respectively, of the produce was sold. The opposite holds true for *tef* where 69% and 40% of grain produced from improved and local varieties, respectively, were sold. That means more local wheat seeds are consumed than local *tef* (96% versus 68% of produce). However, on aggregate equal amounts of wheat and *tef* (48% and 46%) were sold in the market. It means although wheat farming appears to be more market oriented in terms of input use, both *tef* and wheat farmers sell about half of their produce in the markets.

Five years after participating in the National Extension Package program, most wheat farmers (85%) continued adopting the new improved wheat varieties as compared to 35% of *tef* farmers. Better education and longer experience together with better access to and availability of seed helped continued replacement of varieties among wheat farmers.

An examination of the relationship between the adoption of wheat and *tef* technologies and selected explanatory variables over time revealed that adoption and intensity of wheat and *tef* technologies are influenced by different factors and at different level of significance for different factors.

The study showed that awareness, availability and profitability of the new technologies enhanced farmer's learning in the adoption of wheat and *tef* technologies as farmer's knowledge had positive influence on the likelihood and intensity of wheat and *tef* technologies. However, farmer's preference of the colour of *tef* varieties was critical to the adoption of new improved *tef* varieties. On the other hand, wheat and *tef* technologies were found scale neutral as small farmers can increase their production by using purchased inputs efficiently while large farmers can increase their production by using lower rates of fertilizer on larger fields and allocating more areas to improved varieties. Improved wheat and *tef* technologies were labour and draft power intensive, hence, large family labour and livestock ownership were found prerequisites for adoption of these technologies. Surprisingly, livestock ownership had negative insignificant impact on *tef* technologies that is hard to explain. The study further revealed that younger age, larger family labour and farm size, frequency of visit to DA office, better roads, livestock ownership and availability of credit are the key determinants in the likelihood and intensity of improved wheat seed adoption. Large family labour, closer distance to Addis Ababa, livestock ownership and availability of credit in the case of fertilizer and in the case of herbicide better education and small farm size are key factors as was better road on the likelihood and intensity of fertilizer adoption.

For *tef*, the study showed that younger age, large family labour, farmer's knowledg, less riskiness of the improved varieties and availability of credit are key determinants of the likelihood and intensity of improved seed adoption. For herbicide, old age, small family labour and large farm size are key determinants as was availability of credit and small farm size on the likelihood and intensity of fertilizer adoption.

This implies that timely availability of improved wheat and *tef* technologies and provision of credit enhances farmer's learning from their own experience on the adoption of wheat and *tef* technologies and increase food production. Inputs like fertilizer and herbicide are imported from outside and need to be imported and distributed to farmers in time to enhance adoption and increase production and productivity. Development of better roads facilitates the transportation of inputs to the farm and outputs to local and major markets in the promotion of improved wheat and *tef* technologies. Thus, policies and strategies that strengthen the roads would help enhance the use of improved inputs.

The study result indicated that younger farmers adopted improved wheat and *tef* technologies than older farmers suggesting that more attention should be given to younger farmer to enhance adoption of improved technologies and increase productivity. Education of the farmers was not significant in explaining adoption of improved seeds suggesting that policy makers should give more emphasis in expanding primary education and increasing the enrolment rates of their children in rural areas.

Extension did not prove to be important for adoption of wheat and *tef* technologies except for area allocation to improved wheat varieties, as it had no significant influence on the likelihood and intensity of adopting wheat and *tef* technologies. Thus, there is a need to upgrade DAs skills (pre-service and in-service training) to improve their services to accomplish the objectives of NEP, which give emphasis to raise smallholders' production and productivity. Appropriate policies are needed to improve the efficacy of extension for farmers to achieve increased agricultural productivity.

