Ethiopian Economics Association

(EEA)

PROCEEDINGS OF THE EIGHTH INTERNATIONAL CONFERENCE ON THE ETHIOPIAN ECONOMY

Edited by:
Getnet Alemu
Worku Gebeyehu

Volume III

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- ALL ACTIVITIES OF EEA ARE SPONSORED BY THE AFRICAN CAPACITY BUILDING FOUNDATION (ACBF), EMBASSY OF UK (DFID), EMBASSY OF SWEDEN (SIDA), THE NORWEGIAN CHURCH AID, EMBASSY OF NETHERLANDS, EMBASSY OF IRELAND (DCI), FRIEDRICH EBERT STIFTUNG OF GERMANY (FES), AND INTERNATIONAL DEVELOPMENT RESEARCH CENTER (IDRC) OF CANADA.

- THE 8th INTERNATIONAL CONFERENCE WAS CO-ORGANIZED BY THE ETHIOPIAN STRATEGIC SUPPORT PROGRAM II (ESSP II) OF THE INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE (IFPRI).

FOREWORD

The Ethiopian Economics Association (EEA) is pleased to issue the three volumes of the proceedings of the 8th International Conference (the 19th Annual Conference) on the Ethiopian Economy. The conference was held during June 24 – 26, 2010, at the EEA's Multi-purpose Building.

The Ethiopian Economic Association (EEA) has been organizing annual conferences on the Ethiopian Economy every year since its formation. A lot has changed since that date: membership has expanded from a handful to over 3000; a small office manned by a part-time staffer grew to fully functioning Secretariat; assets increased from a few hundred Birr to a large multi-purpose building; a newsletter extended into multiple regular publications including Economic Focus, Quarterly Macro-economic Report, Annual Economic Report, Bi-annual Ethiopian Journal Economics, and conference proceedings; and a simple roundtable discussion broadened into regional and international conferences and many thematic discussion fora. The most important change, which largely made all the others possible, was the establishment of the Ethiopian Economic Policy Research Institute (EEPRI) in 2000 as a research arm of the Association.

I believe that this evolution have symbiotically earned the EEA the respect of the development community including policy makers, business communities, civil society organizations, donors, and the public at large as an independent source of socio-economic analysis and knowledge in Ethiopia.

The 8th International Conference on the Ethiopian Economy attracted a large number of collaborating institutions, many paper presenters, and a high turnout of participants. Officially opened by H.E. Ato Sufian Ahmed, Minister of Finance and Economic Development, the conference was attended by about 470, 300 and 250 participants during the first, second and third days of the conference, respectively. At the Conference 85 papers were presented in three plenary and five breakout sessions. Out of the total, 39 papers were presented by partner institutions like IFPRI-ESSPII, ILRI, FSS, Young Live Ethiopia, National Social Protection Platform lead by UNICEF and World Bank. Individual researchers submitted the rest. The Editorial Committee initiated a review process which ultimately led to the selection of the 31 papers compiled into the three volumes. Volumes I-III are respectively organized under *'Poverty and Social Sector', 'Business Environment, Population and Urbanization,' and 'Agriculture and Related Activities'*.

I would like to take this opportunity to express the EEA's gratitude to the co-organizer of the Conference, the **Ethiopian Strategic Support Program II (ESSP II) of the International Food Policy Research Institute (IFPRI)**.1 I would also like to thank all those who helped make the Conference a success including: paper authors and presenters, individuals who willingly served as chairpersons, and the participants whose active involvement made the conference meaningful and dynamic.

As usual, the staff of the EEA managed the Conference from inception to completion with enthusiasm and perseverance. They deserve a special recognition for that. I also want to extend a special thanks to the Organizing Committee and members of the Executive Committee of the EEA for the dedicated service and leadership they continued to provide to the Association.

Special thanks also go to EEA's partners who have shared its vision and provided it with generous financial support to its activities. These include: the African Capacity Building Foundation (ACBF), the Norwegian Church Aid, the Royal Netherlands Embassy, the Swedish Embassy through SIDA, the Irish Aid, the British Embassy through the Department for International Development (DFID), the Friedrich Ebert Stiftung of Germany, and the Think Tank Initiative (TTI) of the International Development Research Center (IDRC) of Canada.

Finally, I would like to extend my sincere gratitude to H.E, Ato Sufian Ahmed, Minister of Finance and Economic Development, for opening the Conference with a keynote speech, and to the other senior government officials who participated in the Conference their busy schedule notwithstanding.

I want to close by quoting from the inaugural address of Dr. Eshetu Chole, the first president of the EEA. He expressed his vision as follows:

1 ESSP is a unique collaborative project of IFPRI and the Ethiopian Development Research Institute (EDRI). The program, which is based in Addis Ababa, begin its activities in late 2004 with the aim of undertaking timely and actionable research to fill knowledge gaps in the formation and implementation of economic policies, improving the knowledge base available for such analysis, and strengthening national capacity to undertake such work.

> "My vision is that, by the time it celebrates its twentieth anniversary, it will have expanded its membership substantially; established a reputation as a respectable repository of professional knowledge; accumulated a distinguished record of research and publications; further advanced the cause of public education in economics; earned the respect of the public and contributed in several tangible ways to the economic advancement of Ethiopia."

That was 20 years ago. This vision remains valid for the EEA today both in achievement and in aspiration.

Hoping the next 20 years will record even greater achievements!!

Alemayehu Seyoum Taffesse (DPhil)
President,
Ethiopian Economics Association

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Agriculture and Related Activities

DIFFERENCE IN MAIZE PRODUCTIVITY BETWEEN MALE- AND FEMALE-HEADED HOUSEHOLDS IN UGANDA

Bethelehem Koru[1]

1. Introduction

While it has been frequently claimed that women do most of the farm work in Africa, a growing number of studies, including studies in Africa, seems to indicate that women have lower levels of land productivity on their plots. A study done by Udry et al. (1995) in Burkina Faso found higher yields on men's plots than on similar women's plots simultaneously planted with the same crop within the same household. The study showed that yield differentials are due to significantly higher labour and fertilizer inputs on plots controlled by men. A similar study in Burkina Faso done by Bindlish and Evanson (1993) found female heads of households also to be less productive than men, a fact that the authors attributed to cultural, religious and ethnic factors. A study done by Sridhar (2008) in Nepal found that male managed farms produce more output per hectare with a better market input use than female managed farms. A study in Ethiopia by Holden et al. (2001) showed that female-headed households achieved much lower land productivity than male-headed households. Jacoby (1992) in the Peruvian Sierra found a significantly higher productivity for men than women. The World Bank policy report (World Bank 2001a) entitled 'Engendering Development' concludes that internationally, women-headed households and women cultivated plots produced lower yields and revenues.

Some exceptions have also demonstrated that female-headed households achieve the same or higher yield than male-headed households (Bindlish and Evanson 1993; Jamison and Lau 1982). The study by Jamison and Lau (1982) in Thailand and Korea found that gender of the household head does not significantly affect output in both countries, except on mechanized farms in Korea where male household heads were found to be more productive than female household heads.

This study examines gender and maize productivity by analyzing output per acre across female-and male-headed households. While many studies have identified

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systematic gender productivity differentials, there are few studies that have identified the underlying explanation for them. The novelty of this paper is that it adds to the literature by providing more evidence on the causal mechanisms behind the gender productivity differentials. The study combined non-parametric matching and parametric estimators on plot level data of households. We find evidence of lower maize yield for female-headed households than male-headed households. The observed yield differentials is explained by difference in resource endowments, input use and market access between the two households.

The paper is organized as follows. Section two provides a literature review. In part three of the paper estimation methods and data used are described. The results and discussion follow in part four, leading to the conclusion in part five.

2. Literature review

Gender differences in agricultural productivity are often discussed with gender specific constraints. Despite the significant roles women play in agriculture and food security in many developing countries, they continue to have a poorer command over a range of productive resources, including education, land, information, and financial resources (Odame et al. 2002; Welch et al. 2000; World Bank 2001b). The following section will present gender situation in Uganda and their basic difference in terms of access and ownerships of major resource for Agricultural productivity.

i. Access to Land

One of the most significance gender specific constraints that women face in Africa is access to land. Access to land is not just a question of area but also the distance from the residential area and quality of the soil (Arink and Kingma 1991) which has a direct positive impact on gender productivity differentials. In Uganda, women are almost completely dependent on men to access land; women, who are childless, single, widowed, disabled, separated/divorced, or with only female children often have little or no access to land. Land tenure in Uganda and pattern of access, use and ownership by men and women cannot be understood without reference to colonialism. British colonial land policy in Uganda left at least four land tenure systems, freehold tenure where in one has a full right registered ownership; second leasehold tenure, which refers to land leased for a specific period under certain terms; third. Mailo land tenure, which involves holding registered land in perpetuity; and fourth, customary tenure, where land is registered by customary rules often administered by clan/family leaders (Tripp 2004; & Draft National land policy 2007). In all these systems women were exclude from owning land and only retained secondary rights through their male counterparts as wives ,daughters, sisters, among others. This phenomenon continues to characterize their land rights even up to day in many parts of the country. Only a small fraction of women have managed to own land in their own right, estimated nationally at 16% (MOLG &SD 2007; and MoLHUD 2004). Some of these rights have been gained through purchase and very rarely through inheritance from parents or husbands.

Ii Gender issue in Agricultural Technology

Productivity difference by gender is also frequently explained by difference in the adoption of technology, assuming the adoption of technology is likely to vary between men and women (Quisumbing 1995). To the extent that female farmers may have less education, less access to land and own fewer tools, they may be less likely to adopt new technologies (Quisumbing 1995). Thus, their productivity is often lower than male farmers. The inter- and intra-household decision-making process on the allocation and use of these technological resource is also made along gender lines. Studies from (Ventura 1985; Nijiiro 1990 and Kakooza et. Al 2004) reveal that cash crop production which is dominated by men is characterized by availability and utilization of improved farm equipment such as tractors and combine harvesters, and farm inputs such as fertilizers and pesticides. It is also associated with the cash economy where substantial financial benefits are obtained by women, is characterized by traditional farming techniques, rudimentary farm technology and inadequate farm inputs.

In Uganda, adoption of agricultural technology for both men and women is extremely low. The PMA (2000) estimates that fewer than 30% of subsistence farmers use improved seeds, less than 10% practice any form of plant protection and fewer subsistence farmers use inorganic fertilizer of other soil and water amendments. On farm yields are less than one third of the research station yields and most households continue to depend on low input use. A study by (Appleton 1993) highlighted issue in gender agricultural technology. She founds that Women’s priorities and expectations in relation to technology may be fundamentally different from those of men. Also, traditional models of technology development may fail women, simply because they do not address the differences between men’s and women’s technological needs, uses and contributions. The implicit undervaluing of the skills, knowledge and organization of technology use has had serious implications for the status of women as technology producers and users, and also for their involvement in technology development processes.

Iii Extension service and market access

One barrier to the adoption of new technology is gender biased extension service through which many innovations are channeled. Most of the extension agents are men and mostly work with men who are considered heads of households.

The limited access to market is another main issue when making gender-based comparisons. Women's seclusion from the public arena, higher time scarcity, and lack of mobility limit their access to markets in various ways. For instance, women usually have less information about prices, rules and rights to basic services. Moreover, distance from the market may limit an individual's ability to sell or purchase in the market. Women may disproportionately face mobility constraints that limit their ability to travel or sell in markets at some distance from their households and communities (FAO 1988).

3. Data and methods

3.1 Data

This paper is based on data collected from 250 households during two cropping seasons 2007/2008 in Masaka district, Uganda. For our purpose of analysis, 214 households of maize farmers were considered among which 39 households were female-headed and 175 male-headed. The data were collected both at household level and at plot level. Maize is considered as cash and food crop and it is grown twice a year. The first season goes from February to July and the second one runs from August to January. Intercropping of crops is a common practice in the area and maize is mostly intercropped together with crops like beans, groundnuts and cassava. An average of two plots per household was found.

Table 1 shows summary statistics regarding the yield achieved (output per acre) and input used on male-headed and female-headed households plots for all observation. On average, male-headed households achieved a higher amount of output per acre and sold a significantly higher proportion of their output than female-headed households. In terms of input applied per plot, men heads tended to use significantly more improved seeds, fertilizer and hired labour in maize production but there was no significant difference in the application of organic manure between the two households. The data further shows that female-headed households sell less of their maize production. This could be explained by the finding that none of the female-headed households rented in land to plant maize.

Table 1: Comparison of resource use by male-headed (MHH) and female-headed (FHH) households

Resource allocation	Mean MHH (N=338)	Median MHH (N=338)	Mode MHH (N=338)	SD	Mean FHH (N= 84)	Median FHH (N= 84)	Mode FHH (N= 84)	SD	t-value/x2 value
Maize output per acre(kg/acre)	191	120	80	211.386	107	80	40	94.843	3.36***
Plot size(acre)	0.643	0.5	0.25	0.520	0.474	0.25	0.25	0.456	2.73***
Farm size(acre)	4.408	2.5	3	8.907	2.039	2.17	1.75	1.789	2.411***
Land rented in(acre)	0.112	0	38	0.316	0	0	0	0.000	3.25***
Improved seed(1=yes)[a]	0.29	-	98	0.454	0.167	-	14	0.375	2.30**
Fertilizer(1=yes)[a]	0.056	-	19	0.231	0	-	0	0.000	2.23**
Manure(1=yes)[a]	0.083	-	28	0.276	0.095	-	8	0.295	-0.36
Male labour(number)	1.698	1	1	1.345	1.141	1	0	1.220	3.523***
Female labour(number)	1.473	1	1	1.095	1.69	1	1	0.931	1.672*
Hired labour(1=yes)[a]	0.269	-	0	0.444	0.143	-	0	0.352	2.42***
Distance to plot(km)	0.689	0.075	0.25	3.899	0.24	0	0.25	0.698	1.051
Share of output sold	230	120	100	331.227	60.5	53	40	34.000	1.764**

*10%, **5%, ***1% significance level, figures in parentheses are number of observations
a = dummy variables and χ^2 is used for comparisons and SD is standard deviation
Source: Uganda-household-level survey (2008)

3.2 Methods

3.2.1 Propensity score and matching methods

We used both non-parametric and parametric approaches to analyze the data. Propensity score plot matching was used to compare land productivity non-parametrically. Most of the households have multiple plots and the quality of land may vary over plots. In order to control for the quality differences between the two households, we used propensity score matching methods and examined weather the data under study satisfy common support requirement (Becker and Ichino 2002). The propensity score was constructed based on observable plot characteristics. These included soil type, distance to plot from residence, plot size and slope of the plot. We ensured that the common support and balancing requirement was satisfied (Appendix 1) and used the nearest neighbor and kernel matching methods. The idea behind plot matching was to see whether differences in plot characteristics are the cause of productivity differences in case women have access to poorer quality land.

3.2.2 Parametric estimation methods

The parametric approach involves estimation of a Cobb-Douglas production function that includes a dummy for gender as shown by equation (1). As we have multiple plots per households, we were able to carry out panel data models. We applied random effects (RE) models because the variable gender is plot invariant and thus fixed effects(FE) models can not be estimated that could otherwise have been used for controlling the intra-group correlation which may arise due to unobserved cluster effects.

$$\ln Y_m = \beta_1 X + \beta_2 \ln L + \beta_3 \ln k + \beta 4 Z + \beta_5 G + \varepsilon \qquad (1)$$

Where $\ln Y_m$ is the log yield achieved (kg/acre) and X is a vector of characteristics of plot, log of area and distance from residence to the plot. L is a vector of labour inputs which includes both female and male labour available to the household and hired in labor[2]. Furthermore, k is a range of agricultural physical inputs, including fertilizer, manure and maize seed. Z includes other household characteristics and endowments. Note that in the world devoid of market imperfection, the vector of Z should not matter. However, market imperfections will mean that household endowments of physical assets and human capital will matter more generally. G is a dummy variable corresponding to the gender of the household head, which takes a

[2] Cobb -Douglas production function often encountered with the problem of not allowing any of the inputs that take zero value. To avoid log of zero for endowment of male and female labour, constant one is added, assuming it is closed to zero, or at least small relative to the average value.

value 1 for female-headed households. While estimating, the Cobb-Douglas production function, only those sample plots which satisfied common support obtained after estimating propensity score matching models were considered for analyses.

It is generally argued that ε represents the large set of unobserved inputs into the production process (Udry 1996) and it is reasonable to expect the OLS estimation to be biased if ε is correlated with input choice. Nevertheless, the nature of the data further permits the use of random effect estimator to mitigate the problem of unobserved household and plot characteristics. To see the effect of market distance for female heads, we used interaction terms of road distance with a female dummy.

The decision of input choice and use (such as inorganic fertilizer, organic manure, maize seed and hired labour) may be determined endogenously by the household. Farmers are expected to rely on the expected output to determine the amount of input used for the production of maize, while at the same time the amount of input used would determine the output obtained from the production process. We used seed and manure price as instrumental variable to predict improved seed and organic manure respectively. However, we lack sufficient and valid instruments for fertilizer use and hired labour. Therefore, the estimate for fertilizer use and hired labour should be interpreted with care.

A bivariate probit model was estimated to test whether male-headed households use more improved seeds and fertilizer than female-headed households as an explanation for productivity differentials. Maize production has been actively promoted by several programs and organizations in Uganda using a package of improved seeds and fertilizer (Sserunkuuma 2002). Households decide to adopt the major technical innovation from the package (improved seed) and therefore, simultaneously deciding to use fertilizer. Therefore, the decision to adopt one technology can affect the decision to adopt the other. In order to deal with the simultaneity of the technology adoption decision, we adopted the bivariate probit model in which predicted value of improved seeds adoption is included as explanatory variable in the fertilizer adoption model. Due to lack of good instrumental variables for fertilizer and fewer observations (only 19 out of 422 plots received fertilizer), it was impossible to include the predicted values of fertilizers in the improved seed adoption model. Hence, we used the actual fertilizer value in the improved seed adoption model. The predicted value of improved seeds was converted to 1 for the values greater than 0.5 and to 0 for the values less than 0.5. The basic model is specified as follows.

$$MVadopter = \alpha_1 X_1 + \alpha_2 G + \alpha_3\ fertadop + \varepsilon_1$$

$$fertadop = \beta_1 X_2 + \beta_2 G + \beta_3\ MVadopter^* + \varepsilon_2 \qquad (2)$$

Where 'MVadopter' and 'fertadop' are dummy variables indicating whether the household adopted improved seed and/or fertilizer, X_1 and X_2 are vectors of variables expected to affect the technology adoption decision, and 'MVadopter*' is the predicted values of improved seed. G is a dummy variable for gender of the household head which takes a value of 1 for female-headed households. ε is an error term which represent unobserved factors affecting these decisions. Standard error is corrected using the robust option.

4. Results and discussion

Turning to the econometrics evidence, Table 2 shows estimation results of propensity score matching methods. We found that maize productivity was significantly lower for female-headed households than male-headed households after controlling for land quality using nearest and kernel plot matching methods. The remainder of this section is devoted to exploration of the robustness of this result.

