Agricultural Research & Technology
Open Access Journal
ISSN: 2471-6774

Juniper Publishers
key to the Researchers

Research Article
Volume 20 Issue 4 - March 2019
DOI: 10.19080/ARTOAJ.2019.20.556139

Agri Res & Tech: Open Access J

Impact of Technology Adoption on Agricultural Productivity and Income: A case study of Improved *Teff* Variety Adoption in North Eastern Ethiopia

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Submission: January 28, 2019; **Published:** March 25, 2019

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Abstract

The study investigates the potential impact of agricultural technology adoption, exemplified here by adoption of improved Teff (Boset variety) on rural household agricultural productivity and income. The research is motivated by two research questions:

a. Why and how adoption of improved Teff variety affect the income of adopter farmers in the study area?

b. What are the costs and benefits associated with the adoption of improved Teff variety?

To answer these questions, the channels of impact are identified based on an extensive literature review and modeled using a household production function. This approach recognizes the interrelation of households' producer, consumer and labor supply decisions and takes into account potential impact on income from non-farm activities.

The study uses a cross-sectional data collected from a randomly selected 163 sample households from North Eastern Ethiopia. The analysis was conducted using a multivariate regression model, which was developed based on the household production function. The estimated result of a linear regression confirmed that adopter farmers have generated, 24% higher farm income from the resulted increase of agricultural output due to adoption. In addition, farm income of households in the survey responds differently to other production factors. The resulted change in farm income due to a unit change in land, capital and other seeds was significant and positive. However, the change in farm income, due to the change in other production factors labour, irrigation water uses, and fertilizers application was negative and insignificant. This could be due to existence of labour surplus, inappropriate application of fertilizer and inefficient utilization of irrigation water.

The study also identifies farmers, who adopt improved seeds faced higher input cost (fertilizer and seed) and confirms that adoption had increased the production costs of farmers. Finally, the net impact of adoption calculated by combining the effect of adoption on the farming household's farm income and its effect on cost of inputs confirms that the total benefit of adoption is far higher than the associated increase in costs.

Keywords: Impact assessment; Technology adoption; Teff; Boset; Agricultural productivity; Income

Abbrevations: ATA: Agricultural Transformation Agency; EIAR: Ethiopian Institute of Agricultural Research; MoA: Ministry of Agriculture; UN-OCHA: United Nations Office for the Coordination of Humanitarian Affairs; DA: Development Agent

Introduction

During the last decades, due to the expansion of agricultural farmland, there has been a rapid growth of agricultural production in Ethiopia. However, the use and contribution of modern agricultural inputs to overall agricultural growth is relatively low [1]. Given the scarcity of suitable arable land it becomes largely difficult to meet the increasing needs of the rapidly growing population through expansion of the area under cultivation [2]. It is, therefore, evident that, comprehensive efforts are required to increase agricultural production through different intensification and productivity enhancement mechanisms.

The adoption of modern agricultural technologies is believed to improve the income of the smallholder farmers through enhancing agricultural productivity. And improving the agricultural productivity of farmers requires developing and disseminating cost-effective agricultural technologies. Accordingly, increasing agricultural production, reducing poverty and meeting the demands for food without irreversible degradation of the natural resource base are possible [3]. The theoretical case is in favor of agricultural technology adoption as a panacea for improving the income of smallholder farmers through closing agricultural productivity gaps. Therefore, it is important to study the impact of

adoption on the farm households' agricultural productivity and income empirically.

As compared to the availability of literature on the factors influence adoption of improved agricultural technologies, studies assessing the impact of technology adoption are very scarce in Ethiopia. And the existing literature and studies are conducted either at the regional or national level. Furthermore, most of these impact studies are concentrated on Wheat, Cotton, Maize, and Rice varieties. On the other hand, as [4] *Teff* is relatively unknown somewhere else, [5] research with particular reference to the impact of improved *Teff* adoption is very rare. According to Agricultural Transformation Agency (ATA), Ministry of Agriculture (MoA) and Ethiopian Institute of Agricultural Research (EIAR), the focus of *Teff* research has been on breeding yet limited attention given to applied research, such as adoption and impact for many areas. In addition, the report calls for further research on several dimensions, including "Socioeconomics: adoption, impact, and a cost-value ratio of various inputs". Based on these facts, this study attempts to assess the impact of adopting technology on farm households, agricultural productivity, and income, taking improved *Teff* (Boset Variety) adoption in Kobo woreda as a case study. Boset is a recently developed and released genetically modified high yielding *Teff* variety.

In Kobo woreda, the north-eastern part of Ethiopia, *Teff* has extensive coverage of the area planted. But *Teff* productivity in Kobo is among the lowest in the region. For instance, the average yield of *Teff* is estimated 1.3 tons per hectare, which falls below the national average (1.47 tons per hectare) and is far from the potential yield of it (3.91 tons per hectare) [6]. And Kobo is also listed as high priority food insecure woreda for the United Nations Office for the Coordination of Humanitarian Affairs (UN-OCHA) [7]. Improved *Teff* varieties and different agronomic practices have been introduced to resolve the problem of low agricultural productivity, low income, and food insecurity in the area. This makes the woreda interesting to study.

All the above reasons make worth to undertake this study. Therefore, it can contribute to the existing limited literature by bridges the gap of information with regard to the impact of improved *Teff* (Boset variety) on agricultural productivity and income of rural households. Thus, the study can serve as a reference material for policy makers, academicians and researchers. Moreover, this study can give a better insight into the role of modern agricultural technology in the productivity of the agriculture sector, hence, the income of rural households and poverty reduction.