The fact that farm size has an impact on adoption of wheat and *tef* technologies, policy makers should give more emphasis in provision of credit to small farmers who account for most of the cultivated land and production in the country to increase food production. Livestock ownership was critical to the adoption of wheat technologies as crop and livestock productions are complementary. The negative impact of livestock ownership on *tef* technologies is hard to explain and should be investigated further. Policies and strategies to improve the livestock production system (draft power and nutrition) should be designed to achieve increased agricultural productivity.

Wheat and *tef* technologies are labour intensive suggesting that these technologies should not be introduced in areas where there is labour shortages. Thus, policies and strategies should consider availability of active labour force before introducing labour intensive technologies. Similarly wheat and *tef* technologies require more draft power than the traditional technologies, thus, due attention should be given before introduction of these technologies in to an area.

Riskiness of the improved *tef* seed did not stop farmers from using improved *tef* varieties due to significantly higher yield and net benefits obtained compared to the local varieties. This implies that farmers are willing to take some risk in the adoption of new technologies. Therefore, policies and strategies should assist farmers' effort by providing crop failure insurance.

CHAPTER 7

SUMMARY, CONCLUSIONS AND IMPLICATIONS OF THE STUDY

The objective of this study was to assess the role of knowledge gained in the process of adopting improved *tef* and wheat technologies in Ethiopia. As part of the agricultural development-led industrialization program, the Ethiopian government launched the new extension program (NEP) based on the experience of the Sasakawa Global 2000 project. The program took place at a time of major policy changes on marketing of outputs, pricing and subsidies on inputs that affect the agricultural sector. In spite of large number of farmers participating in the NEP and increased utilization of improved technologies, mainly improved varieties and fertilizers, yields of cereals remained low. There has been a growing concern by researchers, extension personnel and policy makers about the effectiveness of adoption of these technologies particularly on the area allocated to and amount of use of these technologies over time and farmers' learning from the NEP to enhance the food shortage problem in the country. Therefore, this study was initiated to identify factors that influence farmer's decision to continue to use new technologies or not after participating in the NEP and determine farmers' knowledge gained from adoption using panel data.

There are several studies on farmers' adoption of improved technologies using static models with cross-section data in developing countries including Ethiopia. Results of static models using cross-section data do not adequately explore the effects of explanatory variables due to failure to account for changes in farmer's perception and attitudes over time, as adoption is essentially a dynamic process. Nevertheless, only very few studies have dealt with learning as a dynamic adoption process and no study in Ethiopia has analysed knowledge gained in the adoption of improved technologies over time.

This study employed a knowledge model and panel data to analyze the effects of knowledge gained from learning as a dynamic process in the adoption of improved *tef* and wheat technologies. Panel data regression models (Xtprobit and Xttobit) were employed to study farmers' decisions to adopt and intensity of use of new technologies. Panel data are better suited to study dynamic changes and the random effect models control for unobserved variables and potential endogeniety. Household characteristics, socio-economic and institutional factors influencing farmers' adoption were analysed for the *tef* and wheat crops.

This study used panel data obtained from a survey of farmers who participated in the NEP from 1995 to 1996 in Northern and Western Shewa zones of Oromiya in Ethiopia. To better understand farmer' adoption decisions, one needs to particularly study farmers who have used the new technologies of *tef* and wheat over time. Northern and Western Shewa zones were selected to represent medium, and high potential production environments, respectively, for growing *tef* and wheat in Ethiopia. Out of the total number of participating farmers in the two zones for the two crops, separate samples of 165 wheat farmers and 234 farmers growing *tef* were selected proportionally and randomly from wheat-based and *tef*-based farming systems, respectively. Selected farmers were interviewed during the 2001 crop season. Data collection was accomplished in a single visit using structured questionnaires to solicit information from the same panel of farmers on their adoption practices to study the dynamics of farmer's knowledge from their own learning over the five years following the introduction of the improved practices in 1997.

