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and
Ethiopian Strategy Support Program (ESSP) of IFPRI

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

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- Partners of all activities of EEA are the African Capacity Building Foundation (ACBF), the Friedrich Ebert Stiftung of Germany (FES), and Think Tank Initiative of the International Development Research Center (IDRC) of Canada.

- The 16th International Conference was Co-organized by the Ethiopian Strategy Support Program (ESSP) of the International Food Policy Research Institute (IFPRI) and the Ethiopian Development Research Institute (EDRI).

- The 16th International Conference co-sponsored by IFPRI, EDRI, Friedrich Ebert Stiftung of Germany, UNECA, UNDP, International Growth Center (IGC), USAID, AKLDP Ethiopia, The World Bank, European Union, Awash International Bank and United Bank S,C.

FOREWORD

The Ethiopian Economics Association (EEA) is happy to issue two volumes of the proceedings of the 16^{th} International Conference (the 27^{th} Annual Conference) on the Ethiopian Economy that was held from July 19 – 21, 2018 at EEA Multi-purpose Building Conference Hall. EEA has been organizing annual conferences on the Ethiopian Economy every year as part of its overall objectives of promoting the development of economics profession in Ethiopia and contributing to the policy formulation and implementation process of our country through research, training, public dialogue forums and publications and dissemination activities.

EEA had launched its international conference series in June 2003, after organizing 11 annual national conferences. This series has proved to be an excellent forum at which not only resident Ethiopian researchers, but also Ethiopian researchers based abroad as well as non-Ethiopian researchers throughout the world conducting research on Ethiopia, or more widely, present and discuss research findings.

This year's conference, as was last seven years, is co-organized by the Ethiopian Strategy Support Program (ESSP) – the collaborative program of the International food Policy Research Institute (IFPRI) and the Ethiopian Development Research Institute (EDRI). It was also co-sponsored by IFPRI, EDRI, Friedrich Ebert Stiftung of Germany, UNECA, UNDP, International Growth Center (IGC), USAID, AKLDP Ethiopia, the World Bank, Population Reference Bureau (PRP), and European Union (EU). The contribution of EEA's partners that includes the African Capacity Building Foundation (ACBF), Think Tank Initiative of the International Development Research Center (IDRC) of Canada and the Friedrich Ebert Stiftung of Germany is also critical for the organization of this important conference and other activities of the Association.

This year's conference, as was last eight years, has been co-organized by the Ethiopian Strategy Support Program (ESSP) – the collaborative program of the International food Policy Research Institute (IFPRI) and the Ethiopian Development Research Institute (EDRI). It was also co-sponsored by IFPRI, EDRI, Friedrich Ebert Stiftung of Germany, UNECA, UNDP, International Growth Center (IGC), USAID, AKLDP Ethiopia, and European Union (EU), Awash International Bank and United Bank S.C. The contribution of EEA's partners that includes the Think Tank Initiative of the International Development Research Center (IDRC) of Canada and the Friedrich Ebert Stiftung of Germany is also critical for the organization of this important conference and other activities of the Association. The Association well recognized the support of sponsors and partners institutions during the opening and closing time of the conference and by displaying the support at the conference program, which has been distributed to all participants and medias; and banners at different corners of the venue.

At the conference about 69 presentations were made in four plenary and four parallel sessions with the attendance of about 938 persons in three days (480, 239 and 219 participants in the first, second and third days, respectively). In addition, two panel discussions and one key note speech were also organized. Out of the total 69 presentations, about 42 were presented by partner institutions like (IFPRI-ESSP), International Growth Centre (IGC), United Nation Economic Commotion for Africa (UNECA), the World Bank, EDRI, AKLDP Ethiopia/Tufts University, Gonder University and Addis Ababa University etc. The rest 27 papers were presented by individual researchers.
The conference was opened by H.E. Ato Demeke Mekonnen, Deputy Prime Minster of the Federal Democratic Republic of Ethiopia, at the presence of higher dignitaries and invited guests. The presence of H.E. Ato Demeke Mekonnen, Deputy Prime Minster of the Federal Democratic Republic of Ethiopia who greatly honored us by opening officially the conference demonstrate the value of the conference to the economic policy making process of the country. H.E. Ato Demeke Mekonnen not only graced the conference by officially opened the conference, but also by attending the first key Note speech on Inclusive Growth in Ethiopia by Professor Stefan Dercon.

The editorial committee reviewed papers that were presented for the publication of the proceedings of the conference and communicated its comments and suggestions including editorial comments to authors. After passing all these process and language editing, the editorial committed selected 14 papers to be included in the proceedings. All these papers are organized into two volumes. Volume I consists of Macroeconomics, Industry and Social Sector Related Topics while Volume II consists of Agricultural and Natural Resources related topics.

At this juncture, on behalf of the Ethiopian Economics Association, I would like to thank the Ethiopian Strategic Support Program (ESSP) of the

International Food Policy Research Institute (IFPRI), for being a regular co-organizer of the EEA's International conferences since 2010. My appreciation also goes to the authors of the papers and the conference participants whose active participations made the conference meaningful and dynamic. The many professionals who dedicated their time to the conference and served as chairpersons deserve due thanks for their special contributions. The staffs of the EEA and Executive Committee of the Ethiopian Economics Association deserve a special recognition for their enthusiasm and perseverance in managing the conference from inception to completion.

The organizing committee and staffs of the EEA deserve a special recognition for their enthusiasm and perseverance in managing the conference from inception to completion. I also want to extend my personal gratitude to the members of the Executive Committee of the Ethiopian Economics Association for the dedicated services and the leadership they provided to the Association.

Our special thanks go to our partners who have shared our vision and provided us with generous financial support to operationalize the activities of EEA. These include, Think Tank Initiative of the International Development Research Center (IDRC) of Canada and the Friedrich Ebert Stiftung of Germany.

I would like also to extend my sincere gratitude to H.E. Ato Demeke Mekonnen, Deputy Prime Minster of the Federal Democratic Republic of Ethiopia, for his an insightful opening address; and other senior government officials who spared their busy schedule and participated in the conference.

Finally, I would like to convey the message that our Association is willing to strengthen its capacity and seek new ways of addressing the economic problems and to be of better service and to meet the expectations of its members and the public at large.

Tadele Ferede (Ph.D)
President
Ethiopian Economics Association

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Agriculture and Natural Resources

Backward Linkage of Agriculture with the Urban Sector in Eastern and Central Ethiopia: Determinants and Implication for Agricultural Transformation

Arega Shumetie[1] and Abebe Ambachew[1]

Abstract

Both descriptive analyses and econometric techniques particularly upper-censored Tobit Model and the OLS regression were used to analyse the household survey data from Etosa and Kombolcha district of East Arsi and East Harerghe Zone, respectively. Food consumption of the rural economy from the industry sector were found to be positively and significantly related if the household is male-headed, with better educational attainment and credit access. Having own-produced food items through irrigation practices, large family and livestock sizes decreased the households' food reliance on the urban sector. Similarly, smallholders with longer farm experience, easy access to education and training, cropland and livestock sizes had strong motive to the purchase agricultural inputs from the industry sector. The research finally recommended that reducing liquidity constraints through credit access and cash crops production as well as increasing awareness through education and training strengthen the rural-urban linkages and accelerate the agriculture transformation of the country.

Keywords: Agriculture; Smallholders; Linkages; Tobit Model; Ethiopia

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1. Introduction

It was recognized that traditional agriculture could be transformed rapidly into a modern sector through the adoption of modern technologies, thereby making a large contribution to the overall economic growth. Agriculture has strong backward linkages in input usage and consumption of industrial commodity (Johnston and Mellor, 1961). The linkage between agriculture and industry depends on the level of urban economic growth (Datt and Ravallion, 1998). Agriculture's role in the structural transformation of many countries, especially in Asia demonstrated successfully through the green revolution. Rural households' income increment in the early stages of economic development is vital for providing market to the domestically produced items (Hazell and Roell, 1983). Additionally, technological change and agriculture productivity growth could result in lower food prices, which in turn held down urban wages to stimulate industrialization and structural transformation (Derek, *et al.,* 2005). The proper economic growth strategy has often conceived as a more or less gradual shift from agriculture to industry, with the onus on agriculture to finance the shift in the initial stage (Jacques, 1997).

Agricultural progress is imperative for economic transformation and rural development especially for the underdeveloped areas (Todaro, 2009). Development in these nations could not be successful if the poorest rural areas are not developed first. The core problems of widespread poverty, income inequality, rapid population growth and rising unemployment originated from stagnation and retrogression of the rural economy. Agriculture should be linked to other sectors to eradicate this economic stagnation problem. Agricultural growth can result in wider economic improvement especially in the early stages of industrialization, and the strategy later labelled as "agricultural-development-led-industrialization" (ADLI) (Adelman, 1984). The strategy focused on the central role what agricultural plays in achieving industrialization through expanding demand for domestic produced goods.

In Ethiopia, food production for the entire population is highly dependent on the backward agriculture. Despite its agricultural potential, the country has become a net importer of food for its growing population particularly in urban areas in recent times. Value chains, modern and innovative small farming systems are still embryonic, which do not consider and take into account the recent circumstances in their production process (DAC, 2010).

Empirical works (Maxwell, 2010; Xinshen *et al*., 2009; Xinshen *et al*., 2007) in the area of agricultural development specifically in Ethiopia, concentrates on how to enhance agricultural productivity, but not how it is interacted with the urban sectors and pave the way to industrialization. Even the very few works (Agnes, 2014; Getnet and Mehrab, 2010.) existing in this area are so weak in their statistical and mathematical analysis about linkage of the rural economy with the urban. This study was, therefore, aimed at assessing the backward linkage of agriculture with the urban sectors and identifying the factors that trigger to realize the strong rural - urban economic linkages that facilitate the agricultural transformation. Moreover, the study tried to assess the existing potentials and related challenges to transform the existing hand-to-mouth agriculture to commercialized one. Generally, this study attempted to answer the question why some rural households spend more on industrial products for their consumption or production activities while other are not.

2. Methodology

2.1 Description of the Study Area

The research considered smallholder farmers from the rural economy in Etosa district of East Arsi zone and Kombolcha district of East Hararghe zone, Oromia regional state. The first site of the study was, Kombolcha, where farmers of the area highly engaged in market-oriented production of vegetables such as potato, cabbage, onion, carrot, *k'aht*, and beetroot. Farmers in the study area produce vegetables three times in a year using irrigation as a supplementary during rainy season and as main source of water in the dry season. They mainly used organic fertilizers for soil fertility maintenance. To facilitate their crop production, farmers purchased water pump, inorganic fertilizer, and hybrid seeds from the nearby markets.

Etosa district is well known for its rain-fed crop production such as wheat, barley, bean and other grain crops. Households in the area may represent the agrarian communities characterized by cereal crop production. In the trade process of the study area intermediate participants were the main actors in the marketing especially potato and other vegetables. Due to the strong participation of brokers and small traders in the marketing system, smallholders of the area do not collect the potential benefits from their crop production. Smallholders had not direct contact with the final consumers, which is a circumstance that enables them to optimize their benefit from their crop production.

2.2 Sources and Methods of Data Collection

Both primary and secondary sources were used to collect quantitative and qualitative data from the study area. Primary data were collected from sample households on production, input usage and technology adoption, and consumption behaviour. Household survey was conducted to generate the required quantitative data by employing structured questionnaires. In addition, supportive qualitative information was obtained through key informant interview and focus group discussion. These all enable the researchers to easily understand farmers' attitude towards their socio-economic linkage with the urban economy and other related issues.

2.3 Sampling Technique

The sampling process was aimed at generating representative sample rural households with better mix of cereal versus cash crop producers, modern technology adopters versus non-adopters, near to versus far from major market places including the export markets. The study employed multi-stage sampling technique in selecting the sample units. In the first stage, the two different agricultural zones (East Hararghe and East Arsi) were purposively selected to get the right mix of households with the contrasting characteristics. Their access to-market outlet and nature of crops they produce were the core issues behind considering the two different places.

The study considered Combolcha district of East Hararghe zone to represent the major cash crop areas and better proximity to the major market places in eastern Ethiopia (Harar and Dire Dawa towns). On the other hand, Etosa district of East Arsi zone represents cereal producing areas that are relatively far from major markets. Secondly, two *Kebeles* from Etosa and three *Kebeles* from Kombolcha were randomly selected. Finally, the household list of each *Kebele* was taken from the respective *Kebele* administration offices to randomly drawn the sample households using systematic random sampling. A total of 212 rural households were selected from the two districts; of which 114 (53.77%) were from Kombolcha while the remaining 98 were from Etosa. Having such different mix of households as a sample, this was extremely important to make multidimensional analysis of the problem at hand. The study identified the socio-economic characteristics of households that may strongly link with the rural and urban sector to facilitate livelihood changes and agricultural transformation.

2.4 Methods of Data Analysis

Quantitative and qualitative data analysis techniques were jointly used to achieve the objectives of the study. Both descriptive statistical analysis and econometric models were employed to analyse the quantitative data and address specific objectives related to it. The descriptive statistics like percentages, proportions, mean, trend analysis, and simple statistical test including t-test were used to address some aspects of the objectives. Censored Tobit and Ordinary Least Square (OLS) regression models were used in the econometric analyses for the reasons discussed below.

Backward and forward linkage of the agricultural with the industry and service sectors is desirable to facilitate the agriculture transformation in Ethiopia. The main focus of this study is to identify the factors that facilitate or hinder the backward linkages of agriculture with the other sectors. There are two channels through which agriculture can have a backward linkage with the industry: through using industrial outputs in the consumption bundle of the farm households and as an agricultural production inputs. Taking these circumstances into account the following two econometric models specified.

Modelling the rural households' consumption pattern/behaviour enables us to identify the determinants of backward linkage of the agrarian economy with the urban sectors through purchase of consumption goods. The consumption bundle of a rural household is composed of own-produced and purchased items. If C_{ri} is defined as the proportion of consumption expenditure of a rural household i from domestically produced industrial products in the total consumption at a given period. The matrix X_{ji} is socio-economic characteristics of the rural households that affect the value of C_{ri} (the determined variable). In order to determine the types of specification, nature of the dependent variable should be taken into account. The possible values of C_{ri}, ranges from 0 to 100, which entails the possibly of two-side censored data. However, the actual distribution of the data was found to be censored from above only, led to use an upper-censored Tobit Model. The Tobit model is a special case of a [censored regression model](), because the latent variable C_{ri}* cannot always be observed while the independent variable X_i is observable. Censoring at a value C_u, which is different from zero result in having the following formulation.

$$C_{ri} = \begin{cases} C_{ri}^{*}\ if\ C_{ri}^{*} > C_u \\ C_u\ \ if\ C_{ri}^{*} \geq C_u \end{cases}.. \qquad \textbf{(1)}$$

Where: C_{ri}^{*} is the latent variable and:

$$C_{ri}^{*} = \text{â} x_{ji} + \text{ì}_i \qquad \textbf{(2)}$$

$$\text{ì}_i \sim \text{N}(0, \text{ó}^2)$$

Where, C_{ri} and X_{ji} are as defined above, â_i, is a matrix of the model parameters, and ì_i is the error term to capture the unexplained part of the model. The independent variables given by matrix X_{ji} consists of household characteristics like age, education, family size, composition, distance from the market; level and sources of income; off-farm employment, ability to smooth consumption and access to information. All the basic assumptions of this method were thoroughly tested and the necessary corrections made to generate robust analysis.

Besides to the above mathematical formulation of smallholders' food consumption, the study models the determinants of the farm households' input expenditure. This enables to identify the determinants of backward linkage of the agrarian economy with the urban sectors.

$$C_{ir} = \text{â}_0 + \text{â}_1 X_{1i} + \text{â}_2 X_{2i} + \cdots + \text{â}_n X_{ni} + \text{å}_i \qquad \textbf{(3)}$$

Where, C_{ir} is the dependent variable that is defined as the monetary value of crop production input expenditure by farm household i from industrial products in a given time.

X_{ji} refers to different covariates that affect crop production input expenditure of farm households. $å_i$ represents error terms to capture unobserved source of variation for the dependent variable. $β_i$ refers to coefficients of the respective explanatory covariates.

The independent variables given by X_{ji} represent socio-economic characteristics of the rural households. Household characteristics like age, education, family size and composition; distance of the household village from the urban centres; level and sources of income; off-farm employment status of household members; ability to smooth consumption and access to information are some of the regressors that were considered in the econometric model that tried to show the backward linkage of the agriculture sector with the industry.

3. Results and Discussion

3.1 Demographic Characteristics of Sample Households

Smallholders of the two sample areas had significant difference in many of the covariates considered to explain them. The overall adult equivalent of the study area was 5.31 on average while households from Kombolcah and Etosa had 4.84 and 5.89, respectively.

Table 1: Characteristics of sample households in the two districts

Description	Kombolcha	Etosa	Combined average	t-value
Adult equivalent	4.84	5.89	5.31	4.14***
Man equivalent	2.67	4.28	3.39	7.75***
Age of head	39.40	49.15	43.81	6.14***
Education (in school year)	1.84	2.31	2.05	3.35***
Distance from nearby market (km)	1.03	4.74	2.72	10.86***
Distance from town (km)	5.83	4.72	5.32	1.29
Total cropland holding (ha)	0.46	2.90	1.59	14.32***
Number of oxen owned	0.54	3.27	1.78	16.29***
TLU	3.33	10.30	6.49	11.92***

Note: *** represents 1% level of significant.

Households in the sample area had 3.39 man equivalents on average while households from Kombolcha and Etosa had 2.67 and 4.28 man equivalent, respectively. Additionally, sample households in the two areas had significant variation in household head education level, distance from the market, cropland, Total Livestock Unit (TLU), and number of oxen.

3.2 Non-Agricultural Activities and Annual Income Collected from Different Sources

Few smallholders participated in non-agriculture activity as additional income source. However, more than 73% of smallholders had the plan to participate in non-agricultural activities including retail shop, transport, constructing house in towns, livestock trade, grain milling service, and other off-and non-farm activities. The most common reasons of selecting those business areas to participate are profitability, easy to manage and qualification of the family member.

The crop production sub-sector is the main source of cash for households in the study areas even though the crop type what they supply to the market are different. Around 24%, 26% and 36% of the smallholders in the study area, respectively sold their crops at the time of price increment, harvesting time, and whenever they wanted cash. Due to lower transport and transaction costs 53% of the sampled smallholders sold their crops to the nearby markets. About 31% of smallholders sold their crops in district level markets that commonly provide better price than the markets in rural areas. Around 5.4% of smallholders sold their crops on the field immediately after harvest. Below 1% of the sample smallholders only have access to the central markets to sale their crops, which implies that they are not collecting the maximum benefit from their crop production because of not accessing the market that provide better price.

Table 2: Households' income from different sources (in Birr)

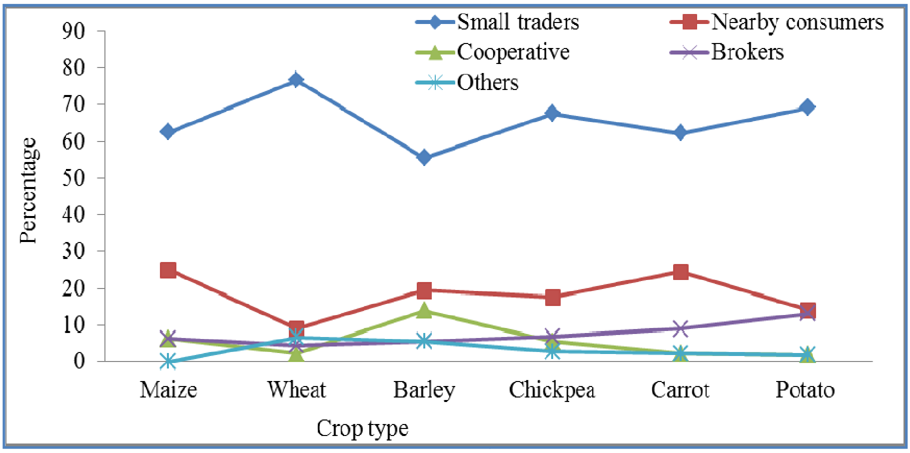
Income source	Kombolcha	Etosa	Combined average	t-value
Livestock sales	**542.19**	**5454.52**	**2770.71**	**9.10*** **
Milk sales	716.70	1640.00	1135.56	2.26**
Petty trade	198.21	550.00	357.81	1.37
Daily labour	130.94	733.72	412.64	1.97**
Other	1593.36	2107.60	1825.52	0.80

Note: *** and ** refers 1 and 5% level of significance, respectively.
Source: Model result, 2017

Table 2 reveals that households in the study area had significant difference in collecting income from livestock, milk, and daily labour participation. Majority of the households in the study area collect income commonly from livestock products wherein those in East Arsi had better income than the other sample area.

Figure 1 reveals that smallholders of the study area commonly sold their crops to the small traders and nearby consumers. Participation of brokers was relatively larger in the vegetable marketing. Small trades have relatively larger participation in purchasing the two dominant crops in the study area (wheat in Arsi and potato in Kombolcha).

Figure 1: Common customers of smallholders in the crop market



Source: Own computation, 2017

Figure 1 reveals that the significant proportion of the agricultural output reached to the final consumers through a long process of marketing, which would reduce the benefit of farm households and may be a strong bottleneck in the agricultural transformation of the country.

3.3 Consumption Type and Expenditure of Households

Households of the two sample areas had significant difference in their consumption expenditure on the different cereals and other food items. The largest expenditure of sample households was on ingredients like cooking oil followed by cereals, wherein households in Kombolcha spend larger money on purchasing cereals because there is no production of these major food items. Table 3 clearly shows that consumable items produced by the urban sector such as bread and spaghetti are included in the consumption bundle of the rural households. However, the level of rural purchase of all items from the urban sector was higher in Combolcha than Etosa. This indicates that the backward linkage of agriculture with the urban sector is stronger in the rural areas that are closer to main market centres and producers of cash crops.

Table 3: Yearly consumption expenditure (in Birr) of sample smallholders

Food source	Kombolcha	Etosa	Combined average	t-value
Oilseed	324.97	94.40	219.25	3.73***
Pulses	1170.83	247.18	749.36	6.35***
Cereal	3556.11	2252.87	2958.53	2.08**
Bread	728.00	208.60	491.00	2.78***
Spaghetti	1348.88	610.04	1011.74	3.53***
Vegetable	220.38	406.98	305.94	3.17***
Ingredient	2412.72	6164.89	4124.88	7.08***

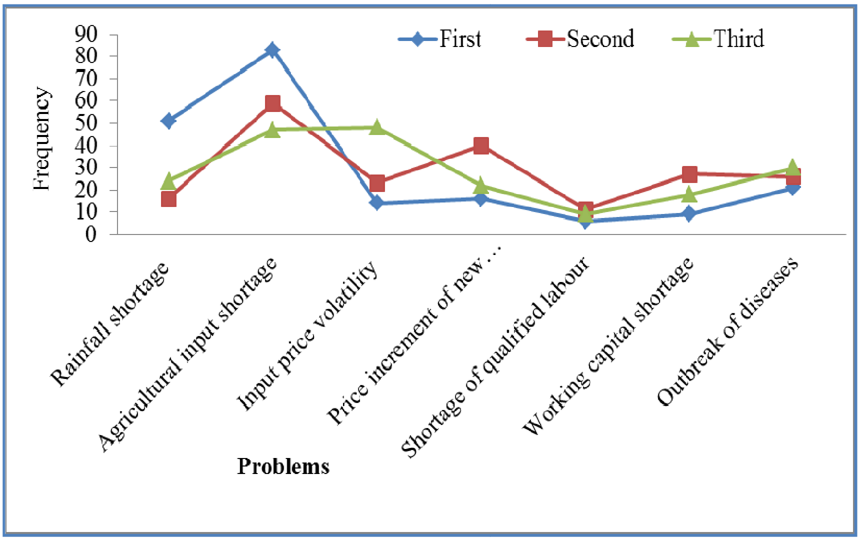
Source: own computation from survey data, 2017

3.4 Crop Production Problems in the Study Area

Sample households were replayed about the major challenges they frequently faced their production of process as it is depicted in Figure 2. Accordingly, smallholders of the area faced problem of accessing agricultural inputs in short distance at affordable price, which is one threat in the overall crop production. The continuous price increment and quantity supply shortage for farmers that have no access to credit result in application of inputs below the standard level. Some hybrid seeds are highly susceptible to insects and diseases that would result in huge loss for smallholders of the area since the inputs are costly. In addition, households frequently faced problem of immediate decay of vegetables and they could not be able to preserve them for long period to sell with better price during off season period. This problem forced smallholders to sell agricultural outputs in the harvesting season at lower prices.

Albeit farmers had awareness and willingness to participate in non-farm activities to diversify income but they could not be able to do so because of financial constraints and lack of entrepreneurial skills. The limited business knowledge and skills hold back households from investing in profitable non-farm activities to generate additional income. As a result, surplus money (saving) from the agriculture are kept at home and used inefficiently.

Figure 2: Most common problems in the crop production



Smallholders identified that marketing related problems are critical ones. Accordingly, households of the study area commonly suffer from problem of price and demand variability in the input-output exchange process. Households of the area also had problem of accessing market information and perishability of the crops to deliver quality products to their customers.

Figure 3: Most common market related problems

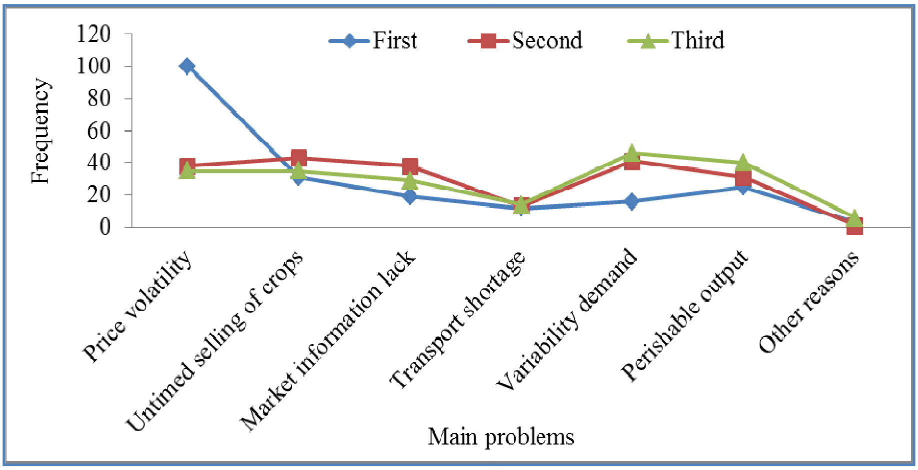


Figure 3 shows that price volatility should be managed and smallholders get the recommended level of fertilizer to facilitate the agricultural transformation through enhancing the linkage of rural and urban sectors of the country.

3.5 Model Results and Discussion

Farm households' expenditure on industrial products (both consumption items and production inputs) is an important indicator of the extent of agriculture's backward linkage to the urban sector and consumption of industrial commodities. This section presents and discusses results of econometric analysis on determinants of farm households' purchased food consumption and crop production inputs.

3.5.1 Determinants of purchased food items' for smallholders from the urban sector

The cash crop, '*Khat'*, production dominancy for households in Kombolcha area results in generation of upper censored dependent variable due to 100% purchase for the overall consumption. Few households in the aforementioned study area allocate their cropland only for the cash crop and are purely dependent on purchased items for their consumption.

The model result in Table 4 revealed that households' purchased food consumption expenditure was significantly affected by many of the covariates considered as an explanatory. Socio-demographic factors like sex and education level of the head significantly and positively affected purchased consumption expenditure of the households from the urban sector. Household's access to credit service also has significant and positive effect (Table 4) on consuming purchased items from domestic or foreign owned industries that operate in the country. The positive and significant effect of higher education attainment and credit access may be due to awareness of the household about importance of diversified food consumption. These all imply that those factors have significant effect on consuming domestically produced items, which enhance performance of industries to produce more if there is demand to their produces.

Table 2: Determinants of household purchased food consumption (Tobit regression result)

Description		Coefficient	Standard error	t-value
Sex of the head		0.2278	0.0834	2.73***
Age of the head		0.0011	0.0019	0.59
Education♣	Read and write	-0.0361	0.0486	-0.74
	Elementary	-0.0093	0.0506	-0.18
	Junior	0.0671	0.0744	0.90
	College or University	0.7475	0.3180	2.35**
Credit access		0.0792	0.0462	1.71*
Distance from the road		-0.0081	0.0071	-1.13
Irrigation		-0.0909	0.0455	-2.00**
Total cropland		0.0296	0.0189	1.57
Adult Equivalent		-0.0242	0.0122	-1.99**
TLU		-0.0224	0.0059	-3.77***
Income milk sale		-0.00024	7.95e-05	-2.95***
Other Income		-6.17e-05	4.01e-05	-1.54
Constant		0.6464	0.1086	5.95***
Sigma		0.252	0.0133	
P-value		0.000	Pseudo R^2	0.621

Note: ♣ Illiterate was the bases

***, ** and * refers 1%, 5% and10% level of significance, respectively.

Households' purchased food consumption expenditure in the study area negatively and significantly affected by access to irrigation, adult equivalent, income from milk sale and the livestock holding. Those covariates are source of crop production inputs, wherein increment in the availability of them would enhance household's capacity to produce more to be food self-sufficient from own production. This circumstance may reduce household's reliance on purchased items for consumption. The intention of consuming purchased items may be lower if the household has plenty of production inputs to produce more in diversified manner. Similarly, having easy access to irrigation may enable smallholders to produce two to three times a year, which would create auspicious environment for the household to have diversified consumption from own production. This effect is a substitution effect. On the other hand, production of irrigated high value crops increases farm household's income and purchasing power of industrial products. This possible effect is an income effect. Therefore, the negative coefficient of the irrigation access (Table 4) indicates that the substitution effect outweighs the income effect. This is expected result since most rural households rely on own food sources.

3.5.2 Drivers of agricultural input purchase of smallholders from the urban sector

Ordinary Least Square regression method was used to investigate determinants of expenditure to purchase crop production inputs by smallholders of the study area. The model was strong enough in explaining variation of the dependent variable having R^2 and Root MSE of 0.6726 and 0.6077, respectively. Table 5 showed that the socio-demographic related variables age and education level of the household head has significant effect on households' inputs expenditure from the urban sector. The model result revealed that experienced household heads significantly increases spending to purchase production inputs from the industry as compared to younger ones. Additionally, a household headed by an individual who is basic literate, elementary or junior school graduate has significant effect on expenditure to purchase crop input. Households headed by junior school graduate have better response than those headed by elementary school graduates in crop input expenditure given that illiterate ones are the base for the two.

Table 3: Determinants of crop production input usage

Description		Coefficient	Robust Standard error	t-value
Sex of household head		-0.5517	0.1422	-3.88***
Age of household head		0.0121	0.0046	2.62**
Education♣	Read and write	0.2036	0.1108	1.84*
	Elementary	0.2710	0.1272	2.13*
	Junior	0.4372	0.2058	2.12*
	College or University	0.1116	0.4785	0.23
Training		0.5019	0.0960	5.23***
Credit access		0.2181	0.1226	1.78*
Distance from the road		0.0332	0.0201	1.65
Irrigation		0.0178	0.1232	0.14
Total cropland		0.1317	0.0493	2.67**
Human labour		0.0298	0.0301	0.99
TLU		0.0638	0.0132	4.85***
Income from milk sale		-7.43e-05	0.0002	-0.39
Income from other activities		-0.0023	0.0022	-1.05
Constant		7.7465	0.2846	27.22***
Root MSE		0.6077	R^2	0.6726

Note: ♣ Illiterate was the base

***, ** and * refers 1%, 5% and10% level of significance, respectively.

Households' accesses to training and credit have positive and significant effect on the expenditure to purchase inputs. Training creates awareness on the importance of spending on inputs that may enhance crop productivity. Additionally, accesses to credit may ameliorate household's liquidity constraint.