Theoretical and Conceptual Framework

The link between improved teff adoption, productivity and income

Based on the review of the existing literature in the previous chapter the following transmission mechanisms through which improved *Teff* adoption will affect the agricultural productivity and household income are identified:

a. Adoption of the technology (i.e. Boset *Teff* variety) is expected to have a positive influence on the agricultural production as it (Boset) takes less time to mature than local varieties. In addition, water-logging resistant and weed tolerant nature of the technology (Boset *Teff* variety), helps to increase yield by protecting the yield that would otherwise be lost due to logging and weeds. Therefore, adoption will lead to increased yields or intensive production practice and diversification of produced crops that may be used for own consumption and/or for being sold at the local markets. Hence, it will lead to an increase in farm income.

b. Adoption of improved seeds is labor intensive. Consequently, it will affect the households' labour time allocation. The increased yield resulted from technology adoption (Boset *Teff* variety) require the farmers to spend more labour time on their field to collect the harvest. While it is expected to increase the farm income, it will reduce the time allocated for other productive (non/off-farm) activities there by income from these sources.

c. In addition, the technology adoption (i.e., Boset *Teff* variety) increase expenditures for a group of farm households that formerly relied on local seed varieties. Further, adoption also changes the use of other inputs like fertilizer, pesticides, herbicides etc. Accordingly, the cost of production, including the transaction and transportation costs, will likely to increase.

In order to assess the impact of improved *Teff* adoption on the income of farm households', this study examines the economic costs and benefits of adoption. It is assumed that improved *Teff* variety adoption has an impact on agricultural production, reallocation of labour time and household expenditures. Being able to infer a causal connection between a project and an impact indicator depends both on the data that are used for the analysis as well as the empirical methods that are employed. In analysing agricultural production, the relationship between inputs and outputs or profitability is often examined through production or profit functions [8]. The model to estimate empirically all quantitative impact of changes in agricultural practice (i.e, improved *Teff* adoption) on production and income is modeled on/adopted from the productivity method /income function framework/ by Löwenstein et al. [9].

Productivity method

Productivity method is a revealed preference method which measures the change in productivity and income of the affected people by the given intervention [10]. The farm households in the area earn total cash income (Y) from different sources including farm income (Y^{fa}), labour income from other productive (non/off-farm) activities (Y^{op}), and also income from transfers (remittances and governmental subsidies) (Y^{tr}). The farm household's total income (Y^{ttl}) can therefore be expressed as follows:

$$Y_i^{ttl} = Y_i^{fa} + Y_i^{op} + Y_i^{tr} \; i = 1 \ldots\ldots nfarming\ households \ldots\ldots\ldots [1]$$

Transfer income will not be affected by adoption of improved *Teff*. Income from other productive activities of the farm house-

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holds in the area is also not affected by the adoption of improved seed (Boset Variety) due to agrarian nature of the area (where farming is seen as the main activity) and limited (none) existence of other productive activities in the area. Moreover, there is a strong cultural bias against non/off-farm activities in the area where farmers prefer to spend their time for leisure or other social activities than participating in other productive activities. Therefore, there is no need for further analysis for these income categories. On the other hand, farm income may be affected through the above described changes in intensive use of production factors and through the increased in productivity of farmland.

In simple agriculture production function, the farm output (X^{fa}) will be produced by combining labor (L), land (Land), and physical capital (K). In the area, farming follows traditional patterns so that farming technology (A) can be assumed to be the same for all households. Farming is not mechanized, characterized by the use of the ard, a primitive ox-drawn plow, and it is more traditional and involves extensive manual work. Farmers in the area have access to irrigation and they use different local seed varieties and chemical fertilizers. Land preparation is done by using animal power. In addition, the use of simple agricultural tools such as picks and hoes is common. All these form the capital stock (K) of the household. More or less the capital stock of the households in the area is assumed to be similar and traditional.

There is one part of the capital stock which is improved *Teff* (Boset Variety) that makes a difference in capital between farm households in the area. This element does vary between households that are adopted improved *Teff* and those who are using local varieties. Most producers in the area are smallholders, occupying on average less than a hectare of land per household. Having large family size with small plot size, we assume either a declining (zero) or positive marginal productivity of labour.

Thus, the households farming production function contains the following explanatory variables.

$$X_i^{fa} = f\left[A, K_i^{+}, L_i^{0+} Land_i^{+}\right] \ldots\ldots\ldots [2]$$

Farmers generate gross income (PX) by selling their output to the nearest market for constant [11] market price (P). The farm income can be calculated by subtracting the individual household's total production cost (C_i^{fa}), which is a combination of fixed (C_i^{f}) and variable costs (C_i^{v}) from gross income. Thus, the households' profits from farming activities can be expressed as follows:

$$Y_i^{fa} = \left[f\left(A^{+}, K_i^{+}, L_i^{0+}, Land_i^{+}\right)\right] * P - C_i^{fa} \ldots\ldots\ldots [3]$$

With $C_i^{fa} = C_i^{f} + C_i^{v}\left(X_i\right)$

Equation (3) reveals that the adoption of improved *Teff* varieties affects farm income of the households' in two channels. One, it is expected that the adoption of improved seeds will have a positive influence on the agricultural production. Hence, the rise in farm yield resulted from the increased in capital stock (i.e. improved *Teff* varieties) will lead to an increase in the income of the farm household that is generated from the sale of the harvested output. The other channel is the expenditure channel. Farm income falls from increasing the costs of farming as those farmers who adopt improved seeds have to pay for the seeds and cover expenses for related complementary inputs such as fertilizer and also have to bear transportation cost of inputs.

Boset *Teff* has a tall and tender stem which is susceptible to damage by wind and rain. Moreover, the grain holding per straw of Boset *Teff* is higher than the local varieties, which puts more pressure on the straw. The higher amount of seeds per Boset *Teff* straw makes it easier to fall to the ground, which causes considerable losses on both the quality and quantity of the harvest. Hence, adopter farmers are expected to apply more fertilizer to strengthen of the straw and control displacement of the steam from its upright position. Consequently, the woreda agriculture office in collaboration with the improved seed distributors of the area insists the farmers to buy the recommended fertilizer quantity while purchasing the seed [12].