Table 2: Gender and maize productivity using propensity score matching

Variable	Kernel matching	Nearest Neighbor
Maize productivity (output/acre)		
Female-headed	4.265	4.265
Male-headed	4.711	4.711
Difference	-0.437	-0.437
Bootstrapped std. error	0.139	0.126
t-statistic	-3.149***	-3.455***
Number of observations		
Female-headed	84	84
Male-headed	338	314

Significance levels: **:5% level, ***:1% level.

Table 3 shows estimation results from the Cobb-Douglas production function given in equation (1). The regression analysis was made as step-wise fashion starting from a simple model regressing in subsequent models as it will be discussed below.

The result of the first simple model (model 1) confirmed that average productivity of maize is 46 percent lower for female-headed households than male-headed households. We included plot characteristics variables in the next model (model 2); production was still significantly lower for female-headed households. However, estimation result after controlling for household characteristics and input use (model 3) demonstrated that gender of the household head was insignificant with a positive sign.

Of the input variables, predicted manure applications, fertilizer and hired labour are positively related with the productivity of maize. However, plot size was highly significant variable and with a negative sign in all models. This is likely due to a bias in plot size estimation; we used plot size reported by the respondent. The inverse plot size-yield relationship has been observed in other African data (Bindlish and Evenson 1993; Carter 1984). The total area of land owned by the households is found to be statistically significant at 5% level. Productivity was found to be higher in the second season.

Bicycle use was found to be significant with a positive sign. In this regard male-headed households have a better market access, due to the fact attributed to the use of bicycle to transport their product. The interaction terms of female dummy with distance from plot to the nearest seasonal road is significant and negatively correlated with maize yield. Distance to the nearest road can be used as a proxy of market access. This finding suggests that productivity was relatively lower for female-headed households the further away they are from the market. This could be due to their more limited mobility due to the cultural restrictions on women’s use of bicycle.

Table 3: Estimation of Cobb-Douglas production function: Log of maize output per acre with household random effect and clustered standard errors[3]

Variables	Model 1	Model 2	Model 3
Sex of household head(female=1)	-0.460**** (0.156)	-0.497*** (0.148)	0.067 (0.303)
Log of plot size		-0.339**** (0.083)	-0.448**** (0.093)
Soil type1(good)		0.197 (0.205)	0.219 (0.224)
Soil type2(fair)		0.211 (0.169)	0.240 (0.177)
Slope1(top hill)		0.172 (0.281)	0.025 (0.302)
Slope2(middle/gentle)		0.471** (0.206)	0.368* (0.223)
Slope3(bottom hill)		0.498* (0.287)	0.296 (0.300)
Plot distance(km)		-0.019 (0.092)	-0.027 (0.092)
Season(1=second season)		0.591**** (0.093)	0.599*** (0.095)
Predicted improved seeds			0.000 (0.205)
Predicted manure			0.811** (0.415)
Fertilizer(1=use)			0.408* (0.261)
Hired labour(1=use)			0.241* (0.149)
Log male labor			-0.074 (0.212)
Log female labor			0.310 (0.200)
HHH education(year)			-0.040** (0.020)
HHH age(year)			-0.028 (0.024)
HHH age square			0.000 (0.000)
Consumer worker ratio			-0.096 (0.108)
Predicted bicycle use[4]			0.520** (0.252)
Livestock(TLU)			-0.013 (0.017)
Rented in			0.121 (0.277)
Log land owned			0.173** (0.088)
Sex*road distance			-0.967** (0.546)
Sex*remittance			-0.480 (0.327)
Constant	4.688**** (0.082)	4.047**** (0.264)	3.686**** (0.684)
Prob>chi2	0.000	0.000	0.000
Number of obs.	375	375	375

Significance levels:*:10%, **:5%,***:1%,****0.1% and figures in parentheses are standard errors

[3] The regression is made on the sample that satisfied common support
[4] Bicycle use is instrumented with bicycle ownership.

Table 4 shows the results of the bivariate probit estimation. We found that gender of the household head had a negative sign both with respect to fertilizer and improved seeds adoption model. However, statistical evidence was found only for the adoption of fertilizer at 0.1% significant levels[5]. Therefore, there is evidence of gender productivity differentials to be explained by lower utilization of fertilizer by female-headed households as compared to male-headed households. This is because men control more resources and therefore male-headed households have a better chance to purchase fertilizer.

The likelihood of adopting improved seeds and fertilizer is higher among households with larger farm size. Land ownership provides a good measure of wealth for the adoption of new technologies. Households who rented in land are significantly more likely to adopt improved seeds. The adoption of improved seeds and fertilizer is also higher among households with the use of organic manure. Distance from maize plot to the nearest market negatively affects the adoption of improved seed. Furthermore, the findings show that the age squared variable is statistically significant, which suggests that younger heads are more likely to take risk associated with new technology than older farmers. Surprisingly, the probability of adopting fertilizer is lower for household who are using bicycle for marketing.

As expected, the number of extension visits positively influences the probability of using improved seed varieties. This is in line with earlier findings in several developing countries as discussed in the literature review.

[5] Similarly, (Croppenstedt and Demeke 1996) in the case of Ethiopia argue that female-headed households are less likely to use and apply fertilizer because they tend to be poorer and more subsistence and labour constrained

Table 4: Bivariate probit model of adoption of technologies with robust standard errors

Variables	Improved seed adoption	Fertilizer adoption
Sex of household head(1=female)	-0.275 (0.255)	-7.237**** (1.885)
Rented in (acre)	0.820**** (0.240)	0.284 (0.643)
Household head education (years)	-0.015 (0.026)	0.009 (0.060)
Household head age (years)	0.066 (0.041)	0.157*** (0.052)
Household head age square	-0.001** (0.000)	-0.002*** (0.001)
Consumer/worker ratio	-0.258** (0.111)	-0.134 (0.234)
Male labour	-0.125 (0.093)	-0.320 (0.201)
Female labour	-0.125 (0.112)	-0.363* (0.201)
Land owned (acre)	0.033* (0.019)	0.043** (0.019)
Tropical livestock units (TLU)	0.010 (0.017)	-0.120 (0.097)
Bicycle use	0.338 (0.266)	-5.761**** (0.784)
Manure use (1=use,0=no use)	1.160**** (0.289)	1.528*** (0.599)
Distance to market (km)	-0.092** (0.041)	-0.008 (0.071)
Distance to nearest all weather road km)	0.086*** (0.032)	0.043 (0.094)
Extension visit (number of days)	0.037* (0.022)	0.004 (0.020)
Access to credit (1=yes)	0.180 (0.169)	-0.198 (0.373)
Access to off-farm income (1=yes)	0.091 (0.175)	-0.102 (0.290)
Fertilizer	0.184 (1.462)	
MV adopter*		-1.680*** (0.631)
Constant	-1.157 (0.887)	-4.471**** (1.286)
Plot characteristics	included	Included
Number of observation	422	422
Share of correct predictions	MVadopter*=0	0.77
	MVadopter*=1	0.78
Log likelihood	-232	
Wald χ^2 (56)	1606.29	[0.000]

Significance level:*10%, **5%, ***1%, ****0.1 and figures in parentheses are robust standard errors.

5. Conclusion and policy recommendation

The study examined the productivity across male-headed and female-headed households. The results from econometric analysis show that productivity was significantly lower for female-headed households than their male counterparts. There was no evidence on the variation of plot characteristics between the two types of households to explain the existing yield differences. Analysis from the bivariate probit model, however, revealed that female-headed households were less likely to adopt fertilizer. This is due to the fact that female-headed household tends to be more resource constrained, which may affect the adoption of technologies, especially fertilizer which is more expensive than improved seeds. Bicycle use was found to be highly significant in the productivity of maize. This finding suggested that male-headed households have a better market access than female heads.

Important policy implications arise from these results. First, closer attention is needed to engendering and strengthening implementation of the existing land laws. Although female-headed households are legally entitled to own land, in practice, access is contingent on social relations. Hence, lack of control over land has direct implications in their ability to access other resources and ultimately on their poverty status. Secondly, use of agricultural inputs remains low generally and particularly among female-headed households. Given the importance of farm inputs in raising the total value product, future policies should be aimed at increasing access to agricultural inputs at an affordable price, particularly for female-headed households that have a low income and hence can not afford to purchase them.

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Appendix 1: STATA output of the propensity score matching

```
***************************************************
Algorithm to estimate the propensity score
***************************************************

The treatment is sexhead

 Sex of the |
  Household |
       head |      Freq.     Percent        Cum.
------------+-----------------------------------
          0 |        338       80.09       80.09
          1 |         84       19.91      100.00
------------+-----------------------------------
      Total |        422      100.00


Estimation of the propensity score

note: slope4 != 0 predicts failure perfectly
      slope4 dropped and 3 obs. not used

Iteration 0:   log likelihood = -209.94558
Iteration 1:   log likelihood = -201.38193
Iteration 2:   log likelihood =  -200.3406
Iteration 3:   log likelihood = -199.49102
Iteration 4:   log likelihood = -199.47144
Iteration 5:   log likelihood = -199.47142


Probit regression                                 Number of obs   =        419
                                                  LR chi2(7)      =      20.95
                                                  Prob > chi2     =     0.0038
Log likelihood = -199.47142                       Pseudo R2       =     0.0499
------------------------------------------------------------------------------
     sexhead |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    plotsize |  -.3627923   .1659063    -2.19   0.029    -.6879626    -.037622
      slope1 |  -.5374584   .3059132    -1.76   0.079    -1.137037    .0621205
      slope2 |  -.3049888   .1879746    -1.62   0.105    -.6734122    .0634346
      slope3 |  -.0822753   .3316661    -0.25   0.804    -.7323289    .5677783
   soiltype1 |   .0827372   .2201314     0.38   0.707    -.3487125    .5141869
   soiltype2 |   .3411776   .1970888     1.73   0.083    -.0451094    .7274645
    plotdist |  -.2081739   .1067848    -1.95   0.051    -.4174683    .0011205
       _cons |  -.5128429   .2251003    -2.28   0.023    -.9540314   -.0716543
------------------------------------------------------------------------------

Note: the common support option has been selected
The region of common support is [.04860948, .41409858]
```

```
Description of the estimated propensity score
in region of common support

                  Estimated propensity score
-------------------------------------------------------------
       Percentiles      Smallest
 1%     .0502037       .0486095
 5%     .0781813       .0486095
10%      .095766       .0502037       Obs                 407
25%      .146567       .0502037       Sum of Wgt.         407
50%     .2006094                      Mean           .2048615
                        Largest       Std. Dev.       .080797
75%      .263829       .4035288
90%     .2976841       .4035288       Variance       .0065282
95%     .3502706       .4140986       Skewness       .2906035
99%     .3965206       .4140986       Kurtosis       2.630125

******************************************************
Step 1: Identification of the optimal number of blocks
Use option detail if you want more detailed output
******************************************************

The balancing property is satisfied


This table shows the inferior bound, the number of treated
and the number of controls for each block

  Inferior | sex of the household
  of block |         head
of pscore  |         0          1 |     Total
-----------+----------------------+----------
  .0486095 |       180         21 |       201
        .2 |       141         61 |       202
        .4 |         2          2 |         4
-----------+----------------------+----------
     Total |       323         84 |       407

Note: the common support option has been selected


*******************************************
End of the algorithm to estimate the pscore
*******************************************
```

Appendix 2: Overview of variables used in the analysis

Variable name	Variable type	Variable definition	Mean	Std. Dev
Log maize yield	Cont.	Log of (output/acre)	4.618	1.148
Sex of HHH	Dummy	1=female, 0=male	0.199	0.399
Education of HHH	Cont.	Years in school	5.627	3.167
Household size	Cont.	Household size	6.562	3.475
HHH age	Cont.	Years	42.2	16.4
Season	Dummy	1=first season, 2=sec season	1.492	0.500
Plot distance	Cont.	Distance from plot to home(km)	0.599	3.506
Improved seed	Dummy	1=improved ,0=local seed	0.265	0.442
Plot size	Cont.	Plot size	0.609	0.511
Male labor	Cont.	Adult male endowment	1.585	1.338
Female labor	Cont.	Adult female endowment	1.516	1.067
Hired labor	Dummy	Hired labour (1=yes)	1.244	0.430
Consumer/worker	Cont.	Consumer worker ratio	1.857	0.878
Market dist.(km)	Cont.	Distance from plot to market	3.132	2.499
Extension	Cont.	Number of days of training and exten. visit	0.199	0.399
Credit access	Dummy	Access to credit (1=yes)	0.402	0.491
Off-farm income	Dummy	Access to off-farm income (1=yes)	0.661	0.473
Remittance access	Dummy	Access to remittance (1=yes)	0.566	0.496
Bicycle use	Dummy	Use of bicycle for market (1=yes)	0.175	0.566
Livestock (TLU)	Cont.	Tropical livestock units	1.981	5.213
Rented in land	Dummy	Rented land (1=yes)	0.090	0.286
Land owned	Cont.	Area of owned land (acre)	3.936	8.106
Manure	Dummy	Use of manure (1=yes)	0.085	0.279
Fertilizer	Dummy	Use of fertilizer (1=yes)	0.045	0.207
Dist.nearest all weather (km)	Cont.	Distance from plot to nearest all weather road	1.122	2.174
Dist.nearest seasonal (km)	Cont.	Distance from plot to nearest seasonal road	0.249	1.063
Slope	Dummy	1=tophill,2=middle,3=bottomhil,4=valey,5=flat	2.441	1.185
Soil type	Dummy	1=good,2=fair, 3=poor	1.898	0.690

FACTORS CONSTRAINING THE PRODUCTION OF TRADITIONAL EXPORTABLE AGRICULTURAL PRODUCTS IN ETHIOPIA: EVIDENCE FROM THE LONGITUDINAL ETHIOPIAN RURAL HOUSEHOLD SURVEY

Kefyalew Endale[1]

Abstract

The study shows the yield and extent of input uses in the production of agricultural exportable products. The effects of different variables on the production are also examined by employing econometric tools. The major data sources are Central Statistical Authority and Ethiopian Rural Household Surveys. The descriptive results show that the yields of exportable products are low compared to other countries that are exporting similar products such as Brazil and Kenya. Input allocations to the production of these products are also low both at national as well as peasant association levels. Hausman-Taylor estimation is used in the econometric analysis. This technique handles individual heterogeneity and it is also preferred to the fixed effect estimator when the variability of the independent variables are minor over time. Most of the variables are significant and with the expected sign. The largest effect is observed in the infrastructural variables; distance to the nearest town and access to improved roads. This implies that the ongoing efforts of expanding infrastructures to the rural areas are indispensible for the increase in production of exportable products. The significant correlation of fertilizer and yield of exportable products is another important point that necessitates studies on cost and benefits of using fertilizer in the production of exportable products.

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1. Introduction

Ethiopia adopted Agricultural Development Led Industrialization (ADLI) development strategy since 1994/95. The strategy argues that growth starts from agriculture[2] and initiates the growth of other sectors especially the industrial sector through backward and forward linkages. It focuses on the improvement of productivity of smallholder producers through dissemination of new technologies, most notably fertilizer. Ensuring food security both at national and household levels and improving the share of high valued manufactured items in the export and more export-oriented economy are among the major objectives of the development strategy (MOFED, 2006).

Despite the efforts and the emphasis given to agriculture, the observed achievements are not satisfactory. The national as well as the household level evidences show that cereal productivity is low. The average national production per capita of the major cereals was only 128kg in the period 1994/95 to 2005/06 (see Endale, K, 2009). Major transformations in the export profiles from primary agricultural to high valued manufacturing are not observed. The export sector is still dominated by primary traditional agricultural items. The share of primary agricultural items increased from 61.4% in 2001/02 to 69.1% in 2005/06 (Table 1.1). This is one of the indications of the lack of transformation in the export profile towards manufacturing. However, this doesn't tell us the whole story. It could arise from a relative higher success in one or more of the other export items in agriculture (example chat) and an increase in the price of agricultural products. Besides, structural shifts cannot be expected immediately.

The lower yields and foreign exchange problems that Ethiopia is facing are some of the issues that need to be addressed. These evidences imply that the objectives of ADLI especially food security and improved share of manufactured items in export are not sufficiently achieved though there are improvements. Dercon and Zeitlin (2009) rather suggest a balanced and yet towards sectors having higher multipliers.

[2] Primacy of agriculture is being challenged by researchers. For example Dercon and Zeitlin (2009) stated that the approach is incomplete because it assumes higher multiplier in agriculture than in other sectors. They argued that marginal growth rates should be weighted by fiscal costs of bringing the increments to growth and most importantly is that the source of growth cannot be asked independently from what is happening in other sectors

Table 1: Share of different export items as a percentage of total export revenues

Year	Coffee (A)	Pulses (B)	Oilseeds (C)	Chat (D)	Leather &leather products	Others[3]	The share of major primary (A-D)
2001/02	36.1	7.3	7.2	10.8	12.3	26.3	61.4
2002/03	34.2	4.1	9.6	11.9	10.8	28.3	59.8
2003/04	37.2	4.4	13.9	14.7	7.4	22.3	70.2
2004/05	39.6	4.2	14.8	11.8	8	21.7	70.4
2005/06	35.4	3.7	21.1	8.9	7.5	23.4	69.1

Source: IMF (2007)

Because of the weak performance of the export sector, there exists foreign exchange problem in Ethiopia and devaluations have been made to deal with the problem. The shortage of foreign exchange makes it difficult to get imported raw materials and intermediate inputs in the manufacturing industries; this was so especially in the year 2008 (see Endale, K and W.Giorgis, T, 2009)[4]. Under such circumstances it is necessary to improve the performance of the agricultural sector which is relatively less dependent on imported inputs. Given the lower tariffs and non-tariff barriers after liberalization, the improvements in yield of exportable agricultural products can increase total export earnings and reduce the problems of foreign exchange. This brings an increase in supply of foreign exchange for the manufacturing industries as well as for fertilizer imports. There is a need to work more on the primary export supply and this necessitates investigating the production side.

The strategy and investment policies favor exportable as against non-exportable primary products. The performances of primary exportable agricultural products are, however, low even after ADLI (Annexes 1to 3). Fertilizer and land allocations are geared largely towards the production of cereals (Annexes 1 to 3). This is largely an implementation problem on one hand and smallholders' decision to give priority to cereals for own consumption on the other. Some modest changes in land size have been observed for oilseeds since 2004/05 (Annex 3). Correspondingly, there is an increase in the share of oilseeds in total export over time (Table 1.1). Though there are other factors that increase the share of oilseeds in total export revenue like the increase in price and devaluations, the increases in land will have positive effects on the total production. Likewise increased use of agricultural technologies like fertilizer and improved seeds can enhance yield and hence export earnings. Though coffee is

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[3] Includes gold, textile garment, live animals

[4] We conducted survey to study the factors affecting performance of manufacturing exports in 2009. During the survey some of them were not operating and few are closed down due to shortage of imported raw materials which in turn is due to lack of foreign exchange. A good example for this is the East African Bottling S.Co which attracted the attention of public and private Medias and returned to its operation through special government support.

the major source of foreign exchange, national level data about its production, land cultivated and input use like fertilizer are not available.