Ownership of large cropland and livestock (in TLU) by household of the study area significantly increase crop production input usage from the industry sector. Expectation of better production from large holding size may encourage the purchase and use of the recommended level of crop production inputs. Livestock is one source of cash to purchase crop production inputs. This circumstance may improve smallholders' capacity to purchase and apply crop inputs as to the standard or recommended rate for each crop. These all imply that the agriculture- industry linkage would be facilitated if smallholders have easy access to alternative cash sources.

4. Conclusion and Recommendations

The study tried to evaluate the backward linkage of the rural economy with the urban sector considering two angles-the purchase of consumable and crop production inputs from the industrial sector. Consumption of the rural economy from the urban sector increases for male headed households with better education and access to finance. However, households that have access to irrigation, larger family and livestock size had a lower expenditure on consumable items from the industry sector. On the other hand, crop production input consumption of agriculture from the industry sector increases with age, education and training, livestock and cropland sizes of the farming household.

Therefore, improving the awareness of the farming community through education and trainings, expanding opportunities to farmers' resources access like draught power, tillable land and credit play vital role in strengthening the rural-urban linkage. Even if access to some resources such as herd size seems to weaken the direct reliance of the rural sector on the urban economy for its direct food consumption, the availability of such resources strengthen the linkage through increasing the demand for crop production inputs from the industry sector. Strong rural-urban linkage has a significant implication on the transformation of the current subsistence agriculture to the modern and more productive sector.

The survey result shows that almost all (99%) of the sampled smallholder farmers had no access to the central market that provides them a better price for their crops. There should be market access in nearby distance to increase households' market participation and allow them to collect all the potential benefits from their crop production that would enhance their capacity in achieving the agricultural transformation.

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Adoption and Impact of Row Planting of Wheat Crop on Household Livelihood: - A Case Study of Duna Woreda in Hadiya Zone, Ethiopia

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Abstract

This study tried to estimate the impact of row planting technology on wheat crop yield, household food consumption expenditure, household agricultural input expenditure and household income of farmers. Cross-sectional survey data were collected from randomly selected 187 farmers. Logit model, and propensity score matching methods were employed to achieve the objective of the study. The study obtained that wheat row planting has significant impact of4.93 quintals yield-per-hectare on wheat crop yield, 5244.75 Ethiopian Birr net on household food consumption expenditure, 4486.52 Ethiopian Birr net on household agricultural input expenditure. And 6079.56 Ethiopian Birr net on household income of farmers increase for adopters as compared to non-adopters. Which indicate that efforts to disseminate existing row planting of wheat will highly contribute to increasing income among farm households. It is recommended that other agronomic practices along with the row planting method need to be considered for increasing wheat crop yield, household food consumption expenditure, household agricultural input expenditure and household income as well as for the successful promotion, adoption and scaling up of wheat row planting practices.

Keywords: Adoption, Wheat, Impact, Propensity Score Matching, Row Planting Technology, Ethiopia

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1. Introduction

Agriculture has been and continues to assume center stage in economic policy of many Less Developed Countries (LDCs) in general and Sub-Saharan Africa (SSA) in particular. Poverty reduction and income growth can generally be achieved through agricultural growth that creates spillover effects to the remaining sectors (World Bank, 2014). However, production and productivity of the agricultural sector in SSA is low due to low technological adoption and techniques among others (Abraham et al., 2014; Gashaw et al., 2014 and Lulit et al., 2012). Agriculture is Ethiopia's most important sector, basis for the country's food security and the livelihoods of nearly 85% of its people. It holds about 50% of the Gross Domestic Product (GDP), 90% of the total export revenue, 85% employment of the country's labor force and it also accounts 70% of raw materials requirement of the country's industries (MEDAC, 1999). And also it is the engine for the country's Agriculture Development Led Industrialization (ADLI) strategy.

Wheat is one of the major food crops in Ethiopia. It is the second important cereal crop with annual yield of about 3.43 million tons cultivated on area of 1.63 million hectares (CSA, 2013). According to the CSA data, wheat occupied about 17% of the total cereal area with average national yield of 21.10q/ha. This is the lowest yield compared to the world average yield of 40 q/ha (FAO, 2009). The national average yield levels are low because highly characterized by rain fed, subsistence oriented, broadcast farming system, low adoption of row planting technology, poor agricultural performance, income variability and high population growth. The low yield has made the country unable to meet the high demand and the country remains net importer despite its good potential for wheat production (Rashid, 2010).

The traditional planting method that is broadcasting seed by hand at high speed rates decrease yield because uneven distribution of the seeds makes hand weeding and hoeing difficult, and plant competition with weeds decreases wheat growth and tillering. One of the crops commonly cultivated using the traditional broadcast planting is wheat. Such a planting technique causes wheat yield reduction. Improved agricultural Technologies such as row planting and transplanting, where the seed rate is reduced and more space between seedlings is given, have been shown to achieve important production increments over traditional broadcasting sowing. Because improved agricultural technologies allow for better weeding, decrease competition between seedlings, and allow for better branching out and nutrient uptake of the plants (Astatke et al., 2002; Chauhan et al., 2014).However; in general, row planting of wheat crop technology are often adopted slowly and several aspects of adoption row planting of wheat technology remain poorly understood despite being seen as an important route out of poverty in most of the developing countries (Bandiera and Rasul, 2010; Simtowe, 2011).

Sowing wheat crops in rows at low rate instead of scattering seeds by hand was introduced in 2014 in the study area. About 400,000 wheat farmers in 200 kebeles located in the four main wheat belt regions of Ethiopia: Amhara, Oromia, SNNPR, and Tigray (Gashaw et al., 2014; Sarah, 2014) were reported to adopt this practice in using a reduced-seed rate through row planting is a major piece of the package. However, small farm households were convinced that 50 kg of the advised seed per hectare was not enough because they traditionally use 75 kg per half hectare. Farmers who sow with the recommended amount of seed have got impressive yield, a deviation of 75% to 80% per hectare (Sarah, 2014).

Promotion and scaling-up of manual wheat row planting has been carried out in the study Woreda through agricultural extension offices for several years. Though the impact of the planting method is linked to problems in implementation of the program and its recommendations, methodological issues, and over optimism of the potential of row planting in real farm setting (Vandercasteelen et al. 2013). The planting technique is seen as best agronomic practice by agricultural policy makers and extension personnel. However, there is lack of empirical study on the impact of wheat row planting technology on wheat crop yield, household food consumption expenditure, household agricultural input expenditure and household income of small farm households. Therefore, this study attempted to evaluate the impact of row planting technology on wheat crop yield, household food consumption expenditure, household agricultural input expenditure and household income of small farm households. Horizontally, the objective was to identify factors that affect adoption of row planting technology in wheat cropping and evaluated its impact on wheat yield and income of households in the study area. Specifically, it has identified factors that affect adoption of row planting of the wheat crop. Evaluated the impact of row planting on yield of wheat and the impact of row planting on household income.

2. Literature Review

Understanding of the factors underlying farmers' decisions of whether or not to adopt agricultural technologies (such as row planting) is crucial in terms of achieving enhanced crop yield through improved adoption of such technologies. The empirical studies important in interpreting the significance of the theoretical explanations. That is, the empirical works can confirm or reject the theoretical assumptions and also suggest the importance and new aspects of the conceptual framework (Feder et al., 1985). Numerous studies have related household and institutional characteristics to adoption behavior and impact with different findings. The following are some of the results of previous studies. In order to increase adoption of suitable row planting, it is important to know the factors that influence the choice of row planting and adoption. The study conducted by (Debelo, 2015), on does adoption of Quncho Teff increases Farmers' crops income. By using kernel matching method result revealed that the crops net income of the farmers who were adopter of Quncho Teff was much greater with 11,790.59 Ethiopian Birr than non-adopters. So it is concluded that the agricultural technology adoption has positive income effect.

Tsegaye and Bekele (2012) investigated, impacts of adoption of improved wheat technologies on household's food consumption in south eastern Ethiopia. They found that age, education, farm experience, off-farm activities, access to credit, extension contact, wheat seed varieties with recommended planting space and livestock holding are significant on wheat row planting and household's income by using propensity score matching model. According to ATT that calories per day increment came on the adopters of row planting method wheat thereby increasing household's income. A study conducted by Tolesa et al. (2014) in Arsi Zone of Ethiopia showed that the impact of Wheat Row Planting on Yield of Small farm household by applying the logit and propensity score matching. Row planting of wheat significantly influenced by educational level, access to pesticides, household size, access to improved seed. According to their study the variables like age of household, access to credit, pesticides services, and livestock holding size and off-farm income in the high land district and household size and off-farm income in the low land district are significantly influence row planting of wheat respectively. Gashaw et al. (2014) in Ethiopia showed that the selected wheat seed, a lower seeding density, row planting, fertilizer recommendations, and marketing assistance as full-package obtain higher wheat yields as compared to non-users.

Mamudu et al. (2012) conducted a study to understand the adoption of modern agricultural production technologies by farm households in Ghana using logit model. Plot size, expected returns from technology adoption, access to credit, and extension services are significant on technology adoption of small farm households in the west district Ghana. As study of (Yonas, 2013), on the topic is there impact of row planting teff crop on households' income by applying the propensity Score Matching (PSM) and Heckman two stage selection model. The variables like level of education, cultivated land size, tropical livestock unit, access to extension services, availability of family labor and nearness to farmers training center are significant on row planting tef crop and on household income. According to the results of a propensity score matching, adoption of row planting had enhanced the teff crop income.

An empirical study carried out by (Ejegayehu and Berhe, 2016) showed that Effect of wheat row planting technology adoption on small farms yield in Ofla Woreda, Ethiopia by using propensity score matching method. According to their study Variables like sex, age, field visit days, and age square are significant on wheat row planting technology adoption on small farmers. The result of their study showed that the marginal farm land adopter was gotten higher production than non-adopter of wheat producer in a single production year. Those results are consistent to the researches that had been done before (Tsegaye and Bekele, 2012; Bola et al., 2012; and Mamudu et al., 2012).

Tolesa (2014) conducted a study on Socio-economic and Institutional Factors Limiting Adoption of Wheat Row Planting in Ethiopia, by applying logit model. The study found that improved seed, agricultural extension services, education, and livestock size are significant on wheat row planting. The study showed that row planting of wheat crop better in midland and high land agro ecology than low land. Study by Debela (2011) in Beressa and Umbullo Watersheds showed that Impact of agricultural technology on farm production. As the study of Debela better farm management and adoption of improved agricultural technologies like chemical fertilizers, improved seed varieties, pesticides, and organic minerals, age of the household head, education level, family size, number of oxen, access to credit, and off-farm activities are significant on agricultural growth. According to the study Ibrahim (2013), with low educational level and small land holdings are less likely to adopt improved seed and fertilizer technologies, by panel data using probit model in Uganda.

An empirical study carried out by Bekalu and Tenaw (2015) in their study showed that Effect of Method of Sowing on Yield and Yield Components of Teff. The economic analysis indicated that row sowing had acceptable MRR (627.7%); and 6775.6 Birr/ha more grain yield income than broadcasting teff. Thus, it recommended that, row sowing for Teff production in the trail area. Advised to undertake further research across soil type, years and locations to draw sound recommendation on a wider scale.

Tolesa et al. (2014) conduct a study on Impact of Wheat Row Planting on Yield of Smallholders in Selected Highland and Lowland Areas of Ethiopia, by applying logit and propensity score matching model. Their study showed that practice of crop rotation, access to improved seed and livestock holding size influences wheat row planting, and land holding size and access to improved seed are insignificant to row planting. Socio-economic /demographic and institutional variables like number of years of residence in the village, access to media, mobile phone, vocational training, livestock ownership, access to improved seed, and income from other crop production were significant on sustainable rice productivity in Nigeria, by using a local average treatment effect (Bola et al., 2012).

The above studies of the empirical literature showed that socio-capital, demographic characteristics and institutional variables like education level of household, access to credit, livestock holding, access to extension contact, income from other crop production, nearness to farmers training center, access to improve seeds and availability of farm labor are influence row planting of wheat crops. Some studies of empirical literature use age of household are significant and positive (i.e. the age of household increases and approach to old, increase adoption level of row planting of wheat crops (Tsegaye and Bekele, 2012). Most of the studies conducted that adoption of row planting technology; there is significant effect on household farm productivity and income.

3. Research Methodology

3.1. The study area:- Duna Woreda, is found in the South Nations, Nationalities, People's Region (SNNPR), in the South West central part of Ethiopia. The Woreda astronomically lies between 7 0 37′19′′ N latitudes and 37 0 37′ 14′′E longitudes. The total population of the Duna Woreda is 148,566, out of these, 75,383 (50.74%) is male and 73,183 (49.26%) is female. Andtotal number of household in Duna Woreda is 18,752. Out of these, 18,109 (95.57%) are men headed households and 643 (3.43) are women headed households. Agro ecologically, the Duna Woreda is classified in to three categories like as Dega 85%, Weina Dega 10% and kola 5%. The annual rainfall varies from 1500mm to 1896 mm. The area receives a bimodal rainfall where the low rains are between March and April while the high rains are from July to September.

The main rainfall occurs in July and August. During the main rains, all crops grown in the area are planted, including maize, teff, wheat, haricot bean, sorghum, and millet. Rainfall during the main rains is unpredictable that most of the time crops fail due to uneven distribution of rainfall over the growing period. The mean annual total rainfall is about 1896mm, and has an average temperature of Woreda is 19CO. The elevation within the Woreda ranges from 2,970m mean sea level Sengiye which is the highest mountain in Hadiya Zone and 1000m mean sea level at the wagabata above which is the lowest place in the Woreda. The average elevation of the Woreda is taken as to be 1985m from the mean sea level. Total area of the Duna Woreda is 43,104 ha (222.57 s/ km) and the population density is 619.58 per s/km. This shows that the population pressure on land was high in the study area. Out of 43,104 ha ofthe land potentially cultivated land is 30,172.8 ha (70%).High proportion of the young age of the population lives in the rural area with high demand for farm land. Regardless of a small proportion of the cultivable land in the Woreda, the population, particularly, young population that demands the farm land is proportionally high.

3.2. Sampling Technique: - A multi-stage probability sampling procedures were used for sample selection. In the first stage, major wheat producing Woreda was purposively selected. The selected Woreda was Duna Woreda. The main reason for purposive selection was due to its high potential for wheat production, and introduction and application of row planting level of wheat production. There are also strong research and extension intervention programs embracing wheat producers in the Woreda. Moreover, newly released improved wheat varieties and wheat row planting practices were relatively more disseminated and practiced in this Woreda. Therefore, it was feasible to assess the impact of wheat row planting on wheat crop yield, household food consumption expenditure, household agricultural input expenditure and household income of farmers in this Woreda. In the second stage, of the probability sampling, a list of major wheat growing lower administrative divisions (kebeles) within the selected Woreda was prepared. Taking in to account the resources available, four kebeles were selected from the Woreda, based on their agro-ecological zone compared to the remaining kebeles of the Duna Woreda. Out of selected four kebeles agro-ecologically Ajerana, Kashira and Barkuncho are Dega and Dabiyago is Weina Dega. In the third and final stage, a list of wheat farmers was prepared for each selected kebele. Sample farmers were selected by simple random sampling technique. The sample size was determined based on the formula given by (Yamane, 1967), and allocation of sample size to each kebele was made proportionate to the size of farm household heads population of each kebele. Accordingly, from a total of randomly selected 187 sample size, 107 were non participant farmers and 80 were participant farmers in row planting of wheat in 2016/17 cropping season.

Table 4: Distribution of sample size by kebele and adoption status

Kebele	Number of households (N)	Probability Proportional Sample (PPS) Size				
		Adopters		Non- adopters		Total Sample (ni)
		Na	na	Nna	nna	
Ajarena (Kebele1)	533	223	18	310	25	43
Kashira (Kebele2)	592	252	20	340	27	47
Dabiyago (Kebele3)	663	288	23	375	30	53
Barkuncho (Kebele4)	556	240	19	316	25	44
Total	2344	1003	80	1341	107	187

ni= total number of households selected from kebele I (I = 1, 2, 3, 4); Ni= total number of households in kebele i; Na = Total number of adopters; Nna=Total number of non-adopters; na = adopting households selected; nna = non-adopting households selected

3.3. Data Collection Technique: - The data for study was collected from both primary and secondary sources. Cross-sectional data was collected from the survey of randomly selected sample farmers. For the primary data collection, specifically designed and pre- tested questionnaire based on the objective of the study, and trained data enumerators was used. The questionnaires schedule was tested at 16 randomly selected farm households in the study area. Both quantitative and qualitative information were collected. The data collection included households' demographic and socioeconomic characteristics (family sizes, age and sex structures, education, etc), land holding (agricultural, grazing, wheat land, and others), farm inputs utilization (seeds, fertilizers, herbicides and fungicides, labor utilization, credit, extension services), farm outputs, input and output prices, agronomic practices including crop rotation, wheat row planting and its inputs and output, and etc. Secondary information like population number, agricultural inputs and outputs, farm land use pattern, rainfall amounts (annual mean and cropping season), temperature and agroecology, etc were also collected. The survey was carried out in the months of May and June 2017.

3.4. Data Analysis Method: - The Binary logistic regression function was invented in the 19thcentury for the description of the growth of populations and the course of autocatalytic chemical, or chain reactions (Cramer et al., 2003). Logistic regression was incorporated to analyze relationships between a dichotomous dependent variable. Our focus here was on binary logistic regression for two groups. Logistic regression combines the independent variables to estimate the probability that a particular event will occur that is a subject will be a member of one of the groups explained by the dichotomous dependent variable.

The Probit and Logit models are commonly used, models. The Probit probability model is associated with normal probability function and the logit model with logistic probability distribution respectively.The advantage of these models over the linear probability model is that the probabilities are found between 0 and 1. Both Logit and Probit models may give the same result. The logistic function is used because it represents a close approximation to the cumulative normal distribution, mathematically easily used model and is easier to work with. Therefore, the Logit model is selected for this study. The model is fitted using method of row planting of wheat technology as dependent variable, socioeconomic variables as independent variables which are influence practice of wheat row planting and the outcome variable, wheat productivity and it would be important to shows the factors that influence the farmers' adoption status. The dependent variable is binary, taking values of 1 if the farmer adopters and 0 otherwise. However, the independent variables are both continuous and discrete.

The justification for using logit is its simplicity of calculation and that its probability lies between 0 and 1. Moreover, its probability approaches0 at a slower rate as the value of independent variable gets smaller and smaller, and the probability approaches 1 at a slower and slower rate as the value of the independent variable gets larger and larger (Gujarati, 2003). Logit model can be specified as:

$$P=E(Y=1/Xi)=\frac{1}{1+e^{-(\hat{a}o+\hat{a}iXi)}}\cdots \quad \textbf{(1)}$$

This will be writing as follows, z_i is equal to $\hat{a}_0 + \hat{a}_i X_i$, then

$$P_i = \frac{1}{1+e^{-zi}}\cdots \quad \textbf{(2)}$$

$$1 - P_i = \frac{1}{1+e^{zi}}\cdots\cdots \quad \textbf{(3)}$$

The probability that a given household is row planter of wheat is expressed in equation two, while the probability for a non-row planter of wheat is expressed in equation three.

Therefore, we can write as

$$\frac{P_i}{1-P_i} = \frac{1/1+e^{-zi}}{1/1+e^{zi}} = \frac{1+e^{zi}}{1+e^{-zi}} = e^{zi}\ldots \quad \textbf{(4)}$$

The ratio of the probability that household is row planter to the probability of that it is a non-row planter of wheat.

$$L_i = \ln\frac{P_i}{(1-P_i)} = z_i = \hat{a}_o + \hat{a}_1X_1 + \hat{a}_2X_2 + \ldots\ldots\ldots + \hat{a}_nX_n \quad \textbf{(5)}$$

Where L is the log of the odds ratio and it is called the logit.The above equation with disturbance term can be written as:

$$z_i = \hat{a}_0 + \sum_{i=1}^{n}(\hat{a}_iX_i) + U_i$$

Wherez_i= function of explanatory variables (X), $\hat{a}_0$ = intercept,$\hat{a}_1, \hat{a}_{2,} \hat{a}_3\ldots\ldots$ $\hat{a}_n$are the slopes of the equation in the model, L_i = log of the odds ratio = z_i, X_i= vector of a relevant characteristic or independent variables, U_i = disturbance term.

In this study, propensity score matching (PSM) was employed in order to evaluate the impact of row planting of wheat on wheat crop yield, household food consumption expenditure, household agricultural input expenditure and household income. The PSM is mainly employed in impact determination absence of baseline data. According to Ravallion (2005), impacts estimated with parametric models are more biased and less robust to miss specification of regression functions than those based on matched samples. To determine the effect of adoption of wheat row planting on the productivity and efficiency of the smallholder household's PSM is used. Adopters in wheat row planting of wheat technology without random, matching randomization when compared to parametric models PSM allows the determination of average effects without of arbitrary assumptions about logistic functional forms, and error distributions. Furthermore, despite that binary logistic models employed enough sample, PSM is confined to match one. Propensity score methods allow the research directly address the question of what can be earned from the data and what cannot (David, 2011).

The PSM technique has been applied in a very wide variety of fields in the program evaluation literature: Dehejia and Wahba (2002), and Smith and amp; Todd (2005) use PSM techniques to estimate the impact of labor market and training programs on income; Jalan and Ravallion (2003) evaluate antipoverty workfare programs; Almus and Czarnitzki (2003) evaluate the impact of research and development subsidies and patent laws on innovation; (Lavy, 2002) estimates the effect of teachers' performance incentives on pupil achievement; and Persson, Jalan and Ravallion (2003). The technique enables us to extract from the sample of non-adopter households a set of matching households that look like the adopter households in all relevant pre-intervention characteristics. The objective of PSM is to find the closest comparison group from a sample of non-adopter farmers to the sample of program adopter farmers. "Closest" is measured in terms of observable characteristics. Small farm household with the similar propensity scores are paired and the average treatment effect is then estimated by the differences in outcomes (Greene, 2012).

In this study, the main pillar of Propensity score matching (PSM) is wheat productive farmers, the adopters' farmers in wheat row planting and potential outcome (wheat crop yield, and wheat crop yield, household food consumption expenditure, household agricultural input expenditure and household income). The idea was to match those wheat productive farmers that adopt wheat row planting with that of non-adopters of row planting group, sharing full observable characteristics. Then mean effect of wheat row planting is measured as the average difference in productivity and income between adopter in wheat row planting and non-adopter in wheat row planting small household groups i.e. the impact is the change in wheat crop yield, household food consumption expenditure, household agricultural input expenditure and household income as an outcome indicator. The use of propensity score matching model is to answer the question "what would be wheat crop yield, household food consumption expenditure, household agricultural input expenditure and household income per hectare for household who planted wheat in row had these household not adopted planting wheat in a row? " Adopter and non-adopter households in wheat row planting is related exactly on farm small household characteristics (age, education, farming experience, land holding size, number of crop types planted in the season, practice of crop rotation, access to credit services and household size, livestock holding size, and non-farm income). These variables were used to select comparison farmers via different matching estimators, nearest neighbor matching, radius matching, caliper matching and kernel matching.

According to Rosenbaum and Rubin (1983), PSM can be explained as the conditional probability of taking a treatment given pretreatment characteristics of the small farm households. Therefore, $Y_i^T$and $Y_i^C$are the outcome variable adopters and non-adopters respectively. The difference in outcome between adopters and non-adopters can be calculated from the following mathematical equation:

$$\Delta Y_i = Y_i^T - Y_i^C \quad \textbf{(6)}$$

Y_i^T: outcome of adopter, when he/she is adopter,Y_i^C: outcomeof non-adopter, when he/she is non-adopter, ΔI change in the outcome as a result of adopters for the i^{th} household. Let the above equation can be determined in causal effect notational form, by assigning D_i=1 as treatment variables taking the value 1 if theindividuals received the treatment (row planting) and 0 otherwise. Then the formula for Average treatment effect on treated (ATT) can be seen as follow:

$$ATT = E\ (Yi^T - Yi^C/D_i = 1) = E\ (Yi^T/D_i = 1) - E\ (Yi^C/D_i = 0) \quad \textbf{(7)}$$

E (Y_i^T/D_i=1): mean outcome for household, with adopters, if he/she would adopter (D_i=1). E (Y_i^C/D_i=0): mean outcome for household, with non-adopters, when he/she would non-adopter (D_i=0). ATT=The Average Effect of Treatment on the Treated for the sample. The Average Effect of Treatment on the Treated (ATT) for the adopters and non-adopters sample households as is given by:

$$ATT=E\,(Y_i^T - Y_i^C / D_i=1) = E\,(Y_i^T / D_i=1) - E\,(Y_i^C / D_i=1) \quad \textbf{(8)}$$

The main evaluation problem in determination of effect is that it is difficult to observe a person's outcome for with and without treatment of treated at the same time. The post-intervention outcome E $(Y_i^T/D_i=1)$ is can be to observe, however, the counterfactual outcome of the i^{th} household when she/he does not a treated the treatment is not observable in the data. According to Rosenbaum and Rubin (1983), there are two basic assumptions to determine importance of outcome variable such as Conditional Independence Assumption (CIA) which excludes the familiar dependence between dependent variables.

$$(Y_i^T - Y_i^C) \perp (D/X_i) \quad \textbf{(9)}$$

Assumption of Common Support which indicated that P(x) lies between 0and 1, and this restriction indicated that the test of the balancing property is performed only on the observations whose PSM fall to the common support region of the PSM of adopters and non-adopters (Becker and Ichino, 2002).

$$0 < P(X) < 1 \quad \textbf{(10)}$$

There are four the most commonly used matching algorithms, which are the nearest neighbor matching (NNM), radius matching (RM), caliper matching and kernel (KM) matching, was employed to evaluate the impact of row planting a wheat crop on wheat crop yield, household food consumption expenditure, household agricultural input expenditure and household income. The dependent variable for the logit model is adopting row planting of wheat crop. Dependent variable is a dummy variable given a value of 1 if the household adopter and 0 otherwise. The outcome variables are wheat crop yield, household food consumption expenditure, household agricultural input expenditure and household income. The independent variables of importance in this study are those variables, which are a consideration to have an influence on adoption of row planting of wheat crop on outcome variable. These included household personal and demographic variables, socioeconomic variables, household socio-capital variables and institution variables. The matching was conducted using STATA computer software version 13 and psmatch 2 command.

Table 2: List of explanatory variables used for the analysis

Definition	Type	Expected sign
Education level in years of schooling4	Categorical/dummy	+
Age of household head (years)	Continuous	-
Family size	Continuous	+
Size of cultivated land (ha)	Continuous	+
Livestock owned in TLU	Continuous	+
Participation in extension services (1 = Yes)	Dummy/binary	+/-
Availability of farm labor (1 = Yes)	Dummy/binary	+/-
Use of credit (1 = Yes)	Dummy/binary	+/-
Sex of household head (1 = Male)	Dummy/binary	+/-
Use of recommended agriculture inputs (1 = Yes)	Dummy/binary	+/-

Finally, to ensure the validity the conditional independence assumption, we conducted a sensitivity analysis as a means of checking for the robustness of our results. The idea is to check whether unobserved factors affecting both the treatment and the measured outcomes thereby resulting in a 'hidden/selection bias' (Rosenbaum, 2002). This was accomplished by checking the degree to which the estimated treatment effect is sensitive to small changes in the specification of the propensity score as proposed by (Grilli & Rampichini, 2011)

4. Result and Discussion

4.1 Description of Wheat Planting Methods: - The number of sample farmers who practiced planting wheat in a row was 80 (42.78%) while those who used the conventional planting method comprise 107 (57.22%) of sample farmers from the total randomly selected 187 (100%) sample farmers (Table 1).

[4] Measured on scales of four categories representing levels of schooling: 1 for no schooling, 2 for primary school (grades 1 – 5), 3 for middle school (grades 6-8) and 4 for secondary school (grade 9 or higher), which was later recoded as 1 = for literate (categories 2, 3 & 4) and 0 = illiterate (category 1) for analysis

Table 3: Sample farm households by adoption status (wheat planting method)

Planting Method	Frequency	Percent
Broadcast	107	57.22
In Row	80	42.78
Total	187	100

Source: Computed from own survey data (2017)

The very majority of the respondents were headed by males 70.05% and the remaining about 29.95% of the sample households were headed by females. According to comparison by participation in row planting, out of the 100% participant households 72.50% is headed by male participants and the corresponding figure for non-participants is about 68.22%. Comparison by participation in row planting, out of the 100% participant households 27.5% is headed by female participants and the corresponding figure for non-participants is about 31.78%.

According to adopters of row planting technology of wheat helped them to increase wheat crop yields, household food consumption expenditure, household agricultural input expenditure and income, and decrease amount seed rate. The non-adopter households were forward different reasons for not participating in the row planting of wheat technology were lack of personal interest, cultivated land is not suitable due to logging water, don 't have enough labor force, not suitable sowing and takes time. In finally the respondents responds that as much as possible government should support farmers by distributing row planting of the wheat machine to substitute labor force and to decrease time expense.

4.2. Binary Logit Regression Result: - A binary logistic regression model was used to estimate and identify determinant factors of row planting of the wheat crop on outcome variables. The goodness fit of a model for the binary logistic regression model, with regard to the predictive efficiency of the models out of 187 sample household include in the model 150 (80%) were correctly predicted. The sensitivity and specificity indicate that 73.75% of adopter of row planting of wheat and 84.11% of non-adopters of row planting of wheat households were correctly predicted in their categories respectively.

There are seven variables determine the probability of participating in row planting technology such as age of household head, the level of education of the household head, family size of the household head, cultivated land size of a household head, Tropical Livestock Unit (TLU), use of credit service and access to extension services.

Table 4: Estimation result of row planting wheat technology adoption binary logit model (n = 187)

Variable	Robust Coefficient	Odds Ratio	S.E	P >|Z	Marginal effect
AGEHH	-.0467232***	.9543515	.0156098	0.003	-.0111192
SEHH	.116301	1.123334	.4559993	0.799	.027526
FSIZE	.319241**	1.376083	.1512633	0.035	.0759728
EDU	.693629**	2.000964	.2711641	0.011	.1650696
CLSIZE	.9678345*	2.632238	.5360575	0.071	.2303249
TLU	.1399694*	1.150239	.0716798	0.051	.0333099
CRUHH	.9171961**	2.502264	.405024	0.024	.2149421
RAI	.5425498	1.720388	.3887685	0.163	.1279105
AFL	.1734129	1.189357	.454173	0.703	.0409221
EXTEN	1.046396***	2.847372	.384173	0.006	.236481
Cons	-6.696468	.0012353	1.859443	0.000	
LR chi2 (10)	60.75	0.334			
Prob > chi2	0.000				

***, ** and * shows the significance level at 1%, 5% and 10% respectively.
Source: Computed from own survey data (2017), at-values for continuous variables and Pearson's chi-square values for categorical variables. Figures in parentheses are standard errors. ***P< 0.01.

Age of the sample households: this variable is a negative relationship with row planting technology and significant at 1% probability level. Itimplies that; odds ratio in favor of adopting row planting of wheat technology decreases by a factor of .95, as the age of the small farm household heads increases by one year. The education level of household heads: this variable is a positive relationship with row planting technology and significant at 5% probability level. The odds ratio implies that as the year of schooling of household heads increased by one grade, household heads who educated is about two times more likely to participate in row planting technology as compared to household heads that are illiterate. Family size of household: this variable is positive relationship with row planting technology and significant at 5%

probability level. That implies the being other things constant, as the family size of household head increased by one, the probability of household being row planter increase by 7.6%.

Use of credit service: This variable is positively related with row planting technology and significant at 5% probability level. Hence, a household heads who got credit is about two times more likely participate in row planting technology as compared to household heads that did not get credit. Access to extension services: it is positively related with row planting wheat technology. This variable is significant at 1% probability level. This is that household heads who are involved in extension services are about three times more likely to participate in row planting wheat crop as compared to household heads who are not involved in extension services.