Comparisons of the main features of *tef* and wheat farmers revealed that wheat farmers are slightly younger (42 versus 45 years), more educated (46% versus 29%) and have slightly higher family size (7.6 versus 7.0 persons) than *tef* farmers. Besides, wheat farmers had significantly higher family labour (3.6 versus 2.3 persons) than *tef* farmers. Thus, most wheat farmers adopted improved technologies due to their better capacity to understand and ability to provide additional required labour for improved technologies.

While average farm size is similar for wheat (2.78 h) and *tef* farmers (2.79 ha), *tef* farmers cultivated larger shares of their land to *tef* (60%) compared to the share of wheat farmers (30%). This suggests that *tef* farmers are more specialized in *tef* production while wheat farmers use more mixed cropping and diversify with barley and pulses due to higher risk associated with wheat production as improved wheat varieties grown in the area are introduction from outside and found susceptible to pests and diseases while *tef* varieties are local selections and hence better adapted. However, *tef* farmers allocated only 20% of *tef* area to improved varieties due to shortage of desirable varieties whereas wheat farmers allocated 90% of wheat area to improved varieties from 1997 to 2001. For instance, more improved wheat varieties (6) and higher quantities of improved seed (120.8 tons) were distributed to farmers compared to only three improved *tef* varieties and 10.8 tons of seed supplied by Zonal extension offices during 1999 and 2000 crop seasons. This clearly led to higher adoption of improved wheat varieties (86% versus 42%) during the study period.

Wheat and *tef* were mainly grown for own consumption. More local wheat seeds (96%) were consumed than local *tef* (68%). However, on aggregate equal amounts of wheat and *tef* (48% and 46%) were sold in the market. It means both wheat and *tef* farmers are not yet market oriented.

Wheat farmers showed a slightly higher demand for information about improved technologies than *tef* farmers as indicated by the number of visits they made to development agent (DA) office in 2001(2.0 versus 1.3, respectively). This was in spite of the fact that both need same time to reach the DA office (1.4 hrs and 1.3 hrs for wheat and *tef* farmers, respectively). On the other hand, wheat farmers were closer to major markets such as Addis Ababa and were located in districts where the capitals are connected to Addis Ababa by tarmac roads compared to *tef* farmers. This suggests that proximity and access to information, input supply sources and markets are among the factors that contribute to higher adoption of improved technologies among wheat farmers.

The results of this study provided empirical evidence of the positive impact of the effectiveness of NEP and farmer's learning in enhancing the adoption of improved *tef* and wheat technologies to increase production. The result showed that adopters of wheat and *tef* technologies have increased their production by 20% and 39%, respectively, than non-adopters. The results could help design appropriate strategies to enhance the adoption and intensity of improved agricultural technologies to meet the priority needs of smallholder farmers and to alleviate the food shortage problem in the country.

The study found access and availability of credit to be more powerful than other factors in explaining adoption and intensity of wheat and *tef* technologies. Availability of credit had positive and significant influence on the adoption and intensity of wheat and *tef* technologies. However, wheat and *tef* technologies (particularly fertilizer and herbicide) are usually rationed and farmers cannot buy what they want for their crops. For instance, on average farmers obtained 148 kg and 202 kg of fertilizers on credit from 1997 to 2001 in wheat-based and *tef*-based farming systems, respectively, while they need 180 kg and 326 kg of fertilizers based on crop area for wheat and *tef*, respectively. Further, the distribution of fertilizers between the two crops is not based on crop response even though there is less response of *tef* to fertilizers as compared to wheat. Usually fertilizers are delivered late and most of the fertilizers go to *tef* as its planting is delayed by one month compared to wheat. Therefore, in the short run timely availability of credit to purchase available inputs based on responses is required in order to promote the adoption of improved wheat and *tef* technologies and increase food production in the country. In the long run, farmers should be encouraged to purchase their inputs on cash if they can afford and be advised not to pay interest rates unnecessarily.

Family labour was powerful in explaining adoption and intensity of wheat and *tef* technologies suggesting that these technologies required additional labour for different operations and hence may not achieve high adoption in areas where there are labour shortages. Therefore, policies and strategies should consider availability of labour before introducing such labour intensive technologies.