The tariff and non-tariff barriers on the exports of developing countries are low following trade liberalization policies (Mbekeani, 2007). Most of the problems on exports of developing countries in international market competitiveness are attributed to the internal problems especially those of the low yield and lower level of production (IF, 2008). IF (2008), pointed out that the low yields in agriculture and animal husbandry are most fundamental level constraints facing Sudan in international competitiveness. Ethiopia's economic structure is also largely agricultural and has lower yields for agricultural products (see Annex 2). Examining the factors that affect the productivity of exportable crops can help to identify the constraints for yield and total production improvement and in setting means of reducing them.

The studies on factors affecting the production of exportable products are few and largely on one crop type, i.e., coffee. The studies give more emphasis to the other aspects like trade liberalizations and competitiveness positions. Geda (2002) showed the effect of trade liberalization on coffee subsector with before and after approach. Adenew (2009) studied the competitiveness of Ethiopian agriculture on pulses, Oilseeds, fruits and vegetables. Given the importance of the existing studies, it is also useful to give insight about the factors affecting the production of exportable products.

This study aims to contribute to the previous studies on the factors affecting production of primary exportable products. Household characteristics, infrastructural variables, environment and access to agricultural technologies are the variables investigated by household level panel data. The analysis is based on four exportable products; coffee, chat, oilseeds[5] and Pulses[6]. They are chosen because of their largest share in the total export revenue. The numbers of households engaged in the production of oilseeds and pulses in the *belg* (off-farm) seasons are noisy and hence only *meher* (main-season) data are used. Data from both seasons are taken for coffee and chat because they are permanent crops. The use of panel household data and wider coverages of exportable crops are the unique aspects of this study from other previous studies in the Ethiopian context.

[5]Include linseed, sesame, lentils, neug and sunflower
[6] Include chickpea, cowpeas, horse beans and haricot bean

2. Literature

2.1. Measurement of productivity

The simplest definition of productivity is the ratio of some measure of output to the input index (Ruttan, 2002). This technique is usually used to compute some descriptive measures such as yield. It has, however, various limitations because there are many inputs used in the production process. The conventional approach of productivity measurement is to divide the total value of output over an index of composite inputs; meaning the sum of all inputs used in the production process (EEA, 2002; Dayal, 1984; Hayami, 1964, Ruttan, 2002; Olaoye, 1985). This is called total factor productivity. But computing total factor productivity is difficult due to lack of prices and cost of inputs and aggregating all inputs in a simple index is difficult (Ruttan, 2002). Another approach of productivity measurement is the partial factor productivity. In this approach output is related to any of the factor inputs (Olaoye, 1985). This implies that there will be as many definitions of productivity as the number of variables. The definition of productivity in this approach is a partial one and it is also the same as average product of the factor. The partial productivity approach is used in the regression because it is difficult to find an index for the variables under consideration.

The regression is conducted by establishing a production function that links output to the inputs. The function can be specified in one or many forms including Tanslog or Cobb-Douglass production functions (Zhang and Fan, 2001). The variables that affect agricultural production and productivity are numerous that range from household characteristics to technology and credit, environmental and infrastructural factors. These factors constrain the performance of agriculture by affecting the operation of economic agents.

2.2 Factors affecting agricultural production

In this section attempts are made to mention those theoretical and empirical literatures on factors affecting agricultural production. The literatures can be broadly classified into the household level characteristics, technologies and credit markets, environmental and rural infrastructural facilities. The following sections briefly address the theories and empirical findings related to the topic of this study briefly.

The first set of variables are the household characteristics. These include landholding size, gender and education status of the head, number of adult family members and oxen. Small farmland holdings have many problems on production and its effect is large population pressure. This causes higher rates of soil erosion, lower soil productivity, expansion towards marginal land, landlessness, land fragmentation, and land disputes among other major consequences. (Timberlake, 1986; FAO, 1998). These lead to a lower level of yield in agricultural production. Another cause of the inverse relationship is that poor households might sell/rent their poor quality land to the richer farmers and this ends increased quality of average land of smaller firms and a lower average quality of larger farmers and this decreases a net fall in the yield on larger farmers (Cain, 1981). Randrianarisoa and Minten (2001) stated that shortages of land are correlated with lack of other productive assets including education and this causes the landless to be less productive and remain poor.

Gender and education status of family members, more specifically which of the head and spouse, can affect the productivity of agriculture. Males are traditionally more dominant in many societies compared to females (Randolph and Sanders, 1988). The roles of women are, however, many and they have better efficiency in governing household and their efforts are concentrated more on the production of major subsistence crops while males are largely engaged in cash crops, off-farm production and livestock grazing (Nwafor, 1979 in Randolph and Sanders, 1988). Gender bias in access to land, education, health, and other basic needs, compared to males, can thus be a cause for poor performance of agriculture according to the literatures.

Rural literacy is an important variable that affects human capital development in agricultural growth and also transforms lower level subsistence agriculture into skill-based one (Shultz, 1961). Some authors make distinctions between general education and agricultural education. Pfaffermayr*, et al.* (1991) argued that higher level of agricultural education increases the marginal productivity of farmers while general education can bring changes in sector of employment from agriculture to non-agriculture. Better education might affect the ability to use information and translate it into better management, leading to a more efficient use of agricultural production factors (Randrianarisoa and Minten, 2001).

Many studies showed the importance of labor use in agricultural productivity (see Randrianarisoa and Minten, 2001; EEA, 2002). Agriculture is highly reliant on labor rather than on other inputs. Randrianarisoa and Minten (2001) mentioned that the labor dependency is due to the comparative advantage in labor use compared to imported equipment in the developing countries. The labor in agricultural activities depends largely on number of working men and women, and also on the number of working children. In most applications, the common proxy is the number of adult male and female members (EEA, 2002). However, the numbers of members does not mean that all of them are involved in the production. Some of them might engage in other off-farm activities, especially when the family size is large and the land owned by the household is small (Brick, A, 2005). The production of cereals, oilseeds and pulses is seasonal and subject to fail if adequate labor is not available in the right time of each stage in the farming process. Finally, livestock in general are important means for raising agricultural production (Geda and Weeks, 2004). Ox is a good proxy for capital in the rural areas due to the absence of modern machinery. Due to the absence of modern machinery in the context of developing countries, oxen are considered to be a good proxy for capital stock in the rural households (Geda and Weeks, 2004).

The second category reviewed in the literature is about technology and credit. Technology-related variables in agriculture include fertilizer use, improved seeds, irrigation (Dayal, 1984; Easter et al., 1977; Hayami, 1964; Morgan and Solarz 1994, Ruttan, 2002). Fertilizer is indispensible in increasing world food production and productivity. Mengeshan (2006) and Easter et al., (1977) stated that the use of fertilizer safeguards various countries from food insecurity. Enormous use of fertilizer is also a cause for agricultural transformation in many countries like Japan (Hayami, 1964)[7]. Improved seeds are also highly valuable for agricultural production. These inputs are useful to increase the effectiveness of fertilizers (Gebreselassie, S., 2006; Grover and Temesgen, 2004).

Irrigation plays a critical role in raising agricultural productivity. As described by Lele (1984), irrigation is a means to deal with production instability arising from shortage of rainfall. Smith (2004) stated that irrigation enables to have more than one cropping season in a year and it increases reliability and consistency of production. This is important to safeguard farmers from any rainfall shocks. Polak and Yoder (2006) pointed out the importance of small-scale irrigation for smallholders as a means of ensuring food security under uncertain environmental conditions.

The adoption of agricultural technologies in rural areas like irrigation, improved seeds and fertilizer depends on the rural credit facilities. Rural credit activities have substantial effects on farm outputs and they are an important aspect of the rural economy (Rosegrant and Herdt, 1981). Access to finance is a means to undertake productive investments to the smallholders (Pischke et al., 1983). The credit markets are, however, imperfect, due to information asymmetry, and this creates credit rationing in most of the cases, and this in turn underemployment of inputs by farm households and lower level of production than the optimal (Feder et al., 1990).The role of credit is not only limited to investments in agriculture but also to start non-agricultural business activities. Lack of credit hampers both agriculture and the ability to diversify alternative sources of income (Montanye, 2003).

[7] He explained that the reason for the increase in fertilizer use was the result of the relative decline in the price of fertilizer relative to the price of farm products.

The third vectors of variables are related to the environmental conditions and rural infrastructure. Agriculture is largely dependent on environmental variables especially in developing countries. Some of the variables in this category include distribution, timing and availability of rainfall, prevalence of frost and flood, soil loss and degradation from heavy rains, water logging and salinity, the co-evolution of pests, pathogens and hosts, and climate changes (Ruttan, 2002). Adequate soil moisture is necessary for fertilizer and improved seeds productivity, and thus it is a crucial factor affecting agricultural production (EEA, 2001/02).

Rural infrastructures are necessary too for improving the way of life in the rural areas, and they are important facilitators of overall growth (Spencer, 2004). Rural roads, markets, water supply, power, telecommunication, bank, veterinary, health centers and primary education are among the major important facilities (Spencer, 2004; Li and Liu, 2009). These facilities improve the access to information, reduce transaction costs and costs of production. These in turn enhance overall efficiencies of the firm (Chen and Lin, 2000). Access to infrastructures can also address the problems of missing markets, incomplete markets for agricultural input and output. This can facilitate input acquisitions like fertilizers and improved seeds.

There are many empirical evidences on the effects of the aforementioned variables on Ethiopia as well as other countries. The studies are, however, largely on non-exportable products and notably on the cereals. Ahmed *et al*., (2005) found positive and significant effects of credit, capital, hired labor, fertilizer and irrigation on sorghum production levels in Sudan. Randrianarisoa and Minten (2001) found that access to primary education is relatively more beneficial for poorer agricultural households while secondary education is not important for agricultural productivity in Madagascar. Masters and Wiebe (2000) found significant effects of land quality on the final output. Morgan and Solarz (1994) reported that droughts arising from poor rainfall and its variability have affected Ethiopia and many sub-Saharan African countries in 1963-1968 and 1982-1985.

In the case of infrastructural variables, Li and Liu (2009) studied the effects of rural infrastructure on agricultural production technical efficiency in China. Their result showed that transportation infrastructure is the crucial infrastructure followed by vocational/technical primary education. They also surveyed the works of Chen and Lin (2002), Peng (2002), Fang et al (2004), Fan and Zhang (2004). Chen and Lin (2000) found that rural infrastructures such as transportation, storages, primary products market, can reduce cost of production and enhance efficiency. Peng (2002) argued that roads can reduce the expenditure of agricultural production and Fang et al (2004) stated that investment in rural infrastructure improves agricultural production. Fan and Zhang (2004) documented the positive impacts of rural infrastructure on regional development

The studies in the Ethiopian context also give emphasis on other aspects of the exportable products. Geda (2002) showed that trade liberalization has increased the volume of coffee export at macro level and it has insignificant or very small effect at micro level. The micro level results, on the other hand, showed that coffee supply is very small or insignificant. Geda also surveyed other micro level studies focusing on liberalization and the coffee subsector. These include Yadeta (1997), Amme (1995) and Dercon and Lulseged (1994). Yadeta (1997) showed that there is a resource shift from food crops to cash crops following liberalization and this has increased the supply of coffee in two districts of Jimma. Amme (1995) found that there is a significant short-run price elasticity of coffee supply to price incentives following liberalization. Similarly, Dercon and Lulseged (1994) noted an increase in coffee production due to liberalization but it is unlikely to be large. Adnew (2009) focused on the factors that determine the competitiveness position of Ethiopian export in these selected items. Human resource, infrastructure and investment environment are among the factors determining competitiveness in his findings.

The production side studies in Ethiopia are largely on the cereals. Geda and Befkadu (2005) showed that land, labor and oxen are important determinants in the production of cereals in Ethiopia and they found dummy for fertilizer use as insignificant. Endale (2009) found land, labor, fertilizer, credit, and rainfall as significant determinants of cereal productivity. Weir, S (1999) showed both private and social benefits from schooling for a farmer's productivity, particularly in the efficiency gain. Zerihun *et al*., (2003) argued that agricultural production in Ethiopia is largely at subsistence level and its responsiveness to policy changes is constrained by infrastructural and institutional constraints. Fufa and Hassen (2005) found that improved seed, labour, oxen, and planting date as most determinants of yield level in maize and sorghum producing districts of Hararghe. Most of the studies have more or less similar findings.

3. Data presentation and analysis

The data source is the longitudinal Ethiopian Rural Household Survey, collected by Department of Economics (Addis Ababa University) in collaboration with Center for the Study of African Economies (CSAE), University of Oxford and the International Food Policy Research Institute. The survey covers 1477 households in 15[8] Peasants Associations across the four major regions (i.e., Amhara, Oromia, Tigray and SNNP.

[8] There are additional peasant associations in the 2000 survey

The survey has been conducted in six rounds between 1994 and 2004. The survey has rich socio-economic, demographic, and environmental, land characteristic, labor use, community services and infrastructures etc. This study is, therefore, based on the four rounds; round 3 (1995), round 4 (1997), round 5 (2000) and round 6 (2004).

3.1 Yield and fertilizer use

The yields of major exportable products are low compared to many countries (Table 3.1). The existence of a higher domestic demand with such poor yield impedes the export supply of these products. A relatively better yield was observed in the fifth round (2000) in most crop categories. This coincided with the good weather condition and improved use of fertilizer in the period (see Table 3.2). The other observed feature from the yield is that it shows ups and downs from one round to the other.

Table 3. 1: Yield in kg/ha of Major Exportable agricultural products

Type of crop		Round 3 (1995)	Round 4 1997	Round 5 2000	Round 6 2004	Average of 1995-2004
Chat		229 (55)	206 (80)	406 (142)	207 (51)	297 (328)
Coffee		387 (157)	324 (193)	558 (169)	251 (300)	358 (819)
Pulses	Chickpea	431 (16)	424 (15)	483 (54)	415 (27)	452 (112)
	Cowpea	326 (34)	322 (46)	530 (63)	424 (75)	418 (218)
	Haricoat bean	256 (5)	486 (37)	350 (56)	435 (66)	412 (164)
	horse bean	361 (149)	398 (125)	567 (206)	440 (127)	455 (607)
	Lentils	287 (10)	386 (13)	425 (17)	385 (14)	380 (54)
Oilseeds	Linseed	258 (39)	301 (87)	293 (47)	258 (24)	286 (197)
	Neug	352 (7)	220 (4)	389 (19)	-	358 (30)
	Sunflower	-	-	326 (23)	-	326 (23)
	Sesame	-	-	617 (2)	-	617 (2)

The elements in parenthesis are the number of observations

Source: ERHS (Rounds 3-6)

The observed yields of these major exportable products are lower in comparison to other countries. The average yield of coffee in the four rounds was 358kg/ha. In another study Ayana (1999) in Geda, A., (2002) reported an average yield of 350kg/ha in modified forest and 450kg/ha in garden coffee. He also reported 400kg in major coffee producing areas such as Keffa, Wellega, Sidama, Shoa, North and South Omo and Hararghe. The household survey evidences as well as the evidences from major producing regions are below the yields observed in other competing countries like Brazil and Kenya. The average yield of coffee for the period 1995-1997 was 582 kg/ha in Brazil and that of world average in the same period was 538 kg/ha

(Mahadevan, 2003). For Kenya, Kibaara, et al. (2008) found an average of 1285 kg/acre[9] from the different parts of coffee producing districts in 2007. These show that coffee productivity in Ethiopia is lower from other producing countries of the world. Quality of exports is another problem affecting exports of Ethiopia though it is not a focus in this study.

The yields in pulses range from 380kg/ha in lentils to 455 kg/ha in haircoatbean. The simple average of the four major pulses was 436 kg/ha. This yield is also lower compared to other regions. FAO (2002) reported a Sub-Saharan average yield of 481 kg/ha and a world average of 808 kg/ha. Mahadevan (2003) reported an average yield of 661 kg/ha for India in 1998/99. In the case of oilseeds, which are the second major source of export earning from primary products, the yield ranges from 286 in linseed to 617 kg/ha in sesame. The observed yield of sesame cannot be representative because there are only two producers. Ghidey (2007) reported that the yield in sesame varies between 200 and 700kg/ha and averaging 400kg/ha in Humera, which is a major sesame producing area in Ethiopia. These yields are also low in comparison with other countries. For example, Mahadevan (2003) showed an average yield of 948kg/ha in 1998/99 in India for oilseeds. The productivity of Chat (Khat) is also low in absolute terms. But attempts to compare the observed yield with that of other countries are not successful due to the absence of data. These show that the yields of traditional exportable products are low both in absolute terms as well as in relative to other regions or countries.

Another important note from the rural household survey is the limited use in improved technologies in the production of these exportable products. The information on improved seed, irrigation and chemical use like pesticide are noisy with large number of missing values. This is mainly due to the poor adoption of these technologies to the production of these exportable products. Though it has a large number of missing values, fertilizer use is relatively better indicator of technology adoption in these products. The fertilizer application rate in most peasant associations is very low (Table 3.2). And peasants in some peasants associations like Dinki, Imdibir, Doma and Geblen have not used a noticeable fertilizer in all rounds.

[9] 1 hectare is approximately equal to 2.471 acre. Hence the yield in terms of hectare is approximately equal to 520kg/ha

Table 3. 2: Average level of Fertilizer use for producing exportable products (in kg/ha)

	Round3 1995		Round 4 1997		Round5 2000		Round6 2004		Average of 1995-2004	
PA	**Dap**	**Urea**	**Dap**	**Urea**	**Dap**	**Urea**	**Dap**	**Urea**	**Dap**	**Urea**
Hersaw	-	-	-	-	7.50	8.33		3.00	7.50	7.00
Yetmen	-	-	-	-	40.00	5.00	-	-	40.00	5.00
Shumsa	-	-	-	-	5.00	2.50	-	-	5.00	2.50
Sirbana Godet	75	-	-	-	17.50	12.50			29.00	12.50
Adel Kek	-	10	62.50	50.00	10.11	8.55	25.00	25.00	20.80	11.05
Korodegaga	15	-	100.00	-	23.81	-	2.00	-	27.57	-
Trirufek	5.00	-	-	-	8.25	38.50	2.00	-	7.06	38.50
Aze deboa	22.67		21.88	25.00	25.43	-	-	-	22.96	25.00
Adado	-	-	-	24.00	25.00	-	-	-	25.00	24.00
Gara Godo	-	-	-	-	1.00				1.00	-
D.B.Milki	50.00	50.00	-	-	26.00	16.67	-	-	28.67	25.00
D.B.Kor	-	-	-	-	26.67	25.00	29.00		27.60	25.00
D.B.Kar	-	-	-	-	11.33	10.00	-	3.00	11.33	6.50
D.B.Bok	-	-	-	-	36.25	17.50	50.00	-	39.00	17.50
Eteya	-	-	-	-	20.97	27.25	-	-	20.97	27.25

Source: ERHS (Rounds 3-6)

The rate of fertilizer use by crop category is also low. Sesame has a higher level of fertilizer use in the four rounds. But sesame has a lower number of observations in the dataset. In other crops, 32kg/ha of Dap is used in chickpea and 27kg/ha in harricot bean (Table 3.3) in the four rounds. In the case of Urea, 34kg/ha is used in coffee and 25kg/ha in lentils. Though the extent of fertilizer use in these products is low, simple inspection of the yield table against the fertilizer use table shows a positive correlation between fertilizer and yield. A better yield in these products was observed in the year 2000 and there was a better use of fertilizer in this period (Table 3.1). The partial correlations of Dap and Urea with yield were 0.12 and 0.07[10], respectively and both of them were significant at 1%. This is an indicator of fertilizer use on yield improvements.