4.3. Propensity score matching model Regression Result: -Propensity score matching model was used to analyze the impact of row planting of wheat crop on wheat crop yields, household food consumption expenditure, household agricultural input expenditure and income. According to (Grilli and Rampichini, 2011) the necessary steps when implementing propensity score matching is: Propensity Score estimation, choose matching algorithm, check overlap/common support and testing matching quality. The main criterion for estimating the common support region is to delete all observations whose PSM is lower than the minimum PSM of adopters and higher than the maximum in the non-adopters (Caliendo and Kopeining, 2008).The summary statistics of propensity scores of farmers (Table 5), the predicted propensity scores for adopters of row planting and non-adopters of row planting of wheat farmer range from .0345565 to .957612. Accordingly, the common support region was satisfied in the range of .0345565 to .957612 by deleting 1 observation from those adopters.

Table 5: Predicted propensity score in the common support region

Observations	Mean	Std. Dev.	Min.	Max.
Non-adopters	.2598412	.2298615	.027161	.957612
Adopters	.649575	.2501255	.0345565	.9590279
Total	.4265722	.3066998	.027161	.9590279

Source: Computed from own survey data (2017)

To determine the best matching estimator among nearest neighbor matching, radius matching, caliper matching, and kernel matching, performance criteria such as balancing test of covariates matched insignificant, low pseudo R2 value, insignificant LR chi-square, high p - value and large size of matched sample by discarding only 1 unmatched farmer from total of 187 sample farmers. Accordingly, a nearest-neighbor matching method with of 2 was found to be the best estimator of the data of wheat crop yields, household food consumption expenditure, household agricultural input expenditure and household income of wheat crop. As a nearest-neighbor matching method 2 the pseudo R2 is 0.016, insignificant LR chi-square is 3.48, p - value is0.995 and large matched sample size by discarding only 1 unmatched farmer from total sample farmers is 186.

Table 6: Selection of matching algorithm

Matching Algorithm		Before matching			After matching		
		Pseudo R2	LR Chi2	P - value	Pseudo R2	LR Chi2	P – value
NN	(1)	0.334	85.28	0.000	0.036	7.94	0.957
	(2)	0.334	85.28	0.000	0.016	3.48	0.995
	(3)	0.334	85.28	0.000	0.028	6.12	0.923
	(4)	0.334	85.28	0.000	0.025	5.54	0.887
	(5)	0.334	85.28	0.000	0.028	6.06	0.820
KM	(0.1)	0.334	85.28	0.000	0.027	5.84	0.838
	(0.25)	0.334	85.28	0.000	0.028	6.20	0.373
	(0.5)	0.334	85.28	0.000	0.062	13.52	0.001
RM	(0.01)	0.334	85.28	0.000	0.337	54.88	0.000
	(0.1)	0.334	85.28	0.000	0.337	54.88	0.000
	(0.25)	0.334	85.28	0.000	0.337	54.88	0.000
Caliper	(0.1)	0.334	85.28	0.000	0.036	7.94	0.957
	(0.25)	0.334	85.28	0.000	0.036	7.94	0.957
	(0.5)	0.334	85.28	0.000	0.036	7.94	0.957

Source: own computation (2017)

Estimation of average treatment effect on the treated (ATT) shows that row planting technology of wheat crop has significant effect on the product of adopter farmers with significant t-statistic (5.56) at 1% significance level ($p < 0.001$). The average yields of wheat crop of adopter households in wheat row planting was higher by 4.93 quintals per hectare in given product year when compared with the average yields of non-adopter households. The wheat crop net income of the farmers who were adopter of row planting of wheat was much greater with 6079.56 Ethiopian Birr than non-adopters in given product year. The result stated that the crops net income of wheat row planting technology adopters is greater than non-adopters. The wheat crop net food consumption expenditure of the farmers who were adopter of row planting of wheat was much greater with 5244.75 Ethiopian Birr than non-adopters in given product year. And the wheat crop net agricultural input expenditure of the farmers who were adopter of row planting of wheat was much greater with 4486.52 Ethiopian Birr than non-adopter in a given product year. From the table 20, it is clear that the ATT of wheat crop's average income with t-value 5.55, wheat crop food consumption expenditure with t-value 3.50, wheat crop agricultural input expenditure with t-value 3.15 and wheat crop product with t-value 5.56, indicating the effective level of significance. So it is concluded in this analysis that the row planting of wheat adoption has positive yields, income, food consumption expenditure and agricultural input expenditure effect on the farm households of the study area. Hence, the adoption of row planting of wheat has a positive impact on the life of the adopters indicating positive welfare effect or reduction of poverty level on the side of the adopters.

Table 7: The Average Treatment Effect on the Treated

Outcome	Variable	Treated	Controls	Difference	BSE	T-stat
Wpdt	Unmatched	12.1392405	7.81308411	4.32615639	0.698314984	6.20
	ATT	12.1392405	7.20886076	4.93037975	0.88741955	5.56*
Inch	Unmatched	13967.0886	7704.85981	6262.22879	937.883871	6.68
	ATT	13967.0886	7887.53165	6079.55696	1096.37439	5.55*
Fceh	Unmatched	13558.2278	8050.65421	5507.57364	1273.4271	4.33
	ATT	13558.2278	8313.48101	5244.74684	1496.89042	3.50*
Aieh	Unmatched	12439.2405	7745.98131	4693.2592	1205.90225	3.89
	ATT	12439.2405	7952.72152	4486.51899	1423.62413	3.15*

Source: Computed from own survey data (2017)

Table 8 reports the estimated treatment effects from the propensity score matching. We find that row planting technology had significant effect on wheat crop yield, household food consumption expenditure, household agricultural input expenditure and household income as evidenced by the significantly higher per capita consumption expenditure and annual income resulting from adoption (p < 0.01).

Table 8: The Average Treatment Effect on the Treated

Outcome	Treated	Controls	Difference	BSE	T-stat
Wheat yield (Qt/year)	12.14	7.21	4.93	0.89	5.56***
Income per capita	13,967.09	7,887.53	6,079.56	1,096.37	5.55***
Agriculture Consumption/year	12439.240	7952.72	4486.52	1423.62	3.15*
Food Consumption per capita	13,558.23	8,313.48	5,244.75	1,496.89	3.50***

Source: Computed from own survey data (2017)

These propensity score matching (PSM) results indicate that adoption of row planting technology had a significant positive impact on wheat crop yield, household food consumption expenditure, household agricultural input expenditure and household income. Hence, adoption of row planting of wheat technology had a positive impact on the wheat crop yield, food consumption expenditure, agricultural input expenditure and income of the adopters indicating positive welfare effect or reduction of poverty level on the side of the adopters.

4.4. Sensitivity test for average treatment effect on the treated: -Sensitivity analysis is a strong identifying assumption and must be justified. According to (Grilli and Rampichini, 2011) sensitivity analysis is the final diagnostic that must be performed to check the sensitivity of the estimated treatment effect to small changes in the specification of the propensity score. In table 9, the result was reported, as a different level of bounds tells us at which degree of unobserved positive or negative selection the effect would become significant (Samuel et al., 2013). The Q_mh+ statistic adjusts the Mantel-Haenszel (MH) statistic downward for the case of positive (unobserved) selection on the impact of row planting of wheat technology while Q_mh- statistic adjusts the MH statistic downward for the case of negative (unobserved) selection. From the result above, under the assumption of absence hidden bias (Γ=1), the Q_mh+ and Q_mh-test-statistic gives a similar result on the impacts of row planting of wheat technology on household yields, food consumption expenditure, agricultural input expenditure and income, indicating a significant treatment effect. The negative values of Q_mh+, therefore, indicate negative selection bias where the most likely participants of row planting of wheat technology tend to have lower yields, household food consumption expenditure, household agricultural input expenditure and household income even in the absence of adoption. Therefore, this can be interpreted as downward bias in estimated treatment effects. This bias is however not significant at different bound levels both for likely underestimation of the treatment effects and overestimation of the treatment effects as indicated by P_mh + and P_mh - values. The table also shows that the study was insensitive to a bias that will double or triple the odds of a change in gross margin as a result of the row planting technology. We conclude based on this concept of the sensitivity analysis that the significance level is unaffected even if the gamma values are relaxed. This shows that average treatment effect on treated is not sensitive to external change. Hence there are no external variables which affect the estimated treatment effects reported above.

Table 9: Sensitivity test of external effect on average treatment effect on the treated

Gamma	Q_mh+	Q_mh-	P-value	P-value
1	.	.	.	.
1.05	-.094055	-.094055	.537467	.537467
1.1	.	-.094055	.	.537467
1.15	-.094055	-.094055	.537467	.537467
1.2	.	-.094055	.	.537467
1.25	-.094055	-.094055	.537467	.537467
1.3	-.094055	-.094055	.537467	.537467
1.35	-.094055	-.094055	.537467	.537467
1.4	-.094055	.	.537467	.
1.45	.	-.094055	.	.537467
1.5	-.094055	-.094055	.537467	.537467

Gamma is the odds of differential assignment due to unobserved factors, Q_mh+ is Mantel-Haenszel statistic (assumption: overestimation of treatment effect), Q_mh- = Mantel-Haenszel statistic (assumption: understatement of treatment effect)

5. Conclusion and Policy Recommendation

5.1. Conclusion: -In this study, we assessed the adoption of row planting of wheat technology and impact of row planting of wheat crop on farm household yields, food consumption expenditure, agricultural input expenditure and income. Both descriptive and econometrics methods were employed for data analysis. A propensity score matching approach was used to compare adopter households with non-adopters in terms of four key measure of household wellbeing; yields as measured by quintal and household food consumption expenditure, household agricultural input expenditure and income as measured by Ethiopia Birr. The matching techniques employed were the nearest neighborhoods matching, radius matching, caliper matching, and kernel matching. Among the algorithms used nearest neighbor matching (2) was found to be the best estimator of data based on balancing test, pseudo R2 and sample size. The results showed that row planting of wheat technology had significantly positive impact on farmers' yields, food consumption expenditure, agricultural input expenditure and income. In addition to that, factors such as; the age of households, education level households, family size, size of cultivated land, holding of livestock, use of credit services and extension services access were found to be important variables to affect farmers' tendency to adopt. The sensitivity analysis also showed that the estimates are almost free from unobserved covariates. Consequently, it can be concluded that the overall the results are remarkably robust and the analysis supports the robustness of the matching estimates.

The implication of the findings is straightforward; even if the adoption of row planting of wheat is quite low in Duna Woreda, those households who could use the technologies could improve their productivity, household food consumption expenditure, household agricultural input expenditure and household income. Therefore, it is used to scaling up the best wheat row planting technology and practices of the adopters to other farmers can be considered as one option to enhance farm yields, household income, household food consumption expenditure and household agricultural input expenditure in the study area while introducing new agricultural practices and technologies is another option.

5.2. Policy Recommendation: -Based on the results of this research, the following core points are presented as recommendations in order to improve the application level and revenue gained from row planting technology in the process of wheat grain production. Improved wheat production technology involves the use of different practices, which require knowledge, and skill of application and management. Education was found to have a strong relation with the adoption of row planting of wheat production technology as it enhances wheat crop yields, household food consumption expenditure, household agricultural input expenditure and household income. Therefore, due emphasis has to be given towards strengthening rural farmer education at different levels for small farm households using farmers training centers.

Increasing the number of cooperatives organization in the rural area in which the farmers will be able to get credit are basis in enhancing the adoption of row planting wheat technology. Further, it is apparent from the study that if farmers get credit more easily, they would use row planting technology to enhance wheat crop yields, household food consumption expenditure, household agricultural input expenditure and household income. Thus, the credit facility should target poor farmers especially those who were not adopting the row planting technology due to lack of operating capital. This may encourage the farmers to do commercial farming practice in which they can build their asset to implement the adoption of row planting of wheat technology on their farms. The agricultural research and extension activities need to consider additional modern agronomic practices. Extension services crucial activities in agricultural sector to improve participation of row planting of wheat technology, through which induce farm wheat crop yields, household food consumption expenditure, household agricultural input expenditure and household income. A significant proportion of farmers had no formal education; the extension program should be targeted to the less educated farmers for its effective delivery through special training, seminars, field demonstrations, and technical support should be facilitated to enhance the adoption rate of row planting wheat technology. The extension should contact farmers individually as well as in group to be awarded in terms of row planting of wheat is suitable to improve household food security and income.The introduction of the above measures into the picture of technology adoption, therefore, could enhance the number of adopters and the cropped area under row planting technology. Hence, expansion in the level of technology adoption would consequently result in substantial wheat productivity, food security and income on a sustainable basis.

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Testing the Environmental Kuznets Curve Hypothesis for the Depletion of Natural Resources in Sub-Saharan African Countries

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Abstract

The relationship between economic growth and environmental degradation indicators, referred to in environmental economic literature as the Environmental Kuznets Curve (EKC) hypothesis has been widely investigated, with a plethora of studies finding enough evidence to support the hypothesis. However, many of these studies employ an aggregate measure of economic activity such as Gross Domestic Product (GDP) per capita, thus failing to establish empirical evidence of the hypothesis for disaggregated or sectoral measures of economic activities. Therefore, this work was motivated from the understanding that disaggregated measures of economic activities produce relatively specific environmental effects. It is in this regard that this study sets out to investigate in to the validity of the EKC hypothesis for total natural resources depletion in 26 Sub-Saharan African (SSA) countries. The study uses panel data from 1981-2016 obtained from the World Development Indicators (WDI) of the World Bank. Natural resources rents and natural resources depletion were used as measures of economic activity and environmental degradation respectively. Panel unit root tests were conducted to test for stationarity of the variables and panel cointegration test was used to establish the presence of a long-run relationship among the variables. Based on the Hausman test, the panel fixed effects model was selected for empirical analysis. Results of the study confirm, contrary to expectation the absence of an inverted

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U-shaped relationship between rents from natural resources and natural resource depletion. A monotonically increasing relationship was found. The implication of this finding is that there is no point in time at which, exploitation of natural resources is going to be an asset and not a liability to the environment. It is recommended that the governments of SSA countries should design and implement strict environmental policies where they are absent and enforce these policies where they are present in a bit to mitigate the adverse effects of the exploitation of natural resources as well as other economic activities on the environment.

Key Words: Environmental degradation, Natural resources exploitation, natural resources rents, economic growth, resource depletion

1. Introduction

The relationship between the indicators of economic performance and those of environmental degradation remains an important subject of discussion in environmental economics literature. This relationship which today has become known as the Environmental Kuznets Curve (EKC) hypothesis, named after Simon Kuznets (1955) stipulates that an inverted U-shaped non-linear relationship exist between environmental degradation and per capita income along a country's growth path. Kuznets hypothesized that income inequality increases first, then decreases with an increase in growth over time. According to the EKC hypothesis, environmental degradation increases in the early stages of growth in per capita income but beyond a certain income level, the trend changes such that an increase in income per capita improves the environment (Stern, 2004). This relationship suggests that growth is detrimental to the environment during the early stages of development because economic resources are ineffectively used while technological progress and economic growth improves environmental quality at some point in the later stages of development (Kubatko, 2008). The EKC concept first became known in economic literature with the works of Grossman and Krueger (1991) and Shafik and Bandyopadhyay (1992), who adopted it from Kuznets.

While the desire to achieve a sustained increase in economic growth and development remains a primary and permanent objective of all countries particularly those of the African continent, the attainment of this objective has consequences for the environment. The EKC framework provides the basis for understanding the arguments advanced by scholars regarding the possible effects of economic activities on the environment. On the one hand are those who argue that production activities create detrimental effects on the environment (Adewuyi, 2001; Gutti et al, 2012; Omorede, 2014)and the best way to protect the environment and even the economy is to reduce the scale of economic activities while on the other hand are those who believe that technological advancement and economic progress are the ways through which environmental improvement can be achieved (Panayotou, 2003).Believers of this thought hold that as incomes increase, the demand for less material-intensive goods and services also increases. Also, there is an increase in the demand for improved environmental quality that triggers the adoption of environmental regulation (Ajide and Oyinlola, 2010) as cited in Sunday (2015).Most empirical studies on the EKC hypothesis are therefore being motivated by the need to understand whether economic activities, as measured by an economic growth indicator are necessarily good or bad for the environment. The current study is carried out within the same context, though it focuses on natural resources exploitation.

It is an established fact that Africa, especially Sub-Saharan Africa(SSA) is endowed with both a great volume and variety of natural resources. The continent is well known as a home to some of the largest deposits of natural resources. For instance, Ethiopia is richly endowed with small reserves of gold, platinum, copper, potash, natural gas and hydropower (Central Intelligence Agency [CIA] World Fact Book, 2018). Lyakurwa (2011) have noted that Angola and Nigeria produce substantial portions of world crude oil; South Africa and other African countries are the major world producers of gold; Zambia is endowed with large copper deposits, Botswana, Democratic Republic of Congo (DRC) and Sierra Leone are major diamond producers while other strategic minerals such as coltan, chrome, manganese and bauxite are major exports from many African countries. Moreover, a significant quantity of world tropical hardwood (timber), cocoa, coffee and rubber exports is from Africa. These resource potentials do not only attract foreign direct investment, but as noted by Adewuyi (2001), are an important source of foreign earnings used in developing infrastructure, providing for social amenities as well as offering employment opportunities to the unemployed population. In short, the livelihoods of African people largely revolves around the exploitation and utilization of natural resources.

Though countries harness their natural resources with the primary objective of achieving their growth and development goals, this is often at the expense of rapid environmental degradation which threatens human existence because environmental resources are often non-sustainably exploited. Gutti et al. (2012) pointed out that a lot of negative effects are created by man on the environment in the struggle for survival and development. In the same light, Adewuyi (2001) posited that the production and consumption of agricultural products have consequences for the environment, and this is a well-established fact. Agricultural production activities involving application of scientific methods such as the use of fertilizers, insecticides, pesticides and other chemicals clearly affect soil fertility in the long run and the application of the traditional slash and burn methods also have environmental implications. Also, the consumption of agricultural products generates wastes disposed in to the environment, leading to the accumulation of waste which consequently results to environmental pollution with its detrimental effects on the health and well-being of man. Adewuyi (2001), Gutti et al. (2012) and Phimphanthavong (2013) have identified some adverse environmental effects of exploiting natural resources as pollution and natural resources overexploitation, wildlife habitat loss, soil erosion, destruction of cultivable pieces of land, deforestation and climate change. Some serious environmental problems such as desertification, insect infestation and wetland degradation are also typical of Africa.

Environmental economics literature has widely discussed the relationship between the level of aggregate economic activity, measured by per capita income and environmental indicators, the highly celebrated EKC hypothesis. Many studies have found support for the EKC hypothesis such as those of Shafik and Bandyopadhyay (1992), Panayotou (1993), Grossman and Krueger (1995), Kubatko (2008), Jiang et. al (2008); Tevie et al. (2011), Yaduma et al. (2013), Phimphanthavong (2013) and Wolde (2015). The environmental indicators for which EKC evidence exist are urban and local air quality indicators such as sulfur dioxide emissions (SO2), suspended particulate matter (SPM), carbon monoxide emissions (CO) and nitrous oxides (N2O) though turning points vary for the different indicators (Borghesi, 1999). A few studies such as those of Harbough et al. (2002), Stern (2003) and Burnett (2009) have shown that growth is ever detrimental to the environment thereby refuting the EKC hypothesis. Shafik and Bandyopadhyay (1992) showed that for some environmental indicators such as carbon dioxide (CO2) emissions, municipal waste per capita and lack of safe drinking water, evidence of the EKC relationship does not exist. Yet, for water quality indicators such as the amount of heavy metals and toxic chemicals discharged in water as a result of human activities (lead, cadmium, mercury, arsenic and nickel), concentration of pathogens in water (measured by faecal and total coliforms) and the amount of heavy metals and toxic chemicals discharged in water by human activities (lead, cadmium, mercury, arsenic and nickel) and measures of deterioration of water oxygen regime (dissolved oxygen, biological and/or chemical oxygen demand), the empirical evidence of the EKC is mixed.

Most EKC studies use an aggregate measure of economic activity such as real per capita GDP. The problem with the use of this aggregate output indicator is that different production stages generate different levels of somewhat similar identical environmental indicators. This implies that their respective income per capita and environmental degradation relationships would may be different and would be more meaningful than in the case where activities are aggregated. It is for this reason that this study decomposes aggregate output and is using an activity within the primary sector; exploitation of natural resources. Scholars have also argued that most of the EKC literature is statistically weak (Stern, 2003; Aslanidis, 2009). According to Stern (2003), this weakness is because little attention is given to diagnostic econometric tests especially the statistical characteristics of data such as serial dependence or stochastic trends. Furthermore, tests of model adequacy are not often conducted. To Perman and Stern (2003), cited in Stern (2003), when such statistics or tests have been taken in to account and appropriate techniques applied, the EKC hypothesis fails to hold. These defects are taken in to consideration in this study.

While most studies have considered the effects of economic growth on the environment, many other studies focus on the environmental effects of exploiting different natural resources. These include works such as those of

Adewuyi (2001), Ayuba (2012), Balogun and Kareem (2013), Omorede (2014) on oil and gas resource exploitation, Kaya (2001) on mineral exploitation, Gutti et al. (2012) and Budnuka et al. (2015) on a series of environmental resources. The main shortcoming of these studies is that the important question of whether the economic system can continue to grow without undermining the natural systems which are its ultimate foundation, to the best of my knowledge has not been given adequate attention. This question is particularly important within the sub-Saharan African context especially considering the pace at which their natural resources are undergoing exploitation. The current study therefore closes these gaps by attempting to provide an answer to the sustainability question within the EKC framework. Does an EKC exist for natural resource depletion in SSA countries and what are the implications for sustainable development?

The continued dependence of SSA countries on their natural resources has not only resulted to an increased overexploitation and depletion of the resources but has also brought other negative socioeconomic effects such as the loss of indigenous and cultural identity and violation of land-rights of communities with little or no compensation; conflicts relating to ethnic rivalry and the ownership of land; child labour, forced labour, unfair wages, the lack of freedom of association, pollution of drinking water; corruption perpetrated by investors and governments and violent clashes between communities, regions and countries because the gains from resource extraction are unfairly distributed (Appiah and Zhang, 2013). In fact, the negative environmental effects of natural resources exploitation are varied and quite feasible in the communities in which the exploitation of these resources takes place.

Besides environmental/natural resources management policies taken at country levels to ensure environmental sustainability, SSA countries have signed a number of international agreements aimed at protecting the environment in the midst of the growing need to foster economic growth and an increasing pressure on the resources by the growing populations. The overall goal of these policies is to foster sustainable development, which has now been embraced as a national policy objective. However, because these laws are sector-specific, efforts to develop a cross-sectoral and sectoral issues related to natural resource management and the environment are yet to achieve the desired aim.

Despite the putting in place of environmental policies or laws, the shocking and most disturbing thing with most SSA countries is that the policies remain an expression of what the authorities are yet to do to protect the environment rather than what they are actively doing. This therefore presents weak environmental regulation on the part of the authorities but however represents a step in the right direction towards not only designing but enforcing appropriate environmental policies. So, the problem is not necessarily environmental policy formulation but more that of implementation. Notwithstanding efforts made, environmental problems as earlier highlighted remains an issue of concern for all SSA countries. It is against this backdrop, that this study is motivated to assess the effects of natural resource exploitation on environmental degradation in SSA by considering the question of whether or not the exploitation of these resources is good or bad for the environment. Specifically, this study seeks to;

Determine the extent to which rents from the exploitation of natural resources is a driver of natural resources depletion in SSA countries by empirically testing for the existence of the EKC hypothesis.

Evaluate the effects of population growth and trade on natural resources depletion.

The rest of this manuscript is organized as follows; section two explores the literature on the environmental effects of exploiting natural resources as well as the EKC literature. In section three, the analytical methods adopted in the study are presented. Empirical findings of the study are presented and discussed in section four while section five concludes and recommends the possible ways in which the environment as well as development can be sustained.

2. Literature Review

2.1 Empirical Literature

Budnuka et al. (2015) examined the effects of the unplanned exploitation of environmental resources in Nigeria. According to this study, owing to agricultural and modern technological development, there is a rising human impact on environmental resources which does not take in to consideration the effect on future generations. Unplanned exploitation of environmental resources has negatively affected both man and his environment in one hand and government on the other hand. The unplanned exploitation of natural resources has resulted to dumping of waste, water pollution, and air pollution amongst others and is regarded as anti-society, hence the need to honour all international treaties on environment is recommended. The study also recommends that the government and her agencies, should beyond the immediate gains from these resources, focus more on planned exploitation of environmental resources. The findings also suggest that the nation is seating on the keg of gunpowder if resources exploitation is not checked very fast. Until appropriate legislation on exploitation of resources is put in place, the study acknowledges that the risk of cancer and heart diseases will continue to increase.

An exploratory and descriptive analysis of the environmental impacts of oil exploration and exploitation was carried out in the Niger Delta of Nigeria by Ayuba (2012). The study brings to light the fact that though oil exploration and exploitation in the Niger Delta is important in sustaining the livelihoods of the indigenous people and benefitting the Nigerian state greatly in terms of contributions to oil revenues, the activity however has disastrous environmental effects. The unsustainable exploitation of oil has made the Niger Delta region one of the five most severely petroleum damaged ecosystems in the world. The results indicate that pollution from oil caused by spillages from the oil industry located mainly in the Niger Delta region of Nigeria has resulted to the massive destruction to farmlands, fishing grounds and declination of fish, sources of drinking water, mangrove forest, crabs, periwinkles, molluscs and birds. The destruction of large areas of mangrove forest over a wide area has affected terrestrial and marine resources. Some oil spillage resulted to the complete relocation of some communities, leading to the loss and surrendering of ancestral homes, fresh water pollution, loss of forest and agricultural land, destruction of fishing grounds hence the reduction of fish population, which constitutes a major source of income for the Niger Delta region population. The study recommends that legislations should be updated and revised, licenses of oil companies and fines should be reviewed in order to ensure compliance, even though it’s difficult for the state to systematically or frequently monitor these sites. Also, environmentally friendly technology that minimizes impacts of petroleum development on the environment should be adopted.

Omorede (2014) assessed the effects of oil and gas resource exploration on the environment of selected oil-producing communities in the Delta state of Nigeria. The work established that some of the problems associated with oil resource exploration include oil spillage; vegetation growth retardation, ill-health to community members; socio-economic deprivation; constant protestation of host communities; and perceived marginalization of the people. This research concludes that oil rich communities of the state have not been compensated adequately for the harm done to them in terms of ecosystem degradation resulting from the many years of oil exploration. The study argues that the oil resource wealth of the community has been turned to a resource curse, disempowering and condemning the area to perpetual underdevelopment. Based on the findings of the study, it was recommended that the government should intensify efforts in maintaining strict compliance of its legal instruments by oil participating companies for sustainable development in the region.

In the same light, the effects of oil spillage on the aquatic environment in the Ilaje community of Nigeria were uncovered by Ayuba (2013). Massive unemployment, health hazards, high death rates, incessant communal clashes, destruction of aquatic life were identified as some of the consequences of environmental degradation and ecological problems resulting from the activities of companies exploiting oil. These problems are due largely to hydrocarbon toxicity which pollutes the sea surface and underground water. The paper argues that compensation paid by government and the oil companies to residents of the affected areas is inadequate to sustain their livelihoods in the long run.

In a similar study, Gutti et al. (2012) investigates in to the environmental impact of natural resources exploitation in Nigeria. The study admits that deforestation, mining and exploration of petroleum have damaged the natural environment in different forms including destruction of natural flora and fauna, air, water and land pollution, ecological disturbances, instability of soil and rock masses, degradation of landscape, desertification and global warming. Waste of arable land and economic crops and trees is the resultant effect of environmental damage. It is recommended that government and the natural resource industry must take precautionary and remedial measures aimed at minimizing the negative effects of natural resources exploitation. The study also suggest a shift of emphasis from waste disposal to waste minimization which is possible through sorting, recycling, bioremediation, afforestation, sewage treatment and pollution control. The regulatory legislation should be provided with appropriate sanctions by government or attach importance on enforcement of the laws and implementation of policies where these regulatory bodies already exist. In addition, compulsory precautions, remedies or compensation for damage done is expected to be carried out by oil and gas industries, mining companies and other natural resources exploitation bodies.

Etuonovbe (2009), like other researchers, assessed the devastating effects of environmental degradation in the Niger Delta Region of Nigeria. The study identifies several environmental issues in the region including flood disasters; heavy soil erosion; salinization or alkalization, desertification resulting from the effects of shifting agriculture on fragile soils, water, air and land pollution which is the result of improper industrial and domestic wastes disposal; noise pollution and pollution due to oil spillage; forest clearing in areas prone to erosion prone and floods; animal over-grazing; poor road construction and maintenance; congestion of traffic and houses in urban areas which lead to the lack of open spaces for active outdoor recreation; proliferation of slums in urban areas and unsanitary and unsafe housing. All these problems affect the health and socio-economic welfare of human beings especially women and children of the Niger Delta region. The study suggests that adopting sustainable development policies will resolve the so-many environmental problems facing the region. Amongst the measures recommended to solve these problems include, gravity, surface sink/tree planting, smokeless fuels, precipitation, air pollution reduction by exhaust, treatment, bag filters, wet collectors, incineration, source separation and international/national legislations.

Grossman and Krueger (1995) examined the link between economic growth and the environment by estimating a reduced-form relationship between income per capita and various indicators of environmental degradation. Four environmental indicators including urban air pollution, fecal contamination of river basins, the state of the oxygen regime in river basins, and contamination of the river basins by heavy metals were used in this study. This study employed panel data from the Global Environmental Monitoring System's (GEMS) tracking of urban air and water quality for different developing and developed countries in the world. After estimating a random effects model, there was no evidence to conclude that environmental quality falls steadily with growth. The results rather showed that for most indicators, economic growth first initially deteriorates the environment and later on improves it. This suggests the existence of EKCs for the pollutants. The turning points vary for the pollutants, but are in most cases reached before a per capita income of \$8000.

Day and Grafton (2001) explore the relationship between economic growth and environmental indicators in Canada. The study uses 10 measures of environmental damage; carbon dioxide emissions (CO2), nitrogen dioxide (NO2), carbon monoxide concentrations (CO), ground-level ozone (O3), sulphur dioxide (SO2), total suspended particulate matter (TSP), concentrations of dioxin, fecal coliform and dissolved oxygen. Little evidence was found to support the fact that the quality of the environment would increase as the country's real per capita income increases. The study recommends a sectoral analysis in adequately assessing the relationship linking economic growth and environment degradation.

Burnett (2009) found no evidence to support the traditional hypothesized inverted U-shaped relationship between economic growth and environmental degradation in the United States of America (USA). However, a statistically significant U-shaped relationship existed for some pollutants but the evidence was too weak to suggest the validity of the traditional inverted U-shaped relationship between growth and indicators of environmental degradation. The study employed indicators of environmental degradation for air pollution in over 100 metropolitan statistical areas in the USA from 2001 to 2005, with the relationship being tested at the state level. The air pollution indicators considered in this study included sulfur dioxide, particulate matter, ozone, nitrogen dioxide and carbon monoxide.

Tevie, Grimsrud and Berrens (2011) empirically tested for the existence of the EKC hypothesis for biodiversity risk in the USA using state-level data for all 48 contiguous states. The study measures biodiversity risk using a Modified Index (MODEX) developed at a state-level and modified or adapted from the national biodiversity risk assessment index (NABRAI). The MODEX was used because it accounts for the impact of human activities and measures of conservation. The study uses spatial econometric techniques which automatically accounts for the effects of spatial autocorrelation inherent in the data. The results do not support the presence of an EKC hypothesis for biodiversity risk in the USA. The spatial lag regression results show that increasing the human population density by 1% would increase biodiversity risk by 0.19%. Spatial dependence explained 30% of the variations given the spill-over effect of risks from one state to the other. The study recommends coordinated efforts both at the state and federal levels to combat the problem of biodiversity loss.

The relationship between economic growth and environmental degradation was examined for Laos by Phimphanthavong (2013) using time series data from 1980 to 2010. Carbon dioxide (CO2) emissions per capita were used as the proxy for environmental degradation. Tests for stationarity were carried out using the Augmented Dickey-Fuller unit root test. The study was especially out to test the validity of the EKC hypothesis which suggests an inverted U-shaped relationship environmental degradation and economic growth. Results show evidence of the EKC hypothesis. Environmental quality first falls in the early stages of economic growth but starts rising after a certain point along the growth path. Results also revealed that factors such trade openness, industrial extension, and becoming a full member of ASEAN were important and significant determinants of environmental degradation in Laos. For Laos to achieve their sustainable development goal, it was recommended that strong environmental and natural resource protection policies be put in place for current and future development.