Inserting equations (3) into equation (1) and considering the assumptions, constant market price for outputs, the total differential of the modified equation (1) can be expressed as follows:

$$dY_i^{m1} = dY_i^{fa} + dY_i^{mp} + dY_i^{nr} = \left[dX_i^{fa}\right] * P - dC_i^{fa} + dY_i^{mp} + dY_i^{nr} = \left[\frac{\partial X_i^{fa}}{\partial A} dA + \frac{\partial X_i^{fa}}{\partial K_i} dK_i + \frac{\partial X_i^{fa}}{\partial Labour_i} dLabour_i + \frac{\partial X_i^{fa}}{\partial Land_i} dLand_i\right] * P - dC_i^{f} + dY_i^{mp} + dY_i^{nr} \ldots\ldots [4]$$

By using equation (4), it is possible to quantify the extent to which changes in agricultural technology (A), the production factors capital (K), labour (L), and land (Land) and the interaction with other income sources (other productive activities and transfer) are systematically affecting the households' total income.

Application of the theory and conceptual framework to the research agenda

In assessing the economic impact of improved seed adoption on agricultural productivity and income of the rural households, the study uses the above theoretical and conceptual framework. In this study improved *Teff* variety used as a factor of production (i.e., Capital) that affect the production and productivity of the farmer. Productivity method that presented in 3.2 is used to estimate the magnitude of the impact (productivity and income) associated with the adoption of improved *Teff*. As described on Bockstael & McConnell [10], productivity method is used to analyses the economic impact of an input which increases revenue or reduces variable cost.

This study focuses on the ex-post economic impact analysis of improved seeds adoption from the perspectives of smallholder farm households that have adopted improved *Teff* variety. It estimates the economic benefit and costs generated from the adoption of improved *Teff* varieties in monetary terms. The actual impact accrued by the smallholder farm households is attributed to improved seed adoption. In the analysis of economic costs and benefits, the viewpoint is very important [13]. Hence, this study evaluates the impacts of improved *Teff* adoption from the perspective of the smallholder farmers that uses it in their production. It compares the magnitude of economic benefit and cost of farm

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households between the two worlds, with improved *Teff* and without improved *Teff*. The differences between the real-world situation, i.e., the world with improved *Teff* varieties, and the counterfactual, i.e., the world without improved *Teff* with local varieties, is quantified and fed into equation (4) in section 3.2 to calculate the overall welfare impact of improved *Teff* adoption on the farm households in the area.

Working hypothesis

Based on the vast literature on the subject and theoretical and conceptual framework outlined in this chapter the following working hypotheses were tested:

a. The adoption of improved *Teff* (Boset) variety increases the output of farm households which results in higher farm income. Hence, there is a strong case that farmers generate more farm income due to adoption of improved seeds.

b. Technology adoption (i.e., Boset *Teff* variety) increase the expenditure of a group of farm households that formerly relied on local seed varieties. Therefore, their cost of production is likely to increase due to adoption.

c. The total benefit generated in improved *Teff* adoption is greater than the total cost of adoption for the farmers in the study area. (the net welfare impact of improved *Teff* adoption is positive)

Methodology

Description of the area

The study is conducted in Kobo woreda which is located in the North Wollo zone of the Amhara region. It is located at 570km from the capital Addis Abeba and 49km from Woldia which is the zone capital. Agriculture is the main economic activity in the woreda in which about 86% of the population is engaged. The farming system can generally be characterized as mixed and includes the production of arable crops and the raising of livestock. Most of the farmers are engaged in subsistence agriculture with relatively small land holdings; which range from 0.25 to 2.5 hectares, and insufficient application of basic agricultural inputs such as fertilizers and pest control techniques. The main crops grown in the area are *Teff*, Sorghum, Maize, and other cereals from July through November. Due to the low rainfall amount and high rate of evaporation and transpiration during the Belg rain, there was no crop grown during this period i.e. farmers were producing once a year. But now, with the use of ground water since 2005, farmers are producing twice a year. In addition to the above cereals, cultivation of the most commercial crops in the country such as tomato, onion and pepper is possible during the dry season i.e. from March/April to June/July [14].

Research design

For the purpose of assessing the impact of improved *Teff* adoption on agricultural productivity and income in Kobo woreda, a cross-sectional research design was adopted to collect data related to the use of improved *Teff* varieties, production factors, output, total income and income composition from different sources and different socioeconomic and demographic characteristics of farm households in the woreda for the production year 2014/15. According to Bryman & Bell [15] "A cross-sectional design entails the collection of data on more than one case and at a single point in time in order to collect a body of quantifiable or quantitative data in connection with two or more variables, which are then examined to detect patterns of association [15]."

The main challenge in assessing the impact of improved *Teff* adoption is to determine what would have happened to the farmers in the absence of improved *Teff* adoption. That is, determining the counterfactual will be necessary. For this specific study the "with and without world" scenario is adopted. The counterfactual is a world without the improved *Teff*, i.e. a world in which the adopter households grow local varieties, and where they use seeds from their last harvest or buy it in lower price. Then the study will use the comparison of the two worlds approach.

Data source and method of data collection

Analysis of this study is principally based on primary data. Primary cross-sectional data is collected for 2014/2015 cropping season using structured household survey questionnaire and to support this information focused group discussion with selected farmers has also been conducted.

The data is collected from a group of farming households (having both adopters and non-adopter farmers) using the structured questionnaire prepared to gather information that helps to address the research question and finally to attain the research objectives. The questionnaire elicited information about household demography, household income, expenditure on inputs, crop production and resource endowment, etc. The data is collected from July, 2015 to August, 2015 with the help of 3 Development Agents (DA). The DAs were selected based on their experience and extended knowledge of the existing social settings of study area. One day training was given to the DAs. Before starting the actual data collection, the questionnaire was pre tested on 10 households who were randomly selected from the study area population enabling the modification of some of the questions. Close supervision and follow up was taken place by the researcher to avoid fault and mistakes and to do timely correction as much as possible. Furthermore, the study also used secondary data. Secondary data was collected form, Central Statistics Agency, Zonal and Woreda offices of agriculture, which is used to back up the findings from primary sources.