[10] The partial correlation was computed from the dataset. The correlations in other rounds are insignificant.

Table 3.3: Crop level fertilizer use

Type of crop		Round 3 (1997)		Round 4 1997		Round 5 2000		Round 6 2004		All Rounds 1995-2004	
		Dap	Urea	Dap	Urea	Dap	Urea	Dap	Urea	Dap	Urea
Chat		-	10	62.5	50	10.1	8.6	25	25	21	11
Coffee		24	-	21.5	24.5	15.8	38.5	-	-	21	34
Pulses	Chickpea	-	-	-	-	31.7	7.5	-	-	32	7.5
	Cowpea	50	50	-	-	14.1	6.7	2	-	16	17
	Haircoat bean	13.3	-	100	-	23.6	-	2	-	27	-
	Horse bean	33	-	22.5	-	21.5	13	36	-	23	13
	Lentils	-	-	-	-	13.3	25	-	-	13	25
Oilseeds	Linseed	5	-	-	-	5	-	-	-	5	-
	Sesame	-	-	-	-	150	150	-	-	150	150
	Sunflower	-	-	-	-	5	2.5	-	3	5	3
	Neug	-	-			-	-	-	-		

Source: ERHS (Rounds 3-6)

3.2 Infrastructures

Infrastructural services in Ethiopia are the lowest in the world though there are minor improvements at national level (see Table 3.4). These affect the development of the country in a variety of ways. Mainline telephone (per 1000 people) was only 6.34 in 2003. The comparative figure of the neighboring Kenya, Sub-Saharan Africa and Low income countries in the same period were, 10.03, 15, and 27, respectively. This index has now increased and Ethiopia has an equal level with that of Kenya in 2008. This is due to a deliberate move by the government towards improving telecommunication services and most rural households have access to wireless telephone.

The total road density increased from 29,571km in 2000 to 42,942 in 2007. This density is still low, about 2/3 of the Kenya's road density in 2004 (WDI, 2010). Given Ethiopia's large area, such the lower road network reflects the lack of integration of different producers of agricultural products with markets and towns. But there are large scale improvements in Ethiopia over time compared to Kenya in terms of number of roads sector (Table 3.4). Another important infrastructure facility is access to banks. From the table one can see that the number of bank branches per 100,000 people in Ethiopia was very near to zero in 2004 while it was 1 in Kenya and 5 in low income countries and 10 in the world.

Table 3.4: Indicators of Infrastructure in Ethiopia and other countries

Infrastructure densities	1996	1998	2000	2002	2004	2006	2007	2008
Telephone mainlines (per 1,000 people)								
Ethiopia	2.55	2.68	3.61	5.26	10	10	10	10
Kenya	9.55	9.83	9.51	10.03	10	10	10	10
Sub Saharan Africa	12	13	14	15	20	20	20	20
Low income countries	12	16	22	26	10	10	10	10
World	129	143	161	175	190	200	190	190
Roads, total network (km)								
Ethiopia	23,832	26,063	29,571	33,297	36,469	39,477	42,429	
Kenya	63,942	63,942	63,942	63,942	63,265[11]	--	--	--
Bank branches (per 100,000)								
Ethiopia	..	..	..	..	0			
Kenya	..	..	..	..	1			
Sub-Saharan Africa	..	..	..	..	..			
Low Income	..	..	..	..	5			
World	..	..	..	..	10			

Source: WDI (2006)

The infrastructure situation in Ethiopia is especially low in the rural areas. The majority of the available services are concentrated in urban centers while in the rural areas, which host more than 85% of the population, the services are low but improving over time (see Table 3.5). As of 2000 survey, none of the peasant associations in the survey have access to bank or to a telecommunication center. Only two peasants associations reported that they have access to daily market as of 2000 which indicate the lack of easy access to marketing of products and inputs. There are, however, slight improvements in some infrastructural facilities as of 2004 and a bank was available in one of the peasant associations.

[11] This figure is below the former periods and it is difficult to give reasons

Table 3.5: Infrastructural services across the sample peasant associations

Type of service	Number of PAs[12] that have access to	
	2000	2004
Improved access to road	9	9
Improved access to transport system	7	8
Electric power	1	3
Bank	0	1
Telecommunication	0	1
Agricultural Extension offices	10	11
Daily markets	2	4
Veterinary services	-	5
Primary schools	5	14

Source: ERHS (Round 4 and 6)

Relatively better improvement is observed in primary school access and daily markets (Table 3.5). Another indicator of the access to the infrastructural facilities is the distance from the nearest service center. The peasant need to travel long distance to get the services such as selling of their products and livestock, educate their children, and purchase inputs such labor and fertilizer, medication to their families and animals. Table 3.6 shows the distances that households need to travel to get various services. The most inaccessible service to peasants is Bank. Its average distance from peasant associations was 32.5km in 2000 and 32km in 2004. Peasants need to travel from 4.5 km in Aze Deboa to 120 km in Shumsha to get access to Bank in 2000. Similarly, they need to travel up to 70 km to have access to telephone service. This has large tradeoffs with labor supply especially in the peak farm seasons.

Table 3.6: Average distances in km to the nearest basic infrastructural facilities

Type of facility	2000	2004
Town	11.00	8.50
Telephone center	16.40	9.80
Bank	32.5	32.00
Daily Market	10.63	10.30
Agricultural Extension Office	6.50	5.00
Veterinary	15.50	10.50
Primary Education	4.00	3.05

Source: ERHS (Rounds 4 and 6)

[12] The total numbers of peasant associations with infrastructural information were 15.

3.3 *Econometric evidence*

3.3.1 Model specification and variable descriptions

Production function can be used to relate the production of exportable agricultural products with the inputs used in the production process and state of technical knowledge (see EEA, 2000/01; Omodho, 2008). Given factors of production capital (K), labor (L) and technology; a production function can be specified as follows;

$$Y = A(t)\,f(L, K) \qquad [1]$$

A (t) represents all the influences that go into determining Y other than K and L. Changes in A over time represent technical progress. For this reason, A is shown as a function of time. Assume dA/dt>0, particular levels of input of labor and capital become more productive over time (see Omodho, 2008). The growth[13] equation becomes

$$GY = GA + e_{yK}\,G_K + e_{yL}\,G_L \qquad [2]$$

This shows that the rate of growth in output can be broken down into the sum of two components: growth attributed to changes in inputs (K and L) and other 'residual' growth (that is, changes in A). Those factors that can be classified into A in agricultural production function are numerous that cover a wider range of household, plot, environmental and community characteristics

The dependent variable is the aggregate value of the exportable crops obtained by a household and the independent variables in this restrictive model are capital (K) and Labor (L). There is no as such capital investment in rural households. Better proxies of capital in rural households are land and oxen (see Weeks and Geda, 2004). The values of farm implements are taken to account for additional capital. With respect to labor, the survey has important questions such as the number of family and hired labor who participate in every aspect of the farming process. However, the data hired labor is noisy and not used. Other alternatives are the number of male and female adult members that participate in the farm activities and the number of male and female children in farm work.

[13] Output elasticity with capital is $\partial f / \partial K \bullet (K / f(K, L) = \partial Y / \partial K \bullet K / Y = e_{YK}$ and output elasticity with labor is $\partial f / \partial L \bullet (L / f(K, L) = \partial Y / \partial L \bullet L / Y = e_{YL}$ (see Omodho, 2008)

To make the model more meaningful, a host of independent variables are incorporated in the right hand side of the above equation. The variables include environmental conditions, household characteristics, agricultural inputs and technology. The variables in these categories include, slope of land cultivated and its quality, credit, timing and adequacy of rainfall. Infrastructural variables are also included in the specification to explore their effects on the production of exportables. These include access to power, transport, market, bank, agriculture extension office etc. Some of the variables such as access to power are excluded in the empirical analysis. This is because there is no any peasant association with access to power. We stipulated that the distance to the nearest service center will reflect the effect of such variables. The estimable equation is given below

$$Y = A\, f(L, K, HH, ENV, INF) \qquad [3]$$

Where Y is the value of exportable crops harvested by household i at round t in natural logarithm[14] , L is labor input, K is land both in logarithm, and HH includes other household characteristics such as number of oxen owned, fertilizer, soil quality and slope, amount of credit use. ENV includes the vector of dummy variables that are related to environment like timing and magnitude of rainfall. Finally, INF refers to the distances and availability of different infrastructures at peasant association level. These include roads, banks, telephone, markets, extension offices and so forth.

3.3.2 Estimation Technique

The data employed for this study is panel data. This involves the use of panel econometric techniques. Panel data that we have used has the following form;

$$Y_{it} = \beta X_{it} + \alpha_i + u_{it} \qquad 4$$

t = 1; 2…T, is the time period (in our case it is the round), Y_{it} , the dependent variable, X_{it} , the independent variables, α_i the unobserved individual heterogeneity, and u_{it} is a residual (and so not observed) that varies both over time and across individuals. This model assumes that time effects are insignificant and it is called a one way error component model (Baltagi, 1995).

If α_i is correlated with $x_{it,}$ the Fixed effects (FE) estimator can be used to obtain consistent estimates of β, provided cov (x_{it} ,u_{is}) = 0 for s = 1; 2….T. On the other hand, Random Effect (RE) model is appropriate when the unobserved effect is uncorrelated with the explanatory variables (Wooldrige, 2005, Green, 2003). The first

[14] All continuous variables are in logarithm and the dummies are in level.

step before reporting the estimated result is the choice of the estimation technique. The technique to choose among FE and RE is Hausman test (Wooldrige, 2005, Green, 2003). If this standard Hausman test rejects the null hypothesis that the conditional mean of the disturbances given the regressors is zero, FE estimator will be reported and the RE has to be reported if the test is not rejected (Baltagi, B.H., et al., 2002). Though fixed effect model shows the significance of the unobserved heterogeneity, it is less likely to bring relevant estimates for time invariant variables. Most of the variables in the dataset change only slightly. In this case the alternative is to switch to the Hausman-Taylor (HT) (Baltagi, B.H., et al., 2002). The additional benefit of the HT estimator is that it addresses endogeneity. The HT technique is viable as it allows correlation among some regressors with the individual specific characteristics and also the estimation of coefficients to time invariant regressors. HT model takes the following form;

$$y_{it} = k * + X_{it}\beta + Z_i\delta + \alpha_i + u_{it} \qquad [5]$$

where $k *$ is an intercept and, Z_i are individual time invariant variables. The X and Z variables are split into $[X_1, X_2]$ and $[Z_1, Z_2]$ vectors. X_1 and Z_1 are assumed exogenous and not correlated with α_i and u_{it} while X_2 and Z_2 are endogenous due to their correlation with the individual characteristic α_i not with u_{it}.

3.3.4 Estimation and discussion of findings

The standard Hausman test shows that the fixed effects are significant at 5% indicating the inappropriateness of RE estimator. This necessitates a need to choose among the HT and the FE. The FE estimator does not bring appropriate coefficients when many of the variables change only slightly over time. It helps in identifying the correlations among regressors and unobserved heterogeneity. Most of the variables under consideration change only slightly and hence the preferred estimation technique is the HT.

Translog production function which involves the use of interactive variables and other non-linearity's like squares of explanatory variables was specified. Most of the interactive and squares of variables are found to be insignificant and hence excluded for parsimony except the square of land. The estimated result shows that most of the variables are with the expected sign.

Size of land and the dummies of soil quality indicators are significant and with the expected sign. The relationship between land and value of production is non-linear. The square of land is negative which might be an indication of the law of diminishing returns with respect to land as its size increases. It is found that harvesting on poor quality land (*teuf land*) and medium level of fertile land (*lemteuf*) are expected to give a lower level of production compared to the harvests from a good soil quality (*lem*). Geddel (gully) dummy was used to account for slope of land but it is insignificant.

Labor variable has the expected positive effect. The number of male family members that took part in farm work and dummy for the participation of children are significant. The number of females is, however, insignificant and not reported in the final regression. This is mainly due to the divisions of labor where most of females' activities are concentrated on governing house and in the production of cereals. A positive effect of females' labor in the rural households is found in the case of cereals in Ethiopia (see Endale, 2009). The significance of children's activities is as expected because they are directly involved in the production system. They also look after cattle during which time the adult labor will concentrate on the farm work and hence more supply of labor.

The value of farm tools/implement owned by the household is another important variable. This variable is the aggregate sum of the current value that farm households would like to sell in the survey periods. This is used as one proxy for capital input in the farm households. The variable appears significant and with the expected positive sign. The other proxy for capital in the rural households is oxen ownership. Its service as a draft power makes it a very useful input in the production system especially in Ethiopia. Fertilizer is an indicator of technology adoption in agriculture. The data in the production of cereals, however, has a large number of missing values. So it is not used in the econometric estimation because it affected the degree of freedom at a significant rate.

The coefficient of total loan size confirms that loans are used to finance the different needs of farm households. This can induce farmers to apply required levels of new technologies like fertilizer, improved seeds, and pesticides. It also helps farmers to withhold their production until the prices of products are high. A surprising effect is observed in the education status of the head and spouse. Both are negative and significant at 1%. This might have to do with the literature that general education can cause a shift in sector of employment from agriculture to the industry or service sectors. Otherwise it is difficult to give an interpretation of the negative coefficients. Gender of the household head is negative but insignificant. The negative sign might be an indicator of lack of equal treatment of women headed households in terms of access to different resources and rights.

Table 3.7: Fixed Effect, Random Effect and Hausman-Taylor Estimated Results

Independent Variables	Dependent variable: value of production at 1997 farm gate prices		
	Hausman-Taylor	Fixed Effect	Random Effect
Tvexogenous[15]			
Inadequate rain (dummy)	-1.689***[16] (0.259)	-0.913 (0.989)	-0.823** (0.338)
Ln(distance to nearest town)	-7.881*** (0.620)	-9.670 (1.978)	-0.747*** (0.241)
Improved access to road (dummy)	6.357*** (0.523)	5.375 (1.856)	0.450 (0.298)
Teuf (dummy for very poor soil quality)	-1.00*** (0.375)	-2.170 (1.289)	0.706** (0.358)
Lemteuf (dummy for poor soil)	-1.29*** (0.359)	-2.965 (1.438)	0.241 (0.334)
Tvendogneous			
Ln(land)	2.615*** (0.406)	4.626 (1.864)	-0.019 (0.112)
Ln(male adults)	0.661*** (0.165)	-0.083 (0.826)	-0.007 (0.133)
Ln (value of farm tools owned by the hh)	0.457*** (0.120)8	1.107 (0.565)	0.009 (0.087)
Ln(oxen)	0.231** (0.096)	0.141 (0.336)	0.125 (0.107)
Lnlandsq	-0.794*** (0.226)	-1.278 (1.1.51)	0.014 (0.021)
Child labor (=1 if working children in hh)	1.478*** (0.384)	2.171 (1.576)	-0.305 (0.302)
Ln(Total loan)	0.462*** (0.035)	0.568 (0.135)	0.195*** (0.054)
Hhhedu (=1 if the head is educated)	-0.781*** (0.165)	-2.015 (0.985)	-0.133 (0.207)
Spoedu (=1 if the spouse is educated)	-0.584** (0.243)	0.337 (1.037)	-0.076 (0.244)
Tlexogneous			
Geddel (=1 if land is gully)	16.638 (108.18)	Dropped	6.426 (16.617)
Hhhsex(=1 if the head is female)	-2.586 (2.173)	-5.193	-0.350 (0.335)
_cons	21.770	23.39	9.079
Sigma_u	10.058	10.323	0.974
Sigma_e	0.149	0.338	0.338
Rho	0.999	0.998	0.892
corr(u_i, Xb)		-0.994	

Note: TV refers to time varying; TI refers to time invariant

Number of observations=114 , Number of Groups = 98

Hausman Fixed, Chi2(15) = 33.41 ; Prob > chi2 = 0.0159[17]

[15] The TVexogneous, TVendogneous and TIexogneous classification of variable are hold only for the HT estimator

[16] ***, ** and * represent significance at 1%, 5% and 10%, respectively. The elements in parenthesis are standard errors of estimated coefficients

[17] The standard Hausman test statistics indicates rejection of the Random Effect model

Dummies based on the perceptions of farmers are used to account the effect of environmental factors. The dummy for inadequate rainfall is negative and significant. It shows the effects of drought on the production of exportable crops. This is an indicator of the problems of being dependent on rain-fed agriculture. It calls for alternative activities like the use of small scale irrigation activities and ponds to deal with the shocks.

The infrastructural indicators have the largest marginal effects compared to the other variables. Distance to the nearest town and dummy for access to improved road are used as an indicator of infrastructural variables. The nearest towns have usually many of the facilities like input and output markets, schools, health centers, and telecommunication services. It is significant and negative as expected. This means longer travelling time reduces the value of production due to higher transaction costs and the tradeoffs with labor supply. The dummy for access to improved road is positive. Rural roads are crucial for input delivery and effective extension services in agriculture. It also activates accesses to market for sale of products.

4. Conclusion and policy implications

The production and yield of major export items are low compared to many countries and input uses are limited. The use of fertilizer and other technologies that enhance productivity is also low. Another observation aside from the low input use was the lack of infrastructures in the majority of the survey areas. This can increase transaction costs and hence can reduce the performance of the farmers. Farmers with access to infrastructural services have up-to-date information with regards to input and output markets, are motivated to use services such as banks for saving and investment, and they have better access to modern technology.

The econometric estimation is conducted by the HT estimator, which is a preferred technique to address individual heterogeneity in the presence of slightly variant regressors. The estimation showed that most of the variables are significant and with the expected sign. Land and its quality are significant and with the expected sign. The relationship between land and value of production is non-linear. The number of adult males that participated in farm work and dummy for children participation are the significant labor variables. The values of farm tools/implement, ownership of oxen, access to loan are other household level variables. Education status of the head and spouse are, however, negative and not expected. This might be because educated family members have a higher tendency to migrate from the rural areas and to be in industry or service sectors. A dummy for female headed households is negative but insignificant. The negative sign is mainly due to unequal opportunities to women. A dummy for inadequate rainfall based on the perception of households was used and it is found as negative. Finally, the infrastructural indicators are significant and with largest coefficient compared to the other list of variables. This has to do with the importance of access to price and input information and the lower transaction cost effect of infrastructures.