Yaduma et al. (2013) explored the CO2 environmental Kuznets curve within the OECD and the non-OECD countries and six geographical regions- East Europe, West, East Asia, West Asia, Latin America and Africa using the quantile fixed effects technique. The study took in to consideration two groups of countries with different levels of development. Comparing the findings from this technique with those of conventional fixed effects method, it was revealed that results of the conventional fixed effects method may suggest a flawed summary of the income-emissions nexus depending on the conditional quantile examined. The Machado and Mata decomposition methods were also extended to the Kuznets curve framework in order to explore the most important reasons for the CO2 emissions gap between the OECD and Non-OECD countries. Empirical results also depict a statistically significant OECD-Non-OECD emissions gap, which turns to reduce as the emissions distribution rises. The decomposition also reveals the presence of some non-income related factors working against the Non-OECD group's greening. The study tentatively concluded that deliberate and systematic mitigation of current CO2 emissions in the Non-OECD group is required.

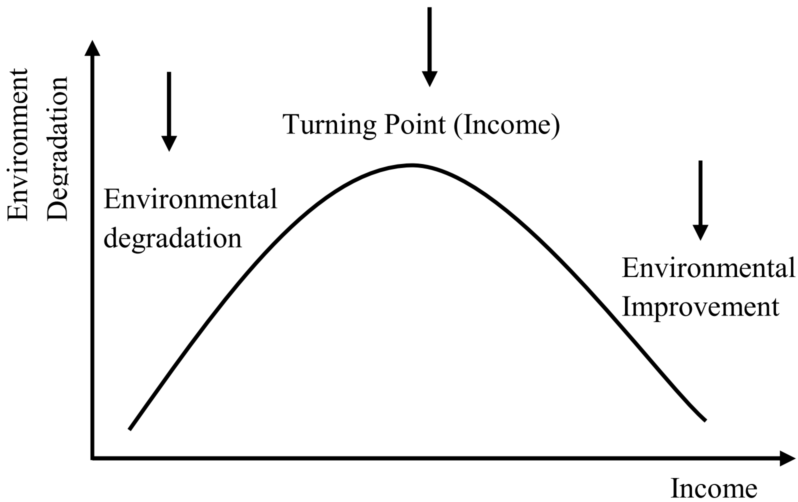
Wolde (2015) empirically tested the relationship between economic growth and environmental degradation in Ethiopia with time series data from 1969/70-2010/2011 in a VECM analysis. In line with other empirical studies, the study confirms the existence of the EKC hypothesis for CO2 emissions in Ethiopia. The study recommends a friendly environmental economic policy.

2.2 Theoretical Foundation

The environmental Kuznets curve (EKC) hypothesis, named after Simon Kuznets (1955) states that environmental degradation initially rises as a country grows richer, but then eventually decreases with further income gains. The environment gets worse-off at low levels of economic activity, peaks as economic activities increase and eventually improves as the country grows richer. The EKC hypothesis therefore stipulates an inverted U-shaped relationship between per capita income and environmental degradation (Shafik and Bandyopadhyay, 1992; Panayotou, 1993; Grossman and Krueger, 1995; Dinda, 2004; Jiang et al., 2008; Kubatko, 2008; Tevie, Grimsrud and Berrens, 2011; Yaduma et al., 2013; Phimphanthavong, 2013; and Wolde (2015).

It was based on actual data on sulphur dioxide emissions (SO2). Per capita emissions of SO2 were said to rise with increases in the gross national product per capita up to the turning point level of income after which these emissions started falling steadily. Figure 2.1 depicts a typical shape of the EKC relationship. If the EKC hypothesis held generally, economic growth would be a means to improve the environment. Environmental quality would fall as the country moves towards higher stages in its growth process.

Figure 2.1: Relationship between Income and the Environment



Source: Yandel et al (2000)

The inverted U-shaped relationship linking income per capita and indicators of environmental degradation is justified on many grounds. According to Kuznets (1955), cited in Wolde (2015), environmental degradation increases in the early stages of growth because agriculture is the dominant economic activity during that stage, with expansion in agricultural activities and land use pattern changes imposing environmental costs. As the economy grows and becomes more dependent on industry, environmental degradation reaches a maximum point, and then later on services dominate the economy and environmental degradation starts improving with economic growth. Panayoto (1993) adds that according to proponents of the EKC hypothesis, an increase in environmental quality at higher levels of development is due to the increasing environmental awareness, technological advancement, increase environmental expenditures and enforcement of environmental laws. Moreover, Kubatko (2008) argues that economic growth is detrimental to the environment during the early stages of growth because of the ineffective use of economic resources while during the later stages of growth, technological progress and economic growth improves environmental quality. These justifications are summarized in what Grossman (1995) calls the scale, composition and technology effects which are the three main channels through which income growth can affect environmental quality.

First, economic growth exerts a scale effect on the environment in the sense that environmental degradation increases as the scale of economic activity increases. This is because to increase output, more inputs are needed and these inputs generate wastes (Borghesi, 1999). Second, through the composition effect, income growth can improve the environment by increasing the share of cleaner activities in the Gross Domestic Product (GDP). Panayotou (1993), noted that structural changes in the economy from rural to urban, agricultural to industrial turn to increase environmental degradation while changes in the structure of economic activities from energy- intensive industry to services and technological-intensive industry increases environmental quality. Third, the technology effect of growth on the environment occurs when countries have the capacity to replace obsolete and dirty technology for cleaner technology as they grow. Thus, environmental degradation increases with per capita income growth during the early stages of growth due to the negative impact of the scale effect but falls with per capita income growth during the later stages of growth because the scale effect is outweighed by the positive effects of the composition and technology effects.

3. Methodology

The data for this study is obtained from the World Development Indicators of the World Bank database covering a time scope of thirty-five (35) years, beginning from 1981 to 2016 inclusive. The study covers 26 countries of SSA, Ethiopia inclusive. The basis for selecting the countries for the study was data availability. The list of SSA countries included in the study are presented on table 3.1. The causal comparative research design is implied, as effects of natural resources rents on natural resources depletion are ex-post.

Table 3.1: Sub-Saharan African Countries included in the Study

1. Benin	10. Gambia	19. Rwanda
2. Burundi	11. Ghana	20. Senegal
3. Botswana	12. Kenya	21. Sierra Leone
4. Burkina Faso	13. Lesotho	22. South Africa
5. Cameroon	14. Mali	23. Togo
6. Congo Democratic	15. Mauritania	24. Uganda
7. Congo	16. Mozambique	25. Zambia
8. Ethiopia	17. Niger	26. Zimbabwe
9. Gabon	18. Nigeria	

It has been argued that relationships between per capita income and environmental indicators can only be better understood within the framework of a general equilibrium model because these relationships are complex and multifaceted. Computational general equilibrium models better account for feedbacks within the economic system and requires data on a wide range of environmental indicators. However, most empirical studies do estimate reduced-form models due to such data unavailability. The problem with reduced-form models is that as Grafton and Day (2001) argue, such models do not explain the growth-environmental quality relationship but measure only the nature of the relationship by relating indicators of environmental quality to those of growth. Just like most studies, this study estimates reduced-form models of natural resources rents and natural resources depletion but incorporates some policy variables within the regression which can enable us better explain the link between resource exploitation and environmental degradation.

The relationship between per capita GDP and measures of environmental pollution is often studied by including a quadratic or cubic order terms in the right hand side of the functional relationship between the per capita concentration of emissions and per capita income with the addition of other key determinants of environmental degradation. This standard functional form adopted in the EKC literature is of the form;

$$E_t = á_0 + á_1 y_t + á_2 y_t^2 + á_3 y_t^3 + âX_t + U_t \quad \textbf{(3.1)}$$

where E_t is the per capita emission of the environmental degradation proxy, y is per capita GDP, X is a vector of fundamental determinants of environmental degradation, U is the error term, t is the time trend and $á_0$ to $á_3$ and â are estimable coefficients. In a panel study, Equation (3.1) becomes;

$$E_t = ñ_i + ã_t + á_0 + á_1 y_{it} + á_2 y_{it}^2 + á_3 y_{it}^3 + âX_{it} + U_{it} \quad \textbf{(3.2)}$$

The terms $ñ_i$ and $ã_t$on the right-hand side of equation (3.2) are intercept parameters that vary across countries or regions i and years t. The take care of time and country specific features. It is assumed that though emissions per capita may be different over countries at any particular level of income, the income elasticity is similar in all countries at a given income level. The year or time specific effects are incorporated to take care of time-varying characteristics and stochastic shocks that are common to all countries meanwhile the country-specific effects are included to account for country-specific features which are time invariant (Sunday, 2015).

Following the EKC literature and the empirical literature on the determinants of environmental degradation, the drivers of environmental degradation include amongst other factors natural resources exploitation including forest, natural gas, minerals, coal and oil; population growth, economic growth, trade openness and the quality of institutions. Pollutants which have often been used in the literature as the proxies for environmental degradation include concentration of carbon dioxide, sulphur dioxide, nitrogen oxide, nitrogen dioxide, carbon monoxide, water pollution measures or land-use changes, ground level ozone and total suspended particulate matter.

For the purpose of this study, natural resources depletion as % of GNI is adopted as the proxy for environmental degradation for the simple reason that it better measures the destruction of the environment which is the result of the exploitation of different types of natural resources both renewable and non-renewable. In addition, the independent variables used for this study are total natural resource rents (% of GDP), used as proxy for natural resource exploitation as it represents the value of output from exploiting natural resources, population growth and trade openness. The model for this study is therefore specified thus;

$$dNRD_{it} = ñ_i + ã_t + á_0 + á_1 dNRR_{it} + á_2 NRR_{it}^2 + á_3 NRR_{it}^3 + á_4 dPOP_{it} + á_5 dTRD_{it} + U_{tt} \quad \textbf{(3.3)}$$

The variables of equation (3.3) are defined as follows;

NRD is per capita natural resource depletion. Natural resource depletion (% of GNI) is defined as sum of net forest depletion, energy depletion, and mineral depletion.

NRR is per capita natural resource rents. Total natural resource rents (% of GDP) is defined as the sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents.

NRR2and NRR3 is the per capita natural resource rents at a later period. Total natural resource rents (% of GDP) is defined as the sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents.

POPis population growth (annual %) defined as the exponential rate of growth of midyear population from year t-1 to t, expressed as a percentage

TRD is defined as the sum of exports and imports of goods and services measured as a share of gross domestic product.

$á_0$toá$_5$ are the coefficients to be estimated, i and t respectively represent a particular country and time and U is the error term.

The signs of $á_1$ and $á_2$ are expected to define the nature of the relationship between variables of interest. If $á_1 = á_2 = 0$ then no relationship exists between NRD and NRR; if $á_1 > 1$ and $á_2 > 1$ then a monotonically increasing or linear relationship exist between NRD and NRR; if $á_1 < 1$and $á_2 < 1$, a monotonically decreasing or linear relationship exist between NRD and NRR; if $á_1 > 1$ and $á_2 < 1$ then an inverted U-shape relationship exist between NRD and NRR; if $á_1 < 1$ and $á_2 > 1$, a U-shape relationship exist between NRD and NRR. The coefficients $á_4$ to $á_5$are expected to be positive because an increase in population growth and trade are expected to increase environmental degradation.

It is common practice that any meaningful study involving the use of time series data requires the data to be stationary so as to eliminate the possibility of biased estimates and nonsensical or spurious regression. This studyuses the Levin, Lin and Chu (t-stat) common unit root test to test for the stationarity of the variables after a graphical plot of the variables to determine whether an intercept term or trend or both intercept and trend existed in the series. These tests were conducted under the null hypothesis of no unit root and validated by comparing the test statistics with the test critical values at various levels of significance. Both the random and the fixed effects model were estimated and the decision of whether or not the fixed effects model was selected was validated by employing the Hausman test. To establish whether a long-run relationship exist, panel cointegration technique was used.

This paper employs statistical tests such as the multiple coefficient of determination (adjusted R^2), t-statistics and F-ratio test to test the reliability of estimated coefficients.Multicollinearity was tested using the pairwise correlations. Breusch-Pagan LM, Pesaran scaled LM and Bias-corrected scaled LM were used to test for cross sectional dependence and the Durbin-Watson statistic used to test for autocorrelation.

4. Results and Discussion

4.1 Results

This study was out to investigate in to the existence of the EKC hypothesis for the depletion of natural resources in twenty six (26) SSA countries using panel data. Data for the study was first subjected to the Levin, Lin and Chu (t-stat) common unit root test since the panel was balanced and the results are presented on table 4.1. This was done after carrying out graphical analyses of the variables, which

Table 4.1: Unit Root Test

Variables	Levin, Lin and Chu (t-stat) Test Statistic	P-Value	Remark
NRD	-16.0537	0.0000	I (1)
NRR	-16.3110	0.0000	I (1)
NRR2	-3.24305	0.0006	I (0)
NRR3	-3.69986	0.0001	I (0)
POPG	-14.0460	0.0000	I (0)
TRD	-13.2120	0.0000	I (1)

Source: Computed by Author using E-views 9

The unit root test results presented on Table 4.1 show that natural resources depletion (NRD), trade (TRD) and natural resources rents (NRR) are stationary at first difference, meaning they contain a unit root meanwhile the squared and cubic terms of NRR are all stationary at their levels indicating the absence of a unit root. This is confirmed by the p-values of the variables which are all significant at 1% level.

To verify if an EKC fits the data on natural resources rents and natural resources depletion for the selected SSA countries, we employed panel fixed effects model as suggested by the results of the Hausman test. The p-value of the Chi-square statistic of Hausman test is 0.0020 which is significant at 1% level indicating that the fixed effects model is appropriate. Empirical results based on the fixed effects model are therefore presented on Table 4.2.

Table 4.2: Panel Fixed Effects Result

Dependent Variable: Natural Resources Depletion (NRD)
Method: Panel Least Squares
Sample Adjusted: 1982-2016
Total panel (balanced) observations: 910

Variable	Coefficient	Std. Error	t-statistic	P-value
D(NRR)	0.429061	0.018692	22.95462	0.0000***
NRR2	0.006589	0.000371	17.76021	0.0000***
NRR3	0.0000679	0.00000383	17.72804	0.0000***
POP	0.294006	0.162532	1.808907	0.0708*
D(TRD)	0.019483	0.012957	1.503742	0.1330
Diagnostic Tests				
Adjusted R-squared	0.786448			
F-statistic	112.5857			
Prob(F-statistic)				0.0000
Durbin-Watson Stat	2.294217			

Source: Computed by Author from Data *** = significant at 1%; * = significant at 10%

The empirical results of the study reveal that natural resources rents (NRR) have a positive effect on the depletion of natural resources in SSA since the coefficient of NRR is positive. An increase in rents from the exploitation of her natural resources would lead to an increase in the depletion of these resources, all things being equal. Precisely, a 1% increase in resource rents would increase resource depletion by 0.43%. This result is highly significant at 1% level given a p-value of 0.000. Furthermore, the squared and cubic terms of NRR are positive implying that natural resources rents at a later time would still have a positive effect on the depletion of natural resources in SSA, everything else being equal. The coefficients of the squared and cubic terms of natural resources rents, NRR2 and NRR3 are also very significant. These results point to a monotonically increasing relationship between total natural resources rents and depletion in SSA. This implies that there is no turning point level of natural resources output where the exploitation of natural resources could lead to a fall in natural resources depletion, suggesting the absence of an EKC for the depletion of natural resources in SSA. The empirical results also show that an increase in population (POP) and trade (TRD) all have a positive effect on natural resources depletion. Accordingly, a 1% increase in population and trade will lead to a 0.29% and 0.019% increase in natural resources depletion respectively. However, only population is significant, given a p-value of 0.0708.

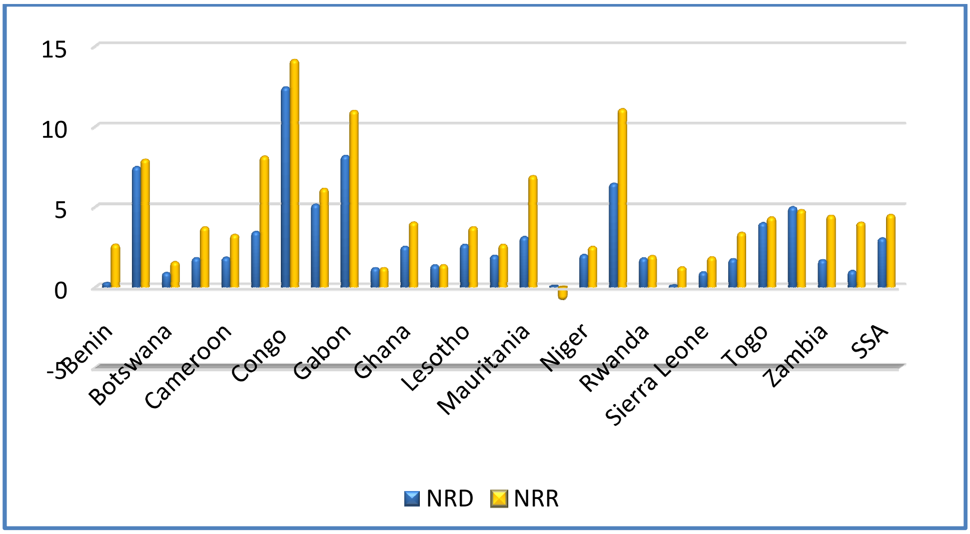
The multiple coefficient of determination (adjusted R-squared) shows that about 79% of the variations in natural resources depletion are explained by natural resources rents, population and trade with about 21% explained by variables not included in the model. The p-value of the F-statistic is significant at 1% indicating that the overall regression result is 99% reliable and can be used for policy recommendation. The value of D.W statistic (2.29) also indicates the absence of autocorrelation in our model. Breusch-Pagan LM, Pesaran scaled LM and Bias-corrected scaled LM test were used to test for cross sectional dependence in the panel under the null hypothesis of no cross sectional dependence. The p-values of these tests are all 0.0000. We therefore reject the null hypothesis at 1% level and conclude that there is no cross section dependence in the panel.

The Kao Residual Cointegration Test was employed to establish the existence of a long run relationship among the variables in the study under the null hypothesis of no cointegration. The p-value of the ADF statistic is 0.0000 meaning we reject the hypothesis of no cointegration in favour of that of cointegration. This means that a long run relationship exist between natural resources rents and resource depletion.

4.2 Discussion

This study was out to test for the existence of an EKC hypothesis for natural resources depletion in SSA countries using a panel data of twenty-six (26) SSA countries from 1981-2016 selected on the basis of data availability from the World Development Indicators of the World Bank. Figure 4.1 shows the average values of natural resources depletion and natural resources rents from 1981-2016 for the 26 SSA countries included in the current study. The bar chart gives us a firsthand idea on the likely nature of the relationship between natural resources depletion and resource rents.

Figure 4.1: Average Natural Resources Depletion and Natural Resources Rents for SSA



It can be observed from figure 4.1 that Congo exhibits the highest rate of resources depletion, almost measuring up with rents from those resources. In addition, for most countries, including Ethiopia, Botswana, Kenya, the Gambia, Mali, Niger, Rwanda, Togo, Uganda and Burundi, natural resources depletion and rents are almost at par suggesting that the exploitation of natural resources would always ever lead to resources depletion. However, the study applied a formal econometric method to test for the validity of the hypothesis.

Using panel least squares to estimate the data based on the Hausman test, the results reveal that no EKC exist for the depletion of natural resources in SSA. Rather, a monotonically increasing relationship between total natural resources rents and natural resources depletion is confirmed, suggesting that as long as SSA countries continue in the exploitation of their natural resources, those resources would continue to deplete. There is no turning point level of natural resources rents where it could be expected that an increase in exploitation would lead to a fall in depletion of the resources and hence environmental improvement. This result makes some sense within the African context because most African economies are known to depend for the most part on their natural resources to sustain their economies despite the fact that the resource-curse is very eminent. Under such circumstances, one would normally expect that an increased exploitation of these resources should translate in to an increase in the overexploitation and degradation of these resources besides other socioeconomic impacts on the environment. This result is in line with that of those who argue that economic activities will always ever result to environmental degradation such as Harbough et al. (2002), Stern (2003) and Burnett (2009). In addition, it has been shown by Shafik and Bandyopadhyay (1992) that for some environmental indicators such as carbon dioxide (CO2) emissions, municipal waste per capita and lack of safe water, evidence of the EKC relationship does not exist.

The absence of the hypothetical EKC theory for natural resources depletion can be explained partly by the ever-increasing population of Africa and volume of trade as shown by these results and beyond. Of the world's population of over 7.6 billion, Africa makes up approximately 1.3 and is increasing, and with agriculture being the backbone of most if not all SSA economies, this rising population is said to put enormous pressure on the natural resources leading to their eminent depletion. An increase in the demand for farmland, building land, energy resources and the need for people to feed their families increases the demand for all types of resources, resulting in their degradation. Thus, not only is agriculture the predominant economic activity, its scale is also said to be increasing to match up with the increase demand for tradeables and food supply to feed the African families.

Again, Africa's increasing trade in largely unprocessed natural resources, driven by the need to settle huge debts contracted from countries of the West is also a reason for the rapid depletion of natural resources. Most SSA countries owe international institutions such as the International Monetary Fund (IMF) and World Bank and other countries of the west billions of US dollars which is always paid in hard currencies. Since Africa is less competitive in manufactured goods and services at the world market, natural resources get degraded because of the need to export. It is also important to note that poor or the complete absence of institutions is a key factor that determines the exploitation and hence depletion of our natural resources. Following the latest Country Policy and Institutional Assessment (CPIA) of SSA countries, it is noted that countries of SSA have weaker institutions amid a difficult global economic landscape, difficult domestic conditions and weaker terms of trade. However, the case is better for resilient economies such as those Côte d'Ivoire, Ethiopia, Kenya, Rwanda, Senegal, and Tanzania. These countries tend to have better quality institutions and policies that foster sustainable growth and the reduction in poverty than other countries.

5. Concluding Remarks

From the findings of this study, it is recommended first that the governments of SSA countries should design and implement strong environmental policies where they are absent and enforce them where they are present in a bit to mitigate the adverse effects of the exploitation of natural resources as well as other economic activities such as agriculture and trade on the environment. Policies geared towards birth control also have to be adopted and implemented so as to gauge the rate of growth in population in order to ensure that it does not put unnecessary pressure on the natural resource base.

There is absolute necessity for SSA countries to reduce exports of agricultural commodities such as timber, crude oil, bananas, coffee, and cocoa amongst others and to rather consider the options of revamping their industrial sectors which transforms these raw materials in to finished products for domestic and foreign consumption. Economic progress would need transformation both in the agricultural and the industrial sector. The sustainable development of Africa would require that the practice of exploiting natural resources with little or without any value addition as the case may be with many African countries should seize because such a practice benefits the country only marginally.

This study was out to investigate in to the existence of the EKC hypothesis for natural resources depletion in twenty six (26) SSA countries using the panel least squares method. The empirical results show that no inverted U-shape relationship exists between natural resource rents and natural resources depletion. A monotonically increasing relationship was observed indicating that the exploitation of natural resources would always result to resource depletion.

This work is only a preliminary study on the EKC for the depletion of natural resources and the results are by no means conclusive since all aspects could not be covered. Further studies on this topic which separate renewable from nonrenewable resources depletion and using more robust techniques such as the appropriate U test are needed. Also, more country-specific studies are needed to ensure an exhaustive study of the subject.

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Valuing Wild Pollination Ecosystem Services to Crop Production in Ethiopia

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Abstract

Pollination serves as a link between wild ecosystem and domestic agricultural production. In Ethiopia, crop production remains the main sources of food; however, there is limited empirical evidence on the contribution of pollination ecosystem service to crop production. To fill this gap, this study analyzes the contribution of wild pollinator to crop production using vegetation cover as a proxy measure for pollination abundance at different buffer distances. We used the panel data of Ethiopian Rural Socioeconomic Survey (ERSS) for the year 2011 and 2013 and applied a fixed effect regression model. The buffer distance is ranging from 100 meter to 3 kilometer. A total of 62 crop varieties have been considered, 32 of them are with the little, modest, great and essential level of crop pollination dependency. Results showed that pollination abundance has a higher impact on crop yield at nearest buffer distances for the essential, great and modest level of crop pollination dependency. Among the vegetation covers, shrub land cover significantly effects on crop production. Shrub abundance at 100m and 250m buffer distances brings higher yield increment (about 31 and 5.4 quintals) for crops that have essential and great level of pollination dependency, respectively. Findings implied that crop-pollination linkage was highly influenced by vegetation abundance and hence has policy and management implications on the potential benefit to address pollinator decline in developing countries.

Keywords: wildpollinator, pollination, buffer distance, crop production, fixed effect.

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1. Introduction

Pollination ecosystem service is valuable for the production of agricultural crops, particularly for agrarian countries. Pollination service supports farmers production practice (Dale and Polasky, 2007; Ricketts et al., 2008; Gallai et al., 2009; Boreux et al., 2013) due to the fact that production and productivity of most agricultural crop are highly dependent on pollination (Klein et al., 2007; Aizen et al., 2008, Aizen et al., 2009; Gallai et al., 2009). For instance, Klein et al., (2007) reviewed that approximately 70% of the world food crops are dependent on pollination in some extent and 35% of world food crop production is highly dependent on animal pollinators. However, pollination ecosystem service declines through time (Allen-Wardell et al., 1998; Aizen et al., 2009; Bennett et al., 2009; Potts et al., 2010; Burkle et al., 2013) and puts negative influence on agricultural productivity. The extent of pollinator habitat abundance around the agricultural farm land across alternative buffer distance to crop production influences the production level of the crop (Lonsdorf et al., 2009) particularly for traditional agricultural practice dominated countries. On the other hand, adapting pollinators through different mechanisms is very common in many developed countries (Mburu et al., 2006) while almost all developing countries are dependent on wild pollination service. We would like to investigate how proximity to pollinator habitats of vegetation cover impacts pollination ecosystem service to crop production.

Among the various factors that contribute to the decline in animal pollinators, habitat destruction is a major cause (Kremen and Ricketts, 2000; Kremen et al., 2002). From the human-induced activities that affect the abundance of pollinator community for example decline in the vegetation cover particularly forest and shrub-land covers has taken the uppermost share in this regard. Vegetation cover has been considered as a major habitat for wild pollinators (Donaldson et al., 2002; Power, 2010; Wratten et al., 2012; Bommarco et al., 2013). However, animal pollinators especially insects are facing challenges of climate change, land use change and intensification of agriculture (Ghazoul, 2005; Potts et al., 2010; Vanbergen, 2013). On the other hand, pollinators indirectly benefited from land conservation practices that improve vegetation cover (Hopwood, 2008; Nicholls and Altieri, 2013) attribute to positive externality to crop production through pollination service.

Plethora of research conducted in several parts of the globe and mostly in developed nations (such as Kremen et al., 2004; Ghazoul, 2005; Kremen and Chaplin-Kramer, 2007; Allsopp et al., 2008; Kremen, 2008; Keitt, 2009; Bommarco et al., 2013; Kennedy et al., 2013; Breeze et al., 2014) that argued a strong reliance of crop production on pollination service. Likewise, Wild pollination would play a significant role on the productivity of crops in developing countries especially when countries are entirely dependent on agriculture (Evans, 1996; Hoisington et al., 1999; Tilman et al., 2001; Yirga and Ftwi, 2010). Despite the abundance of animal pollinators the country has, there is no empirical study on the values of pollination ecosystem services specifically for crop production. Therefore, our study intends to provide evidence on the values of pollination service to crop production in Ethiopia.

Pollination ecosystem service is area specific (Aisbett and Kragt, 2010; Tolessa et al., 2017) and affected by the location of crops and pollinator as well. The decline in the pollinator community puts considerable pressure on agriculture and natural ecosystem (Vanbergen, 2013; Steffan-Dewenter et al., 2005). The loss of the pollinator diversity principally puts pressure on crop production and productivity (Biesmeijer et al., 2006; Garibaldi et al., 2013). In the agriculture sector, uses of inputs such as chemical fertilizers, pesticides and herbicides contradict the abundance of pollinators and reduce agricultural crop production. (Desneux et al., 2007) while pollination is one of the basic inputs for crop production determines yield level (Allen-Wardell et al., 1998; Boyd and Banzhaf, 2007; Potts et al., 2010; Bommarco et al., 2013; Hanley et al., 2015). Thus, the cumulative effect of natural and human-disrupted habitat loss of pollinators would result in a significant loss of crop production (Richards, 2001; Postel et al., 2012).

Mostly animal pollinators are hosted in green vegetation covers, therefore, the vegetation cover of forest and shrub abundance have a direct impact for abundance of animal pollinators such as bee, insects, ants, and bats (Watson, 2001; Brosi et al., 2008; Williams and Winfree, 2013; Morales et al., 2017; Fontúrbel et al., 2017; Liebhold et al., 2017). Buffer distance /proximity of cropland to vegetation covers (i.e. forest and shrub land) may increase the chance of getting wild pollination service (Ricketts et al., 2004) and to the reverse an increase in vegetation cover buffer distance results in a decline/poor pollination service (Priess et al., 2007; Carvalheiro et al., 2010) hence the average foraging distance of various wild pollinators are limited to a diameter of 6km (Pasquet et al., 2008). In this study, we value pollination service via buffer-distance[4] (100m, 250m, 500m, 1000m, 2000m and 3000m) of vegetation cover as a proxy for pollinator abundance (Martínez et al., 2009).

The remainder of the paper organized as follows: Section 2 presents empirical approach for valuing pollination services to crop production. Section 3 briefly presents the data used in this study. Section 4 result and discussion. In the end, section 5 present concluding remarks and policy implications.

2. Economic Valuation of Pollination: Empirical Approach

Valuation of pollination services is different from other ecosystem services in its nature (Lundberg and Moberg, 2003); it is area specific and affected by other natural and anthropogenic system in the surrounding (Kremen et al., 2007). Pollination provides both market and non-marketed economic values (Losey and Vaughan, 2006).The market values of pollination service mainly related to commercial pollination service obtained from managed pollinators; which is not applicable in developing countries context as they do not have managed pollinators for the purpose of boosting crop production. While, non-marketed economic value of pollinators can be pinpoints in two ways: people drive pleasure from seeing pollinators and knowing they exist, which is existence value (Rolston, 1994; Kareiva, 2011; Vanbergenet al., 2014) and pollination ecosystem service provides an indirect use value to the society through its positive externality (Mburu et al., 2006) which is the focus of this study. Such values are direct benefits to people from the presence, diversity and abundance of pollinators. In this paper we value the economic values of pollination for agricultural crop production.

[4] In this study buffer distance refer the radius from around the farm land to pollinator habitat i.e. vegetation cover. Therefore, 100m buffer distance represents 100m radius from the farm land in all directions, 250m buffer distance represents the radius distance of from 250m-100m, 500m buffer distance refers radius of 500m-250m, 1000m buffer distance is from 1000m-500m, 2000m buffer distance is from 2000m to 1000m and 3000m from 3000-2000m.

The primary economic values of pollination are crop production through increasing the quantity and quality of produce, and the market values of pollination influenced by the price of specific pollinator-dependent crop production (Hanley et al., 2015).The level of agricultural crops dependency on the pollinators are classified as: essential (on average 95% of pollination dependent), great (on average 65% of pollination dependent), modest (on average 25% of pollination dependent), and little (on average 5% of pollination dependent) (Klein et al., 2007; Hanley et al., 2015).