Sample size and sampling technique

In order to make valid inferences and increase the degree of accuracy of the results, a well-designed sampling frame is a pre-requisite. For this study, initially secondary data from the woreda agriculture office is collected and used to identify the population of the study area that can be possibly categorized as the sampling frame. In this study a two stages sampling technique was adopted for the selection of sample respondents (a group having both im-

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proved *Teff* variety adopters and non-adopters). In the first stage, from the total of 40 kebeles in the woreda, one kebele (kebele 08) is selected purposively based on the distance from woreda capital, relatively rural kebele which has better *Teff* production potential and high improved *Teff* (Boset) variety adoption rate (80%). The total farming household-head population size of the selected kebele (kebele 08) is 1,430 (i.e, total poplution for the study) of which 157 are women headed and the rest are male headed.

At the second stage, based on the data (registration list of kebele 08 farmers) from the woreda agriculture office, and Ambasel Farmers' Cooperative Union (distributor of improved seeds in the woreda) the actual improved *Teff* variety users in 2014/2015 cropping season were identified. Using the same data, a list (with both adopters and non-adopters) was prepared and households were assigned a random number, then a representative sample of 163 farming households (11.4% of the total population) were selected from the list using simple random sampling technique. From the selected 163 households 123 (75.5%) were adopter and 40 (24.5%) were non-adopter households.

Method of data analysis

Descriptive and inferential statistics were used to estimate the impact of improved *Teff* adoption on the sample households. Descriptive statistics such as tabulation, percentages, and frequencies were used to describe demographics, income and factor endowment of the sample population. In addition, chi-square test and t-test were used to assess if there are possible differences in our sample by differentiating adopter and non-adopter households. Multivariate regression models, based on the theoretical framework elaborated in section 3.2, is also used to analyse the output and income impacts of improved *Teff* adoption in the study area. STATA version 12 software package is used to analyse and estimate statistical and regression models.

Econometric method: To analyses the impact of improved *Teff* adoption a linear multiple regressions analysis was used. As described in the theoretical framework of the paper the farm households in the area earn total cash income (Y_total) from different sources including farm income (Y_Farm), labour income from other productive (non/off-farm) activities (Y_Non_farm), and also income from transfers (remittances and governmental subsidies)(Y_Transfer). The theoretical framework also describes farm income as the total output produced by households multiplied by price minus farming cost (refer equation (3) of chapter three). Based on the assumption of constant price and fixed farming cost the total differential of equation [4] from chapter three gives a working model:

$$Y\_total = \beta_0 + \beta_1 BOSTED\_SEED + \beta_2 LABOUR + \beta_3 LAND + \beta_4 CAPITAL + \beta_5 SEEDS + \beta_6 FERTILIZERS + \beta_7 IRRIGATION + \beta_8 AGE + \beta_9 SEX + \beta_{10} DEP\_ratio + \beta_{11} Y\_Non\_farm + \beta_{12} Y\_Transfer + ei \ldots\ldots\ldots [5]$$

i = 1…n farming households

Definition of variables

a. 'Y_total' is the total annual income of households. This is cash income of households from different sources of income. It is the sum of income from farm activities, income from other productive activities and income from different transfers in one year.

b. 'BOSET_SEED' is the amount of money spent on improved *Teff* seed for each household per cropping season. It is measured in Ethiopian birr. The improved *Teff* variety in this study stands for using Boset variety. This variable is used to estimate the impact of Boset variety on the selected outcome variables.

c. Adoption of technology is a mental process of applying a given innovation. There is no universal agreed length of time to say households as adopters or non-adopters. In this study adopters are farmers who use improved *Teff* (Boset variety) in 2014/2015 cropping season while non adopters are farmers who are experienced in growing of local *Teff* varieties. As many studies verify that adoption influence household well-being positively and significantly [16,17] and similar to these findings in this study it is hypothesized that adoption of improved *Teff* variety is expected to have a positive and significant impacts on productivity and household income.

d. 'LABOUR' is the total labour days (either family labour or hired labour) spent on planting, weeding and harvesting. It is measured in terms of man days for 2014/15 cropping season.

e. 'LAND' is the total area cultivated by the farm household for the 2014/2015 cropping season. It is measured in terms of hectares.

f. 'CAPITAL' is the value of all physical capital (hoes and ploughs used for cultivation) for each household per cropping season. It is measured in Ethiopian birr.

g. 'FERTILIZERS' is the amount of money spent on chemical fertilizers for a 2014/2015 cropping season. It is measured in Ethiopian birr.

h. 'SEEDS' is the amount of money spent on other seeds (without Boset) for each household per cropping season. It is measured in Ethiopian birr.

i. 'IRRIGATION' is the amount of money paid for irrigation water used by the farm households for the production year 2014/15. It is measured in Ethiopian birr.

j. 'Y_Non_farm' is annual income of households generated through participation in other productive activities. Other productive activities in the survey refers both to self-employment in non-farm sectors such as petty trade, craft work/carpentry, etc. or off-farm employment such as; daily labour, guard, etc.

k. 'Y_Transfer' is annual income of households from remittances and government subsidies. This is mainly remittances received form family member abroad and, in the city, and subsidies form government.

l. 'AGE' is a continuous variable referring to the age of the household head measured in years.

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m. 'SEX' is a nominal variable used as dummy where it equals to 1 if the household head is male and 0 otherwise.

n. 'DEP_ratio' is household members below the age of 15 and above 65 divided by the total household between the ages of 15 to 65. It shows the burden on the productive part of the population.