The study identified the following areas of intervention;

1. Infrastructural indicators have the largest effects on the values of production. This shows that the ongoing involvement of government in the road and telecommunication access to the rural areas is a right direction and needs to be continued. Infrastructural improvement to the rural areas is among the priority areas of intervention to improve the performance of the exportable products.

2. Lack of complementary inputs especially fertilizer is noticed in the descriptive analysis. The important question in fertilizer application in exportable products is the organic-inorganic issue. Two important points can be noted with this. First, a positive correlation was observed in one of the survey periods where there was a better employment of fertilizer. This supports the uses of fertilizer up to the desired levels. Second, the organic-inorganic decision has to be made based on cost benefit analysis. It is obvious that organic exportable products have a higher price than that of the inorganic ones but they have a lower yield. Study has to be undertaken that compares the benefits of additional prices from the organic products with the costs in terms of lower yields. If the benefit from inorganic is better from the organic, then more efforts has to be made in marketing to find foreign markets to export products. It is also necessary to look at the experience of other successful countries with the inorganic products like Brazil in the case of coffee.

3. Investments in soil conservation enhancing technologies better agricultural practices, efficient use of agricultural inputs and water. Land and livestock managements are necessary to improve or maintain yields. The use of small scale irrigation activities is very essential to address the problems of rainfall shocks.

4. Investments in innovations of improved farm tools/implement that are affordable to farmers are needed many of the farmers in Ethiopia rely on traditional tools. Innovation of other better tools that are affordable to peasants can improve the productivity of farmers. Improved access to financial services can increase the adoption rates of improved tools as well as fertilizers and improved seeds.

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Annexes

Annex 1: Fertilizer Applied in thousands of Quintals (National Level)

Years	Cereal	Pulses	Oilseeds
2000/01	3,068.29	132.11	26.42
2001/02[18]	2,091	53.15	7.53
2003/04	2,311.46	82,68	47
2004/05	2,535.44	197.37	77.85
2005/06	3,509.57	117.86	82.75
2006/07	3,544.23	158.81	95.67
2007/08	3,962.67	160.46	136.24

Source: CSA, various years

Annex 2: Area in thousands of Hectares and production in thousands of quintals (National Level)

Years	Cereals			Pulses			oilseeds		
	land	Production	Yield	land	production	yield	land	production	yield
2001/02	6,370	87,068	14	1,017	10,212	10	426	2,044	4.80
2002/03	6,324	63,440	10	1,065	8,232	8	474	1,966	4.15
2003/04	6,994	90,007	13	1,100	10,373	9	571	3,129	5.48
2004/05	7,643	100,365	13	1,349	13,496	10	825	5,266	6.38
2005/06	8,081	116,242	14	1,292	12,712	10	796	4,964	6.24
2006/07	8,463	128797	15	1,379	15,786	11	740	4,970	6.72
2007/08	8,730	137,169	16	1,517	17,827	12	707	6,169	8.73

CAS, various years

Annex 3: Fertilizer applied per hectare of land (in kg) (National Level)

Years	Cereals	Pulses	Oilseeds
2000/01	32.83	5.23	1.77
2001/02	33.06	4.99	9.92
2003/04	36.25	17.94	13.63
2004/05	45.92	8.74	10.03
2005/06	43.86	12.29	12.02
2006/07	46.82	11.64	18.41
2007/08	45.39	10.59	19.27

Based on CSA survey

[18] Data is not available for the year 2002/03

Annex 4: Shapiro-Wilk test for normal data

Variables (continuous variables are in logarithmic)	Obs	W	V	z	Prob>z
lvaluepdn (value of production)	2764	0.94356	89.781	11.573	0.00000
lland (Hecare of land in logarithm)	2684	0.94971	77.894	11.196	0.00000
loxen (number of oxen owned in log)	2219	0.95985	52.328	10.105	0.00000
lmad (number of male adults in log)	3512	0.98652	26.612	8.513	0.00000
lfad (number of female adults in log)	3908	0.98212	38.859	9.528	0.00000
lUrea (Urea applied in log)	54	0.98544	0.728	-0.681	0.75219
Ln(value of farm tools owned by the farmer)	3652	0.99898	2.095	1.921	0.02739
Chlabor (1 if a children are involved in farm work)	5770	0.99944	1.722	1.433	0.07598
Spouse education (=1 if spouse is educated)	5770	0.99997	0.089	-6.386	1.00000
Hhheu (1 if the head is educated)	5770	0.99996	0.135	-5.286	1.00000
lDap (Dap applied in log)	147	0.97842	2.468	2.046	0.02039
Lloan (cash loan taken in log)	2535	0.99766	3.44	3.17	0.00076
ldntown (distance to nearest town in log)	3244	0.88362	213.939	13.883	0.00000
ldnteleph (distance to the nearest telephone)	3587	0.95378	93.012	11.767	0.00000
ldnbank (distance to nearest bank in log)	4799	0.98566	37.447	9.494	0.00000
ldnagricoff (distance to the nearest extension office	843	0.90692	50.252	9.632	0.00000
ldnmkt (distance to the near daily mkt outside PA)	3078	0.91852	142.845	12.815	0.00000
ldnvetern (distance to nearest veternary)	3020	0.92591	127.685	12.517	0.00000
Inadeqrain (dummy for inadequate rain)	5774	0.98031	60.628	10.818	0.00000
Rastontime (Dummy for timing of rainfall)	5774	0.99969	0.945	-0.148	0.55896
Lem (Dummy for best soil quality)	5774	0.95287	145.117	13.118	0.00000
Lemteuf (dummy for medium soil quality)	5774	0.90374	296.397	15	0.00000
Teuf (dummy for poor soil quality)	2637	0.8788	184.76	13.408	0.00000
Meda (Dummy for suitable slop)	5774	0.95395	141.782	13.057	0.00000
Dagetama (dummy for poor slop of land)	5774	0.87926	371.766	15.597	0.00000
Geddel (dummy for a very poor land slope)	2631	0.83884	245.168	14.134	0.00000
Road (Dummy for access to improved road)	5774	0.99983	0.512	-1.762	0.96094
Transport (dummy for improved access to transpt)	5774	0.99984	0.484	-1.912	0.97209
Accpower (Dummy for access to electric power)	5774	0.99913	2.67	2.588	0.00483
nagrextoff (number of extension offices with in PA)	5774	0.99987	0.395	-2.45	0.99286
Ndmkts (number of daily markets with in PA)	5774	0.99998	0.074	-6.875	1.00000

Annex 5: xtsum of the variables used in the econometric analysis

Variable	Mean	Std. Dev	Min	Max	Observations
lvaluepdn - overall	7.908359	1.529143	2.079442	13.56706	N = 2760
between		1.275856	2.495105	11.57685	n=1277
within		0.959516	12.409201	12.36616	T-bar=2.16132
Lland overall	.3871723	1.610995 -	5.6	5.4806	N=2682
between		1.292947	5.6	5.4807	n=1302
within		1.038342	-4.9	5.7167	T-bar=2.06
loxen overall	7173202	0.7817795	0	4.382027	N=2219
between		0.6478888	0	4.382027	n=1211
within		0.4760643	-1.502444	2.984785	T-bar=1.8323
lmad overall	.5138677	0.6125047	0	3.218876	N=3512
between		0.5337969	0	2.772589	n=1427
within		0.3372127	-.7285856	2.593309	T-bar = 2.4611
lfad overall	.4919088	0.6141579	0	2.995732	N = 3908
between		0.5239112	0	2.639057	n=1534
within		0.3552644	-.8326706	2.415621	T-bar = 2.548
lUrea overall	4.167155	1.131108	.9162908	6.802395	N=54
between		1.097808	.9162908	6.802395	n =51
within		0.3319151	2.683375	5.650936	T-bar=1.0588
lDap overall	4.520598	1.267184	.6931472	7.003066	N=147
		1.234924	.6931472	6.802395	n=138
chlab overall	.7616984	0.4260814	0	1.0000	N=5770
between		0.294416	0	1.0000	n=2111
within		0.3144918	0 .01170	1.52000	T-bar=2.73
hhhedu overall	.4622184	0.4986137	0	1.0000	N=5770
between		0.3863817	0	1.0000	n=2111
within		0 .364705	-.287	1.2120	T-bar =2.73
spoedu overall	.5750433	0.4943793	0	1.0000	N=5770
between		0.3815343	0	1.00000	n=2111
within		.3323569	-.1749567	1.330000	T-bar=2.7
Lnfartools overall	4.448713	1.386268	-.6931472	9.170000	N=3652
Between		.9960308	.6931472	7.800000	n =1478
within		1.025068	.6909545	8.436021	T-bar=2.47091
within		.2795714	2.78773	6.253466	T-bar=1.0652
lloan overall	6.642272	1.439323	0	10.64542	N=2535
between		1.312779	2.970414	10.4631	n=1283
within		.8724091	2.659622	10.22104	T-bar =1.9758
ldntown - overall	2.498816	.4854326	1.252763	3.218876	N=3244
between		.3331688	1.252763	3.218876	n=1680
within		.2910471	1.580985	3.423013	T-bar=1.9309
ldnteleph overall	2.381878	.7778719	.6931472	4.248495	N=3587
between		.6853806	.6931472	4.248495	n=1561
within		.2560586	1.259514	3.504241	T-bar=2.2978
ldnbank overall	3.03462	.9830354	1.098612	5.192957	N=4799
between		.8837128	1.386294	5.192957	n=1854
within		.4238015	1.037465	4.449923	T-bar=2.5884
Variable	**Mean**	**Std. Dev**	**Min**	**Max**	**Observations**

ldnagrexof overall	1.808385	.8939821	-2.140066	2.890372	N=843
between		.7568372	.0034843	2.890372	n=532
within		.0987803	-.5136389	3.108032	T-bar=1.58
ldnmkt overall	2.188597	.8575852	-.6931472	4.189655	N=3078
between		.9447568	-.6931472	4.189655	n=1248
within		.4276691	.4866156	3.915536	T-bar=2.4664
ldnvetern overall	2.42089	.7847116	-1.178655	3.78419	N=3020
between		.7370928	-1.178655	3.78419	n=1091
within		.3093812	-.0987223	4.183974	T-bar=2.768
Inadeqrain overall	.1090815	.2853632	0	1	N=5774
between		.1849989	0	1	n=2111
within		.2340253	.15908	1.659	T-bar=2.735
rainontim overall	.7092137	.4541644	0	1	N=5774
between		.3806898	0	1	n=2111
within		.3374365	-.0407863	1.459	T-bar = 2.735
lem overall	.2670407	.4337619	0	1	N=5774
between		.3497372	0	1	n=2111
within		.2987806	-.4829593	1.0174	T-bar=2.735
lemteuf overall	.1274153	.3232669	0	1	N=5774
between		.2502078	0	1	n = 2111
within		.2355642	-.62258	.877	T-bar = 2.735
teuf overall	.1070493	.2991175	0	1	N = 2637
between		.2689445	0	1	n = 1286
within		.1915569	-.6429507	.8570493	T-bar = 2.0505
meda overall	.311511	.4525174	0	1	N=5774
between		.3621385	0	1	n=2111
within		.3144597	-.438489	1.061511	T-bar =2.735
dagetama overall	.1165474	.3082385	0	1	N=5774
between		.2552222	0	1	n=2111
within		.204117	-.6334526	.8665474	T-bar=2.735
geddel overall	.0295884	.1624953	0	1	N=2631
between		.1130602	0	1	n=1286
within		.1227868	-.4704116	.7795884	T-bar = 2.0459
Road overall	.6636647	.4724961	0	1	N=5774
between		.3623267	0	1	n=2111
within		.289524	-.0863353	1.4137	T-bar =2.735
Tranport overall	.6598545	.4737989	0	1	N=5774
between		.3547127	0	1	n=2111
within		.3028771	-.090146	1.4099	T-bar=2.735
Power overall	.2301697	.4209778	0	1	N=5774
between		.3452487	0	1	n=2111
within		.3174897	-.5198303	.9802	T-bar = 2.735
Ext off. overall	.6468653	.4779855	0	1	N=5774
between		.3395227	0	1	n=2111
within		.3358715	-.1031347	1.396865	T-bar = 2.7352
Dailymkts overall	.4868375	.49987	0	1	N = 5774
between		.3787016	0	1	n = 2111
within		.383903	-.2631625	1.2368	T-bar = 2.74

DETERMINANTS OF THE CHOICE OF MARKETING CHANNELS AMONGST SMALL-SCALE MAIZE FARMERS: THE CASE OF BURA-BORAMA KEBELE, SOUTHERN ETHIOPIA

Mamo Girma[1]

Abstract

The objective of this study is to identify the transaction cost factors and household characteristics that influence the decision of marketing channel choice by smallholder maize farmers in rural kebele of Bura Borama, district of Shashemene. The main hypothesis of the study is that farmers' choice of marketing channel is influenced by transaction costs (e.g. information, transport, negotiation and monitoring costs) and household characteristics (e.g. age, education). Households facing higher transaction costs are excluded from using certain marketing channels, even if these market outlets exist. A multinomial logit model is used for empirical estimation using data from a survey of 103 maize farmers of Bura Borama. Empirical findings of this study reveal that the most important factors that explain farmers' decision of marketing channel choice are farmers' age, years of education, farm size, access to transportation, access to information, time spent to accomplish a one time sales and a possible delay in payment during transaction. The result suggests that policy intervention of government and/or other concerned institutions should focus on reducing some of these transaction costs through the provision of institutional support to smallholder maize farmers. These supports could be in the form of improving access to market information, establishing producers' organization and improving the rural road networks which link production areas to markets.

Key words: Transaction costs, marketing channel choice, smallholder farmers, maize, Multinomial logit, Bura Borama

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[1] This paper is a shortened and edited version of my Master's Thesis "Choice of Marketing Channels and Transaction costs: The case of maize marketing in Bura-Borama kebele, Shashemene Area" from Addis Ababa University (Mamo Girma, 2009). I would like to thank my supervisor Dr. Dejene Aredo for his valuable guidance with the thesis. I would like to thank Dr. Degnet Abebaw for his useful comments on the model specification of the paper. Furthermore the author wishes to acknowledge the financial assistance provided by the Post-harvest Unit of Sasakawa Global 2000. The views expressed in the study are those of the author, and the usual disclaimer applies. E-mail: mg_mamo@yahoo.com

1. Introduction

Poverty being a rural phenomenon in sub-Saharan Africa (including Ethiopia), development of efficient agricultural marketing is believed to be very vital to enhance the participation of smallholder farmers in the market and ensure the "poverty-reducing impacts of agricultural growth" (World Bank, 2008). It is believed that a well functioning agricultural (such as cereal/maize) marketing which is very vital for agricultural growth and transition of smallholder farming towards commercial farming is ultimately determined by access to market (Jooste 2001; Randela 2005; Fernando 2006). Access to reliable markets provides opportunities for smallholders to improve their income and livelihood because it increases the price farmers receive for their products, citrus paribus. For instance, empirical studies in Guantamala (vegetables), Malawi (tobacco), India (dairy), and Kenya (sugarcane) show that an increase in income for smallholders has been associated with adoption of commercial farming (Minot and Hill, 2007). Nevertheless, the functioning of agricultural marketing in developing countries is hampered by high transaction costs incurred during market exchange. As stated by Bart and Kyle (2000), the existence of transaction costs is the major reason why most food markets in developing countries still suffer from inefficiency despite the profound efforts to liberalize markets since 1990s.

Literature reveals that the performance of maize/grain market remains poor and inefficient in Ethiopia despite the reform. It is largely due to missing markets, poor infrastructure, and high transaction costs (Amaha (2001); Eleni (2001); Dereje and Abdissa (2001); Eleni and Goggan (2005:3); and Dender (2002)). For instance, Eleni (2001) notes that transaction cost particularly searching cost and transportation cost (distinct from transaction cost[2]) determine trading exchange in the grain market. She also found that farmers usually rely on grain brokers in the presence of high transaction costs. Farmers are less dependent on grain brokers where there is low transaction costs due to good social network that created better information on price and market. The role of intermediaries (assemblers, wholesalers) is still dominant in maize marketing. This makes the market inaccessible to the smallholder maize farmers. Although the main steam??? market generates better return for producers, the majority of smallholder farmers couldn't participate in the main regional grain market.

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[2] In her analysis transportation cost is categorized as physical marketing cost, which is different from transaction cost. However, literatures on marketing channel choice including Hobbs (1996); Boger (2001); Ferto and Szabo (2002); Irini Maltsoglou and Aysen Tanyeri-Abur (2005:6);Forhad Shilpi and Dina Umali-Deininger (2007:9); Lu (2007), have considered transportation costs as a significant part of transaction costs and this paper follows the latter argument.

The liberalization of markets has broadened the choice of market channels for smallholder farmers. This, in the presence of well functioning cereal markets, is very useful because it enables the market agents including farmers to choose between the appropriate outlets needed. In most liberalized African markets, these marketing channels include state marketing agency, private traders, relatives/neighbors, vending at local markets, associations and cooperatives and private companies. Up to very recently, the role of the state market agency (EGTE), private companies, associations and cooperatives as potential alternative market outlets to smallholder maize farmers were non-existent in Bura-Borama. Maize farmers in the area under study sell direct to consumers at the local or regional markets, retail markets, rural assemblers, and wholesalers. Farmers' decision to select a particular market channel affects the quantity sold as well as the return obtained.

A combination of the Marketing Channel Approach (MCA) and the theory of Institutional Economics can provide a framework to identify the factors influencing farmers' decision of marketing channel choice. Although there is a wealth of literature on grain marketing in Ethiopia, to the best of my knowledge, research on a commodity specific (such as maize) market channel choice in grain markets employing transaction cost economics is scant. The purpose of this study is, therefore, to describe and understand the maize marketing chain and to investigate the extent to which transaction costs and household characteristics influence farmers' decision of marketing channels. It is hypothesized that a household's decision of a particular marketing channel choice is determined by the various types of transaction costs (such as information, bargaining, monitoring, and transportation costs), and some household characteristics. On the basis of a sample of maize farmers, a multinomial logit model is employed to estimate farmers' decision of marketing channel choice in Bura Borama kebele, one of the maize surplus areas within the districts of Shashemene. The paper, however, considers only the sellers and doesn't take into account the behavior of buyers in maize marketing. Findings of the study are expected to assist the government and other relevant institutions that have interest in maize marketing and in designing appropriate strategies towards improving agricultural market development activities in the study area.

This paper is organized into five sections. Section 2 provides an overview of maize marketing in Ethiopia. Section 3 presents the methodology and specification of the model. Section 4 reports the results of regression analysis on the choice of maize market among smallholder farmers in Bura-Borama. Finally, section 5 presents concluding remarks and some policy implications.