The amount of yield/output affected as a result of wild pollination varies with the extent of crop-pollination dependency (Klein et al., 2007). Thus, we considered pollination as one of the input to crop production. In this case, crop yield considered as dependent variable and pollination services (Ps) considered as one major input as follows:

$$y_i = f(x_i, p_s, \varepsilon) \qquad \textbf{(1)}$$

Where Yi is crop yield, Xi is a vector of farm inputs like fertilizer, seed and pesticide and ε represents stochastic. However, as we mentioned above the level of dependency between crops varies, construction of separate production function would be important to the farmer choice of what to cultivate (Hanley et al., 2015). And the input nature of pollination is a bit different from other inputs. Hence, pollination is a direct input (feed the crop directly without limitation or interference of manmade factors such as price). Therefore, we need to consider pollination input in a different way, according to Hanley et al. (2015) by using a scale up function (M) with a value lies between zero and one, leads us to the former production function (equation 1) with business as usual composition of inputs such as seed and fertilizer:

$$y = \left\{ \left(f\left(x\right) \right) M \left(p_s\right) \right\} \varepsilon \qquad \textbf{(2)}$$

Here we are observing that pollination has direct relationship with crop production, implies that pollination directly influences consumer's welfare. Pollination plays significant role for maintenance of supply on the crop that consumers would like to grow. Also, crop supply has horizontal effect on the price of crop and the effect is proportional to crop dependency on pollination service (from essential to little) and finally resulting in either increasing or decreasing in consumer surplus that they would generate from their crop (Rucker et al., 2001).

The other difference of pollination service from other inputs is that, it does not require input cost rather it is a positive externality. Principally the wild pollination enhance farmers crop yield while minimizing cost (without incurring additional cost). Thus, the nature of pollinators reduces the marginal cost of production and maximizes producer welfare (Hein, 2009).

We intend to estimate the effect of pollinator input to production of the categories (i.e. according to the level of pollination dependency) of crops using panel dataset. For this, fixed effect and random effect modes are the most common and frequently used panel data models. Most importantly, the fixed effect model gives more efficient and consistent estimate than random effect model due to its quality to deal with unobserved heterogeneity (Hausman and Taylor, 1981; Plümper and Troeger, 2007). According to Allison (2005) the general fixed effect model for crop production looks like;

$$y_{it} = \mu_t + \beta\chi_{it} + \alpha_i + \varepsilon_{it} \quad i= 1, \ldots, n; \quad t= 1, \ldots, T \qquad \textbf{(2)}$$

Where μ_t is an intercept that is allowed to vary with time/unknown constant differing across individuals, β is row vector of coefficients, and ε_{it} random disturbance term which satisfies the assumption of a standard linear model, χ_{it} is assumed to strictly exogenous, α_i represents a set of fixed/time invariant parameter. In this model (fixed effect) we considered the time invariant parameters as fixed parameter of a given household. Our study relies on two round panel dataset, hence the time variable is two (production in two periods). Therefore, following Allison (2005), looking separately production in the two time periods becomes;

$$y_{i1} = \mu_1 + \beta\chi_{i1} + \alpha_i + \varepsilon_{i1} \qquad (2)$$

$$y_{i2} = \mu_2 + \beta\chi_{i2} + \alpha_i + \varepsilon_{i2} \qquad (3)$$

We want to analyze production from the two period, let have the difference of the above two equations.

$$y_{i2-}y_{i1} = (\mu_2 - \mu_1) + (\beta_{i2} - \beta_{i1}) + (\alpha_i - \alpha_i) + (\varepsilon_{i2} - \varepsilon_{i1}) \qquad (4)$$

As a result, the final fixed effect equation for the two year period crop production becomes

$$\Delta y_i = \Delta\mu_i + \Delta\beta\chi_i + \Delta\varepsilon_i \qquad \mathbf{(5)}$$

The above equation (Equation 4) shows the difference score for which alpha represents the effects of all the time invariant/stable variables that have not been included in the production model. This difference score removes the effects of omitted time-invariant variables in the production function that considered pollination inputs as a main determinant of crop production and control the effect of other variables too.

3. Data and study Area

We used Ethiopian rural socioeconomic survey (ERSS) data, collected by Central statistical Agency (CSA) of Ethiopia and the World Bank (WB)for the year 2011/12 and 2013/14 (ERSS, 2014).The land use-land cover data at different buffer distances has been extracted from SERVIR land cover data using Landsat imaginary with 30m by 30m resolution for the years 2011 and 2013. The data covered the major rural parts of the country except some of the non-sedentary population zones (i.e. Afar and Somali regional states).The range of data items that each ERSS main season dealt with all cereals, pulses and oilseeds and the most commonly grown vegetables, root crops and permanent (perennial) crops. Holders growing at least one or more of these and/or other crops were enumerated and data on crop area and yield condition recorded, hence data on production of these crops acquired. For all enumeration areas in respective years, production/output of 62 different types of crops (like: cereals, pulses, spices, vegetables, oilseeds, fruits and cash-crops) were collected. The detail on the type of crops, the crop pollinators and the mean pollination dependency of the crops are presented in Table 1.

The crop pollination dependency ratio has been calculated based on (Klein et al., 2007; Gallai et al., 2009) and using the FAO database5(FAO, 2015) . The mean value of pollination-driven yield reduction lies between 90%-100% is 95% (i.e. pollination is reported as "essential").The mean pollination-driven yield reduction ranges between 40-90% is 65% (i.e. pollination is reported as "great"). The mean pollination-driven yield reduction ranges between 10-40% is 25% (i.e. pollination is reported as "modest"). The mean pollination-driven yield reduction ranges between 0-10% reduction is5% (i.e. pollination is reported as "little"). Pollination-driven that doesn't show an increase in yields take a zero dependency ratio (Klein et al., 2007; Hanley et al., 2015).

[5] The Food and Agriculture Organization of the United Nations (FAO's), Global Action on Pollination Services for Sustainable Agriculture. http://www.fao.org/pollination/pollination-database.

Table 1: Crops identified in our study and their pollination-yield relationship

S. No.	Crops	Yield increase in the presence of animal pollinators	In the absence of pollinators yield maybe less by	Mean Pollination dependency
1	Pumpkins	Essential	More than 90%	0.95
2	Gishita	Essential	More than 90%	0.95
3	Watermelon	Essential	More than 90%	0.95
4	Scared basil	Great	40-90%	0.65
5	Rue	Great	40-90%	0.65
6	Mango	Great	40-90%	0.65
7	Cardamom	Great	40-90%	0.65
8	Peach	Great	40-90%	0.65
9	Coriander	Great	40-90%	0.65
10	Avocado	Great	40-90%	0.65
11	Haricot beans	Modest	10-40%	0.25
12	Horse bean	Modest	10-40%	0.25
13	Gibto	Modest	10-40%	0.25
14	Soya beans	Modest	10-40%	0.25
15	Nuegs	Modest	10-40%	0.25
16	Rape seed	Modest	10-40%	0.25
17	Sesame	Modest	10-40%	0.25
18	Sunflower	Modest	10-40%	0.25
19	Chilies	Modest	10-40%	0.25
20	Guava	Modest	10-40%	0.25
21	Coffee	Modest	10-40%	0.25

22	Strawberry	Modest	10-40%	0.25
23	Chick peas	Little	0-10%	0.05
24	Line seed	Little	0-10%	0.05
25	Ground nuts	Little	0-10%	0.05
26	Red paper	Little	0-10%	0.05
27	Lemons	Little	0-10%	0.05
28	Oranges	Little	0-10%	0.05
29	Citron	Little	0-10%	0.05
30	Green paper	Little	0-10%	0.05
31	Tomatoes	Little	0-10%	0.05
32	Comtatie	Little	0-10%	0.05
33	Barley	Doesn’t show an increase in yields		0
34	Maize	Doesn’t show an increase in yields		0
35	Oats	Doesn’t show an increase in yields		0
36	Rice	Doesn’t show an increase in yields		0
37	Sorghum	Doesn’t show an increase in yields		0
38	Wheat	Doesn’t show an increase in yields		0
39	Cassava	Doesn’t show an increase in yields		0
40	Lentils	Doesn’t show an increase in yields		0
41	Field peas	Doesn’t show an increase in yields		0
42	Vetch	Doesn’t show an increase in yields		0
43	Cinnamon	Doesn’t show an increase in yields		0
44	Ginger	Doesn’t show an increase in yields		0
45	Bananas	Doesn’t show an increase in yields		0

46	Papaya	Doesn't show an increase in yields	0
47	Pineapple	Doesn't show an increase in yields	0
48	Cabbage	Doesn't show an increase in yields	0
49	Carrot	Doesn't show an increase in yields	0
50	Cauliflower	Doesn't show an increase in yields	0
51	Garlic	Doesn't show an increase in yields	0
52	Kale	Doesn't show an increase in yields	0
53	Lettuce	Doesn't show an increase in yields	0
54	Onion	Doesn't show an increase in yields	0
55	Sweet potato	Doesn't show an increase in yields	0
56	Potato	Doesn't show an increase in yields	0
57	Godere	Doesn't show an increase in yields	0
58	Spinach	Doesn't show an increase in yields	0
59	Sugar cane	Doesn't show an increase in yields	0
60	Tea	Doesn't show an increase in yields	0
61	Tobacco	Doesn't show an increase in yields	0
62	Yam	Doesn't show an increase in yields	0

Sources: (Klein et al., 2007; Hanley et al., 2015; FAO, 2015)

4. Result and Discussion

4.1 Descriptive statistics

This section presents the main characteristics of plot and farm households that include household specific, farm-specific, input and climate variables. Farm households participated in this survey are male dominated (82%) and the majority of them are under productive age groups (on average 46 years old). Farm households have an average of six family members. Most farm households live with average of 15 minutes' walking distance from the nearest main road but with an average of 1hr and 10 minutes walking distance to get the nearest market for input, output and other commodities.

On average the farm households handle one-fourth hectare of land with an average of 3 separate plots. Most of the farm households have certified plot (95%) which might increases their confidence for decision making and management of farm land. Farm households show promising progress on the applications of one or other types of inorganic fertilizer (51%) while organic fertilizer is very low (4%). From Table 2, farm households practicing land management activities mainly soil and water conservation (51%), terracing (24%), and counter ploughing (18%). However, the farm households have shown lower participation to watershed management (0.43%) and afforestation (0.28%) practices on their plot or communal lands to which this might have an influence on the abundance of pollinator community around their farm land.

Vegetation covers (forest and shrub land cover) data specifically distance buffers from farm land are considered as a pollinator abundance measurement to crop production. Availability of shrub land covers is better as compared to forest cover at the nearest buffer distance. As we can see from Table 3, the availability of forest and shrub land covers are also increases at the farthest buffer distances; probably this might reduce pollinators' abundance and availability as the distance from the plot increase and might have the positive effect to production.

Table 2: Summary statistics of variables

Variables	Mean	Sd	Min	Max
Gender of the head (1 if male, 0 female)	0.822	0.383	0	1
Marital status (1 if married, 0 otherwise)	0.825	0.380	0	1
Household size	5.800	2.289	0	17
Male household members	2.576	1.822	0	10
Female household members	0.427	1.062	0	8
Distance to road (in minutes)	15.48	15.96	0	241.6
Distance to market (in minutes)	70.25	46.72	0.400	283.3
Days worked by male hired labor (number)	5.066	158.5	0	16,286
Farm area (hectare)	0.259	1.958	0	112.4
Extension advise (1 if got extension advise, 0 otherwise)	0.148	0.355	0	1
Irrigation use (1 if irrigated plot, 0 otherwise)	0.047	0.212	0	1
Inorganic fertilizer (1 if yes, 0 otherwise)	0.511	0.500	0	1
Organic fertilizer (1 if yes, 0 otherwise)	0.043	0.205	0	1
Soil and water conservation (1 if yes, 0 otherwise)	0.517	0.500	0	1
Terracing (1 if terracing applied, 0 otherwise)	0.249	0.432	0	1
Water catchment (1 if yes,0 otherwise)	0.004	0.0655	0	1
Afforestation (1 if afforested, 0 otherwise)	0.002	0.0535	0	1
Counter ploughing (1 if counter ploughed applied, 0 otherwise)	0.180	0.384	0	1
Improved seed (if improved seed used, 0 otherwise)	0.628	9.329	0	1,100
Any advisory service (1 if got any advisory, 0 otherwise)	0.722	0.448	0	1
Certified land (1 if certified, 0 otherwise)	0.949	0.218	0	1
Summer temperature (oC)	18.29	2.814	10.30	31.90
Summer precipitation (mm)	628.6	195.3	77	1,184
Production per hectare (quintal)	23.54	51.31	0	997.0

Source[1]: own estimate from ERSS, 2011/12&2013/14

[1] The source dataset for monthly temperature and precipitation are extracted from 0.5 degree by 0.5 degree gridded time-series data. It was first downloaded from Climate Research Unit, University of East Anglia (Harris et.al. 2014, Osborn and Jones 2014). Then, the monthly temperature and precipitation data values for sampled households were interpolated from the gridded time series data and household-level GPS coordinates measured during the survey. Thin plate spline interpolation technique was implemented to generate these data.

Table 3: Summary statistics for vegetation covers across 100m-3km buffer distances

Vegetation cover (ha)	100m Mean (sd)	250m Mean (sd)	500m Mean (sd)	1000m Mean (sd)	2000m Mean (sd)	3000m Mean (sd)
Forest	1.66 (85.66)	10.30 (557.70)	42.06 (2,322.69)	173.84 (9,820.25)	677.41 (38,863.04)	1,511.98 (87,578.02)
Shrub	2.11 (104.12)	12.85 (683.37)	48.77 (2,631.12)	190.55 (10,539.01)	759.01 (42,927.29)	1,682.77 (96,203.85)

Sources: Own estimate.

On the other hand, most crops in Ethiopian farming practices are dominated by cereal production especially in the north and northeastern part of the country. More than half (about 30 crops) are non-pollination dependent (59%), 10 crops were found with little level of pollination dependency (8%), 12 crops were found modest dependent (21%), 7 crops were found great dependent (7%) and 3 crops were found essential (3%). Looking at overall pollination dependency, about 41% of the crops are pollination dependent which implies a loss of pollination service would reduce significant production. Among the pollination-dependent crops, modest-dependent takes the highest proportion (21%). Crop production-pollinator dependency is presented in Table 4.

Table 4: Crop pollination dependency

Production dependency	Freq.	Percentage
Non-dependent	15,220	59.18
Little	2,301	8.95
Modest	5,421	21.08
Great	2112	8.21
Essential	663	2.58
Total	25717	100

Sources: Own estimate

4.2 Empirical Result

4.2.1 Values of pollination service to crop production

Following Hausman test, the correlation between the error term and explanatory variables in the panel is statistically significant (Prob>chi2 = 0.0000), fixed effect is the appropriate model (Hoechle, 2007; Torres-Reyna, 2007). We examine the effects of vegetation cover in various buffer distances as pollinator abundance to crop production by considering the crop pollination-dependency. For this, we considered forest and shrub land cover as a proxy to measure pollination abundance to analyse the effect of pollination ecosystem service to crop production with various levels of crop-pollination dependency from 100m to 3 km buffer distances.

At 100m buffer distance shrub land cover found to be statistically significant for essential crop production at 1% level. A one hectare increase in shrub land cover within 100m radius/buffer distance results 31 quintal (32.77*0.952) increase in essential crop production. On the other hand a one hectare increase in forest cover within 100m buffer distance increases essential crop yield by 18.5 (19.54*0.95) quintal, however, the effect of forest cover is statistically insignificant. Similarly at 250m buffer distance shrub land cover has played positive contribution to essential crops. At 250m buffer distance, a one hectare increase in shrub land cover results in 5.4 (5.68*0.95) quintal increases in essential crops production. A one hectare increase in shrub land cover at 500m, 1000m, 2000m, and 3000m result in a yield increment of 1.2, 0.39, 0.1, 0.05 quintals, respectively. In all buffer distances forest covers has shown positive and statistically insignificant effect to production of essential crops.

Shrub land cover shows positive externality to the productivity of crops with great level of pollination dependency. Within 100m buffer distance, a one hectare increase in shrub land covers on average increases the yield of crops that are great level of pollination dependency 12.78 (19.67*0.65) quintals. At 500m buffer distance yield increases by 0.66 quintals as a result of increase in

[2] We estimate the amount of yield increases as a result of pollinator abundance based on the average crop yield reduction in the absence of pollination service (pollination dependency ratio) and the fixed effect coefficient. For this we multiply the regression coefficient by 0.95 for essential, 0.65 for great, and 0.25 for modest level of crop pollination dependency.

shrub land cover. At 1000, 2000 and 3000 buffer distance, shrub land cover has positive and statistically significant influence to production of great crops. Within buffer distances of 100m, 250m, 500m and 3km forest cover has positive and insignificant effect to great crops yield; however, at 1km and 2km buffer distances forest cover has negative influence.

For crops that are modest level of pollination dependency have significantly influenced by shrub land abundance from 100m to1km. At 100m buffer distance a one hectare increase in shrub land cover increases modest crop yield on average by 0.8 (3.26*0.25) quintals. Accordingly at 250, 500 and 1000 meters production of modest crops on average increases by 0.18, 0.04, and 0.01quintals.

Table 5: effects of vegetation cover to crop production

Vegetation cover (hectare)	Essential	Great	Modest	Little
Forest_100_ha	19.54	2.46	0.81	8.36
	(14.23)	(5.46)	(1.43)	(8.48)
Shurb_100_ha	32.77**	19.67*	3.26**	-6.95
	(13.64)	(11.78)	(1.40)	(7.05)
Forest_250_ha	1.13	0.61	0.03	0.92
	(2.54)	(1.06)	(0.40)	(1.75)
Shrub_250_ha	5.68***	3.27	0.73***	-0.76
	(2.19)	(2.09)	(0.27)	(1.44)
Forest_500_ha	0.24	0.07	0.07	0.17
	(0.56)	(0.22)	(0.12)	(0.37)
Shurb_500_ha	1.29***	1.02*	0.16**	-0.14
	(0.48)	(0.55)	(0.08)	(0.32)
Forest_1000_ha	0.08	-0.02	0.03	0.02
	(0.14)	(0.05)	(0.03)	(0.10)
Shrub_1000_ha	0.41***	0.34**	0.04*	-0.02
	(0.14)	(0.17)	(0.02)	(0.09)
Forest_2000_ha	0.02	-0.00	0.01	-0.01
	(0.04)	(0.01)	(0.01)	(0.03)
Shrub_2000_ha	0.12***	0.08**	0.01	0.01
	(0.04)	(0.04)	(0.01)	(0.03)
Forest_3000_ha	0.01	-0.00	0.00	-0.01
	(0.02)	(0.01)	(0.00)	(0.01)
Shrub_3000_ha	0.06***	0.03*	0.01	0.01
	(0.02)	(0.02)	(0.00)	(0.01)

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 Source: own estimate

In general shrub land covers shows statistically significant positive externality to crop yield particularly for essential, great and modest crops. This could be due to the relative abundance of shrubs in terms of diversity and being accessible habitat for wild pollinators. Our result is consistence with the finding of Hicks et al. (2014). This could show the possibility of getting natural habitats for wild pollinators in the nearby shrub and this might increases the chances of getting pollination ecosystem service which enhance the productivity of crops. This is in line with the findings of previous studies (Kremen and Ostfeld, 2005; Carvalheiro et al, 2010; Munyuli and Mushambanyi, 2014).

Forest cover shows positive and statistically insignificant influence to production for essential, great, and modest crops. This might imply the spatial distribution of forest cover round farm lands. In contrast shrub lands are easily accessible and relatively abundant within short buffer distances to farm land areas.

We also estimate the monetary values of pollination service to crop production by taking the quantity of produce increases due to pollinator abundance and the average price of crops which have essential, great and modest level of pollination dependency. From this, we get extremely significant yield increase and correspondingly the result shows higher increase in yield as a result of pollinator abundance across different buffer distance from vegetation cover. For instance, within 100m buffer distance a one hectare pollinator abundance increase income of the farmer by ETB 6413, 5395, 643 for essential, great and modest crops, respectively.

Table 6: Monetary value of vegetation cover (i.e. Shrub land cover) across buffer distances

Crops	100m	250m	500m	1000m	2000m	3000m
Essential (kg*price)	6413.09	1111.57	252.45	80.24	23.48	11.74
Great (kg*price)	5395.48	896.96	279.78	93.26	21.94	8.23
Modest (kg*price)	643.85	144.17	31.6	7.9	1.98	1.98

Source: computed from fixed effect regression coefficients and CSA, 2013 price data3

[3] We used CSA (2013) price per kg data and take the average for each crop pollination category; 2.06, 4.22, 7.9 ETB for essential, great and modest crops, respectively.

5. Conclusion and Policy Implication

Around one-third of the world crop production depends on pollination ecosystem service, many scholars agree on this but the question is how to quantify the effect of this service on production while conserving the natural environment particularly vegetation cover (i.e. of forests and shrub). To capture the effects of pollinators on crop production proxies to vegetation cover which are habitat for wild pollinators are considered as a solution approach in this study. For this, we consider buffer distances of 100m to 3km from farm plot to forest and shrub land coverswhich are considered as the main habitat to pollinators. For the purpose of this study, we use Ethiopian rural socioeconomic survey data and an integrated plot level extracted land use-land cover data used as proxy for pollination ecosystem service to crop production.

The result showed that the extremely significant and positive effect of proxy to shrub land covers to crop production. At all buffer distances to shrub lands cover affects production of essential, great, and modest crops. Compared with forest cover, shrubs are more diversified in type and easily accessible and habitable for wild pollinators. Similarly, forest covers has shown positive and statistically insignificant effect to crop yield. This might imply the dispersed nature of forest which might not be convenient for hosting wild pollinators. Our result also estimates the monetary values of the pollinators to each crop categories. Based on the estimate pollinators input to crop production of each category is really substantial for the farm productivity.

Based on the result, the following policy implications are drawn. 1) Both farmers and the responsible stakeholder need to identify crops pollination dependency for local production practice and accordingly farmer could manage their plot. 2) Shrub land cover has to be appropriately managed at short distance radius from farm lands to increase pollinator abundance for the purpose of pollination ecosystem service to crop production. 3) Government and extension workers needs to aware farmers about the relevance of pollinators for crop yield improvement as their influence is negative.

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Annex-I

Table 7: Yield increment across buffer distances from vegetation cover (i.e. Shrub land cover)

Crop types	measurement	100	250	500	1000	2000	3000
Essential	Production per hectare/quintal	31.1315	5.396	1.2255	0.3895	0.114	0.057
	Production per hectare/kg	3113.15	539.6	122.55	38.95	11.4	5.7
	Production value (kg*price)	6413.089	1111.576	252.453	80.237	23.484	11.742
Great	Production per hectare/quintal	12.7855	2.1255	0.663	0.221	0.052	0.0195
	Production per hectare/kg	1278.55	212.55	66.3	22.1	5.2	1.95
	Production value (kg*price)	5395.481	896.961	279.786	93.262	21.944	8.229
Modest	Production per hectare/quintal	0.815	0.1825	0.04	0.01	0.0025	0.0025
	Production per hectare/kg	81.5	18.25	4	1	0.25	0.25
	Production value (kg*price)	643.85	144.175	31.6	7.9	1.975	1.975

Table 8: The effect of control variables to crop production per hectare (in quintal)

Variables	Coef.	SE
Gender of the head	-13.70	23.03
Household size	3.08	2.43
Number of male household members	-1.25	2.57
Number female household member	-8.60	5.66
Marital status	-24.72**	11.72
Distance from road to homestead (minutes)	16.91***	4.67
Distance from market (minute)	-8.41**	3.91
Hired male labor (days' work)	-0.18	0.28
Farm area	-0.48	3.41
Got extension advise	-7.17*	3.82
Got any advisory	-1.24	4.55
Applied irrigation	9.03	8.84
Inorganic fertilizer	-1.82	4.14
Organic fertilizer	16.17	13.42
Soil &water conservation	-8.93	7.20
Improved seed	-0.11	0.23
Land certified	0.89	15.03
Applied afforestation	9.68	16.76
Counter ploughing	11.67**	5.70
Applied terracing	10.51*	5.60
Water catchment	4.63	39.69
Summer precipitation	-0.38	0.39
Summer temperature	-11.22	24.12
Constant	825.50	713.83
Observations	16,559	
R-squared	0.10	
Number of pltid	16,217	

Source: own estimation *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Determinants of Adopting Improved Bread Wheat Varieties in Southeastern Highland of Ethiopia: A Double-Hurdle Approach

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Abstract

The improvement of agricultural productivity using technology is an important avenue for increasing output and reducing poverty in sub-Saharan countries. However, low adoption of high yield varieties has been identified as one of the main reasons for low productivity in Sub-Saharan Africa. Consequently, the study examined the effect of demographic, socioeconomic and institutional factors affecting adoption and adoption-intensity of improved bread wheat varieties (IWVs), using a cross-sectional data collected from 140 sample households in the southeastern high land of Ethiopia in 2014/15 year. We estimated a Double-hurdle model to analyze the determinants of intensity of IWVs adoption, as adoption and use intensity were two independent decisions influenced by different factors. Based on the likelihood ratio test, the Tobit model was rejected against the double hurdle model. Empirical estimates of the first hurdle reveals that wheat farming experience, distance to cooperatives, renting a tractor and combine harvester, Urea application, and net income from wheat grain sale all significantly increased the likelihood of IWVs adoption. Households with a female head were also found to have a high probability to adopt than male-headed. Estimates of the second hurdle revealed that the decision to use optimal intensity of IWVs by smallholder farmers was influenced by seed availability, row planting, and distance to cooperative all significantly and positively. The intensity of adoption was also found to be negatively related to the proportion of farmland allotted for wheat production. Accordingly, policies and interventions that are informed about such factors are required to accelerate adoption and adoption-intensity of IWVs in Ethiopia in order to realize a wheat Green Revolution and fight food insecurity in a sustainable manner.

Keywords: Adoption, Improved Wheat Varieties, Tobit model and Double-hurdle model

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1. Introduction

Agriculture is a dominant sector of Ethiopian economy and it plays an important role in stimulating the economic development of the country, which has had an impressive track record of growth and poverty reduction in recent year (IMF, 2016). Although measures of human development have improved but remain unacceptably low, because the poorest sub-sector of rural households are chronically reliant on food aid and social safety net programmes (MoFD, 2010). However, this would be realized if and only if strenuous efforts are made by the government and other concerned stakeholders including smallholder farmers to increase agricultural production and productivity in Ethiopia, like the case of Asian Green Revolution.

Many studies (Kassie *et al.,* 2011; Shiferaw *et al.,* 2008; Dixon *et al.,* 2006; Irz *et al.,* 2001) indicate that high poverty reduction elasticities for agricultural productivity growth, through generating high incomes for farmer, reducing food price, and generating more tax[2]revenues. For instance it has been estimated that a 1% increase in crop productivity reduces the number of poor people by 0.48% in Asia (Thirtle *et al.,* 2003), in India a 1% increase in agricultural value added/ha leads to a 0.4% reduction in poverty (Ravallion and Datt, 1996), in Africa each dollar investment in the sector has a multiplier effect ranging from 1.5 to 2.7% (UNECA, 2005), in sub-Saharan Africa, the contribution of agriculture to poverty reduction was estimated to be 4.25 times the contribution of equivalent investment in the service sector (Christiaensen *et al.,* 2011), and every 1% increase in wheat productivity reduced the extent of poverty by 0.5-1.0 % (World Bank, 2005). Cognizant, agricultural technological improvements are crucial to increase agricultural productivity and thereby reduce poverty and meet food demand without degradation of the agro-ecosystems (Kassie *et al.,* 2011; Asfaw *et al.,* 2012).

Even though adoption of improved input technologies for staple crop production is fundamental to the transformation of rural Africa, thereby to achieve food security, reduce poverty (Teklewold *et al.,* 2013), and improve

[2] For instance, in Japan in the last decades of the 19th century, early industrialization was financed by land tax, accounting over 80% of fiscal revenues at the time (Ghatak and Ingersent, 1984).

the well-being of millions of African poor households, unlike many Green Revolution-type systems whose success has been manifested in the widespread adoption of high yield plant varieties and associated packages across millions of hectares, adoption of improved technology has not been fully embraced by the smallholders in Africa (Dethier *et al.,* 2012; Spielman *et al.,*2010; Langyintuo and Mekuria, 2008; Moser and Barrett, 2002). This is because of lack of correctly identifying the factors that prevent farmers from adopting improved, high yielding crop varieties in the content (Langyintuo and Mekuria, 2008). Although many African governments do not collect or report such cross-section data, and without such intensive descriptive information about who is adopting technologies and who is not, it is challenging to formulate policies for increasing agricultural production and productivity (Doss *et al.,* 2003).

Despite its vast agricultural potential, Africa's low-income countries have remained a net importer of agricultural products in the last decades, especially cereals (Rakotoarisoa *et al.,* 2011) implying that cereal import has been increasingly important in ensuring food security. For instance, in 2010 alone, sub-Saharan Africa countries imported a total of 18.2 million MT of wheat, valued at nearly US$5.1 billion (FAOSTAT, 2013). Most drivers of wheat consumption in sub-Saharan Africa includes increase in country's GDP (a proxy for income), growing populations, urbanization, and women's participation in the labour force and government policy[3] (Mason *et al.,*2015; Jayne *et al.,* 2010). Indicating, the critical importance of improving production and productivity of wheat in Africa through development, dissemination, and adoption of improved wheat technologies, in order to promote economic growth and poverty reduction in Africa.

Wheat is among the most important crops grown by smallholder farmers in Ethiopian highlands, at altitudes ranging from 1500 to 3000 m.a.s.l. Even though wheat ranks fourth in total cereal production (17.5% during 2005-2012) next to maize, sorghum, and teff (CSA, 2011), the country falls short of being self-sufficient in wheat production and continually remains a net

[3] Government policies that increase wheat consumption in sub-Saharan Africa probably is keeping wheat price low relative to the price of domestically produced stable crops (*ibid*).

importer (FAO, 2014), especially in drought year when food deficits are large. Over the last decades, International Maize and Wheat Improvement Center (CIMMYT) has been collaborating with Ethiopian Institute of Agricultural Research (EIAR) in the development and dissemination of 44 improved bread wheat varieties with associated technological packages, however, the adoption of these technologies is low (Asrat *et al.,* 2010) and have not been analyzed systematically (Shiferaw *et al.,* 2014). Although the literature on the adoption of crop technologies is large, most studies have looked at other crops (Ahmed, 2015; Asfaw et al., 2012; Asfaw, et al., 2011; Croppenstedt, et al., 2003; Wubeneh and Sanders, 2006; Ghimire, et al., 2015) and much less is known about the factors affecting adoption probability and intensity of IWVs in the study area, particularly at the household level. Furthermore, there is relatively thin published information on the adoption of improved wheat technologies in the study districts. Therefore, this study is aimed at analyzing the socioeconomic and institutional determinants of adoption and intensity of use of IWVs to design better adoption programmes that will enable agricultural policymakers to design policies that will address factors determining the adoption of IWVs at national and continental level.

2. Material and Method

2.1 Description of the Study Area

The survey was conducted in Arsi zone, Oromia National Regional State of Ethiopia in 2014/15 year. It shares boundaries with East Shewa zone in the north and northwest, West Arsi zone in the south and southwest, Bale zone in the south, southeast and east, West Hararghe zone in the north and northeast. Based on the 2014 CSA data, Arsi zone has a total population of 3,202,689 of whom 1,600,932 are women and 1,601,757 are men. Out of the total population 423,223 are urban inhabitants while the remaining are rural inhabitants. The Zone has an area of 19,825.22 square kilometers. Limuna Bilbilo wereda has a total population of 219,922 of which 187,222 are rural inhabitants. While Hitosa wereda has a total population of 151,694 of whom 125,800 are rural dwellers (CSA, 2013).

Arsi zone has four agro-climatic zones; lowlands (29%), midlands (27%), highlands (40%) and frost (4%). The average temperature for the zone ranges from 10 to 25 ^{0}C and the altitude ranges from 500 to 4245 m.a.s.l., these altitude differences provides the zone broader opportunity for the production of different types of crop such as cereals, pulses, vegetables, fruits, oilseeds, and spices. The zone is referred as surplus grain producing areas in the country, as a result different institutions (such as Ethiopian Seed Enterprise (ESE), Oromia Seed Enterprise(OSE), Kulumsa Agricultural Research Center (KARC) and Arsi University) and development projects are implemented in the past (such as Chilalo Agricultural Development Unit followed by Arsi Bale Rural Development Project).