A counterfactual world is generated by assuming a world without the adoption of improved seed (Boset variety). In this simulated world, the beneficiary households do not adopt improved *Teff* (Boset variety) and are heavily dependent on local *Teff* varieties. The differences between real world, i.e. the with-boset world, and the counterfactual, i.e. the without boset world, were analysed using equation [1].

Results and Discussion

Socio-economic and demographic characteristics of sampled households

In general, the descriptive analysis of shows that there is no statistically significant difference in age, gender, education status, household size and dependency ratio between adopter and non-adopter groups of our sample. The descriptive statistics regarding the input and institutional services utilization by households gives an insight as to whether there is available difference in our sample households with respect to asset endowment, utilization of agricultural inputs and institutional services by comparing the two subgroups of our sample. Based on the analysis, there is no statistically significant difference in the asset ownership, landholding, labour days spent on farming activities, utilization of capital goods, use of irrigation water and fertilizers between the adopter and non-adopter households of our sample. However, even though it is not statistically significant, adopter households had invested higher amount of money on fertilizers than those who relied on local *Teff* varieties. Moreover, households with improved *Teff* (Boset) variety were reported to have invest higher amount of money on seeds (Boset and all other seeds) which is statistically significant at 99% confidence interval. Considering the utilization institutional services there is no statistically significant difference in access to credit and agricultural extension services between those two subgroups of our sample.

Hypothesis testing

To estimate the impact of improved *Teff* (Boset) variety adoption on the income of sampled households, linear multiple regression analysis based on the model presented in section 3.5 is conducted. In the first approach, the influence of the independent variables from equation (4) are used to estimate farm households' total income (Y_total). The regression uses the stepwise approach starting with a model which contains the full set of independent variables that are then reduced to find the model with the best statistical parameters. In addition to theoretically discussed independent variables different control variables were added to the regression. These are age of the household heads, sex of the household heads and dependency ratio of the households. Table 1 summarizes the results of the regressions based on the working model presented in section 3.5.

Table 1: Estimation of the sample households' Total Income (Y_total).

Variables	Y_total_ETB (Model 1)		Y_total_ETB (Model 2)	
	Coefficient	P Value	Coefficient	P Value
BOSET_SEED	46.268	0	44.762	0
LABOUR	-53.866	0.061		
LAND	12,702	0	11,134.41	0
CAPITAL	3.637	0.006	4.409	0.001
SEEDS	4.654	0.003	3.71	0.007
FERTILIZERS	-0.744	0.464		
IRRIGATION	-2.052	0.339		
AGE	37.064	0.651		
SEX	-1,626.05	0.592		
DEP_ratio	-3,055.69	0.439		
Y_Non_farm_ETB	0.996	0	0.955	0
Y_Transfer_ETB	1	0	1.045	0
Constant	-2,569.68	0.634	-10303.71	0.007
Number of Observation	163		163	
Prob>F	0		0	
Adj R2	0.745		0.728	

Source: study findings 2014/2015; Significant coefficients at 1% in bold

The regression results in the above (Table 1) shows the contribution of each factor of production, non-farm income, transfers income and demographic variables towards change in total income of the household. Both models showed variation in total income due to change in different theoretical and controlled variables. The P value of the F statistics shows the overall model is statisti-

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cally significant and the model fits the data very well. The adjusted R-squared value of Model 1 and Model 2 is 0.745 and 0.728 respectively. This means that Model 1 and 2 have relatively the same explanatory power to explain the changes in total income due to the change in independent variables.

All significant variables in Table 1 shows the expected signs. In Model 1, household's factors of production *LAND, CAPITAL, SEEDS* and the use of improved *Teff* (*BOSET_SEED*) plus its income from other productive activities (*Y_Non_farm*) and transfer income (*Y_Transfer*) are significantly different from zero and influence the household's total income. On average, each additional Ethiopian birr investment on improved *Teff* (*BOSET_SEED*) and other seeds (*SEEDS*) increases the total income of the household by 46.268 and 4.654 Ethiopian birr respectively. Moreover, each additional hectare of land cultivated brings 12,702 Ethiopian birr additional income for the household. However, household's application of chemical fertilizer (*FERTILIZRS*), its use of irrigation water (*IRRIGATION*) and the number of days that farmers spent on their farms (*LABOUR*) are found to be insignificant to change the total income. This means there is no change in total income due to the change in each respective input. Likewise, the control variables dependency ratio, age and sex of the households are statistically insignificant. Result is also similar in Model 2, where only explanatory variables that has systematic and significant influence on household's total income are considered.

So far, the study has examined the possible influence and signs of coefficients of the independent variables included in the above regression analysis. Afterwards the researcher analysed the potential transmission channels between improved *Teff* (Boset) variety and households' welfare in a more detail and systematic manner to test the proposed hypotheses in section 2.4 of the paper. The analysis and estimation of the effect of improved seed (Boset) adoption on farm households' welfare through different possible channels (i.e. Output and Expenditure), is done by applying a simulation approach. The simulation approach uses a counterfactual by assuming a world without the adoption of "Boset" variety. In this simulated world, the adopter households do not have access for "Boset" variety and are heavily dependent on the existing local *Teff* varieties. The differences between real world, i.e. the with-Boset world and the counterfactual, i.e. the without-Boset world will be simulated and compared.

The output channel: more farm income due to increase in agricultural production

Hypothesis I: The adoption of improved *Teff* (Boset) variety increases the output of farm households which results in higher farm income. Hence, there is a strong case that farmers generate more income due to adoption of improved seeds.

In order to test the above specified hypothesis and examine the impact of different production factors including Boset variety (*BOSET_SEED*) on households' farm income the researcher estimates the farm income (*Y_Farm*) of the farm households' based on the theoretical framework presented in section 2.2 of equation (3) and (4). The result of Stata output is summarized in the following table.

: Estimation of the sample households' farm income (Y_Farm).