2. Overview of Maize Marketing in Ethiopia

A well developed maize marketing chain that links smallholder farmers with the final market is highly important in Ethiopia to improve income of the poor farmers and reduce rural poverty. This is because maize is predominantly produced by smallholders and is a major staple food crop with over 80% of the total population being both primary producers and consumers of maize (Dawit et al, 2008); hence, related to food security to a large extent. Maize is at the top of all cereals in terms of total volume of production and yield per hectare (FAOSTAT, 2008; CSA, 2008) while it is second next to *teff* in terms of total area cultivated (CSA, 2008). Maize is also an important staple food in Ethiopia especially in Southern part, rural people and urban poor people, while it faces low demand as food staple among the people in the north and well-off urban population. The main cereals with higher demand in the urban areas are *teff* and wheat. An attempt to raise the urban demand through increasing the quality of maize would be of paramount importance to improve the gains for smallholder farmers. Furthermore, data from FAOSTAT (2008) shows that Ethiopia is the fourth largest maize producer in Africa following South Africa, Egypt and Nigeria, which may generate a comparative advantage to the country to involve in regional marketing in Africa. Empirical evidences on grain marketing reveal that a very small proportion of food grains production is marketed as the larger portion of the produce goes for direct household consumption due to the subsistence nature of the production (Amha, 2001:61). Nonetheless, among cereals maize had the highest share of total marketed surplus (25%), followed by *teff* (21%), and wheat (14%), (RATES, 2003).

Following market liberalization in Ethiopia in the 1990s, the dominant role of the state in wholesale cereal trading (through the Agricultural Marketing Corporation (AMC)) was abolished. Before the reform, regional wholesalers were required to sale their purchases to AMC at a fixed price. With the reform, AMC was renamed as EGTE (Ethiopian Grain Trade Enterprise) in 1999. The reform encourages private wholesalers to involve in grain marketing. Thus, liberalization of maize market tends to offer different ways or market outlets in which maize product reaches final consumers. A producer can sell directly to a consumer, or exchange can proceed through a number of intermediaries (e.g. assemblers, wholesalers, retailers) (Mandefro, et al, 2001; Eleni, 2001; Amha, 2002; Girma, 2002; RATES, 2003). Together with maize primary producers, these intermediaries form the maize marketing channels in Ethiopia. Participants (e.g. farmers and intermediaries) along the maize/cereal marketing channels assume different tasks and can be described as follow.

Primary Maize Producers: - As indicated earlier, small- scale subsistence farmers undertake the larger proportion of maize production. They put aside most of their produce for consumption and sell the left-over. Due to the prevailing high transaction costs, (Eleni and Ian, 2005:3; RATES, 2003:14) farmers sell their produce (either carrying sacks themselves or using donkey) within a short distance (within a distance of 20 km) from the main regional markets.

Rural Assemblers/Local collectors: - They are also known as "farmer-traders" who assemble grains from a large number of farmers in the village or farm-gate and transport them to the regional markets using horse-driven carts, pack animals as well as small tracks (Eleni, 2001; RATES, 2003). According to a study by RATES (2003), the rural assemblers undertake about 40% of maize purchase from small holder farmers or around 37.5% of total maize marketed.

Private Wholesalers: - In general, in Ethiopian cereal marketing five types of wholesalers are identified: wholesalers in surplus areas, wholesalers in major terminal markets, wholesalers in deficit areas, private companies that perform various business activities, and EGTE. They usually engage in large volume of grain purchase from various sources (such as smallholder farmers, rural assemblers) and sell grains to the different market outlets (such as the retailers and consumer markets) in the regional grain markets of Shashemene as well as the central market in Addis Ababa. In the case of maize, they manage around 74% of the total marketed quantity, (RATES, 2003).

Retailers: - Retailers deliver the grains to the final consumers. Although license is required to enter to the business, most of the retailers are unlicensed[3] where they cover 38% of the total marketed volume of maize (RATES, 2003:21).

Grain Brokers: - An important feature of the Ethiopian grain marketing is the use of brokers by wholesalers and retailers. Being dominantly located in the central markets (Addis Ababa), they usually coordinate inter-market grain flow and provide information on market price of the day to traders. According to Eleni, (2001), Grain brokers:

> *acknowledged receipts of the grain from regional wholesalers, inspect its quality, determine its market-clearing price, and proceed to sell it on behalf of their clients.*

[3] Amha (2002:69) noted that there were also many unlicensed grain traders in various markets. For instance, in the market of Maki town out of 45 grain traders, only 15 were licensed. In Shoa-Robit, out of 20 grain traders only 5 were licensed. In Addis Ababa *Ihel Berenda*, there were about 1,000 unlicensed grain traders. From the perspective of licensed grain traders, the presence of a large number unlicensed traders was considered as a constraint.

Consumers: - The liberalization of grain markets has broadened the supply sources of consumers. They can purchase grain directly from farmers, from assemblers, from regional traders (wholesalers), or from retailers.

3. The study area and data

This study was based on primary data collected from maize farmers in the rural *kebele* of Bura Borama[4], some 12kms south of the town of Shashemene along the major highway to Wolayita and ArbaMinchi. It is one of the 19 rural lowland (*kolla*) *kebele* in Shashemene district and situated over 2400 hectares of land. Of this area of land around 1235 ha is allotted for crops cultivation such as maize, *teff*, sorghum, and *dagusa*. Out of 1235 ha, 872 ha is allotted for maize production, which is the major food stable in the area. Around 845 households reside in the rural *kebele* of Bura Borama. The economy of the area largely depends on agriculture, which is highly rain-fed and dependent on draught plow. Despite the presence of few commercial farmers who produce mostly for market, the majority of farmers are small-scale or subsistence cultivating maize mainly for own consumption. Rural communities in Bura Borama highly rely on maize for their livelihood. Maize is used to prepare the local food (*kita and injera*), the local alcoholic drinks (*areqe and tella*), as well as for feeding animals.

The survey targeted only those farmers who traded maize in 2006/07 cropping year as the study intended to investigate the marketing channel choice decision of farmers during the same year. The year was considered as a normal year in the study area. However, a list of maize farmers who were involved in maize exchange in the specified year was not available. As a result, the sample is not random; rather the respondents were selected through a non-probability sampling methods (i.e. purposive sampling). Sampling units were selected through convenience and judgment of the interviewers in collaboration with the Development Agent (DA) and extension officer. Most of the respondents were household heads. Households were visited house-to-house, farm-to-farm and at market points. The sample size was 110 but the observation was reduced to 103 due to missing values.

The survey was conducted from July- August 2008. The questionnaires consisted of both open-ended and close-ended questions used for personal interviews. The questionnaires were pre-tested in the same area. Enumerators who have previous experiences in similar survey and who are fluent in the local language (Oromogna) were employed for data collection. The main reason for using such enumerators was

[4] Bura Borama *Kebele* is selected for this study due to its higher volume of maize production, accessibility and proximity to the *Arada* market, as compared to other maize producing *kebeles* in Shashemene district.

mostly to minimize the problem related to potential language barrier with respondents, as they are Oromogna speakers, not to mention the fact that Oromigna is the working language in the study area. Moreover, they could also accommodate interviewees who could neither read nor listen any other language than Oromigna. The enumerators had also good understanding of Amharic and English languages. Data were collected on a wide range of issues such as personal and household characteristics, types of maize seed cultivated, maize marketing conditions, marketing channels, transaction costs, storage and processing arrangements, and major constraints in maize marketing and processing. Farmers were asked to report their most preferred marketing channel where they used to sell the largest volume of their maize during 2006/07 and the reason for preferring a specific market channel. With this the assumption of discrete choice can be maintained. Before the field visit, numerous relevant secondary sources were reviewed. These sources include articles, reports, proceedings, journals, and various Internet sources. The study also entailed focus group discussion with farmers and key informant interviews with major chain actors to identify and understand the maize marketing channels and to supplement the information collected from the survey.

4. Theory and model specification

4.1 Transaction cost

The Neo-Classical Economic Model[5] assumes that transaction costs are zero as agents access information perfectly and make rational decision. Unlike this assumption, however, New Institutional Economics (NIE) assumes that transaction costs do matter and institutions exist as transaction cost-minimizing arrangements. Transaction Cost Economics (TCE) is a branch of NIE and recognizes that transaction cost, determined by institutions and institutional arrangements, is vital to economic performance. The underlining concept behind transaction costs is derived from Coase Theorem which specifies “if private parties can bargain without costs over the allocation of resources, they can solve the problem of externalities on their own” (Schmid, 2006:20). In relation to this argument, Kahnonen and Leathers (1999) argue that transaction costs exist due to “the fact that the production and consumption are done by separate economic agents.” This means different transaction costs are generated along the marketing channels/chains until the produce reaches the final consumers and the existence of uncertainty or imperfection

[5] TCE relaxes many of the perfect competition assumptions of neo-classical economics. These are homogenous products, many buyers and sellers, perfect information, absence of entry barrier, rational economic agents, perfect mobility of resources, well-defined property rights, and institutions are ignored (or assumed to be fixed). However, TCE argues that information is not always perfect and transaction costs can be high and that the costs of undertaking transactions can’t be ignored (Irini Maltsoglou and Aysen Tanyeri-Abur; 2005:2).

in information may result in firms incurring costs during market exchanges. The marketing channel is the chain of marketing activities that a product flows through various transaction nodes on its way starting from the farmers or producers to consumers (Mandefro et al 2001). Transaction costs include the costs of information, negotiation, monitoring, co-ordination, and enforcement of contracts. The types of activities that frequently cause transaction costs include:

- searching market information and screening market opportunities
- negotiation and elaboration of contracts
- handling of produce (i.e. storage, transport, administrative costs, and claims)
- monitoring and enforcement contracts (e.g. costs of quality control)

The existences of these costs are derived from three main behavioral assumptions: bounded rationality, opportunism (manifesting itself as adverse selection and moral hazard) and informational asymmetry. According to Hobbs (1996), vertical coordination mitigates against the opportunistic behavior because mutual interest guides the exchange relationships. The principal dimensions that characterize a transaction are the frequency of the transactions, the degree of uncertainty surrounding the transaction and the degree of asset specificity (Hobbs, 1996; Williamson, 1985).

The application of TCE on problems of agri- food chain has become increasingly familiar in agricultural economics since the 1990s. This is because the functioning of agricultural marketing in developing countries is hampered by high transaction costs incurred during market exchange as “many of the institutions, or formal rules of behavior, that are taken for granted in developed countries which facilitate market exchange are absent in low-income countries” (Makhura (2001). As stated by Bart and Kyle (2000) the existence of transaction costs is the major reason why most food markets in developing countries still suffer from inefficiency despite the profound efforts to liberalize markets since the 1990s. As a result, grain markets in Sub-Saharan Africa remain thin, risky, informal and cash-based leading to high transaction costs (Kherallah et al., 2000). A study by De Janvry et al (1991) identified transportation costs to and from the market as an important part of transaction costs. Presumably this is because smallholder agriculture generally is dispersed over wide areas, and infrastructure connecting farms with markets is often poor. This entails high costs in relation to search for means of transportation. This makes market distance and the types of transport as vital determinants of transaction costs in agricultural marketing of many Sub-Saharan African countries.

Transaction costs have, therefore, an effect on the choice of grain marketing channel, and the type of market outlet used by farmers may be indicative of the specific forms of transaction costs encountered by households. For instance, Eleni (2001) has found increased use of grain brokers by farmers in the presence of high transaction costs and less dependent on grain brokers where farmers face low transaction costs due to good social network that created better information on price and market. Apart from transaction costs, the choice of market channels among smallholders, among other factors, will depend on household-specific characteristics such as age, level of education, gender and social networks and organization (Prabhu et al (2005).

4.2 Specification of the empirical model

For decisions related to channel choice, the common practice is applying a binary or multinomial logit model, depending on the number of marketing channels involved, (Lu, 2007). When the choice set consists of only two options, binary or probit models are the most frequently used econometric models for an empirical analysis. However, if the choice sets are more than two, then the multinomial logit discrete choice model is used (Green, 2000). Green also notes that logit model is appropriate for data, which are individual (household) specific. According to Boger (2001), the multinomial logit model links transactions' characteristics with the market channels in which they occur. Another study by Park and Lohr (2006) applied the multinomial logit model to investigate the marketing channels employed by organic producers. The authors reported that the multinomial logit (MNL) and the maximum likelihood procedures provided a framework that supports the use of discrete models for dealing with selectivity effects and for estimating its parameters. Medina and Ward (1999) also used multinomial logit model to explain the marketing outlets used by beef buyers. They indicated that since the outlet choices represented alternatives without order or ranking the use of multinomial logit model was appropriate to explain the outlet selection mobility.

As noted earlier, a polychotomous response model (see Greene 2000) can be applied to explain inter- household variation in the choice of a specific marketing channel. It is assumed that each alternative marketing outlet choice entails different private costs and benefits, and hence different utility, to a household decision maker. This study assumes that farm's decision is generated based on its utility maximization. The analytical model is constructed as follows. Suppose that the utility to a household of alternative j is Uij, where j = 0, 1, 2,…, J *… (1)*. From the decision maker's perspective, the best alternative is simply the one that maximizes net private benefit at the margin. In other words, household i will choose marketing channel j if and only if $Uij > Uik$, $\forall \ k \neq j$ *… (2)*. It is important to note that a household's utility cannot be observed in practice and what a researcher can observe is the factors influencing the household's utility such as household and personal characteristics and attributes of the choice set experienced by the household (Deginet, 2008). Based on McFadden (1978), a household's utility function from using alternative J can then be expressed as follows:

U **(Choice of** j **for household** i **) =** $Uij = Vij + \varepsilon ij$ **(3)**

Where, Uij is the overall utility, Vij is an indirect utility function and εij is a random error term. The probability that household *i* selects alternative *j* can be specified as:

$$\begin{aligned} Pij &= \Pr(Vij + \varepsilon ij > Vik + \varepsilon ik) \\ &= \Pr(\varepsilon ik < \varepsilon ij + Vij - Vik, \forall k \neq j \end{aligned} \qquad (4)$$

Assuming that the error terms are identically and independently distributed with type *i* extreme value distribution, the probability that a household chooses alternative *J* can be explained by a multinomial model (Greene, 2000) as follow:

$$Pij = \frac{\exp(\beta i \chi ij)}{\sum_{j-0}^{J} \exp(\beta j \chi ij)} - \qquad (5)$$

where χij is a vector of household of the i^{th} respondent facing alternative J and βJ is a vector of regression parameter estimates associated with alternative *J*.
Following equation (5) above, we can adapt the MNLM fitting to this study as follow:

$$P(CHOICEij = j) = \frac{\exp(\beta' j \chi i)}{\sum_{j-1}^{3} \exp(\beta' j \chi i)}$$

Where
i represents i^{th} farm household, and i = 1, 2,...., 103;
j represents different marketing channels, $j = 1$ for direct sales to consumers at wet markets (DIRE), $j = 2$ for sales at the farm gate to assemblers (TRAD), and $j = 3$ for sales to wholesalers (WHOL) at the whole sale market.

P represents the probability of a maize marketing channel j to be chosen by farm household *i*;

$CHOICEij = j$ means that maize marketing channel *j* is chosen by farm household *i*;

χi = (AGE i , EDUC i , CART_OWN i , KNOW i , DELAY i , SPENT i , COORDTRP i)

It is a common practice in econometric specification of the MNLM to normalize equation (5) by one of the response categories such that $\beta j = 0$. In this regard, the MNLM can alternatively be specified as follow:

$$Pij = \frac{\exp(\beta j \chi i)}{\sum_{j-1}^{J-1} \exp(\beta j \chi i)} \quad (6)$$

The coefficients of explanatory variables on the omitted or base category are assumed to be zero. The probability that a base category will be chosen can be calculated as follow:

$$Pij = \frac{1}{1 + \sum_{j-1}^{J-1} \exp(\beta j \chi i)} \quad (7)$$

For better understanding the values attached to the coefficients, it is recommended to compute the marginal effects, Green (2000:859). The marginal effects of the attributes on probability of choice are determined by differentiated equation (5):

$$\delta j = \partial Pj / \partial \chi i = Pj = Pj\left[\beta j - \sum_{j=0}^{J}(Pj)(\beta j)\right] \text{ for } j = 1,2,...J \quad (8)$$

where:

Pj is the probability for farmers choosing market channel j.

βj is a vector of regression parameter estimates associated with alternative j.

In our case, farmers have three channels to sell maize, $J = 3$, and the alternatives $j = 1,2,3$, represent sale in the outlets, directly to consumers at the wet market, to wholesalers and to assemblers respectively.

The model predicts the relative probability that a producer would choose one of the three categories based on the transaction characteristic. For this analysis, the marketing channel wholesaler (WHOL) was used as comparison base because this marketing channel was chosen by the majority of maize farmers in trading their maize. The marginal effects were calculated using the STATA command- mfx- for the three categories. Econometric analysis of the data was done with Sata 10 software.

The dependent variable (the marketing channels (CHOICE) chosen) in the analysis is measured by the probability of selling maize to either of these markets. According to the survey result, three different marketing channels were identified. These include; direct sales to consumers at the wet market (1= DIRE); sales at the farm gate (2= FARMG) to rural collectors and sales at the wholesale market (3= WHOL). Some households may favor one outlet while others may not be using the same outlet due to market conditions that feature in high transaction costs.

To determine factors affecting the dependent variable a number of independent variables hypothesized to reflect the existence of different forms of transaction costs are considered in the estimation model. These independent variables are organized into – information costs, negotiation costs (such as transportation costs), monitoring costs, as well as household characteristics. The variables most commonly used to capture the socio-economic conditions of the household are age, education, household size, farm land holding, off-farm income and access to modern maize seeds. The model included the following relevant independent variables of the aforementioned categories taking into account economic theory, previous studies as well as the nature of the study.

Access to Market Price Information (KNOW): it is assumed that maize farmers try to first determine the price that they expect to receive before making a decision about how to market a product and to whom to sell it. Smallholder farmers would only be able to influence their buyers if they have access to relevant information about prices, products, marketing opportunities and trends. As Gastao (2005) cited Masuku (2001) access to (production and marketing) information measured as opportunity for radio listening and newspaper reading differentiated farmers selling more agricultural produce from those selling less. The variable (KNOW) was included in the model in order to assess farmer’s ability to acquire information on market price from reliable sources.

Efforts to Coordinate Means of Transportation (COORDTRP): Among other things, good transport coordination effort by producers is vital to transport products to the market with relatively lower costs. In this study transportation cost is turned out to be a major problem and a variable (COORDTRP) is used as a proxy to estimate the costs of transportation. It is noted as a problem when individual farmer himself/herself organizes means of transportation because it increases searching costs and direct transport cost while such costs are expected to be less when a farmer coordinates transport with other farmers. Thus, it is hypothesized that problem in coordinating problem negatively related to farmers' decision to move to market and positively related to the decision to sale to rural collectors.

Ownership of means of transport (OWN_CART): given transportation cost is a major problem in many rural markets, possessing means of transportation (e.g. cart, bicycle, truck etc) is expected to positively influence the probability of farmers' participation in the mainstream market. The reason is that households that owned these physical assets had lower transportation, communication and information costs and subsequently fewer obstacles to entering the market (Matungul, 2002). In this study farmers were asked whether they had owned means of transportation (i.e. animal, cart) and the variable OWN_CART was included in the estimation model to test such relationship in the study area.