2.2 Data Sources and Methods of Collection

For the study, both primary and secondary data were collected. The field was conducted during 2014/2015 to collect qualitative and quantitative data, from primary and secondary sources. Primary data were collected from farm households (HH)[4] by using structured questionnaire and employing trained enumerators under the supervision of the researcher. The questionnaire was pretested and amended based on the feedback obtained to ensure validity and reliability. Secondary data were collected from CSA, Food Security Research Project, Office of Agriculture and Rural Development, FAO, International Research Institution Report and On-line publications.

2.3 Sampling Procedure

Multi-stage random sampling technique was employed to collect data. The first stage involves purposive selection of districts or *Woreda* noted for bread wheat production, these includes Digalu and Tiyo, Lemuna Bilbilo, Munessa, Lode Hetosa, Hetosa, Tiyo, Shirka and Arsi Robe districts.

The second stage involved purposive selection of two high bread wheat producing *kebeles*[5] Gonde Finchama and Gadissa Derara from Hetosa and Lemuna Bilbilo districts, respectively. Finally, the list of households growing

[4] Household refers to agricultural HH when at least one member of the HH is engaged in growing crops and/or livestock in private or in combination with others (SCA, 2011).
[5] *Kebele* refers to the smallest administrative unit in Ethiopia.

bread wheat was obtained from Agricultural and Rural Development office record for the selected "*Kebeles*" and finally 140 farms HH were selected based on proportional random sampling method. Data collected include the socioeconomic and institutional variables such as gender, schooling, marital status, experience, farm size, wheat grain price, seed availability, row planting, receive training, extension, take credit, distance to cooperative, rent machinery, DAP application, Urea application, net return from wheat sale and household size to provide the most up-to-date information on improved bread wheat technology adoption to policymakers and researchers.

The independent variables are defined in Table 1 along with their expected signs on their coefficients. These of variables were tested for collinearly. The estimated maximum tolerance level was 0.6717 between the variables net income from wheat and total wheat land planted; we can conclude that multicollinearity is not a serious problem.

2.4 Econometric Specification

According to Rogers (1962) adoption is "the mental process an individual passes from first hearing about an innovation[6] to final adoption". However, for rigorous theoretical and empirical analysis we adopt Feder et al. (1985) and Feder and Umali (1993) definition of technological adoption which is viewed from individual (micro-level) adoption and aggregate (macro-level) adoption perspectives, and aggregate adoption is measured by aggregate level of use of seed technology within a given geographical region/a given population. Our model is based on the micro level, where each decision unit must choose whether to adopt the innovation and its intensity of use if adopted. Feder and Umali (1993) also classified adopter as those who have ever used and continue to use technology while farmers who have never used and those who have only used technology at some point in time are categorized as non-adopters of seed technology, thereby incorporating time dimension in the adoption definition.

[6] According to Feder and Umali (1993), agricultural innovation is a technological factor that changes the production function and regarding which there exists some uncertainty.

Unlike the typical binary dependent variable models such as Logit and Probit models applied for studying the dichotomous issue of the probability of adopting a new agricultural technology or not like the case of Finger and Benni, 2013; Mariano *et al.,* 2012; Nagatu and Parikh, 1999; Ahmed, 2015 and Wafula *et al.,* 2015, our objective goes beyond that and helps in understanding the intensity of adoption of improved bread wheat varieties. Consequently, we applied the Double-Hurdle (DH) mode developed by Cragg (1971) for this purpose.

Several studies used the DH approach to study adoption of a given technology such as Kapalasa (2014); Mignouna *et al.,* (2011); Asfaw *et al.,* (2010); Getachew *et al.,* (2009) and Shiferaw *et al.,* (2008) as it has an advantage over the dichotomous model by permitting to determine the intensity of use of agricultural technology once adoption has taken place. This study uses the DH model which is a parametric generation of the Tobin (1958) model due to the presumption that factors that influence the household's decision to the adoption of bread wheat varieties are different from those that affect the extent of adoption (Green, 2001).

The limitation with the Tobin (1958) model is that it allows one type of zero observation, called a *corner solution,* since it is based on the assumption that zero observations are due to respondents' non-participation decision, which arise from other factors such as economic, institutional and demographic characteristics (Martínez-Espińeira, 2006). For instance, under Tobit model farm households with positive desire to adopt a given agricultural technology have unconditional access to the new technology, however, in most of the sub-Saharan countries like Ethiopia where seed supply system is underdeveloped, this is often untenable as farmers wanting to plant new varieties often face seed access constraints (Asfaw *et al.,* 2010) and the Tobit model has no mechanism to distinguish such farm households from those with unconstrained ones and consider a zero amount of land under agricultural technology, hence yield inconsistence parameter estimation (Croppenstedt *et al.,* 2003). The other limitation to the Tobit model is that the probability of a positive value and the actual value, are determined by the same parameters (Burke, 2009), however, DH model allows for the possibility that participation and intensity decisions are affected by a different set of parameters.

Although, Heckman (1979) model addresses the problem associated with the zero observations by considering the respondents' self-selection, means that all the zero comes from the respondents' deliberate choices. This model differs from Tobit model by assuming that, sets of different variables could be used in the two-step estimations, however, this makes *Heckit* model similar to the DH model. Also the Heckman and DH model are similar in identifying the rules governing the discrete outcomes, which are determined by the selection and level of use decisions. However, the *Heckit* assumes that there will be no zero observations in the second stage once the first-stage selection is passed. In contrast, the DH model considers the possibility of zero outcomes in the second-hurdle which arise from the individuals' deliberate choices or random circumstance. However, if sample selection bias is an issue, the *Heckit* model[7] is favored over the DH model but the sample-selection bias is not an issue in this study as Mills ration is insignificant, thus the Cragg DH model is optimal.

The DH model is a parametric generation of the Tobit model, whereby two separate stochastic processes determine the decision to adopt and the level of adoption of technology. In our case, the two decisions are the decision to adopt and the decision about the intensity of adoption[8]. The first decision variable (y) takes the value 1 for farmers who have adopted IWVs and 0 otherwise. However, the expected utility of adopting a technology (y_i^*) is latent variable[9]. Hence, the first decision (adoption hurdle) of the households is formulated as:

$$y_i^* = x_i'\alpha + \varepsilon_i$$

$$y_i = \begin{cases} 1 & if \quad y^* > 0 \\ 0 & if \quad otherwise \end{cases}$$

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[7] The results of the Heckman's two-step approach estimations are not reported but are available (Appendix 1) to see if sample selection bias is an issue based on the inverse Mills ratio (λ).

[8] Intensity of adoption is the share of farmland utilizing the technology (Feder *et al.,* 1985).

[9] Latent variable occur when farmers decide to adopt but are prevented from doing so because of various circumstances (Vanclay, 1992).

where y^* is latent adoption variable that takes the value of 1 if a household grew IWVs and 0 otherwise, x_i is a vector of household characteristics and α is a vector of parameters. Not all improved bread wheat adopters grow IWVs at the same level of intensity. As stated previously, the intensity of adoption is measured in terms of the proportion of farm area allocated to IWVs. The intensity of adoption (intensity hurdle) of IWVs given as in a Tobit like function:

$$t_i^* = z_i^{'}\beta + \mu_i$$

$$t_i = \begin{cases} t_i^* = z_i^*\beta + \mu_i & if \quad t^* > 0 \quad and \;\; y^* > 0 \\ 0 \;\; otherwise \end{cases}$$

where t_i is the observed response on how much land one allocated to IWVs, z is a vector of the household characteristics and β is a vector of parameters.

The decision of whether or not to adopt IWVs and how much land to allocate to IWVs can be jointly modelled, if they are mode simultaneously by the farmers; independently, if they are made separately; or sequentially, if one decision is made first and affects the other one (this is the *dominance* model) (Martínez-Espiñeira, 2006). If the independence model applies, the error terms are distributed as follows: $\varepsilon_i \sim N(0,1)$ *and* $u_i \sim N(0,\delta^2)$. If both decisions are made jointly (the Dependent DH) the error term can be defined as $(\varepsilon_i\, u_i) \sim BV\; N(0,Y)$ where

$$Y = \begin{bmatrix} 1 & \rho\delta \\ \rho\delta & \delta^2 \end{bmatrix}$$

The model is said to be a dependent model if there is a relationship between the decision to adopt and the intensity of adoption. This relationship can be expressed as follows:

$$\rho = \frac{\operatorname{cov}(\varepsilon_i u_i)}{\sqrt{\operatorname{var}(\varepsilon_i)\operatorname{var}(u_i)}}$$

If $\rho = 0$ and there is dominance (the zeros are only associated to non-participation, not standard corner solutions) then the model decomposes into a Probit for participation and standard OLS for Y.

Following Smith (2003) we assume that the error terms and ε_i and u_i are independently and normally distributed and thus we have the following expression:

$$\begin{pmatrix} \varepsilon_i \\ u_i \end{pmatrix} N \left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & 0 \\ 0 & \delta^2 \end{pmatrix} \right]$$

And finally, the observed variable in a DH model is $t_i = y_i t_i^*$ and the log-likelihood function for the DH model is:

$$LogL = \sum_0 \ln \left[1 - \Phi\left(x_i'\alpha\right)\Phi\left(\frac{z_i'}{\delta}\right) \right] + \sum_+ \ln \left[\Phi\left(z_i'\alpha\right)\frac{1}{\delta}\phi\left(\frac{y_i - x_i'\beta}{\delta}\right) \right]$$

Thus in this study, we estimate the decision to adopt and the extent of adoption using a DH model. A simple specification test that evaluates for Cragg's DH-model against the Tobit model can be used using the same set of explanatory variables, through a comparison of the log-likelihood functions values of the Tobit, Probit and Truncated models estimated (Martínez-Espiñeira, 2006). Assuming that the same set of independent variables appears in all the three equations, the following value λ will be distributed as a chi-square random variable with degrees of freedom equal to the number of explanatory variables under the null hypothesis that the Tobit model is the correct (Goodwin *et al.,* 1993):

$$\lambda = -2\,(f_{Tobit} - f_{\Pr obit} - f_{Truncated}),$$

where the $f_i's$ represent the respective estimated log-likelihood function values.

Studies on factors influencing the adoption and intensity of use of agricultural technologies (such as Asfaw *et al.,* 2011; Akinbode *et al.,* 2015; Finger and Benni, 2013; Katengeza *et al.,* 2012; Mariano *et al.,* 2013; Mignouna *et al.,* 2011; Ransom *et al.,* 2003; Shiferaw *et al.,* 2008; Nkonya *et al.,* 1997) have pointed out the influence of the following factors for the adoption decision and use intensity: socioeconomic (e.g. age of head, household size, sex of head, literacy, household asset, wealth and off-farm activities etc.), farm characteristics (such as farm size and land tenure, distance from market, distance to nearest agricultural office etc.), technology characteristics (e.g. grain yield, drought resistance, disease tolerance, etc.), institutional environment (e.g. contact with extension agent, membership of a social group, farm experience, rural finance through credit, access to improved technology etc.), market attributes (e.g. grain color, grain size, test, price etc.) and environmental factors (such as demographic location etc.). (see Table 1 for hypotheses associated with these variables). Moreover, risk attitudes, farmers' environmental preferences as well as attitudes and behavioral norms have been indicated as potentially important.

Table 1: Definition of variables and hypothesized effects for IWVs adoption model

Variables	Definition	Hypothesis associate with the explanatory variable
Dependent variable		
IWVs adoption	1=farmer plants IWVs, 0=otherwise	
IWVs area	Area allotted for IWVs	
Independent variable		
Gender	1=HH head is male; 0=otherwise	Male-headed HH are expected to have higher adoption probability (e.g. Dixon *et al.,* 2016) & intensity of use.
Schooling	Years of formal education by the HH head	Better educated farmers are expected to have higher adoption probabilities (e.g. Ahmed, 2015; Feleke and Zegeye, 2006) & intensity (e.g. Nkonya *et al.,* 1997).
Marital Status	1=HH head is married; 0=otherwise	Married households are expected to have higher adoption probability & intensity of IWVs.
Experience	Years of wheat farming experience of the HH head	Farmers with better farming experience are expected to have higher adoption probabilities (e.g. Akinbode *et al.,* 2015) & use intensity (e.g. Mariano *et al.,* 2012).
Farm size	Total wheat area planted in ha	Large area under wheat tend to have higher adoption probabilities (e.g. Ransom *et al.,* 2003) & intensity (e.g. Shiferaw *et al.,* 2008)
Wheat grain price	Market price of wheat grain in ETB[1]/kg	Higher wheat grain price increase adoption probability & intensity.
Seed availability	Availability of IWVs in local store; 0=otherwise	Availability of IWVs in local store increase adoption probabilities & intensity (e.g. Ransom *et al.,* 2003; Ghimire *et al.,* 2015)
Row planting	1=Farmer sow IWVs by row	Planting IWVs by row is expected to have higher adoption probability & intensity of use

[1] Ethiopian birr(ETB); ETB 21.279=US$ 1 at the time of the survey and it highly varies, 2014/15

	planting; 0=otherwise	(e.g. Abay *et al.,* 2016; Gashaw *et al.,* 2016).
Receive training	1=Farmer received training; 0=otherwise	Farmers who receive training on IWVs management have higher adoption probability (e.g. Mariano *et al.,* 2012) & intensity.
Extension contact	1=Farmer have access to advice from extension agents; 0=otherwise	Farmers who have access to extension service have higher adoption probability & intensity of use (e.g. Ransom *et al.,* 2003; Mariano *et al.,* 2012).
Take credit	1=Farmer received any credit; 0=otherwise	Farmers who have access to credit are more likely to adopt IWVs than constraint farmers (e.g. Feleke and Zegeye, 2006; Dixon *et al.,* 2006).
Distance to cooperative	Distance to the nearest cooperative in kilometers	The distance of the farm to the nearest input supplier cooperative is expected to favor technological adoption (e.g. Mariano *et al.,* 2012).
Rent machinery	1=Farmer rent any tractor or harvester; 0=otherwise	Renting farm machinery tend to have higher adoption probability (e.g. Mariano *et al.,* 2012; Wafula *et al.,* 2015) & use intensity as machinery are complementary farm asset.
DAP application	DAP application/ha in kg	DAP application increase adoption probabilities & use intensity (e.g. Nkonya *et al.,* 1997).
Urea application	Urea application/ha in kg	Urea use increase adoption probability & use intensity (e.g. Nkonya *et al.,* 1997).
Net return	Net return from wheat sales in ETB	High net return from IWVs cultivation favor technology adoption (e.g. Feder and Umali, 1993; Kebede *et al.,* 1990).
Family size	Number of family members	Large HHs adopt new technologies more often than small HHs (e.g. Abdulai *et al.,*2008; Mignouna *et al.,* 2011; Akinbode *et al.,* 2015) due to the availability of more labor to use the new technology.
Non-wheat income	Total income from source other than wheat farming in ETB	Farmers who have high non-wheat income are more likely to adopt seed technology than those who do not (Mariano *et al.,* 2012).

3. Results and Discussion

3.1 Improved bread wheat varieties cultivated in the study district

Sampled households grow a wide range of bread wheat cultivars, including local seeds. Out of the total respondents 33.9% sow the most popular variety Digalu, 30.4% sowed more than one variety but less than three cultivars to avoid the risk associated with improved seed attributes subject to maximizing crop harvest. While the remaining 16.5% sowed only Kubsa, 10% sowed only Kakaba, 7.6% sowed only Danda'a, 1.3% sowed only Shorma and 1.3% sowed Pavan. According to the respondents, Kubsa and Galema were preferred for their high yield, but both cultivates are susceptible to yellow rust. Digalu variety is resistance to stem rust comparatively from Kubsa and Galema but now it has become susceptible even including Danda'a and Kakaba (Alemayehu *et al.,* 2015).

3.2 Socioeconomic characteristics of bread wheat farming households

In this subsection, the socioeconomic and institutional characteristics of the sample households will be presented comparatively for adopters and non-adopters of IWVs. Some of these characteristics are the explanatory variables of the estimated models we present further on. Table 2 presents the t-value comparison of means of selected variables by adoption status for the surveyed sampled households. The dataset contains 140 farm households and of these, about 55% were adopters, that is, planted at least one of the IWVs on their farm land during 2014/15 cropping season. The analysis of the data shows that there is no significant difference between mean age of adopter (44.01 ± 10.75) and non-adopters (45.19 ± 10.77) although the group varies significantly ($p < 0.05$) in terms of their education level, suggesting the importance of education for the adoption of new technologies. No significant difference is observable between mean farm experience among adopter (25.12 ± 11.29) and non-adopter (25.79 ± 10.93). The area planted of IWVs is about (2.26 ± 1.46) and (2.23 ± 1.75) ha for adopter and non-adopter, respectively.

IWVs had superior yields over the local landraces, at a significance level of 1%. The average yield from the local varieties was about (3.04 ± 0.5) ton/ha which compares with 3.85 ± 0.89 ton/ha for improved varieties. This represents an average yield gain of 28% in switching to IWVs. Furthermore, IWVs adopter (665.13 ± 91.12) sold their wheat produce at a higher price than non-adopters ((661 ± 53.74) per quintal, because of the fact that IWVs have higher market preference than the local seed by consumers. The average distance to input supplier cooperative where input is purchased was considerably greater for an adopter $(4.83 \pm 3.52\,km)$ of IWVs as compared to non-adopter ($4.23 \pm 2.72\,km$), at a significance level of 1%. Since this distance was based on farmers' responses and not on a direct measurement, it may not be very accurate; however, it is the sine qua non for comparing the relative distance between adopters and non-adopters.

Table 2: Mean of farm and farmers' characteristics of adopter and non-adopter

Variable	Unit	Adopter (N=77)	Non-adopter (N=63)	t-value
Dependent variables				
IWVs used per ha	tons	8.95 (6.17)	0.00	
Adoption	1/0	1.00	0.00	
Dependent variables				
Age	years	44.01(10.75)	45.19(10.77)	-0.64
Schooling	years	3.29 (3.29)	2.49 (2.49)	1.14**
Experience	years	25.12 (11.27)	25.79 (10.93)	-0.36
Farm size	ha	2.26 (1.46)	2.23 (1.75)	0.12
Wheat production	Tons	3.85 (8.9)	3.04 (5.0)	6.44***
Price of wheat grain	Birr/qt	665.13 (91.12)	661.48 (53.74)	0.26
Distance to cooperative	km	4.83 (3.52)	4.23 (2.72)	1.10*
Rental cost of machine	birr	3241.9 (43334.7)	2330 (3702.19)	1.32
DAP application	Kg	101.76 (106.9)	112.6 (122.3)	-0.56
Urea application	Kg	19.4 (29.2)	7.9 (15.4)	2.83***
Net income	ETB	20175 (28504)	14686.5 (17065.9)	1.34
Family size	no	7.09 (2.56)	7.63 (3.01)	-1.15
Non-wheat income	birr	7188.25 (13861)	4687.7 (8574.5)	1.23

Source: Own survey, 2014/15

All farmers surveyed in both districts applied DAP fertilizer to the optimal amount, the mean application was 101.76 ± 106.9 kg/ha for adopter and 112.6 ± 122.3 kg/ha for non-adopters, and did not differ significantly. However, the application of Urea fertilizer per ha for both adopter

19.4 ± 29.2 (kg) and non- adopter (7.9 ± 15.4 kg) was very low relative to the recommended rate, and it was statistically significant at 1% level, supporting the importance of Urea application for IWVs adoption. No significant differences between adopters and non-adopters are indicated for the rental cost of farm machines (such as tractors and harvester), net income from wheat grain sell, family size and income other than wheat.

Sampled respondents were composed of both male and female households (Table 3). The majority (79.3) were male-headed while 20.7% were female-headed. The female-headed households' proportion for adopters and non-adopters were 15.7% and 5%, respectively. The variable is statistically significant ($p < 0.1$) for adopters and non-adopters. In many cases, data are collected on whether a given technology has been adopted or not, without considering farm households are seed access constrained or not.

Table 3: Socioeconomic characteristics of the respondents for discrete variables in %

Variable		Adopter (N=77) %	Non-adopter (N=63) %	Chi-square
	Female	15.7	5	
Gender	Male	39.3	40	6.432*
	Married	50.7	43.6	
Marital Status	Other wise	4.3	1.4	1.371
	Yes	19.3	1.4	
IWVs availability	No	35.7	43.6	21.456***
	Yes	5	13.6	
Row planting	No	40	41.4	4.216**
	Yes	34.3	15.7	
Received Training	No	20.7	29.3	10.418***
	Yes	50.7	35	
Extension visits	No	4.3	10	5.892***
	Yes	7.9	7.9	
Credit	No	47.1	37.1	0.264
	Yes	37.9	32.6	
Rent farm machine	No	17.7	21.4	3.957**

Source: Own survey, 2014/15

However, the study reviled that availability of IWVs at local input supplier cooperative was highly significant ($p < 0.01$) between adopter and non-adopter. Revealing that sampled households who have access to IWVs tend to adopt the technology more than those who are access constrained. Even though row planting is one of the technology package introduced by Ethiopian Agricultural Transformation Agency (ATA) Wheat Initiative, few of the sampled respondents (18.6%) used a reduced-wheat seed rate through row planting, while the remaining 81.4% did not, the variable is also significantly different between adopter and non-adopter at 5% level. As far as institutional variables are concerned, about 50% of respondents got training specific to wheat production while regarding extension service except for 14.3% of the sampled respondents all of them indicated that they get the extension service with different frequency. Out of the total sampled households, greater percentages of respondents (70.5%) used a labor-saving complementary asset (such as tractor and combine harvester) and the difference is statistically significant (p <0.5) between adopter and non-adopter supporting the importance complementary farm assets for the adoption of new agricultural technologies. No significant differences between adopters and non-adopters are indicated for marital status and credit.

3.3 Determinants of adoption of improved bread wheat varieties

The results for the Tobit model are reported in the first two columns of Table 4, while the other columns show the results of the DH model using the same set of explanatory variables. Assuming that the same set of explanatory variables appears in Tobit, Probit and Truncated models. Following the specification test $(\lambda = -2(f_{Tobit} - f_{\Pr obit} - f_{Truncated})$ that evaluates the Tobit model against the DH model, our case has a value of $\lambda = 32.084$, whereas $di\ \chi^2 tail\ (19, 32.084)$ has a significance value of $\alpha = 0.03$ accordingly we reject the Tobit model as it is not appropriate, in favor of the Probit and Truncated regression model (DH model) over the Tobit model. Confirming that, some variables predict the decision to adopt IWVs, but not the intensity of adopting IWVs, making the Tobit model inappropriate to explain why some respondents state a zero value.

The Tobit model indicates that adoption of IWVs is significantly (p<0.1) and negatively influenced by gender of the household head, contrary to the expectation. Revealing that if household head is male, the chance of adopting IWVs decrease by the factor of 31.38 as compared to the female head. This finding is in agreement with Degefu et al. (2017). Unlike gender, IWVs availability at local seed store positively and significantly ($p < 0.01$) influenced adoption, as was expected. The partial derivate for this variable suggests that adoption of IWVs rises by 36.77 kg for each additional increase in the availability of seed in a local store of input supplier cooperatives. This is consonance with Langyintuo and Mekuria (2008) that explained the reluctance of seed companies to expand their retail networks is a disincentive for increased adoption rates. Also, study conducted by Ghimire et al. (2015) and Lunduka et al. (2012) revealed that availability of seeds in the local stores eases the households to purchase and cultivate new improved varieties in their field. Another interesting significant ($p < 0.1$) institutional variable is extension visits, the result revealed that the higher the extension contact, the higher the adoption of IWVs by the sampled households.

Table 4. Tobit model versus Double-Hurdle model

	Tobit analysis		**Double-Hurdle analysis**			
	Tobit coefficients	**Marginal effects**	**Probit coefficients**	**Marginal effects**	**Truncated coefficients**	**Marginal effects**
Gender	-31.381*(-1.68)	-13.133	-1.246***(-2.63)	-.464	-14.344(-.75)	-8.57
Schooling	1.865(.91)	.781	.066(11.41)	.025	-.192(-.06)	-.115
Marital status	-16.1(.60)	-6.731	.067(.10)	.026	-28.833(-.88)	-17.235
Experience	1.084(1.41)	.454	.046***(2.62)	.018	.835(.77)	.5
Farm size	-7.495(-1.17)	-3.137	-.07(-.42)	-.027	-30.19***(-2.59)	-18.05
Price of wheat	-.009(-.10)	-.004	.002(.56)	.001	.014(.13)	.008
Seed availability	87.868***(4.84)	36.772***	0(omitted)		57.685***(2.51)	34.48
Row planting	20.524(.98)	8.589	.437(.82)	.172	56.352***(2.04)	33.685
Training	19.104(1.06)	7.885	.306(.90)	.118	-4.751(-.17)	-2.84
Extension	46.705*(1.80)	19.546*	.502(1.15)	.181	60.825(1.06)	36.358
Take credit	13.268(.63)	5.553	.405(.92)	.159	40.136(1.40)	24
Distance to cooperative	5.783**(2.24)	2.42**	.117**(2.14)	.045	7.762***(2.20)	4.64
Rent machine	40.053**(2.52)	16.762**	.995***(2.74)	.357	29.846(1.27)	17.84
DAP application	-.009(-.14)	-.004	-.007(-1.38)	.003	.055(.67)	.033
Urea application	0.545*(1.85)	.228*	.026**(2.58)	.01	.141(.42)	.846
Net return	5.17e-05(.12)	2.16e-05	3.0e-05**(2.01)	1.05e-05	4.43e-05(.09)	2.65e-05
Family size	-0.334(-.14)	-.14	.052(.98)	.02	-4.128(.-.95)	-2.468
Non-wheat income	5.94e-04(.99)	2.49e-04	7.75e-06(.59)	2.98e-06	9.4e-04(1.22)	5.62e-04
Cons	86.166(-1.02)		-3.96(.132)		-.020(-.01)	
No. of obs. =140			No. of obs. =111		No. of obs. =78	
LR chi2(18) =68.83			LR chi2 =.0003		Wald chi2(18) =20.18	
Prob>chi2 =0.000			Pseudo R2 =.2904		Prob>chi2 =0.3227	
pseudoR2 =0.07			Log likelihood =-54.056		Log likelihood =-404.6	

χ^2 test Double-Hurdle versus Tobi

$$\lambda = di\ 2 * ((probll + truncll) - tobll) = 32.084,\ di\ \chi^2 tail\ (19, 32.084) = 0.03,$$

level of significance. We use 19 degrees of freedom because the Tobit uses 18 parameters, Probit 18 and Truncreg 19, the difference in a number of parameters used is 19. We reject the null at $\alpha = 0.03$ the level of significance. Thus rejects the Tobit model as it is not appropriate, in favor of the probit and truncated regression models.

Note: Some variables are omitted from the hurdles due to lack of convergence during estimation. This could arise due to identification problem; t-values are shown in parenthesis; Asterisks indicate level of significance: *** =0.01; **=0.05; *=0.10.

In fact, the coefficient of extension visits variable shows that these households have 19.55 Kg more adoption rate than farmers who have fewer visits of extension. The plausible explanation for this is that such institutional settings critically promote adoption of agricultural technologies by counterbalancing the negative effects of lack of formal education thereby facilitating adoption. This result is consistent with early literature Kapalasa, (2014); Ransom et al. (2003); Feleke and Zegeye (2006). Contrary to the expected distance to input supplier cooperative had a positive and significant ($P < 0.1$) effect on adoption of IWVs. The finding revealed that the marginal effect of a kilometer increase in farmers' distance from the input supplier cooperative results in an increasing adoption of IWVs by a factor of 5.783, keeping other factors constant.

This result is contrary to Asfaw et al. (2012) and Mariano et al. (2012), which had revealed a negative influence of distance from the office of agriculture on technology adoption. The main reason for the positive coefficient is that most of the input supplier cooperatives in Ethiopia are located near to district town or main road where most of the households have limited land holing and engage themselves in other non-farm activities. Use of farm machinery such as a tractor or combine harvester are a common labor-saving complementary asset used by sampled farmers while farming bread wheat, that is why we use farm machinery as an explanatory variable in our adoption model. The result suggests that adoption of IWVs will be increased by 16.76% if sampled farmers rent farm machines to plow their wheat land. This result is in agreement with Mariano et al. (2012) who revealed that farmers who own labor-saving assets are more likely to adopt certified seed technology. Similarly, every increase in the application of Urea fertilizer would increase adoption of IWVs by 0.23%. This is in line with the result of Nkonya et al. (1997) who found that adopting Urea and improved seed technologies together provides synergetic benefits as improved seed have high responses to fertilizer application.

In the DH model, the Probit coefficients estimated, and the implied marginal effects, are contained in the third and fourth columns of Table 4, respectively, while the last two columns contain those coefficients that relate to the Truncated model. The decision to adopt or not is explained by the same set of variables as in the Tobit model. However, in this case, Extension contact variable, although exhibiting the same sign, it is not significant in the DH model. The marginal effects of the probit show changes in the probability of adoption of IWVs for an additional unit increase in the independent variables. Contrary to expectation, the marginal probability results (fourth column) indicate that the probability of adopting IWVs rises by 4.64% if the household is female-headed, revealing that male-headed households are less likely to adopt IWVs than female-headed, which suggests success in targeting vulnerable female households in Ethiopia by the government and NGOs. A similar result was found by Awotide et al. (2014). Likewise, each additional wheat farm Experience, since farmers become a decision maker on his/her own field raises IWVs adoption probability by 0.18%, subsequently increased farming experience furnished farmers with more knowledge that increase their rationality in use of IWVs. This is consonance with the finding of Idrisa et al. (2012). As in the Tobit model, another interesting, and unexpected result is that, the farther the distance between sampled respondents and the input supplier cooperatives, the higher the probability of adopting IWVs. For this variable, a unit increase in distance from input supplier cooperative raises the probability of adoption by 4.5%.

Labor-saving farm machinery such as tractor and combine harvester is a complementary asset used by sampled farmers while farming wheat. The study revealed that farmers who use labor-saving farm machinery are more likely to adopt IWVs at 1% significance level, and the probability of adoption of IWVs increases by 3.57% if a farmer has rented farm machinery. A similar result was found by Wafula et al. (2015). Likewise, the result indicates that the probability of adopting IWVs increase by 0.1% for each additional increase in Urea application. Implying that, the decision to plant IWVs was concurrent with fertilizer application decision. Net return being an indicator of returns or loss of a particular crop, it is a useful tool for selecting crop varieties by farm households (Mazid *et al.,* 2009). The effect of each additional net income from wheat grain on the probability of adopting IWVs is the lowest, only a 0.003%. This is in agreement with the finding of Feder and Umali (1993) and Kebede et al. (1990) who revealed that positive effect of extra income on the probability of technological adoption.

In the Double hurdle model, the Truncated model estimated shows, in contrast with the Tobit model, the variables representing Gender, Extension visit, Renting farm machine (such as tractor and combine harvester) and Urea application are not significant. However, important variables such as land allotted to wheat, IWVs availability, row planting and distance to input supplier cooperatives are all significant at 1%. The result revealed that each additional hector of land farmed reduced IWVs adoption intensity by a factor of 18.05 kg per ha. This is in agreement with the find of Nkonya et al. (1997). Also, studies from Asia revealed that during the Green Revolution first, large farmers adopted high-yielding variety package in the 1970s, small farm households caught up in the 1980s, causing an inverse relationship between the intensity of adoption and landholding size (Back, 1995). However, this result was inconsistent with the fining of Ransom et al. (2003). Adoption of agricultural technology by the poor can be limited by lack of access to inputs (Hazelland Haddad, 2001), especially for poor farmers with positive desire demand because of the imperfection in local seed markets (Asfaw *et al.,* 2011). For this variable, if the respondent interviewed had an access to IWVs in the local seed store, the level of IWVs adoption intensity raises by 34.48%, a result that is very similar to one obtained in the Tobit model. The finding agrees with Ghimire et al. (2015) and Mignouna et al. (2011).