Variables	Y_Farm_ETB (Model 1)		Y_Farm_ETB (Model 2)	
	Coefficient	P value	Coefficient	P value
BOSET_SEED	45.175	0	44.933	0
LABOUR	-54.457	0.053		
LAND	13,214.35	0	11,740.21	0
CAPITAL	3.826	0.003	3.721	0.006
SEEDS	4.869	0.002	4.557	0
FERTILIZERS	-0.654	0.548		
IRRIGATION	-1.712	0.367		
Y_Non_farm_ETB	0	0.994		
Y_Transfer_ETB	0.022	0.884		
Constant	-4,981.79	0.044	-8,319.75	0
Number of Observation	163		163	
Prob>F	0		0	
Adj R2	0.63		0.609	

The regression results in the above (Table 2) shows the effect of a change in each production factor on the farm income of the households. The P value of the F statistics shows the overall model is statistically significant and fits the data very well. The adjusted R-squared value of the first model is 0.63 and the second model is 0.609. This means that, almost both models have the same explanatory power to explain the changes in farm income resulted from changes of one or more independent variables. The models were diagnosed for possible existence of multi-collinearity using VIF. The STATA output for VIF show that there is no significant collinearity between variables in both models. All the variables have VIF of less than 3 or TOL of greater than 0.1 with mean VIF of 1.42 in Model 1 and mean VIF of 1.39 in Model 2.

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The coefficients in the model shows the change in the outcome variable (*Y_Farm*) for a one unit increase in the predictor variable, keeping the remaining predictors constant. The estimated coefficient of the conventional agricultural input variable labour (*LABOUR*) shows a negative sign, and quite interestingly, chemical fertilizers (*FERTILIZERS*) and household's use of irrigation water (*IRRIGATION*) also show a negative sign. This means that, a unit change in labour days on the field, amount of chemical fertilizers applied and amount the of water use affect the household farm income in the opposite direction with the extent of the respective coefficients. However, all these three inputs are statistically insignificant to affect the farm income of the households. The insignificance of labour is in line with the initially assumed and now confirmed hypothesis that the traditional agriculture practiced in the area might be characterized by labour surplus (cf. section 2.2).

Fertilizers are insignificant may be due the currently existing blanket fertilizer amount (100kg per hectare) recommendation in the national and regional level which does not consider location and crop specific aspects. And "Such blanket fertilizer recommendations have negatively influenced chemical fertilizer efficiency and profitability since…fertilizer requirement is affected by soil moisture, soil fertility status, cropping history and cropping systems [18]." The insignificance of irrigation water uses to affect the farm income of households is may be due to ineffective and inefficient utilization of the water from the pressurized irrigation system.

The other explanatory variables show the expected sign of directions. Hence, the most important determinant of farm income is area of land cultivated. On average, each additional hectare of land cultivated increases the farm income of the sample households by 13,214.35 Ethiopian birr keeping other variables constant. The use of improved *Teff* (*BOSET_SEED*) variety also has higher impact on farm income. On average, 1 Ethiopian birr spent on 'Boset' seed brings about 45.18 Ethiopian birr change in farm income ceteris paribus. Looking in to the p value in the first model, the use of improved *Teff* (Boset), land physical capital and other seeds are statistically significant at 1% level of significance. However, labour fertilizers and irrigation are statistically insignificant in determining the value of farm income. Likewise, both income from other productive activities and transfer income are statistically insignificant to explain the change in farm income. This confirms our assumption in section 2.2 that there is no link adoption will affect the households' labour time allocation in the area. As for the transfer income, it may be due to the small representation of households with transfer income in our sample households.

The second regression model is also statistically fit except, for a small change in the coefficients of the previously statistically significant variables that are included in the second model. On average each additional Ethiopian birr investment of farmers on 'Boset' seed increases their farm income by 44.93 Ethiopian birr. In similar direction, increase in 1 hectare of land cultivated increases farm income by 11,740.21 Ethiopian birr. Furthermore, a one unit increase in capital stock increases farm income by 3.72 Ethiopian birr and each additional money spent on other seeds increases farm income by 4.55 Ethiopian birr. All production factors are statistically significant at 1% level of significance.

After predicting the farm income of sample households' using their real-world data and the coefficients from the above regression models, the result of comparison between the observed and predicted farm income is depicted in Figure 1 below.

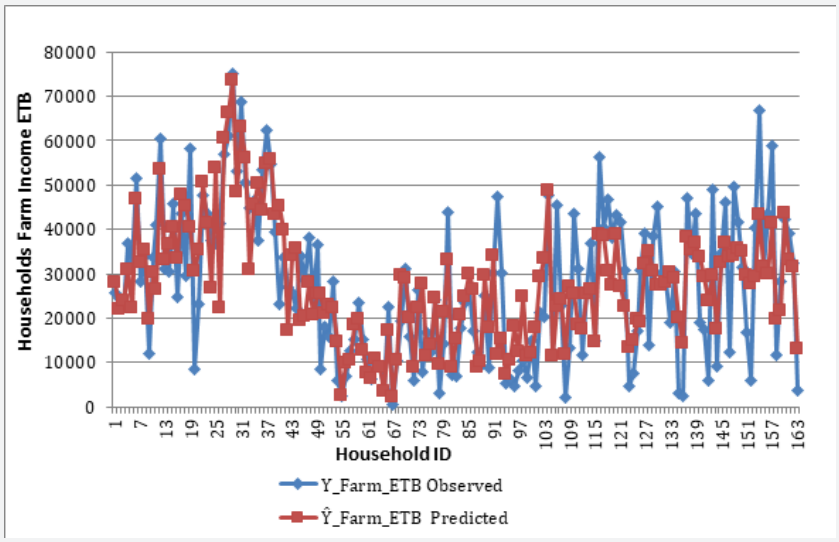

Figure 1: Predicted and observed farm income of households.