Payment Delay (DELAY): monitoring costs are not expected to be a serious problem for maize farmers while selling their product is because payment is made in cash immediately upon sales. The only monitoring cost that may accrue to farmers could be related to payment delay presumably due to poor maize quality. The quality of maize can be affected by poor storage facility and poor threshing system. The variable DELAY was included and farmers were asked to indicate whether there was a payment delay upon transaction. It is hypothesized that payment delay is negatively related to the probability of participation at the wet market while it is positively related to decision to sale at the farm gate.

Total Time Spent to Reach the Market (SPENT): the longer the time to reach the mainstream market the lesser will be the probability of this market outlet to be chosen by producers as it implies high transaction costs. In this study farmers were asked to indicate the total time (hrs) they required to reach to the mainstream grain market to sale their product. The variable SPENT was used in the model.

The following household characteristic variables are also included in the model.
Age of the Household head (AGE): (AGE) is measured as a continuous variable in years. The age of producers was obtained by simply asking them their present age. The variable AGE was used in the estimation model in order to understand how age affects the decision of market outlet choices. It is expected that older farmers are more likely to participate in markets of cash crop than younger farmers due to the effects of age on experience about trading opportunities (Goetz, 1991).

Level of Household Head Education (EDUCH): education enhances the ability of the household to make appropriate decisions by enabling them to think critically and use information sources efficiently. It is expected that farmers with more education could be aware of more sources of information and more efficient in evaluating and interpreting information related to price as well as other marketing issues. The variable EDUCH was used to measure effect of household's education level on marketing channel choice decision.

Farm size (TFARMSZ): total farm size refers to the total area of land employed for maize cultivation measured in hectare (ha). The relationship between the size of the field and market participation has to do with increased household production for consumption and for sale Gastão (2005). Larger farm ownership can offer farmers wider opportunities to think of more diversified strategies that can move them beyond subsistence farming than smaller land holding.

Household Size (FAMSIZE)*:* household size could influence market participation through its effect on labor in the area of cultivated land and on the volume of production that could be consumed and sold. However, a study by Goetz (1992) cited by Gastao (2005) found that a larger household size also meant that more food was needed to feed and the larger the consumption requirement meant the less a household could sell. Thus, household size may positively or negatively influence farmers' decision to choose a particular marketing outlet.

5. Results and discussion

5.1 Descriptive analysis

Table 1 below presents the descriptive statistics of the variables used in the analysis.

This study consisted of respondents with varying ages, ranging from 26 to 75 years (mean= 37 years). Education levels of the household heads in Bura-Borama are low, with high proportion (23.3%) of farmers never having attended school. On average a household in the sample has 8 household members. The survey result shows that family size decreases as schooling level increases as large family is observed among household heads, who had no formal education. It is reported that small land size, among other things, is a major problem that hinders the pace of commercialization of agriculture; partly because they cannot rent it out and make money out of it and partly because they cannot allocate a portion of their land for other market-oriented high value commodities. Farmers interviewed own maize land ranging from 0.25ha - 3ha[6].

[6] Based on the information obtained from the Development Agent (DA) in the study area; those farmers who own more than 3ha are described as model farmers. Those farmers who have a variety of income sources than farming (i.e. farmer trader), use different inputs (e.g. modern maize seeds, fertilizers), rent land from other farmers, store maize, have relatively high financial capital, save money in the bank and have better living condition than other farmers.

Table 1: Descriptive statistics of the variables used in the analysis

Variables	Obs	Mean	Std.Dev.	Min	Max
AGE	103	36.73786	12.30332	26	75
EDUCH	103	2.466019	.8496312	1	3
FAMSIZE	103	7.951456	3.807574	2	22
TFARSZ	103	1.897282	1.186652	0.25	6
OWN_CART	103	.3883495	.489758	0	1
KNOW	103	.2718447	.4470859	0	1
DELAY	103	.1359223	.3443819	0	1
SPENT	103	2.372816	1.309108	1	8
COORDTR	103	1.174757	.3816164	1	3

Source: Field survey, July-August 2008.

The most preferred maize market channel is found to be the wholesale market (67%) followed by assemblers (19.4%) and direct sell to consumers (13.6%). They noted that a relatively high price, fixed selling place and payment in time were the main reasons for the selection of the wholesale market, ceteris paribus (Mamo, 2009). Maize farmers usually meet the wholesalers or their agents at the nearby village market station along the highway. The average price at this market was 151 Birr per qt, ranging from a minimum price of 100 Birr to 300 Birr per qt. To transport maize from their homestead to the nearby wholesaler’s collection place along the highway, most (45.0%) of them used animal cart followed by pack animal (27.2%), bus (20.26%) and head loading (4.4%). Those farmers who settled along both sides of the highway used bus. Those farmers who live in remote areas of the kebele either used head loading, or pack animals or rented animal cart. Those farmers who couldn’t move their product to the wholesale market for various reasons happened to sell to rural/farmer collectors at the farm gate and tolerate a relatively low price. Recently the role of rural collectors has been declining.

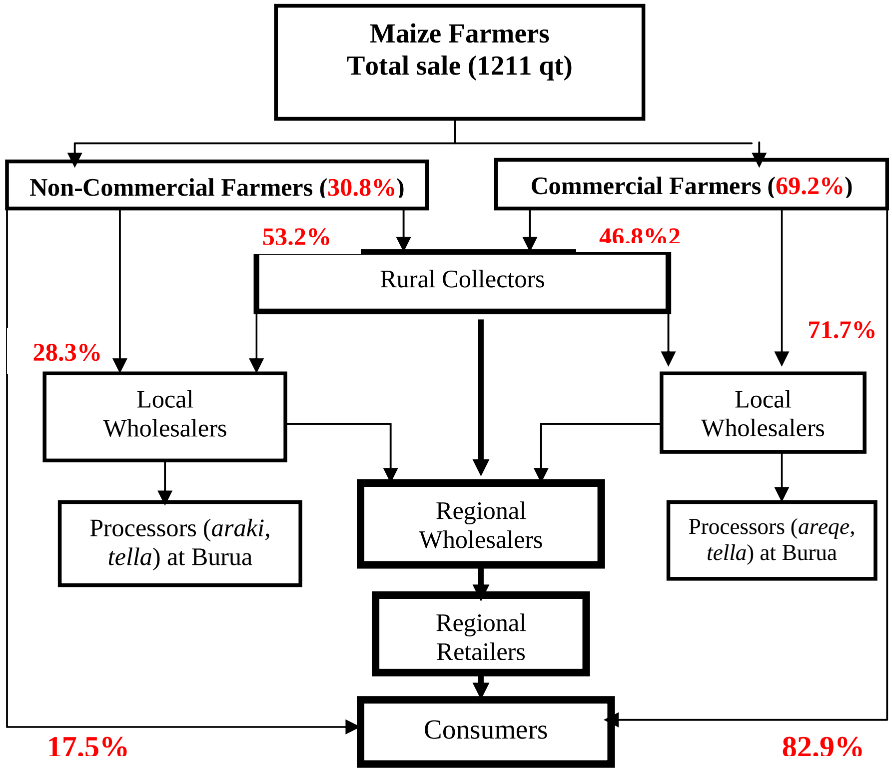
Although previous studies (Eleni, 2001; RATES, 2003) noted that producers could access the main regional market up to 20 kms range, this is not necessarily the case in the study area. According to the survey result, the average distance to reach this market from the farm-gate is 13 kms and yet most farmers failed to take their product to the regional grain market. On average it takes 2 hrs for farmers to access this market from their homesteads. As a result, it is very rare that farmers in the study area take small quantities of maize product to the regional grain market at Arada (*ehil berenda*) in the town of Shashemene. The major reasons why farmers fail to participate in the regional market of Shashemene, among other things, are poor road networks from the farm to the main asphalt, lack of appropriate transportation facilities and high transportation cost (Mamo, 2009).

The majority of respondents know about market price from traders (38.0%) and their neighbors (36.7%). This result is consistent with earlier studies (Eleni, 2001). This is an indication of the extent to which farmers relied on traders and their neighbors to get market information where relationship and trust matters a lot. On the other hand, farmers' access to information through telephone (4.1%), television (2.4%), and newspaper were turned out to be insignificant. For some others (16.7%) radio was somewhat an important source of information. Thus, the ability of farm households to obtain useful market information from original sources is highly limited. On average farmers had to spend at least 2 days to gather information and decide their selling price. This together with poor road networks linking the farm to the market made accessing useful and relevant market information from original sources very difficult.

The proportion of maize traded is different for different marketing channels as the form and type of transaction costs entailed along the marketing channels are different. During 2006/07 harvesting season, farmers who have had commercial-oriented production (i.e. traded more than 50% of total production) tended to account for larger volume of total maize traded with about 69.2 % while non-commercial farmers contributed only 30.8 % to total volume of maize sales (see Figure 1). One very important finding of the study is that non-commercial smallholder farmers dominated maize transaction at the farm gate (i.e. farmers' sales to assemblers) with 53.2 % share in total maize sales at this marketing channel. This implies that for small quantities of maize sales farm gate markets are more convenient.

Apart from the farm gate, however, the survey result shows that commercial farmers dominate the share of maize sales. For instance, commercial farmers as compared to non-commercial farmers contributed 71.7% and 82.9% of total maize transactions to the wholesalers and consumers respectively. This suggests that the volume of maize transaction along the marketing channels is positively related to the degree of commercialization. This can be clearly observed from figure 1 below where volumes of maize sales decrease along the channels for non-commercial farmers while it is significantly increasing for commercial farmers.

Figure 1: Maize marketing channels in Bura-Borama, 2006/07



Source: Own compilation, Field Survey, July – August 2008

Note: Numbers along the chains refer to the share of maize sales by commercial and non-commercial farmers at each marketing channel.

5.2 Determinants of marketing channel choice by smallholder maize farmers

Table 2 presents marginal effects from multinomial logit regression on the choice of marketing channel. Explanatory variables were checked for multicollinearity (using the correlation matrix and Variable Inflation Factor (VIF) and heteroscedasticity (using whitest). The Hausman specification test was also applied to check that the Independent of Irrelevant Alternatives (IIA) assumption was not violated. The model explains 42.3% of the variation in marketing channel choice among smallholder maize farmers in the study area. The results from the multinomial logit model are in the form of log odds ratios that relate alternative choices to a base or reference category (wholesaler channel). The result shows that some of the variables are significant at both market outlets while some others are significant in one marketing channel but not in the other channel.

The results suggest that the probability that maize farmers' decision to sale directly to consumers at the wet market is significantly and positively influenced by access to market price information (KNOW), level of household education (EDUCH) and possession of means of transportation (OWN_CART) to transport maize to the market. The age of the household head (AGE), transport coordination problem (COORDTRP) and the occurrence of payment delay upon transaction (DELAY) and the time spent to reach market and accomplish a one time sell (SPENT) are significantly and negatively influenced by farmers' decision to choose the wet market for direct sell to consumers as compared to sale to the wholesalers (reference group). The probability of choosing to sell to rural collectors (at the farm gate) is significantly and positively influenced by household head age (AGE) and lack of coordinated effort by farmers to organize transportation (COORDTRP), and negatively by time spent to reach the mainstream market (SPENT) and total farm size (TFARSZ).

The result shows that household head age (p- value = 0.000) is significantly and negatively related to direct sale to consumers (DIRE) and significantly and positively (p-value = 0.060) related to sale to rural collectors. This implies that an older person being less mobile would go for the schemes that made marketing available at his doorsteps.

Table 2: Results of multinomial logit model for the choice of marketing channels$

Independent Variables	Direct sells to consumers Choice = 1	Sells to rural collectors Choice = 2
Constant	1.176561	1.092714
	(3.003139)z	(2.132656)
AGE	-3.619767	.5665547
	(.9809012)***	(.3008653)*
EDUCH	3.040763	-.028043
	(1.245441)**	(.4041048)
TFARSZ2	-.1417006	-.1520131
	(.1111817)	(.0776083)*
OWN_CART	2.535941	-.1679719
	(.9873945)**	(.7223707)
KNOW	1.965351	-.3351369
	(.9760877)**	(.728233)
DELAY	-6.042461	-.2955383
	(1.63115)***	(1.292759)
SPENT	-1.191946	-2.476289
	(.4271378)***	(.5976932)***
COORTRP	-3.544346	1.316733
	(1.523213)**	(.7465816)*
N= 103,	Probability > chi2 = 0.000,	LR chi2 (16) = 63.24
Pseudo R2 = 0.4237,	Log likelihood = -49.975756	

Note: *= Significant at 10%; **= significant at 5%; *** = significant at 1%
$ (Choice==whol is the base outcome)
z Values in brackets are standard errors

This may give sense because as farmers get older, they may be physically weak to travel to the distant market to sell and they would rather go for the relatively closer outlet that can be made possible by rural collectors. Moreover, most of the old farmers were uneducated and, therefore, they were found less likely to move to the market, as they may be less active in understanding and processing the required market information. This result is consistent to earlier study by Musemwa et al (2007). Level of education was found significant (p- value = 0.015) to have a positive influence on the decision of farmers to participate in direct sells to consumers. All the farmers who were using the wet market have had some education. This implies that as farmers' level of education increases there would be higher probability of choosing the marketing channel where they can directly sell to consumers at the market, ceteris paribus. Total farm size seems to have more of a quadratic relationship with the probability of choosing rural collectors and to investigate its effect farm size squared (TFARSZ2) was calculated. Farm size squared is significantly (p- value = 0.050) and negatively correlated to the decision to sell to rural collectors compared to wholesalers. This implies that as the land size increases, farmers are less likely to decide to sell to rural collectors. Presumably this is because larger farm size means larger cultivable land for maize and hence more productivity. As indicated earlier the wholesale market provides market for large volume of sells as compared to rural collectors (Eleni, 2001; Lu, 2007).

The ability of the farmer to acquire useful information on market price (KNOW) is significantly (p- value, 0.044) and positively related with the decision of the farmer to go to the main market to sell. Put differently, there exists a negative relationship between selling directly to consumers and information costs. This implies that as the search and information costs increase, rural households sell more of their maize to middlemen (i.e. assemblers) instead of selling to final consumers.

One of the major components of transaction cost this paper claim to have stronger impact on the decision of farmers where to sell is transportation cost. This is consistent with earlier empirical findings (Prabhu et al, 2005) where higher transportation costs limited smallholders' access to market. Although distance to market is found to be more common proxy to estimate transport cost, this study couldn't use it as some of the households failed to provide accurate information on the distance to their preferred marketing channel. Transport cost can be estimated by using a proxy variable (COORDTRP) that indicates the prevailing problem to coordinate means of transportation with producers. The variable COORDTRP was significantly and negatively correlated to the decision to sell at the wet market (p-value = 0.020) while it is significantly and positively correlated to sell to assemblers at the farm gate (p –value = 0.078) in reference to the wholesale market (reference group). The result shows that lack of coordinated action by farmers lead to lower probability of market participation and higher probability of the decision to choose the outlet at the farm gate. Furthermore, farmers' access to animal cart (OWN_CART) was significantly and positively (p- value = 0.010) influencing the decision to directly sell to consumers at the main market. This result is consistent to previous studies, Eleni (2001).

Another variable that influences maize farmers' decision to choose a certain marketing channel is the possibility of payment delay (DELAY). It significantly (p-value = 0.000) and negatively affected the probability of choosing direct sale to consumers over wholesalers (reference category). A payment delay while selling directly to consumers will induce farmers to switch to the wholesalers. The time spent to reach the market and accomplish a one-time sale (SPENT) is significantly and negatively correlated (p- value = 0.005) to the decision of the farmer to involve in direct sale to consumers. It is also found significantly (p – value = 0.000) and negatively influenced the probability that farmers may decide to choose the market outlet to sell to rural collectors. Keeping other things constant, this suggests that the longer the time required reaching the preferred market channel in relation to the reference outlet choice, the higher the probability that farmers prefer wholesalers to the other market outlets. Presumably, the longer time spent to arrive at the market associated with poor coordinated means of transportation might have explained why only a small number of farmers had preferred the outlet (DIRE) to the other outlets.

6. Conclusion and implications

Maize markets are far from being efficient in Bura-Borama due mainly to the prevailing high transaction costs, citrus paribus. Although the mainstream market generates better return for producers, the majority of sampled smallholder farmers couldn't be able to participate in the main regional grain market. The role of intermediaries (mainly wholesalers) is still dominant in maize marketing, leaving the market inaccessible for the smallholder maize farmers. Despite liberalization, EGTE, associations, cooperatives and large companies play no significant role in the marketing of maize in the study area. It is believed that a well functioning cereal/maize marketing is turned out to be very vital for agricultural growth, and transition of smallholder farming towards commercial farming is determined by access to market. Facilitating this transition requires a comprehensive analysis of the nature of these production systems (subsistence versus market-oriented), the marketing of these products as well as factors affecting marketing and production performance.

Descriptive results of the study show that a small proportion of total maize production was traded while a larger proportion went for self-consumption during 2006/07 implying that maize farming in Bura-Borama remains predominantly subsistent and non-market oriented. Lack of access to credit, small size of land possession, lack of information related to market issues and lack of storage facility were the main impediments to maize marketing and processing. Farmers highly rely on traders and their neighbors to get market information on maize market price where relationship and trust matters a lot.

Furthermore, the results from the econometric analysis show that maize marketing channel choice among smallholder farmers in Bura-Borama was influenced both by household characteristics and transaction cost factors. Household characteristics such as household age and education are important determinants of the choice of market channels among smallholder maize farmers in the study area. Our estimation result indicates that those farmers who are older and uneducated are more likely to prefer rural collectors to final consumers at the market implying that an older person being less mobile would go for the schemes that made marketing available at his doorsteps. As farmers' level of education increases there would be higher probability of choosing the marketing channel where they can directly sell to consumers, ceteris paribus. As the land size increases, farmers are less likely to decide to sell to rural collectors compared to wholesalers, which is convenient for large volume of sell. Presumably this is because larger farm size means larger cultivable land for maize and hence more productivity and able to provide large volume of maize for sell. The findings also suggest that the longer time spent to arrive at the market associated with poor coordinated means of transportation and lack of access to animal-cart might have explained why only a small number of farmers had preferred the market to sell to consumers at the local or regional market to the other outlets. The farther the distance to the day market, the more likely farmers are to wait traders to come to their farm gates and the less likely they are to sell to the local market. Hence, households tend to minimize transaction cost such as transportation costs by selling to rural collectors who usually visit farmers at their doorsteps. Farmers who appear to have access to relevant market information are more likely to sell their maize directly to consumers at the market while those that are unable to acquire relevant market price information are unlikely to sell to consumers; they rather tend to sell to middlemen (i.e. collectors, wholesalers).