Regarding row planting, if sampled respondents use a reduced wheat-seed rate through row planting, adoption of IWVs increase by 33.69%. The plausible reason for this is that using a reduce-wheat seed rate through row planting is one of the pieces of the agricultural technology package introduced by ATA wheat Initiative. This finding is in agreement with Abay et al. (2016) and Gashaw et al. (2016) who revealed that the effectiveness of complementary package interventions supports smallholders' to adopt the agricultural technology. Contrary to the expectation, the marginal effects show that each addition kilometers from input supplier cooperatives raises adoption intensity of IWVs by 4.64%. Revealing that, farmers who live far from the input supplier cooperative are more likely to use IWVs compared to farmers who live near to the technology source once they adopt the technology, a result that is similar to the one obtained in the Tobit model.

4. Policy Implication

This study investigated the factors affecting the adoption and adoption intensity of IWVs in the Southeastern highland of Ethiopia. The choice of IWVs technology adoption and use intensity was assumed to have affected by a combination of demographic, socioeconomic and institutional factors. The specification test performed has strongly rejected the Tobit model in favor of the more flexible Double-Hurdle model. Confirming that, some variables predict the decision to adopt IWVs, but not the intensity of adoption, making the Tobit model inappropriate to explain why some respondents state a zero value.

We assumed the same set of explanatory variables in Tobit, Probit and Truncated models and most of the results are reasonably consistent between methods. Also, the result is in line with previous empirical results in the literature. The probability of IWVs adoption on the DH probit model increase with the level of wheat farming experience, renting farm machinery (such as tractor and combine harvester), distance to input supplier cooperatives, Urea application and net return, but it is a decreasing function of male headship of the household. Based on the Tobit model adoption intensity of IWVs increase with the level of seed availability, extension visits, distance to input supplier cooperatives, renting farm machineries, Urea application and decreases with male-headed household while the Truncated DH model result revealed that adoption intensity of IWVs increase with seed availability, row planting, distance to input supplier cooperative and it is a decreasing function of farm size.

We can derive several policy implications from the above results of this study. First, similar to other studies of technology adoption among smallholder farmers in developing countries, farm experience plays a central role in the adoption of IWVs by furnishing farmers with more knowledge that increase their rationality in use of agricultural technology. Secondly, addressing the lack of labor-saving farm machinery assets such tractor and/or combine harvester though renting at the lowest cost or increasing access to the farm machinery with the help of government or NGOs at credit or subsidy base at a village will increase the probability and intensity of adopting IWVs.

Thirdly, IWVs technologies should be made available to farmers who reside within a long distance from rural kebele, through availing farm service centers within reasonable distance from farmer's farm or else encourage farmers to form seed multiplier cooperatives which will in turn multiply and supply IWVs to farmers, hence to ensure IWVs availability at distance place. Fourthly, there is a need to develop high yielding IWVs that reduce associated cost of production and simultaneously increase the financial benefit, as farmers perceive such innovation are profitable they will adopt for the high net benefit they earn from the technology. Fifthly, application of Urea fertilizer was concurrent with IWVs application decision since the two technology together provides synergetic benefits as IWVs have a high response to Urea fertilizer, therefore there is a need to avail such types of complementary inputs with the required quantity and quality to enhance adoption and adoption intensity of IWVs. Sixthly, the result revealed that some success has been achieved in targeting vulnerable rural female-headed households by the Ethiopia government and NGOs unlike many developing nations, as a result female-headed households had high probability and intensity of adopting IWVs as compared to male headed households.

Seventhly, the government should consider long-term strategies that promote intensive promotion and utilization of reduced-wheat seed rate through row planting and increase the availability of IWVs in local seed store through strengthening public and private partnership to increase the adoption intensity of IWVs, ones the technology is adopted. Since lack of IWVs in the nearest seed multiplier cooperative is the major constraint which impedes the adoption of improved varieties, government system should take the lead in seed technology promotion and dissemination at the initial stage and create an enabling environment for effective participation of the private seed sector as there are no private seed supplier companies who supply IWVs for the farmers in the study area during the survey period.

Also, there is a need to develop a bottom-up seed distribution approach that can enhance and accelerate the adoption of new technology by the very poor people of the study area rather than target only the model farmers as it empowers the poor farmers as seed traders and increases the availability of IWVs at the local area. Lastly, extension service should be strengthened so as to expose farmers to modern farming techniques and improved technologies, through enhancing and institutionalizing the role of ICT in disseminating field trial results and facilitating farmers' access to government programs and services.

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Appendix 1: Estimation of the Heckman two step model result

Heckman selection model - - two-step estimation Number of obs. = 140
Wald chi2 (18) = 32.94
Prob> chi2 = 0.0170

	Coef.	Std. Err.	Z	P>|*Z*|	[95% Conf. Interval]	
IWVs used per hector						
Gender	-12.84	18.371	-0.70	0.485	-48.847	23.165
Schooling	0.124	1.899	0.07	0.948	-3.597	3.845
Marital status	-28.895	23.659	-1.22	0.222	-75.265	17.475
Experience	0.459	0.738	0.62	0.534	-0.988	1.907
Farm size	-27.461	10.798	-2.54	0.011	-48.625	-6.297
Price wheat	-0.562	0.052	-1.08	0.281	-0.158	0.045
Seed availability	53.553	21.424	2.50	0.012	11.562	95.544
Row planting	31.876	17.481	1.82	0.068	-2.385	66.138
Training	13.049	18.846	0.69	0.489	-23.888	49.986
Extension	16.699	30.380	0.55	0.583	-42.846	76.243
Take credit	10.451	19.621	0.53	0.594	-28.005	48.907
Distance to cooperative	4.120	2.377	1.73	0.083	-0.538	8.779
Rent machine	16.111	16.937	0.95	0.341	-17.085	49.307
DAP application	0.017	0.065	0.27	0.787	-0.109	0.144
Urea application	0.317	0.251	1.26	0.209	-0.177	0.808
Net return	0.0005	0.0004	1.05	0.292	-0.0004	0.0014
Family size	-2.214	2.652	-0.84	0.404	-7.412	2.983
Income other than wheat	0.0008	0.0005	1.55	0.121	-0.0002	0.0017
Cons	92.040	64.463	1.43	0.153	-34.305	218.385
Dy						
Gender	-1.108	0.416	-2.66	0.008	-1.924	-0.291
Schooling	0.066	0.042	1.58	0.113	-0.016	0.147
Marital status	0.730	0.552	1.32	0.1860	-0.351	1.812
Experience	0.024	0.150	1.58	0.115	-0.006	0.053
Farm size	-0.508	0.174	-2.92	0.003	-0.849	-0.168
Price of wheat	-0.0004	0.0009	-0.41	0.678	-0.002	0.001
Seed availability	1.798	0.533	3.37	0.001	0.752	2.843
Row planting	-0.0543	0.458	-0.12	0.906	-0.953	0.844
Training	0.561	0.326	1.72	0.085	-0.077	1.199
Extension	0.234	0.413	0.57	0.571	-0.575	1.043
Take credit	-0.107	0.382	-0.28	0.778	-0.855	0.641
Distance to cooperative	0.656	0.049	1.33	0.183	-0.031	0.163

Rent machine	0.942	0.309	3.05	0.002	0.338	1.552
DAP application	-0.002	0.002	-1.05	0.294	-0.005	0.001
Urea application	0.014	0.007	1.93	0.053	-0.0002	0.029
Net return	0.0003	0.00001	2.75	0.006	9.68e-06	0.00006
Family size	-0.013	0.0497	-0.26	0.794	-0.1105	0.0845
Income other than wheat	0.00001	0.00001	-1.70	0.088	-3.9593	0.2763
Cons	-1.841	1.080	-1.70	0.088	-3.959	0.276
Mills						
lambda	39.993	28.372	1.41	0.159	-15.615	95.601
rho	0.731					
sigma	54.723					

Censored obs. = 64; Uncensored obs. = 76

The Impact of Dairy Feed Technology Adoption on Milk Production in Ethiopia: Evaluation with Matched Difference-in-Differences Technique

Melkamu Tadesse Wazza[1]

Abstract

In Ethiopia, the need to increase dairy productivity is a pressing necessity. To this end, the adoption of relevant technologies has been in place. However, the effect of the interventions was not yet sufficiently and rigorously identified. In this study, the impact of dairy feed technology on milk production in Ethiopia is estimated using a socioeconomic panel data collected from 3,776 rural and small towns' households. Both Average Treatment Effect and Average Treatment Effect on the Treated were estimated using Matched Difference-in-Differences Technique. The combined method reduces the risk of bias in the estimation. The finding shows that the Average Treatment Effect is positive and significant (p<0.05) with a value of 74.43 liters per lactation period per agricultural household. The Average Treatment Effect on the Treated is 90.43 liters per lactation per agricultural household (p<0.01).

Dairy feed technology has a positive and significant effect on milk production in rural and small towns of Ethiopia. However, the overall level of household's milk production is even far below the national potential for some recognized local breeds as well as improved cattle breeds' production record. Also, there are large numbers of agricultural households still dependent extensively on traditional dairy feeds including grazing grasses in a pasture. These necessitate the need to exert further effort to adopt dairy feed technologies at a household level.

Keywords: *Dairy Feed Technology; Milk Production; Impact Evaluation; Matched Difference-in-Differences; Ethiopia*

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1. Background

The agricultural sector in Ethiopia accounts for about 46 percent of national gross domestic product (GDP), 90 percent of exports, and 80 percent of employment (AfDB, 2012). The livelihood of 90 percent of the poor also rely on crop and livestock production (Yu et al., 2011). The contribution of the livestock sub sector is about 27% of the agricultural GDP. Dairy production is also known for its role as a source of income through the sale of raw milk and milk products. A dairy cow serves not only as wealth and insurance but also as a valuable source of household (HH) nutrition. The latter is even more worth as far as children are concerned. This is because chronically undernourished children are economically less productive as adults (Hoddinott et al., 2014).

Despite a large number of cattle, the country remained a net importer of dairy products (Yilma et al., 2011). This is attributed to the subsector's low productivity which is below the level of most developing countries (Melesse et al, 2013; Metaferia et al., 2011; EEA, 2006). Studies indicate that production of milk per animal is extremely low and it is only 1.85 liters per cow per day in Ethiopia (Dehinenet et al., 2014a; SNV, 2008). Consumption of milk and milk products is also below the standards of most developing countries. Felleke et al. (2010) indicated that the per capita milk consumption of Ethiopia is only 20 kgs per annum. This is below the average for Sub-Saharan Africa (25kg) as well as below the average for neighbor Kenya (90kg). It is by far lower than the FAO/WHO recommended amount (200 kgs per capita per annum).

In countries like Ethiopia where there is high population pressure and where both cultivable and grazing land is scarce, expanding cultivated land is not a recommended approach to increase agricultural production. As a result, future growth of agriculture must rely on improved technologies which help to increase agricultural production through its effect on agricultural productivity (World Bank, 2008).

Increasing dairy productivity is a very fundamental issue for improving livelihood and enhancing food security in Ethiopia. The low dairy productivity and hence the low milk production in Ethiopia combined with the need to increase it through dairy feed technology (DFT) resulted in the widespread adoption of proven dairy feed and management technologies both by the government and different development partners (Felleke et al., 2010).

In evaluating the impact of agricultural technologies in Ethiopia, there is relatively higher emphasis given by researchers towards crop production technologies in general and that of fertilizer, improved crop varieties and agronomic practices in particular (Zegeye et al., 2001; Doss, 2003; Matsumoto & Yamano, 2010; Mulugeta & Hundie, 2012). Other similar studies include studies which were focused on evaluation of Productive Safety Net Program (PSNP) (Andersson et al., 2009; Gilligan et al., 2009; Alem & Broussard, 2013); food security program (Berhane et al., 2013); agricultural extension (Dercon et al., 2008; Biratu, 2008); social protection (Weldegebriel & Prowse, 2013); and perception on the adoption of agricultural technologies (Negatua & Parikhb, 1999).

Though there are interventions of the dairy technologies in general and that of DFT's in particular, and resulted in the improvement of productivity and reproduction efficiency of dairy animals somehow (Melesse et al., 2013), to the best of the author's knowledge, the impact of DFT's adoption on milk production is not properly studied and documented. If there are some research works done, their geographical area and scale, or study population as well as methodologies employed or outcome considered were different (Gunte, 2015; Dehinenet et al., 2014b; Amlaku et al 2012 in Melesse et al., 2014; Melesse & Jemal, 2013; Goshu, Kassa, & Ketema, 2013; Goshu et al., 2013; Andersson et al., 2009).

2. Objective of the Study

In countries like Ethiopia where poverty is pervasive and the capital shortage is severe, the wise use of resource is decisive. This condition compels one to evaluate programs and have a clear understanding of the effects of interventions as well as knowledge on how and when to disperse the limited money and effort.

The objective of this study is to evaluate DFT (Dairy Feed Technology) adoption programs and estimate the impact of DFT on cow milk production in rural and small towns' households of Ethiopia. This study will help a lot in providing credible estimates of the effects of the endeavors to make evidence-based policy and planning on the management of the subsector's technology selection and diffusion process. This is because various development actors, planners, policy analysts, consultants and others can make use of the findings on how to improve DFT interventions at various stages of implementations as well as the type of the technology to be adopted. The study will also contribute to the literature gap found in the not-well-studied lacuna of the subsector as well as on impact evaluation methodologies.

3. Theoretical Literature

3.1 Milk Production and Technology Adoption

The major factors which affect milk production include breed of the animal, feed, climate and geographic location, and management factors. Each of the above factors can be exploited with the application of appropriate dairy technologies (Quddus, 2009). Feed technologies are among the important technologies available for the dairy farmer to increase milk production and the associated HH income. Desta (2002 in Kluszczczynska, 2012) indicated that poor nutrition is one of the main reason for low milk yield for local cows. Shortage of feed is also identified as the major challenge for dairy production (Gerosa & Skoet, 2012). The Merriam-Webster Dictionary defines technology as:

"…the practical application of knowledge especially in a particular area… the capability given by the practical application of knowledge" (http://www.merriamwebster.com).

Productivity growth in general and dairy productivity, in particular, can be achieved by two ways. According to Gray et al (2011 in Karanja et al., 2012), these can be either through technological progress and/or through technical efficiency improvement. Accordingly, technological change is based on the development and adoption of new technologies or management systems, and technical efficiency is based on the rate of adoption of available technologies.

Technology adoption is expressed in literature in different ways. Hall & Khan (2002) define technology adoption as the choice to acquire and use a new invention or innovation. Some defined adoption as a discrete state where a farmer can be considered as an "adopter" or as "not an adopter". Rogers (1962 in Feder et al. 1982) considers technological adoption as a (mental) process that happens from first hearing to final adoption. They define the final adoption at an individual (farm) level as:

…the degree of use of a new technology in long-run equilibrium when the farmer has full information about the new technology and its potential (Feder et al.,1982:3).

The rate of technology adoption is also defined differently based on the researchers' subject of interest. For example, Feder et al. (1982) and Akpan et al. (2012) used intensity of adoption as a proportion of area allocated to new variety such as the quantity of fertilizer per acre. Adeogun et al. (2008) in their study aimed at estimating the parameters of the adoption process of hybrid fish defined the intensity of adoption utilization as the proportion of area devoted to hybrid catfish culture. They calculated this by taking the number of pond(s) devoted to hybrid culture divided by a total number of functioning pond(s).

Factors affecting dairy feed Technology Adoption

Technology adoption in general and that of agricultural technology adoption, in particular, is affected by different factors. Household resource base, the degree of intensification and participation in crop/livestock markets, proximity to markets, and physical environments are suggested as the principal factors explaining HH adoption behavior. Institutional and socio-economic characteristics such as tenure type, dairying experience (and crossbred dairying), age, gender, education level of the HH head, HH income, access to extension and credit service, family size, structural farm factors such as size (e.g. dairy farm size, land holding), dependency ratio, and price of the technology/cost are among the factors affecting adoption of agricultural technology in general and dairy technology in particular (Feder et al., 1982; Doss, 2003; Gebremedhin et al., 2003; Melesse et al., 2013).

Impact Evaluation

Gertler et al. (2016) define and elaborate impact evaluation as follows:
"Impact evaluations are a particular type of evaluation that seeks to answer cause-and-effect questions. … looks for the changes in outcome that are directly attributable to the program" (Gertler et al., 2016:8).

In this definition and on others, it is revealed that causality and attribution distinguishes impact evaluation from other kinds of evaluations (Khandker et al., 2010). Causality means that specific action (such as adoption of DFT) leads to a specific, measurable consequence (more milk yield). Attribution implies the acknowledgement (tribute) that ought to be given only to an intervention (Stock & Watson, 2007).

The main challenge of an impact evaluation is to verify the counterfactual-the missing data-what would have happened to the beneficiaries if the program had not existed? (Khandker et al., 2010). Both experimental/randomization or quasi-experimental impact evaluation methods can address the issue of counterfactual and hence causality and attribution. Though randomization can respond to the missing data issue (and hence minimize selection bias in program impacts), there are several concerns with it in a real world such as ethical reservations, external validity, partial or lack of compliance, selective attrition, and spillovers which, in practice, make the treatment assignment to be non-random (Stock & Watson, 2007).

Because of the above practical reasons, quasi-experimental (or natural experiment) is common in social science. This mimic randomization and carried over non-experimental settings. The randomness is due to differences in individual conditions that make it appear as if the treatment is randomly assigned (Stock & Watson, 2007). There are different approaches in quasi-experimental impact evaluation to tackle the basic question of the missing counterfactual. Each of these methods addresses the potential selection bias in program targeting and participation through their own assumptions. The underlying assumptions in each method are the basis for their model specifications. The commonly employed quasi-experimental impact evaluation techniques are discussed hereunder.

Propensity Score Matching (PSM) is one of the quasi-experimental techniques which assume that the selection bias is based only on observed characteristics, and hence the method uses this observed characteristic as a base for computing probability of participating in the treatment. Here, characteristics not affected by the program intervention are used to find a group (large group) of non-participants (a counterfactual or control group) consisting of individuals who have observational similarity to the treatment group as possible. Matching will then be conducted based on this probability (propensity score) to non-participants. The mean difference in outcomes across these two groups will then be calculated as average treatment effect of the intervention. The Propensity score (ps) is defined as the probability of assignments to a specific treatment, conditional on the observed covariates (Rosenbaum & Rubin, 1983;1984). There are also different approaches available for matching participants and nonparticipants on the basis of the ps (Caliendo et al., 2005).

Difference-in-Difference (DiD) is the other quasi-experimental technique where data on participants and nonparticipants collected before and after program implementation are used to compare and estimate program impact. The DiD method assumes that time invariant unobserved selection is present and that the treatment effect is determined by taking the difference in outcomes across treatment and control units before and after the program intervention (Gertler et al., 2016; Khandker et al., 2010). The mean results of the outcome indicator for the treated and non-treated will be used to estimate impact through the differences in the mean outcome of interest. The above two methods, i.e., PSM and DiD can be combined and become more useful (White & Raitzer, 2017; Khandker et al., 2010).

Impact Estimators

The term treatment effect refers to the causal effect of a given treatment/intervention (e.g., DFT) on an outcome variable of interest (e.g., total milk production) (Rosenbaum & Rubin, 1983).

AVERAGE TREATMENT EFFECT (ATE): this is the mean (average) effect of an intervention on two different groups that are assigned to treatment (intervention) and groups that are not assigned to treatment which serve as control groups. It is defined as the difference between the outcome of the participants in the presence of an intervention and the outcome of the non-participants in the absence of the intervention. ATE is the treatment effect for the overall target population in the study subjects (treated and untreated) together (Khandker et al., 2010; Gertler et al., 2016).

AVERAGE TREATMENT EFFECT ON THE TREATED (ATET): this indicates the average gains for participants, conditional on these participants receiving the program. ATET is then the average treatment effect for treated HHs (Gertler et al., 2016).

POTENTIAL-OUTCOME MEANS (PMOs) or COUNTERFACTUAL OUTCOMES): the counterfactual outcome is the missing data in impact evaluation where for a treated subject that did actually receive treatment, an outcome which is not observed and would have experienced had the subject not been exposed to the intervention (Khandker et al, 2010; StataCorp, 2015).
Assumptions on Estimating Treatment Effects

COMMON SUPPORT ASSUMPTION (OVERLAP ASSUMPTION): this assumption requires that there needs to be a region of common area where HHs with the same characteristics have a probability of being both participants and nonparticipants (Khandker et al., 2010; Gertler et al., 2016). Mathematically, it is represented with: $0 < P(T_i = 1|X_i) < 1$. By this condition, each HH has greater than zero likelihood of receiving each treatment level. The assumption is satisfied when there is a possibility of getting observations in both the control and the treatment groups at each combination of covariate values (StataCorp, 2015).

CONDITIONAL INDEPENDENCE (UNCONFOUNDEDNESS) ASSUMPTION: is the condition that given a set of observable covariates X that is not affected by treatment, potential outcomes Y are independent of treatment assignment (Khandker et al., 2010).

EQUAL TREND (PARALLEL-TREND) ASSUMPTION: one important concern with DiD method is that it will not help us to take away the difference between treatment and control groups that change over time. However, to have a valid estimate of the counterfactual, it is required that no such time-varying differences exist between the two groups (Gertler et al., 2016).

Empirical Literature

The Ethiopian rural dairy system contributes 98% the total national milk production and it is composed of mixed crop-livestock system and agro-pastoral system. The production is mainly (82%) from the local zebu breeds. The exotic breeds and hybrids are only 3% of the total milking cows (Felleke et al., 2010; Yilma et al., 2011). The local breed population in Ethiopia is still high (about 99.28% of the total cattle); and, only a few (less than 1%) are hybrid and exotic breeds (CSA, 2009). Most of the milk produced in the rural Ethiopia (46.36%) is used for household consumption and only 5.9% was sold (CSA, 2015). The rural dairy system is also the main user of agricultural extension services.

The challenges for the development of dairy production in Ethiopia include among others shortage of feeds especially agro-industrial by-products, lack of market outlets for milk and milk products, inefficient and untimely artificial insemination (AI) services and poor semen quality, lack of cross-breed heifers, shortage of water and inefficient and inadequate milk processing technologies (Yilma et al., 2011).

The adoption of dairy technology in Ethiopia date back to early 1950's when 300 Friesian and Brown Swiss dairy cattle breeds were received from the United Nations Relief and Rehabilitation Administration (UNIDO 2009 in Melesse et al., 2013). Since then there have been different livestock interventions undertaken across the nation. These program and project interventions were aimed at introducing new technologies and knowledge both in terms of technical, material and financial support to the livestock and dairy sub-sector (Felleke et al., 2010).

There are different studies conducted with regard to dairy production and performance as well as dairy technology adoption in Ethiopia. For example, a study conducted in Ada'a and Lume districts show that breeding, feed, health management and husbandry technologies were among the widely adopted technologies in Ethiopia. Breeding technologies being the most adopted (Melesse et al., 2013).

Studies conducted in Ethiopia and Kenya on dairy farming indicate that feed costs are the major costs associated with production. Those studies further show that inadequate amount and inferior quality of feed are the major challenges to enhance livestock productivity (Thorpe et al., 2000; ESAP 2006). This is then a necessity to cultivate improved animal feed and then feeding cattle.

Dairy farming studies conducted in Ethiopia and Kenya indicate that feed costs are the major costs associated with production. Those studies further show that inadequate amount and inferior quality of feed are the major challenges to enhance livestock productivity (Thorpe et al., 2000; ESAP 2006). This is then a necessity to cultivate improved animal feed and then feeding cattle.

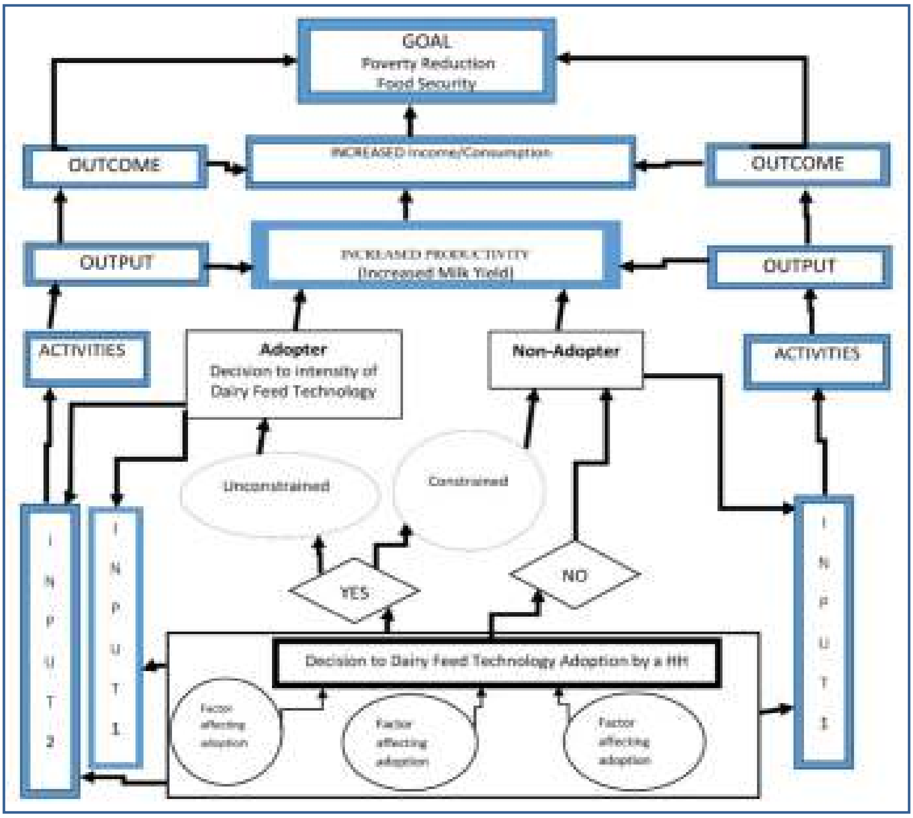
The earlier studies on technology adoption are concerned mainly with descriptive analysis on the use and diffusion of agricultural technologies such as new seed varieties and associated technologies like fertilizer and irrigation. But now, care is to see the impact of technology adoption on various social issues implying the importance of methodological concerns to address the matter appropriately (Doss, 2003).

4. Conceptual Framework

Impact evaluation can be depicted by the principle of logical framework (log frame) design which helps to identify the results' indicators and assess the program's stated objectives. The logical frame begins with the supply of different resources (inputs) and subsequently end with different chains of development results (Bardini, 2001; EC, 2002; Rogers, 2012). The effects of dairy feed technology (DFT) adoption as an intervention can be seen with a logical framework principle by examining how its application could bring a chain of development results (including milk production).

The DFT adoption mechanism and the possible results chain is explained by the conceptual framework on Figure A. The adoption of different DFT by farmers in a given period of time should first be considered from the point of maximization of the expected utility (expected profit), which is subjected to different constraints. This depends on farmer's distinct choice of feed technology from among different combinations of technologies. The technology combinations could be traditional or a set of components of the modern technology package (Feder et al., 1982). Thus, adoption decision to a dairy technology is subject to different factors surrounding the farmer's condition. Once a farmer decides to adopt or not, and also constrained or not-constrained to utilize the available DFT, the farmer will be exposed to different inputs depending on his/her choice. Those farmers who didn't adopt the modern DFT will be continuing with the traditional feed technologies (input 1). But those farmers who choose to adopt the modern DFT will be exposed to both traditional (a certain amount of input 1, eg. grazing in a pasture) and modern feed technologies (input 2, eg. concentrate and other packages). The adopters will then select among the different modern DFT packages subject to their constraints. This exposure to feed types will then lead farmers to two pathways: the non-adopters' pathway having only traditional dairy technologies, and that of adopters' having different feed adoption intensities. Once the farmers adopt any of the available feed technologies subject to their constraints, they will continue to be engaged in their respective activities, and they will have their own pathways of results/objectives (Figure. A).

Figure A: Dairy feed technology adoption process and its possible results chain with a logical framework design for impact evaluation



Source: Own Construction

Caption

Technology adoption is considered to occur in two-stage processes. A farmer first needs to be willing to adopt DFT. The farmer must then pass distinctive constraints he/she faced. The choices available include not only the traditional choices (input 1) but also the modern/improved technology packages (input 2). Non-adopters utilize input 1 only. But adopters make use of both input 1 and 2 in different intensities. The effect of technology adoption on milk yield and others will be revealed along the results chain with each pathway to be followed.

5. Research Methods

5.1 The Study Area and Data

Ethiopia is in North East Africa with latitude and longitude of 8° 00 N and 38° 00 E. The country is one of the most populous nations in the continent next only to Nigeria. The total population and rural population projection of the country in 2017 are estimated to be more than 94 million and 75 million, respectively. The country is also known for its huge livestock population (49.3 million cattle) both in Africa and in the world (Yilma et al., 2011).

This research relies on multi-topic panel data from the two recent waves from the Ethiopia's Living Standards Measurement Study (LSMS), which were conducted by the Central Statistical Authority of Ethiopia (CSA) with technical support from the World Bank in the years 2011 and 2013. The data on the two waves focus on HH's welfare characteristics and agricultural activities. The samples were represented from 290 rural and 43 small towns enumeration areas with a successfully re-interviewed 3,776 HHs from 333 enumeration areas. It is also representative for the four large regions (Oromiya, Amhara, SNNP, and Tigray) of the country and also to the other regions taken altogether (Afar, Benishangul-Gumuz, Gambella, Dire Dawa, and Harari) (CSA & LSMS, 2013;2015).

Program Intervention and Variables

Nature of the intervention (Program Treatment)

The livestock programs and projects including the DFT are carried out in Ethiopia both by the government and other development partners. They implemented different types and packages and farmers utilized the DFTs by selecting any type and amount from those available to them.

Operational definition of variables and technical terms

Different variables were constructed based on their definitions. These include, for instance, construction of milk production per liter per lactation period, farm- and non-farm income to construct total household (HH) income, use of elevation for defining traditional agro-ecological zones, use of fields and parcels to construct total HH landholding, use of cattle in HH for constructing

Tropical Livestock Units (TLU), use of HH size to construct Adult Equivalent size, etc. Proper data cleaning was also carried out.

HOUSEHOLD (HH): Unit of analysis in this study is a household (agricultural household). Hence, the dataset were merged using the unique identifier, i.e., Household's identification number (id). The CSA/LSMS document (CSA & World Bank, 2011:7) defines a household as:

"…is either a person living alone or a group of people, either related or unrelated, who live together as a single unit in the sense that they have common housekeeping arrangements (that is, share or are supported by a common budget).

A household is considered to be an agricultural household when at least one member of the household head, reference person or main income earner is economically active in agriculture (UN, 1984: 157) .

RURAL and SMALL TOWNS: The CSA/LSMS (2011) indicates that small towns are towns with the population of fewer than 10,000 people and with urban settings. The study considers those areas with less population and sparse human settlement than the small towns and having no urban settings as rural areas.

DAIRY FEED TECHNOLOGY (DFT) ADOPTION: package components of the DFT, like that of any other agricultural technology packages, though important for better results if used together, may not be used together (Feder et al., 1982). Hence, the farmer may adopt complete package or any of the accessible components due to various constraints imposed upon him. In developing countries like Ethiopia, a farmer also continues to adopt different DFT while still maintaining the traditional practices. Thus, feed technology adoption in this study is considered as percent utilized of one or any combination of those available DFT.

FEED TECHNOLOGY NON-ADOPTERS: grazing grasses in a pasture is traditional practice and low productive way of rearing livestock. Hence, it is not considered as DFT in this study. So, HHs using amount greater than or equal to 90% of feed materials from grazing grasses in a pasture, or a combination of grazing grasses and using only 10% crop residues are considered non-adopters. For impact evaluation, adopters are defined based on the 2013 survey data. The crop residue combination with such amount is necessary because any farmers in the mixed crop-livestock production system have more chance of feeding their cattle with crop residues at least in the main harvest season. Excluding this fact will not help to explore the reality on the ground. Hence, in this study, crop residue utilization less than or equal to 10% was not considered to be a technology adoption.