According to the regression results presented in Table 2, a unit change in the amount of money paid for 'Boset' *Teff* variety contributes 45.17 Ethiopian birr under Model 1 and 44.93 Ethiopian birr under Model 2 to the households' average yearly farm income. However, in the counterfactual world, i.e. a world without improved *Teff*, households do not have access to 'Boset' seed and they are entirely dependent on the available local *Teff* varieties. As local *Teff* varieties are susceptible to weeds and they take longer

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time to mature than 'Boset,' the sampled households' would have produced less agricultural outputs in the counterfactual situation which in turn reduced their income generated from farm.

In order to estimate the farm income of sample households, without improved seed (Boset), the study used the unstandardized coefficients from the regression estimation in the above models. As the result from the estimation shows, on average households' farm income would fall from 27,561.31 Ethiopian birr per annum (empirically observed) by 6,590.30 [19] Ethiopian birr based on Model 1 and 6,555.29 [20] Ethiopian birr based on Model 2. This means on average farm income of the households increase by 23.7% - 23.9% from the counterfactual income due to adoption of improved *Teff* (Boset) variety. Therefore, the finding of study supports the hypothesis that the adoption of "Boset" variety contributed to the households farming income and households earned more income due to increase in agricultural production.

The next step is predicting our population income. Since our samples are taken randomly from the total population of 1,430 farming households and it was known that adoption rate of 'Boset' seed in the sample kebele is 80% (cf. section 3.4) then we can easily calculate the impact of adoption on the total population. Thus, 80% of the total 1,430 households, i.e, 1,144 households are adopters. Extrapolating the above empirical results from the sample to those 1,144 adopter households, the total income effect of improved seed (Boset) adoption via the output channel is estimated to be from 7,499,251.76 to 7,539,303.20 Ethiopian birr per year.

The expenditure channel: less income due to additional input costs

Hypothesis II: Technology adoption (i.e., Boset *Teff* variety) increase the expenditure of a group of farm households that formerly relied on local seed varieties. Therefore, their cost of production is likely to increase due to adoption.

To this point the study discussed the gross benefits generated due to adoption of improved *Teff* (Boset) by farm households. In this section the study identifies and calculates the costs farming households' incurred due to adoption of improved *Teff* (Boset) variety. The data on additional costs of adoption were collected from the sample respondents. They were asked if their production cost has changed in relation with the adoption of "Boset" variety and if yes to specify the type and amount of extra payment they made due to adoption. This helps to calculate the additional economic costs individual households incurred, if they are willing to adopt 'Boset' variety.

Accordingly, on average all the sampled adopter households in the survey spent extra 83.29 Ethiopian birr on seeds. This may be due to the fact that the selling price of improved seed (Boset) is higher than the available local varieties in the area. Similarly, adopter households had paid 299.67 Ethiopian birr extra cost of fertilizer [21] than if they would have been used available local *Teff* varieties. The reason of this extra cost of fertilizer is due to the obligatory purchase of additional chemical fertilizers with improved seeds (Boset) from Ambasel Farmers' Cooperative Union. Furthermore, sampled household farmers reported that there is no any other additional cost than the above stated costs due to adoption. Thus, the sum of the extra payment for seed and fertilizers which is 382.96 Ethiopian birr give us the average annual expenditure of our sample households due to adoption of improved *Teff* variety. Therefore, this finding is in line with our assumption of the expenditure channel and confirms our hypothesis that adoption of improved *Teff* (Boset) variety increases the expenditure of a group of farm households that formerly relied on local seed varieties.

The next step is extrapolating the above empirical figure from the sample to those 1,144 adopter households, the total effect of improved seed (Boset) adoption on income via the expenditure channel is expected to amount 438,106.24 Ethiopian birr per annum.

Net welfare effect of improved *Teff* (Boset) adoption

Hypothesis III: The total benefit generated in improved *Teff* adoption is greater than the total cost of adoption for the farmers in the study area. (The net welfare impact of improved *Teff* adoption is positive).

Table 3: Net welfare effect of improved Teff (Boset) adoption (in Ethiopian Birr).

Gross Annual Benefit	**From increase in farm income**	**7,499,251.76 to 7,539,303.20**
Annual Cost	Due to increase in seed and Fertilizers expenditure	438,106.24
Net Annual Benefit (Gross annual benefit minus annual costs)		7,061,145.52 to 7,101,196.96

Source: study findings 2014/2015.

So far, the study estimated the possible benefits and costs of improved seed adoption through the output and expenditure channels. The next step it to calculate the overall effect of adoption on household's welfare. This is done by subtracting all the total expenses from the total benefits of adoption. As the overall result from Table 3 shows the gross annual benefit of all the 1,144 adopter households in the area for production season 2014/15 is between 7,499,251.76 and 7,539,303.20 Ethiopian birr. On average, adopter households incurred additional cost of 382.96 Ethiopian birr on seeds and fertilizers. Hence, by multiplying the number adopter households (1,144) by the average additional cost of adoption (382.96), the total annual cost of adopting 'Boset' *Teff* is 438,106.24 Ethiopian birr. Therefore, the net annual benefit of improved *Teff* (Boset) adoption for production year 2014/15 is estimated from 7,061,145.52 to 7,101,196.96 Ethiopian birr. This supports the hypothesis that the total benefit generated in improved *Teff* adoption is greater than the total cost of adoption for the farmers in the study area (the net welfare impact of adoption is positive). The resulted changed in the average annual household farm income can be attributed to the adoption of improved

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Teff (Boset) variety adoption. Converting the this net increase in households income to the PCI level shows that, the adoption of 'Boset' variety increases the PCI of adopter household members by 1,425.34 [22] -1,433.43 Ethiopian birr (USD 67.34-USD 68.12) from the counterfactual situation.