Farmer's knowledge gained from own learning had positive impact on continuing adoption and increased levels of wheat and *tef* technologies. However, the study revealed that most farmers discontinued growing improved *tef* varieties because of the undesirable colour (not as white as the local cultivars).

Risk was significant only on the likelihood and intensity of improved *tef* seed adoption because farmers who continued adoption were willing to take some risk due to significantly higher yield, lower yield variance and net benefits obtained. This implies farmers are willing to adopt less risky technologies. Therefore, policies and strategies should be designed to enhance farmers' capacity to take some risk in their effort to increase agricultural productivity.

The age of the farmer was significant on adoption of improved wheat seed and on the likelihood and intensity of improved *tef* seed and herbicide on tef. Younger farmers adopted more improved wheat and *tef* technologies than older farmers suggesting that more attention should be given to younger farmers to enhance adoption of improved technologies and increase productivity.

Farmers' education was significant only in the likelihood and intensity of use of herbicide on wheat and *tef* which suggests that use of herbicide need some care due to its hazard and computation in determining the rates. Policies and strategies should therefore place more emphasis on expanding primary education and increasing school enrolment rates of children in rural areas to achieve increased agricultural productivity in the future.

Farm size was critical in the adoption of improved wheat and *tef* technologies. In the case of wheat, farmers can increase their production by spraying lower rates of herbicide on larger wheat fields while *tef* farmers can increase their production by using herbicide and applying higher rates of fertilizer on smaller areas of *tef*. Although small farmers account for most of the cultivated land and production in the country, the fact that farm size has some positive influences on adoption of wheat and *tef* technologies implies that policy makers should give equal attention to large as well as small farmers in designing technological intervention for increased productivity and food production.

Except for area allocation to improved wheat seed, extension did not prove to be important for adoption of improved *tef* and wheat technologies. As extension is the main source of information for small farmers appropriate policies need to be designed to improve its efficacy for farmers to achieve increased agricultural productivity.

Distance to Addis Ababa was critical in the adoption of improved wheat technologies mainly fertilizers and herbicide as proximity to information, sources of input supply and markets save time and reduce transportation costs. Better roads are also essential for the likelihood and intensity of use of improved wheat seed and fertilizers as they improve timeliness of delivery of inputs and marketing of outputs and reduce transportation costs. Given the critical role of proximity to major markets (Addis Ababa) and better roads for promoting adoption and productivity gains, investment in improved road infrastructure is crucial. Thus, policies and strategies to expand the existing road infrastructure and build new ones based on production potential are highly recommendable.

Adoption was found profitable and provided acceptable rate of return on investment than non-adoption. This implies that as improved wheat and *tef* technologies are more profitable than traditional technologies farmers allocate more area to improved varieties and use more levels of fertilizers and herbicide to increase production. Policies and strategies should be redesigned to provide adequate support services (in technology development and distribution, provision of credit in kind and infrastructure development) to improve profitability (yield advantage) of new technologies.

Despite large number of farmers adopted the improved wheat varieties on 90% of the total wheat area, about 10% of wheat area are still planted to old improved varieties that are banned out of production by the Variety Release Committee due to their susceptibility to diseases. This practice could lead to complete crop failure and endanger the food security of the family and the country at large. Thus, the reasons why farmers continued growing these susceptible varieties should be investigated.

Results of the analyses suggest there is more research focus on wheat than on *tef* as indicated by number and quantity of improved wheat varieties distributed to farmers (six as compared to only three for *tef* and 121 tons versus 11 tons for *tef*). This clearly leads to higher adoption and intensity of use as indicated by percentage of farmers using (86% versus 35%) and area allocated to improved varieties (90% versus 20%). This implies that more research effort is needed to increase the supply of improved *tef* varieties that meet farmer’s demand in order to be adopted on the existing large *tef* areas and increase production.