FEED TECHNOLOGY ADOPTERS: as milk production requires a lot of energy and other nutrients, consuming different types of improved feed types like supplementary feeds and concentrates is related to increased milk production and productivity (Lukuyu et al., 2007). Utilizing these feed types require improved methods of harvesting, handling and storing. And hence, HHs utilizing a combination of crop residue, hay, improved feed and/or agro-industrial by-products are considered to be feed technology adopters. In this study, a combination of any one of these feed types when utilized more than 10% are considered to be DFT. But, crop residue, if utilized alone, it should be utilized more than 10% to qualify as DFT.

TREATMENT and OUTCOME VARIABLES FOR IMPACT EVALUATION: DFT adoption is a treatment (intervention) variable. The outcome variable used is the amount of milk production. HH's total milk production per lactation period in days measured in liters is used to see the impact of the DFT. This variable is constructed from the dataset by changing all other units like kilograms, grams, and other traditional units like cups and glasses into the common and standard measurement by using the international metric system. Average lactation period for each HH in months is found in the data set. The total HH milk production in liters (TMilk) is then calculated as follows:

TMilk= [Milk yield/cow/day (liters)] * [number of lactating cows in the HH] *[average lactation period (days)]

PARTICIPANTS AND NON-PARTICIPANTS: participants are those HHs who actually get involved in adopting DFT. Both groups (treated and control) are not participants in time period one (2011). But, in time two (2013), we have both participant and non-participants. Non-participants are those HHs who actually are not get involved in adopting DFT as per the requirement in this study. These groups are existing in both time-one and time-two.

TREATMENT GROUPS and CONTROL GROUPS: Treatment groups are those participants who actually get involved in adopting the treatment. But those participating HHs in time two are also treatment groups in time one. So, treatment groups are available in both time periods. Control groups (untreated groups) are those non-participant HHs which are identified by having propensity score (ps) closest to the participants. They then serve as a comparison group. By this, they help to estimate the counterfactual outcomes.

PROPENSITY SCORE (PS): the propensity score (ps) is the probability that each HH is participating in DFT adoption in the second period (i.e., 2013) given variables (X) of observed characteristics of the first period. It is a single number ranging from 0 to 1 and it outlines all of the observed characteristics.

MATCHING: is the process of finding those HHs' which could be the closest artificial comparison group from a sample of non-DFT adopters (non-participants) to the sample of those HHs who actually adopted DFT (participants). Based on the propensity score (ps) obtained from baseline characteristics, treated and untreated comparison groups will be matched with panel set using inverse-probability-weighted regression adjustment.

Variable Choices and Explanation

The major, common and contextual variables are allowed in the specification based on their literature support. Variables which might be affected by DFT and those variables hypothesized to be associated with DFT but not with milk production are not kept in the model. Several trial and errors were run among variables to specify that the ps are balanced across adopters and non-adopters within blocks of the ps. The different explanatory variables which were supposed to affect the adoption of DFT are described in Table A.

Table A: Summary of explanatory variables used (Source: Own Presentation)

Explanatory Variables' Name	**Measurement of the Variables**
Age of Household (HH) Head	Age dummies: dAge1= $\begin{cases} 1 \; if ageof HHheadis < 30 \\ 0 \quad else \end{cases}$ dAge2= $\begin{cases} 1 \; if ageof HHheadis \geq 30 \; and < 50 \\ 0 \quad else \end{cases}$ dAge3)= $\begin{cases} 1 \; if ageof HHheadis \geq 50 \\ 0 \quad else \end{cases}$
Sex of HH head	Male_dummy= $\begin{cases} 1 \; if sexof HHheadismale \\ 0 \quad if female \end{cases}$
Family size in terms of adult equivalent (AE_hh)	Converted from household size and age data into adult equivalent size
HH Landholding (Total)	Crop fields in hectare (constructed from meter square) and transformed into logarithm (log_landH)
HH distance to the nearest market	In kilometers (dist_market)
Total livestock holdings	Tropical Livestock Unit/ (TLU) Constructed and transformed into logarithm
Rural indicator	Dummy (rural_dummy): = $\begin{cases} 1 \; if aHHisresidinginruralareas \\ 0 \quad if theHHi \text{灼/獲}esidinginsmalltowns \end{cases}$
Access to post planting crop/agricultural extension	agri_extn_dmy = $\begin{cases} 1 \; if Yestopostplantextensionparticipationby HHhead \\ 0 \quad if No \end{cases}$
Traditional agro-ecological zones	Dummy (dtAEZ) = $\begin{cases} 1 \; if highlands(Dega, Wdega, Wurch, Kur) \\ 0 \quad if Lowlands(Bereha, \text{艦}olla) \end{cases}$
Shock (drought)	ddrought = $\begin{cases} 1 \; if Yes(encountereddrouAhtasaseverechalle\text{Ⱃ}ge) \\ 0 \quad if No \end{cases}$

Agricultural Engagement	FarmT_dummy= $\begin{cases} 1 \; if engaged in livestock only \\ 0 \quad if both in crop and livestock \end{cases}$
Dry season water accessibility by HH	Dwater_dumy= $\begin{cases} 1 \; if \; access \; to \; dry \; season \; water \; is \; easy \; to \; the \; HH \\ 0 \; if \; difficult \end{cases}$
Years of schooling of HH head	Years of schooling of the HH head from illiterate (cannot read and write up to Ph.D.) (Scholing_yrs)
HH access to credit	credit_dummy $\begin{cases} 1 \; if \; yes \; to \; access \; to \; credit \; service \; by \; the \; HH \\ 0 \; if \; No \end{cases}$
Gross annual HH income	log_tot_hh~2; transformed to logarithm; measured in Ethiopian Birr (constructed from farm and non-farm HH incomes)
Cost of livestock production	cost_prdn_ls costs associated with feed, vaccine and drug for livestock in ETB
Region dummies	Regional States of Ethiopia
dOromiya	$= \begin{cases} 1 \; if Oromiya national region \\ 0 \quad else \end{cases}$
dAmhara	$= \begin{cases} 1 \; if Amhara national region \\ 0 \quad else \end{cases}$
dSNNP	$= \begin{cases} 1 \; if South NNP national region \\ 0 \quad else \end{cases}$
dTigray	$= \begin{cases} 1 \; if Tigray national \; region \\ 0 \quad else \end{cases}$
dOthers	$= \begin{cases} 1 \; if Afar, BGumuz, \; Gambela, Dire Dawa, Somali, Harari regions \\ 0 \quad else \end{cases}$

Model specification and the matched Difference-in-Difference procedure

Randomization trials cannot work because of the presence of program targeting and self-selection into programs. When only two-period data are available, DiD method is employed (Wooldridge, 2012). But using DiD alone will limit the study to consider only unobservable differences. When DiD is combined with PSM, the shortcomings of both methods will be belittled (Khandker et al., 2010; Cuong, 2015). Hence, a combined DiD-PSM (matched Difference-in-Differences technique) was employed.

The ideal DiD estimator needs a comparison of participants and nonparticipants before and after the program intervention. This implies that baseline survey (initial situation) of both non-participants and (later) participants, as well as additional (follow-up) survey of both groups need to be conducted so that the difference is calculated between the observed mean outcomes for both groups before and after the intervention (Khandker et al., 2010; Gertler et al., 2016). But in practice, a baseline survey is difficult to obtain. The baseline data problem is worse in developing countries (Bamberger, 2010). In this study, too, there were no baseline data. However, the problem was addressed by appropriate specification and procedure.

The datasets for the study are available for both t (2011) and $t + 1$ (2013) but the program was already in place in t (2011). In such case where there is no strict before and after scenario, the DiD method can still be implemented with some alternative ways (Cuong 2010a; Doss, 2003; Feder et al., 1982).

One alternative to deal with the no-baseline condition is achieved by discarding all program participants the initial period (t) from the data. This was possible because the group of non-participants in both periods (t and $t + 1$) were large enough. The usual PSM is done to find the ps, p(x), based on all observed covariates X from the baseline data, i.e., from those observable characteristics not affected by program participation. While doing this, the balancing property of the PSM was assured to be satisfied. This guarantees that the HHs with the same ps have the same distributions of all covariates for all the blocks categorized. The common support area is also identified. This process results in matched sample composed of closest comparison group from a sample of nonparticipants to the sample of program participants. This helps to reflect any observable heterogeneity in the initial conditions between the two groups.

The matched sample HHs in the initial data created were kept for the subsequent merge with the panel $t + 1$ data. The DiD method was then employed by matching with data in $t + 1$ (2013) treated units to untreated units and compute the difference in time in terms of mean outcomes for the two groups. Taking the differences in outcomes over time helps difference out time-invariant unobserved heterogeneity and thus potential unobserved selection bias.

Impact Estimation with the inverse-probability-weighted regression adjustment (IPWRA) estimator

It is difficult to estimate the ATE of DFT adoption by simply subtracting the sample means for the treated and control HHs. This is due to the fact that there are many other factors (covariates) which are related to the counterfactual outcomes and related also to DFT itself. But, once the covariates were specified and the analysis was conditioned on those covariates, the remaining effects on DFT are not related to the counterfactual outcomes. The teffects estimation have many desirable properties for measuring treatment effects (UW, 2015). The counterfactual issue will be solved by the teffects conditioning on those covariates to make DFT and milk production independent. StataCorp (2015) defines the treatment effects that can be estimated from observational data using the teffects command as follows:
Average treatment effects (ATES) is the average effect of the treatment in the population.

$$ATE = E(\mathcal{Y}_1 - \mathcal{Y}_0) \qquad \textbf{(1)}$$

Average treatment effects on the treated (ATET) is the average treatment effect among those that receive the treatment (T):

$$ATET = E(\mathcal{Y}_1 - \mathcal{Y}_0 | \mathrm{T} = 1) \qquad \textbf{(2)}$$

Potential-outcome means (POMs): if the treatment level is defined to be, T, then POM for treatment level Tis defined as the average potential outcome for that treatment level:

$$POM_T = E(\mathcal{Y}_T). \quad \textbf{(3)}$$

The IPWRA estimator is a doubly robust estimator that combines the outcome modeling strategy of regression adjustment (RA) and the treatment modeling strategy of inverse-probability weighting (IPW) (White & Raitzer, 2017; StataCorp, 2015). The RA model uses linear regression models to predict the outcomes of each subject and the IPW model uses a logistic regression model to predict treatment status. The IPWRA estimator combines both models. The main advantage of IPWRA estimator is that, although it requires us to build two models, correct specification of either of the two models still allows accurate estimation. And after all, when the regression function is correctly specified, the weights do not affect the consistency of the estimator (StataCorp, 2015). The code used for obtaining ATE, ATET and POMs in such cases of weighted least regression is given by (White & Raitzer, 2017; StataCorp, 2015):

$$teffects\ ipwra\ (\boldsymbol{Y}\ x_1 \ldots\ x_k, linear)(\boldsymbol{T}\ x_1 \ldots\ x_k, logit), atet\ vce\ (robust)\ldots \quad \textbf{(4)}$$

Where Y is total milk production (linear outcome variable); $x_1 \ldots x_k$ are covariates; linear implies the linear regression model used to predict the outcome variable; T implies DFT (dummy) and logit imply the logistic regression model used to predict treatment variable; atet and ate are ATET and ATE options; vce (robust) is for robust standard error to prevent the problem of heteroscedasticity.

6. Results

6.1 Descriptive statistics

6.1.1 Description on the sample and outcome variable

Table B represents the sample used in evaluating the impact. We don’t have participants at time 1 (i.e., 2011). Non-participants and treatment groups at time 1 were 3421 and 1516 HHs, respectively. At time 2 (i.e., 2013), the number of participant and non-participant HHs were 1686 and 1773, respectively. The treatment groups at time 2 were 1686 HHs.

Table B: Frequency of sample households

Survey Year	Sample size (n)	Participants	Non-participants	Treatment Group	Control Group
2011	3421(49.72%)	0	3421	1516	1905
2013	3459(50.28%)	1686	1773	1686	1773
Total	6880	1686	5194	3202	3678

Source: Own presentation with CSA/LSMS panel data

The total HH milk production is a continuous variable measured in liters. The distribution for milk production by HH was found to be positively skewed and leptokurtic ($p<0.01$) (sktest). The statistical description of the total milk production between adopters and non-adopters is presented in Table C.

Table C: Total milk production in liters per lactation period between adopters and non-adopters

Participation dummy	Min	Mean	SD	Max
0 (Non-participants)	0	305.4434	930.2663	18240
1 (Participants)	0	325.1105	914.7753	23760
Total	0	311.0316	925.8266	23760

Source: Own presentation with CSA/LSMS panel data

Two-sample Wilcoxon rank-sum test shows that the total annual milk by HHs is statistically significantly higher in the group of adopters than in the group of non-adopters ($p<0.01$). This indicates that there is correlation between DFT assignment and milk production output that is conditional on observed covariates. In such cases, the treatment assignment is not ignorable. This justifies the use of matching methods to correct sample selection bias.

Description of Results of Propensity Score Matching and its quality

The result of matching on observable initial conditions by regressing 2013 participation variable on 2011 explanatory variables is shown in Table D.

Table D: Baseline propensity scores matching sample

Survey Year	Sample size (n)	Participants	Non-participants	Treatment Group	Control Group
2011	3421	-	3421	1516	1905
Total	3421	-	3421	1516	1905

Source: Own presentation with CSA/LSMS panel data

The balance on the propensity score (ps) indicated that the balancing property was satisfied. The observable heterogeneity in the baseline condition were then controlled by the predicted scores. Among adopters, the predicted ps range from .0395363 to .9514983, with a mean of .6296822. The predicted ps among non-adopters range from .030245 to .9159817, with a mean of .4754756. Thus, the extent to which distributions of ps in DFT adopters and non-adopters overlap is identified by the common support region of [.03953635, .9159817]. This is shown in Table E. Hence, those HHs with estimated ps less than .03953635 and greater than .9159817 were not included in the matching process.

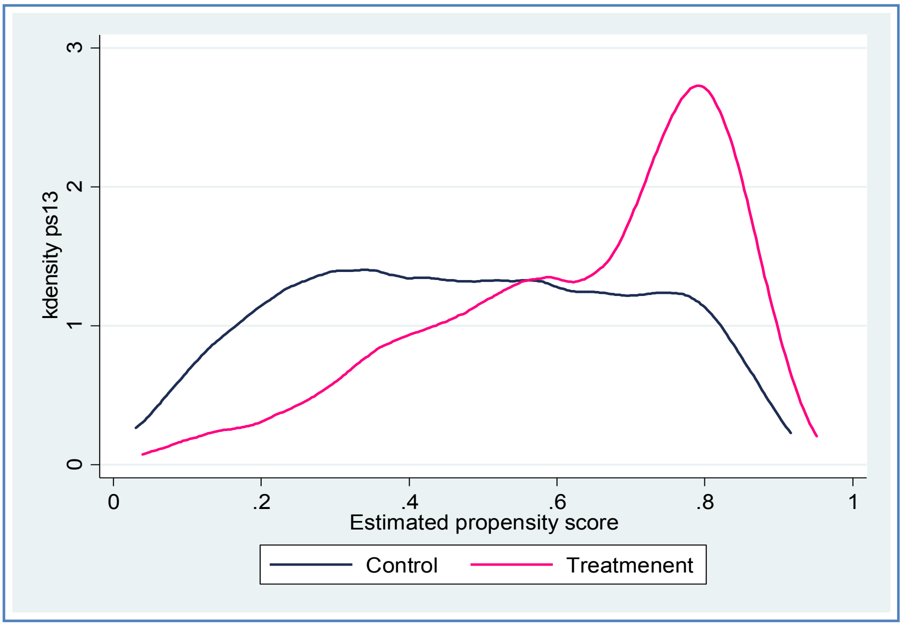
Table E: Summary statistics of propensity scores for both participants and non-participants

Participation dummy	Frequency on support	Frequency Off support	Min	Mean	SD	P50	Max
Non-adopters	1888	4	.030245	.4754756	.2238512	.4788163	.9159817
Adopters	1529	0	.039536	.6296822	.1983588	.6836424	.9514983
Total	3417	4	.030245	.559582	.2238687	.586938	.9514983

Source: Own presentation with CSA/LSMS panel data

The ideal condition for the common support is that the ps distributions between the two groups would overlap entirely (Lanehart et al., 2012). The results of the ps distribution, histograms of estimated ps and the kernel density (Figure B) for both groups show that the ps distribution for the two groups are alike in a wide range indicating that the groups could match very well.

Figure B. Kernel density of propensity scores distribution. Source: Own presentation with CSA/LSMS panel data. Note: Print requires color.



From the control group, 55.19% (1888/3421) HHs and from the treated group, 44.69% (1529/3421) HHs were on the common support. Only 0.0012% (4/3421) HHs in the control groups were off the common support. This indicates that we have sufficient observations from both groups.

The observable characteristics of the two groups should be approximately equal. This was checked successfully with both covariate plot for each variable and with the use of over identification test. The balance of the covariates can be seen visually from figure C1 and C2 taking HH land holding and access to post plant agricultural extension service as an example.

Figure C1

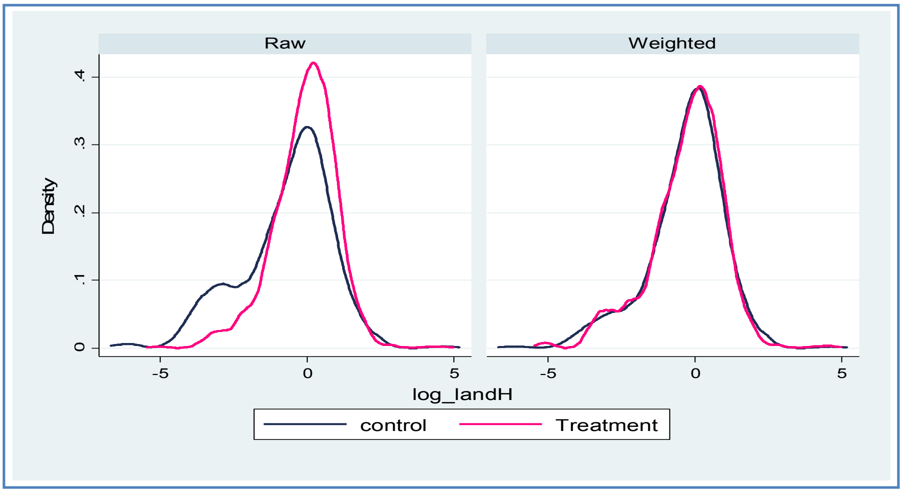
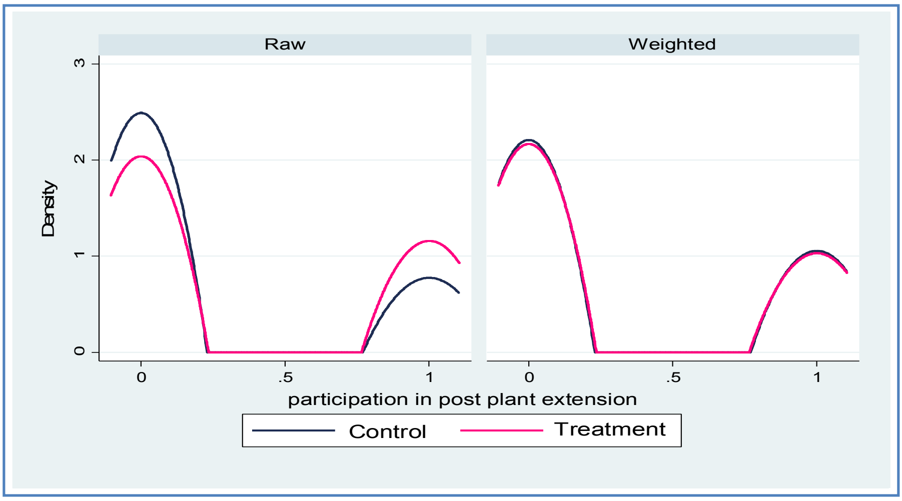


Figure C2



C1 and C2 (above). Covariate balance plot (Household Landholding and participation in agricultural extension).

Source: Own presentation with CSA/LSMS panel data. Note: Print requires color. Note: Print requires color.

Caption:

Balanced data between the covariates of the two groups can be achieved by reweighting the observational data (like household's landholding and participation in post plant agricultural extension). This can be visually detected with balance plot in the figure. The more the weighted samples are indistinguishable, the more the estimated propensity score balance the covariate. The result here also indicates that the weighted distributions (densities) of land holdings between the two groups (Control and Treatment) are approximately equal. In such case, we successfully mimic randomization.

Description of results of difference-in-difference matching

The matching sample obtained from wave two data based on the ps of baseline covariates (wave one data) is presented in Table F.

Table F: Difference-in-difference matching sample

Survey Year	Sample size (n)	Participants	Non-participants	Treatment Group	Control Group
2011	2220(52.00%)	-	2220	1197	1023
2013	2049(48.00%)	1213	836	1213	836
Total	4269	1213	3056	2410	1859

Source: CSA/LSMS panel data with own calculation

The matching sample shows that there were no participants in time one and in time two, there were a total of 1213 HHs participating in program intervention, i.e., DFT. From the total sample obtained after difference-in-difference matching (n=4269), 52.00% are from t (2011) and 48.00% are from $t + 1$ (2013). The total percent for treated group and control group is 56.45% and 43.54%, respectively.

Results on Treatment Effects (Impact Estimates)

Results on Average Treatment Effects

The output on Average Treatment Effect (ATE) shows that the ATE was positive and statistically significant ($p<0.05$) (Table G). The finding indicates that DFT adoption causes dairy milk production of the agricultural HHs to be increased by an average of 74.43 liters per lactation period per HH from the average of 227.29 liters per lactation for those HHs who did not adopt DFT.

Table G: Treatment effect results for ATE and ATET

Total household milk production in liters per lactation period	Coef.	Robust Std. Err	Z	p>|z|	[95% Conf. Interval]	
Average Treatment Effect (ATE)	74.425	28.737	2.59	0.010	18.10195	130.7484
Potential-Outcome Mean (POmean)	227.288	19.716	11.5	0.000	188.6458	265.9295
Average Treatment Effect on the Treated (ATET)	90.432	34.72	2.60	0.009	22.3739	158.4904
Potential-Outcome Mean (POmean)	235.213	23.663	9.94	0.000	188.8354	281.591
ATE in percentage	.327449	.146829	2.23	0.026	.0396699	.6152286
ATET in percentage	.384469	.175016	2.20	0.028	.0414435	.7274944

Source: Own presentation with CSA/LSMS panel data

Results on Average Treatment Effects on the Treated

The result of Average Treatment Effect on the Treated (ATET), i.e., on those HHs who did, in fact, adopt the DFT, show that the ATET was positive and statistically significant ($p<0.01$) (Table G). The finding indicates that among DFT adopting agricultural HHs, DFT causes milk production to be increased by an average of 90.43 liters per lactation from the average of 235.21 liters per lactation that would have occurred if these HHs had not adopted the feed technology.

Treatment Effects in percentage

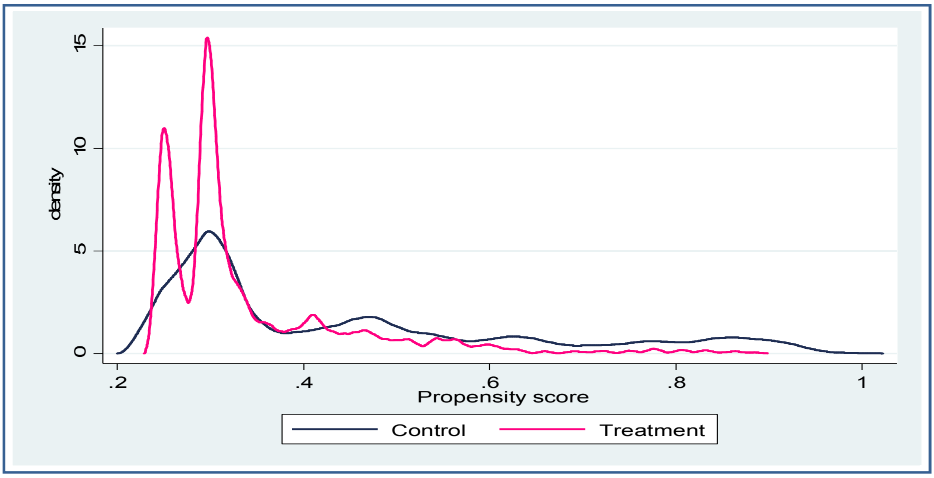
The ATE as a percentage of the mean milk production that would occur if no agricultural HHs adopt is employed for the purpose of easy scaling and interpretation of the result. The output showed that DFT adoption increases the per lactation milk production of an agricultural HH on average by a statistically significant 32.7 percent ($p<0.05$). The average effect among the HHs who actually adopted DFT was also statistically significant 38.4 percent ($p<0.05$) (Table G).

Post-estimation checks for assumptions

Post-estimation check for the Overlap Assumption

One of the assumptions required in estimating treatment effects is the overlap assumption. The overlap here means that adopters with similar non-adopters can actually be matched. Thus, it is checked to see whether violated or not by drawing the overlap of the density of predicted probabilities between treated and control groups after estimating the ATE/ATET of DFT on milk production. When this assumption is not violated, the unobserved outcomes for the HHs can be predicted and accounted for. The estimated probability of a non-DFT-adopting HH is a non-adopter and the estimated density of the predicted probabilities that DFT-adopting HH is a non-adopter is presented in Figure D.

Figure D: Post-estimation test showing no evidence for violation of overlap assumption



Source: Own presentation with CSA/LSMS panel data. Note: Print requires color.

Caption:

The correct estimation of counterfactual milk yield needs matching technology adopted households with those of similar non-adopters. This is possible only if there is no evidence for rejecting overlap assumption, or if the assumption holds true. The test result here indicates that each household have a positive probability of adopting the dairy feed technology. This means that we can accurately estimate the impact of DFT.

It can be visually detected from the overlap graph that the estimated density has no mass around 0 and 1. Rather, the estimated densities have most of their respective masses in the regions on which they overlap each other. This means that there is a likelihood of getting observations in both the control and the treatment groups at each combination of covariate values. Thus, there is no support that the overlap assumption is violated. This ensures that the predicted inverse-probability weights do not get too large and this, in turn, means that the IPWRA estimators have the double-robust property for the functional form combinations used. Hence, the effects of DFT on milk production can be estimated reliably.

Post-estimation check for Conditional Independence Assumption

In this study, assignment of households to the DFT adoption is assumed to be independent of the covariates. This can be checked by verifying whether the distribution of the covariates is balanced over treatment levels or not. The weighting in observational covariates was checked both by exploratory methods (Figure C1 and C2) and by formal test. Several trial and errors in specifying the model were made to achieve a superior balance. Over--identification test result applied (Stata 14) indicted that we do not reject the null hypothesis that the specified treatment model balances the covariates. Hence, the model is well specified and the treatment estimates are credible.

Placebo Regression for Robustness Check

Unbiasedness for a panel data form only two perids can be checked by placebo regression (Gertler et al., 2016). Here, the outcome variable was replaced by another fake outcome, i.e., outcome not affected by DFT. Other researchers who used placebo regression in such cases include Abebaw and Haile (2013 in Elias et al., 2013) and Cunguara and Moder (2011 in Elias et al., 2013). In this study, the placebo regression was employed using adult equivalent size as (a fake) outcome variable (Table H). The treatment variable was also included in the model.

Table H: Placebo regression using Adult Equivalent size

Adult Equivalent size (AE_hh)	Coef.	Robust Std. Err	Z	p>|z|	[95% Conf. Interval]	
Average Treatment Effect (ATE)	-0.0569	0.063	-0.9	0.368	-0.18088	0.670505
Potential-Outcome mean (POmean)	3.6379	0.054	67.7	0.000	3.53257	3.743216
Adult Equivalent size (AE_hh)						
Average Treatment Effect on the Treated (ATET)	-0.0373	0.0700	-0.53	0.594	-0.174623	0.100026
Potential-Outcome mean (POmean)	3.7289	0.06505	57.32	0.000	3.6014	3.8564

Source: Own presentation with CSA/LSMS panel data

The outcome variables are already known not to be caused by DFT. The regression on the above placebo outcome was conducted separately to check for both ATE and ATET. The findings for both ATE and ATET indicate that DFT does not have statistically significant causality on Adult Equivalent. This suggests that there are no significant omitted variables and unobserved characteristics are not influencing program participation that affects the impact estimates obtained. Therefore, the unconfoundedness assumption (conditional independence assumption) can be maintained. Hence, the causal interpretation of the results is plausible.

Also, though it cannot be proved, the validity of the assumption of equal trends can be judged with the help of the fake outcomes (Gertler et al., 2016). Thus, the results on the fake outcomes above (Table H) indicate that the comparison groups for DFT adopting groups are not flawed. This means that the counterfactual estimates obtained were valid. Consequently, there is no evidence that, in the absence of the DFT intervention, the HH's milk production in the DFT adopting groups would not have moved in tandem with the milk production of that of the non-adopting comparison group's. This means that the estimated treatment effects are not biased and are valid.

6. Discussion

Due to the difference either in methodology, treatment type or outcome interest, the impact evaluation findings on the specific issue to compare with are lacking in the Ethiopian context. But, somehow related work is the one done by Dehinenet et al. (2014c) on the impact of dairy technology adoption on livelihoods by using PSM from cross-sectional data. Conducting this study in selected regions of Ethiopia, they found an ATET estimate 42% higher total milk consumption per day at farm level by dairy technology adopter HHs than non-adopters. In their findings, the dairy technology adopter HHs sold 1674 liters more milk per annum than the non-adopters. Not only their outcome variable is different from this study, but also their study was conducted on purposively selected high dairy potential areas and using only improved blood cattle. They associated the technologies with improved breeds and improved techniques in feeding, breeding, and animal health to increase milk productivity. But the positive effect of dairy technology is clearly visible.

The study sample and, of course, the reality in Ethiopia (Felleke et al., 2010) is that the total number of the local zebu cattle by far outweigh the total number of cattle population. In this study, for instance, 98.75% of the total cattle population is local breeds. Ahmed et al. (2004) and Yilma et al. (2011) indicated that the milk production potential of the zebu breed in the highlands mixed crop-livestock system of Ethiopia is 400-500 kilograms of milk per lactation per cow. They also showed that the milk production capacity of local cattle of Boran, Horro, Barca, Arsi, and Fogera is 494 to 809 kg per lactation. The summary statistics in this study shows that the range of annual milk production per lactation per HH is between 305 and 325 liters (313.59- 334.16 Kg) for non-adopters and adopters, respectively. Ahmed et al. (2004) indicated that the improved animals have the potential to produce 1,120 - 2,500 liters over 279-day lactation. This means that the milk production performance for the study population is low when compared with some of the high performing local breeds of the country as well as in comparison with the local highland breeds in the country. The milk production is even far lower than the average potential for the high-grade cows in Ethiopia.

7. Conclusion and Recommendations

The DFT adoption has a significant effect on HH's milk production in rural and small towns of Ethiopia. It can be seen from the impact findings that those HHs in the rural and small towns' who adopted DFT are benefiting significantly more from the adoption. This suggests to invest in smallholder dairy feed technologies is a rewarding endeavor.

Though DFT's adoption has a significant effect on milk production in rural and small towns of Ethiopia, the overall level of agricultural HHs' milk production is even far below the national potential for some recognized local as well as improved cattle breeds. This necessitates the need to the exertion of further effort to adopt DFT. Hence, the food security programs and poverty reduction strategies of the country should not simply go for smallholders' production but essentially need to direct in a way to exploit the dairy farming sub-sector. For this end, special emphasis should be taken to change the dairy production system into technology tapping venture. The number of HHs engaged on traditional farming (grazing in a poor pasture for most of their times), needs to be substantially decreased and the feed technology options need to be increased. As the country's population is expanding from time to time, and as the per capita farmland is getting smaller and smaller, there is a need to shift the farming system simultaneous into labor-intensive agriculture where the dairy sub-sector's potential can be exploited more. This necessitates the need to exert further effort to adopt dairy feed technologies at household level.

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