Summary, Conclusion and Policy Implications

Summary and Conclusion

Agriculture is the main sources of Ethiopia economy and the people at large. Even if it is very important to the people at large and it contributes more to the GDP of the country, the sector has been still dominated by the smallholder and the level of production is very low due to less use of the modern technology and limited use of best agronomic practices. Especially the productivity of *Teff* crop is very low as compared to other cereal crops whereas the land allocation is the highest one as compared to other crops. To reverse this situation, a continuous emphasis is being placed by the Government on its policies on the viability of intensification of improved agricultural technologies and extension practices as a vital measure for increasing crop production. In order to reflect the impacts of such policy directions, evaluation studies are important. This study applied a theory-based impact assessment approach (i.e., productivity method) to evaluate the impact of technology adoption, exemplified here by adoption of an improved *Teff* variety, on agricultural productivity and income of farmers.

The study used a simulation approach to calculate the impact of improved *Teff* (Boset) adoption on income of farm households. In this method a counterfactual world, i.e. a world without 'Boset' seed, is simulated using real world data. This helps to build a "credible counterfactual" in which the impacts of the adoption can be compared. It also helps to identify different channels that adoption affects the welfare of the adopter households. This approach is different from control/treatment group comparison and allows real world changes. Hence, it shows not only the changes that occur but also why the changes occur. As such this study is different from previous studies which only use treatment/control group comparisons and adds to the existing literature. The study uses a cross-sectional data collected from a randomly selected 163 sample households from keble 08 of kobo woreda. Using quantitative approach, the paper tested three hypotheses in line with the different research questions [23-26].

The estimated result of a linear regression confirmed that adoption of improved *Teff* (Boset) variety has a significant impact on the farm income of adopter households. Adopter farmers have gnereated higher farm income from the resulted increase of agricultural output due to adoption. A simulation result shows that household's farm income increases on average by 23.7-23.9 percent due to the use of 'Boset' variety compared to the counterfactual world where farmers do not have access to 'Boset' seed. In addition to 'Boset' seed, farm income of households in the survey also responds differently to other production factors. The resulted change in farm income due to a unit change in land, capital and other seeds was significant and positive. However, the change in farm income, due to the change in other production factors labour, irrigation water uses and fertilizers application was negative and insignificant. This could be due to existence of labour surplus, inappropriate application of fertilizer and inefficient utilization of irrigation water.

The study also identifies additional costs associated with improved *Teff* (Boset) variety adoption and confirms that adoption had increased the production costs of farmers who grow 'Boset' variety. Adopter farmers spent more money on purchase of seeds and fertilizers than if they would have been used the availablel local *Teff* varieties. This extra paymet on seeds and fertilizers is due to the relatively higher price of improved seeds than the local varieties and the additional obligatory fertilizer purchase with those seeds from the local seed distributor.

In testing the hypothesis that the total benefit generated in improved *Teff* adoption is greater than the total cost of adoption for the farmers in the study area (the net welfare impact of improved *Teff* adoption is positive) the researcher calculates the net impact of adoption by combining the effect of adoption on the farming households farm income and its effect on cost of inputs (i.e., additional costs of seed and fertilizers). Accordingly, the study confirms that the total benefit of adoption is far higher than the associated increase in costs. Using the sample result, the extrapolated annual net welfare effect of adoption on the study area was estimated between ETB 7,061,145.52 and ETB 7,101,196.96 which is equivalent to ETB 1,425.34 – ETB 1,433.43 increase over per-capita counterfactual income.

Moreover, the empirical findings also show that all the sampled households covered in this study are mainly dependent on agriculture for their livelihood and have lower PCI than the national average. Thus, this increase in annual PCI stemmed from the increase in farm income of adopter households has a significant impact on their lives. In addition to the above findings, the study also tried to investigate whether there are systematic difference and similarities in characteristics of sampled households across adoption status using descriptive and inferential statistics.

Policy implications

The result of this study suggested that improved *Teff* adoption has provide tangible benefits to the technology adopters in terms of agricultural productivity and net farm income. As a country that has over 6 million farmers growing *Teff*, the scaling up of this practice to other areas will have a huge impact on the livelihoods of the majority of the poor. So, based on the findings of the study, the following recommendation are forwarded.

During the field survey the researcher had learned that, there is late delivery and shortage of improved *Teff* seed in the area. This is due to the local distributor has lack of capacity in finance, human capital, sufficient and clean warehouse and efficient logistics system. Hence, the government and stakeholders should give technical and financial support for local distributors of improved seed varieties to make the agriculture extension effort more suc-

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cessful in the study area and at large in the region and the country level. Additionally, it is better to create an opportunity that multiplication and distribution of improved seed, to be done through the channels of out growers (farmers) and additional cooperative unions in the area.

Due to the aggressive efforts of the government to intensify the use of agricultural technologies, the existing compulsory package of fertilizer with improved seeds is discouraging farmers from adopting improved *Teff*. Based on the analysis, the application of fertilizer was found not significant to affect the farm income of farm households in the study area. However, farmers are obliged to buy additional fertilizers with improved seeds which costs them additional payment and that reduce the benefit of adoption. It shows the current blanket recommendation of fertilizers is not profitable and the respective regional and woreda agricultural offices should give value for local knowledge and traditional soil fertility preservation mechanisms. And policies related to fertilizer application recommendation should take in to consideration the area and crop specific aspects. The recommended type and amount of fertilizer should be based on soil calibration results of each specific area.

It is also important to note that the utilization of the pressurized irrigation scheme in the area needs further attention. The result of our farm income regression analysis shows the use of irrigation water was insignificant to explain the farm income of households. This shows there is inefficient utilization (overuse) of the water. Hence, there should be a mechanism that the woreda agriculture office and the area farmers' cooperative union to work in cooperation to manage and control the efficient and effective use of irrigation water.

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20. Calculated by multiplying the average money spent on "Boset" seed by the sample households (145.90 ETB) by the co-effiecient of Boset seed in Model 2(44.93 ETB).
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