Findings of the study imply that policy makers in collaboration with other concerned development partners should design appropriate intervention mechanisms in the rural maize markets such as Bura-Borama to ensure markets work better for the smallholder maize farmers and reduce transaction costs during exchange. To start with, provision of relevant information about production and markets should be seen as an integral part of any agricultural market development programme. Encouraging commodity exchange and market information system can help smallholder farmers to reduce transaction costs. Secondly, there should be efforts to be made to strengthen existing Farmers' Cooperatives and to encourage the establishment of Producer Organizations (POs) towards a collective action to lower transaction costs. Thirdly, improvement of rural road networks with the intention of linking smallholders to markets should be seen as an integral part of any development strategy of agricultural marketing in the study area.

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SUPPLY SOURCE SELECTION IN THE DOWNSTREAM DAIRY SUPPLY CHAIN IN NORTHERN ETHIOPIA, TOBIT MODEL

Abebe Ejigu Alemu

1. Introduction

The Ethiopian livestock population is the largest in Africa and 10th in the world. However, its contribution to Ethiopia's economy is limited as the number of livestock is still generally regarded as a sign of wealth, rather than as an asset generating income. As a result, most livestock products are not marketed. And in case they are marketed, they rarely meet minimum quality and safety standards due to poor storage and processing conditions. Moreover, the quantity produced is too small to generate linkages with value chains and attract investors in dairy processing though it has huge potential to attract investment in the subsector.

Despite the large cattle population, the quality and the amount of milk and milk products are not enough to satisfy the domestic demand let alone envisaging export (Staal, Alejandro and Mohammad 2008; Sintayehu et al, 2008; Mohammed and Peter 2007; Mohamed, Ehui, and Yemesrach 2004). Because of the large number of smallholder farmers involved in cattle rearing and dairy production, proper management and marketing of the dairy supply chain entails the potential to substantially improve household income and reduce poverty. However, lack of efficiency and quality, and the informal nature of the market constrain the development and expansion of the sub-sector. Vertical Coordination (VC) can enhance this situation by improving quality and quantity of milk production.

As the large number of producers are smallholder farmers, the chain affects these farmers who are supplying a huge volume of dairy products to the market. If the dairy farming is well coordinated with high value chains, it will help increase market access and increase the income. It will also enable them improve the expenditure, nutrition and health of the households. Furthermore, it helps improve the productivity of dairy and improve household milk consumption (Mohamed, Ehui, and Yemesrach 2004).

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Most of the rural households in Ethiopia possess dairy cattle that provide an important supplement to the households' livelihoods. Dairy production is mainly at household level. Although there exist few cooperatives that produce and sell milk and milk products, the bulk of dairy production is at small scale household level. With regard to marketing, the traditional spot market mechanism has been dominating the coordination between traders and suppliers in rural areas. Nevertheless, contracts are currently replacing the traditional spot market coordination techniques. However, little study has been done concerning the patterns of coordination and what motivates traders to operate on contractual business.

This paper aims at identifying key determinants that affect the adoption of vertical coordination mechanism in the downward dairy supply chain. Specifically, the objectives include characterization of the dairy supply chain, coordination mechanisms used and identification of key determinants for adopting a particular channel and testing their statistical significance.

The remaining part of the paper is organized as follows: the next section briefly reviews the literature and theoretical framework; section three gives a brief description on the methodology; the fourth section presents the results; section five presents the discussion and the last section concludes the paper with some policy implications.

2. Literature and theoretical framework

Previous studies and the survey conducted revealed that the dairy supply chain is consisting of primary producers (rural, sub-urban and urban producers); cooperatives and farmers associations that often collect milk; other milk collectors; processors; and retailers including restaurants, supermarkets, and cafes (Mohammed and Peter 2007; Mohamed, Ehui, and Yemesrach 2004; Sintayehu et al. 2008).

The dairy sector in the nation includes about 500,000 smallholder rural farmers who produce about 1,130 million liters of milk a year, of which 370 million liters is sold as raw milk, 280 million liters is processed into butter and cheese, and 165 million liters is consumed by the calves (Mohamed, Ehui, and Yemesrach 2004). The remaining 315 million liters was marketed through both informal and formal retailers via cooperatives and farmers' organizations. In addition, large private dairy farms and state farms supplied three and two million liters respectively to consumers using the formal shops via state and private dairy processing firms that are dominantly operating in and around the capital Addis Ababa (Mohamed et al. 2003; Francesconi, Heerink and D'Haese 2009).

Vertical coordination (VC) is the process of harmonizing or synchronizing several interrelated and sequential decisions involved in efficiently producing and marketing the nation's food supply (Branson and Norvell, 1983). VC can be thought of as an institutional arrangement between two extremes of spot market and full ownership. Within this interval, there are many different forms of coordination such as contracts and alliances of which contracting takes the lion's share in agrifood coordination in the developed and the developing world. The degree of control of the integrator increases when one moves along from the spot market to full vertical integration (Peterson, Wysocki and Harsh, 2002:152). VC may occur at various stages in a supply chain.

VC mechanisms help link small farmers with domestic and global markets through processors, collectors, and retail and supermarket chains. Economic agents in the chain could tackle producers' problems of information, finance and the market through VC arrangements. VC can also help improve quality and quantity and improve smallholders' earnings and wealth (Maertens et al, 2007). Furthermore, VC mechanisms link producers with high value chains that enable to transform the subsistence agriculture to market-oriented agriculture in the developing and least developed countries as producers start to focus on consumers' wants (Bijman 2002).

There are several marketing arrangements in the continuum of VC. Dairy supply chain is often dominated by contracts that existed between traders and producers (Abdulai and Birachi 2009). The continuum of VC consists of spot markets, marketing contracts, and vertical integration (Peterson, Wysocki and Harsh 2002:152). These coordination mechanisms help facilitate linkages between producers and traders. Increasingly, the efficiency of agrifood supply chains is being improved through VC.

Though producers could have a range of coordination mechanisms (from open markets, contracts to vertical integration), producers' adoption depends on the searching costs, negotiation costs, and monitoring costs emanating from product characteristics, level of asset-specific investment, uncertainty, and frequency of transactions (Williamson, 1975; Hobbs, 1977). Moreover, their access to credit, farm inputs, technology, transportation and communication infrastructure limits farmers' participation in the market (Boger, 2001; Bienabe et al., 2004; Gebremedhin, 2001; Chowdhury, 2004). Cooperatives and contractual arrangements are being applied as coordination mechanism so as to improve the market power and market security to producers. Such institutions facilitate the participation of producers in the market and help enforce contractual relationships among economic agents participating in the market (Williamson, 1991; North 1990; Bienabe et al., 2004).

Contractual arrangements relieved smallholders' shortage of finance and lack of access to input and technology markets. Smallholders acquire inputs and technology on credit and make payments once they harvest their produce. Hence, VC arrangements are driven by risk, transaction costs, size, farm demographics, and socio-economic characteristics (Davis and Gillespie, 2007).

However, the preconditions associated with contracts have been limiting the smallholders' market participation. The failure of smallholder farmers in meeting stringent quality and safety requirements results in their exclusion from contracts. The rising quality standards by supermarkets and the investment requirements to meet standards are found to threaten the inclusion of smallholder producers in contracting. It results in exclusion of the smallholder producer from the market which puts doubts on the benefits of contracts (Gulati et al. 2007; Humphrey 2005; Halldorsson 2007).

Given the above counter arguments, however, there is an increasing trend in using contracts and it mitigates the problem of production and marketing risk by ensuring a guaranteed source of supply with specific quality requirements to processors or intermediaries and ensuring farmers an immediate market outlet for their produce (Gulati et al. 2007; Maertens et al. 2007; Miyata et al. 2007; Danielou et al. 2005; Kherallah and Kirsten 2001).

Perishable products such as milk require quick transportation and movement to the respective consumer. However, monitoring costs tend to be high since products like milk are easily adulterated. Understanding the nature of the milk, for instance, Kenyan traders adopt contractual arrangements as coping mechanism to the above adverse conditions (Abduli and Birachi 2008).

Requirement of investment for storage and processing equipment drives farmers to collectively organize (cooperate) themselves. Improving farmers' capacity contributes to the reduction of information asymmetry and improves the bargaining power through improving quality and productivity. Cooperative organizations are driven by the capacity requirement of farmers where they get farm management skills, technical advices since they have tight relations with farmers (Bienabe et al. 2004).

Transaction costs play an important role in the organization of firms and contracts. Firms aiming at profit maximizing or cost minimization need to include both production costs and transaction costs. According to Williamson production costs are costs for having machines or buildings that help to transfer inputs to outputs. Transaction costs are costs of making exchange that comprised of information, negotiation and monitoring costs.

Information asymmetry may result in firms incurring costs when they attempt to exchange (buy or sell goods or services). For instance, lack of information about potential sellers may lead to buying at higher prices. Under some circumstances, transaction costs may be lower if the transaction takes place in an open (spot) market, whereas in other situations costs may be lower under other forms of VC as contracting or integration.

Transaction cost rests on opportunistic behavior of the economic agents assuming that opportunistic behavior results in lack of share of information among the partners specifically in the open market as it is based on self interest (Peterson, Wysocki and Harsh 2001). VC mitigates against the opportunistic behavior because mutual interest guides the exchange relationships (Hobbs 1996); such opportunism declines as one goes from spot market to vertical integration (Peterson, Wysocki and Harsh 2001). Traders prefer contracts to open market transactions in case where sellers demonstrate high tendency of self interest and opportunistic behavior.

Variables that are used to characterize any transaction are frequency, uncertainty and asset specificity. Transactions can be frequent or rare depending on the nature of the product. The frequency of transaction determines firms' decisions to vertically integrate, contract or use the open market. When transactions are frequent, it allows better information exchange, build up of trust and lower costs of non-compliance (Williamson 1979).

The degree of quality uncertainty forces firms to have commitments with members in the supply chain. Uncertainty over product quality or reliability of supplies drives channel members to contract as a warranty to quality and supply. If product characteristics are easily observed which do not require detailed inspection at the time of delivery, open markets may work well compared to contracting (Hobbs and Young 2000). However, for products like milk in rural markets, the product quality cannot be easily observed and it demands much time to inspect and check the quality. Hence, closer coordination is preferred to open markets.

Perishable products demand traders to quickly transact it and move products to prevent deterioration of quality (Hobbs and Young 2000). Moreover, the quality of milk is easily adulterated and spoiled since there are no quality control devices. Hence, there is high incidence of quality problem in rural Ethiopia. Adulteration of quality forces traders to contract to guarantee quality.

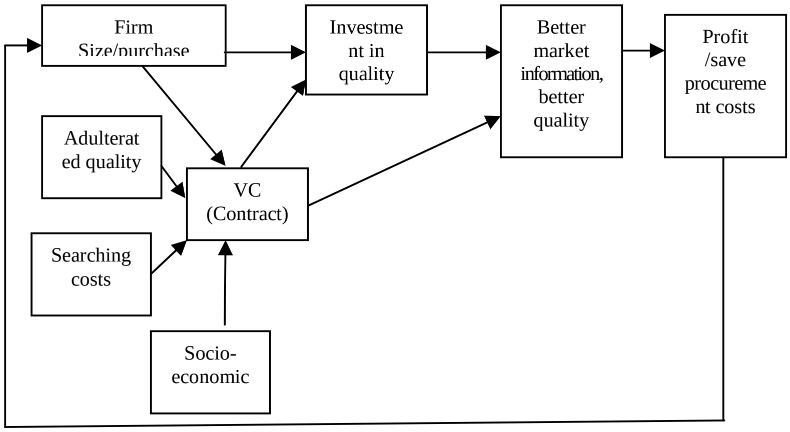
The importance of food quality and safety is getting momentum due to consumers' requirements (Boger 2001; Furesi, Martino and Pulina 2006; Maertens et al. 2007). Preferences of buyers on quality requirement forces producers to maintain quality and food safety. Maintenance of food quality and safety demands technology that is missing amongst the rural producers. Quality and safety requirements and mitigation against quality deterioration requires modern technology and inputs (Hobbs 2003). However, many of the rural producers in developing countries lack financial capital to own technology. Hence, such maintenance of quality forces traders to supply technology, input and credit support by signing agreements with suppliers (Gulati et al, 2007, Maertens et al. 2007; Danielou, Labaste and Voisard 2005; Blandon, et al, 2008).

Socio-economic characteristics such as sex, education and experience have effects in receiving information and processing them (Abduli and Birachi 2008). Males and females process information and perceive risk differently that has an association with transaction costs. Their reaction to risk and opportunities will also vary accordingly. Women producers are likely to face high transaction costs due to higher perceived risks attributable to lower economic endowments and social and cultural setting to women (Abduli and Birachi 2008).

Experience and education demonstrate accumulation of human capital and learning about the market. Those who are educated and experienced are likely to be more informed and knowledgeable about the market that enable them reduce the effects of the opportunistic behavior of the supplying partners. Hence they are more likely to operate in open markets than contracts (Abduli and Birachi 2008).

The schematic presentation of the theoretical framework identified for this study purpose is presented in fig. 1. Traders will be driven to contracts if they need uninterrupted quality and quantity supply, if the payment period is a bit longer, if their size is small to supply immediate cash to the supplier and if they are located in relatively big towns where their sales are higher and they are affected in a very little way during fasting periods.

Figure: 1. Motives to contract



3. Methodology

3.1 Description of the study area

To test the hypothesis, a survey study which is embedded in the case area of Geba catchments (5200 km^2) was set up. The catchments represent main Agro-ecological zones of the Northern Ethiopian Highlands. Four districts with a large number of hybrid cows were selected since they are regarded as surplus milk producers who presented fresh milk and other milk products to the market. The people of these districts are characterised by performing mixed agriculture; crop production and animal husbandry. The districts were Dega Temben, Enderta, Hintalo Wajirat and Kilite Awulao. Dairy cooperatives also operate in these four districts.

3.2. The data

The data used in this study were collected from primary sources. Structured survey questionnaire was administered in May 2009 in 10 towns of Tigray with a sample of 90 dairy related traders consisting of various local businesses such as cafés, snacks, and dairy marketing cooperatives. Except in the towns of Mekelle (the regional capital), Adigrat and Wukiro; in the remaining seven towns all the available dairy related businesses were included in the sample. However, 30% of traders in Mekelle, 50% of traders in Adigrat and Wukiro were randomly selected after having the list of traders from the district Trade and Industry Bureau. However, replacement was made in case the trader dropped operation or was unwilling to respond, which mainly happened in Mekelle and Adigrat. The census of 2007 from Trade and Industry Bureau was taken to select sample respondents.

3.3. Tobit Model

The values of the dependent variable can be censored as the information we have is above zero; that is, dairy traders buy all or part of their supply requirement in contract, the Tobit model is preferred as it considers the values above 0. A Tobit Model is derived following Tobin (1958) and the model supposes that there is a latent or unobservable variable y_i* that depends linearly on explanatory variables x_i* via a parameter β that determines the relationship between the latent variable and the independent variables. The model is specified as:

$$y_i* = \beta' x_i + \varepsilon_i, \varepsilon_i \sim N(0, \sigma^2) \quad (1)$$

$$y_i = \begin{cases} y* & if \quad y_i* > 0 \\ 0 & if \quad y_i* \leq 0 \end{cases} \quad (2)$$

where y* is the latent variable, β' is a kx1 vector of unknown parameters, x_i represents a kx1 vector of independent variables, ε_i are residuals, y_i is the dependent variable. The maximum likelihood estimation method will be employed to estimate the coefficient parameter.

3.4 Variable description

The size of the firm: the size of the firm is proxied in terms of the volume of sales (**salvol**) and it is expected that the larger the size the more is the quantity of fresh milk demanded that is difficult to find from the open market. This motivates traders to adopt contractual arrangements. **Starting capital:** this variable is used as a measure of the level of investment of the firm and it is assumed that if the firm has invested on specific assets, it will prefer contractual arrangements to manage supply risk.

Need of financial resource: those traders with small starting capital and unable to make immediate payments need to adopt contracts due to the fact that contractual arrangements do give time to traders to settle payments. Variables used are starting capital (capstart) and credit payments (creditpt).

Location of traders: those traders located in zonal cities will have regular buyers who are less affected by the fasting periods. Those buyers located in small towns are a bit conservative who do not consume milk during the fasting periods. Regularity of demand forces traders to have regular source of supply that motivated traders to contract. The proxy variable used is MEKADI (traders in Adigrat and Mekelle) and it is expected to positively contribute to contract arrangement.

Types of business: The types of businesses operating in dairy are cooperatives, cafés and snacks and other retailers like collectors. Therefore, in comparison to cooperatives, cafés prefer open markets. In comparison to other retailers, cooperatives prefer contracts. From among these traders, cafés are regular businesses that demand fresh milk consistently. Cafes sell milk in various forms and they need consistent and quality supply from traders. The variable Café is included in the model.

Desire to Guard quality: fresh milk quality adulteration is a common malpractice that affects the free flow of fresh milk from producers to traders. This problem is serious if the exchange is conducted in open markets. The opportunist sellers diffuse milk quality disregarding their future relationship with the buyer. Hence, traders try to reduce quality problems through contractual arrangements.

Number of sellers in open markets (**spnumsel**) and how difficult is getting information (**spdiffinfo**) from open markets also affect traders' adoption of vertical coordination mechanisms. If there are sufficient sellers in the market, traders prefer open markets as it reduces searching costs and to buy at competent price.

Table 1: Variables and expected signs against volume of purchase and contract participation

Variables	Specific questions developed	Unit of measurement	Expected Sign to Contract
Dependent variable			
Proportion of contract purchase	**Conproportion**	Continuous, minimum of 0.	
Independent variables			
is it difficult to get market information in the spot	**Spinfodiff**	categorical, 1-4; easy-difficult	+
starting capital	**Capstart**	continuous	+
Sales volume	**Salvol**	continuous	+
Frequency of transaction	**Freqtranns**	continuous	-
Payment on credit	**Creditpt**	binary, if yes 1; no 0	+
Protecting quality risk using contract	**qualrskcon**	binary, if yes 1; no 0	+
Number of sellers in the spot	**Spnumsel**	Categorical, 1-4; many-insufficient	-
Type of business	**Cafė**	binary, 1 if it is café, 0 otherwise	?
Location	**Zonet (MEKADI)**	binary, 1 if it is located in the zonal cities; 0 otherwise	+

4. Results

4.1 The dairy supply chain

Previous studies and the survey conducted revealed that the dairy supply chain consisting of primary producers (rural, sub-urban and urban producers); cooperatives and farmers associations that are mainly collecting milk; other milk collectors; processors; and retailers including restaurants, supermarkets, cafės, (Mohammed and Peter, 2007; Mohammed et al., 2004; Sintayehu et al., 2008).

In Ethiopia the dairy sector includes about 500,000 smallholder rural farmers who produce about 1,130 million liters of milk a year, of which 370 million liters is sold as raw milk, 280 million liters is processed in butter and cheese, and 165 million liters is consumed by the calves (Mohamed et al, 2003). The remaining 315 million liters was marketed through both informal and formal retailers via cooperatives and farmers' organizations. In addition, large private dairy farms and state farms supplied three and two million liters respectively to consumers using the formal shops via state and private dairy processing firms that are dominantly operating in and around the capital Addis Ababa (Mohamed et al, 2003; Francesconi, 2009).

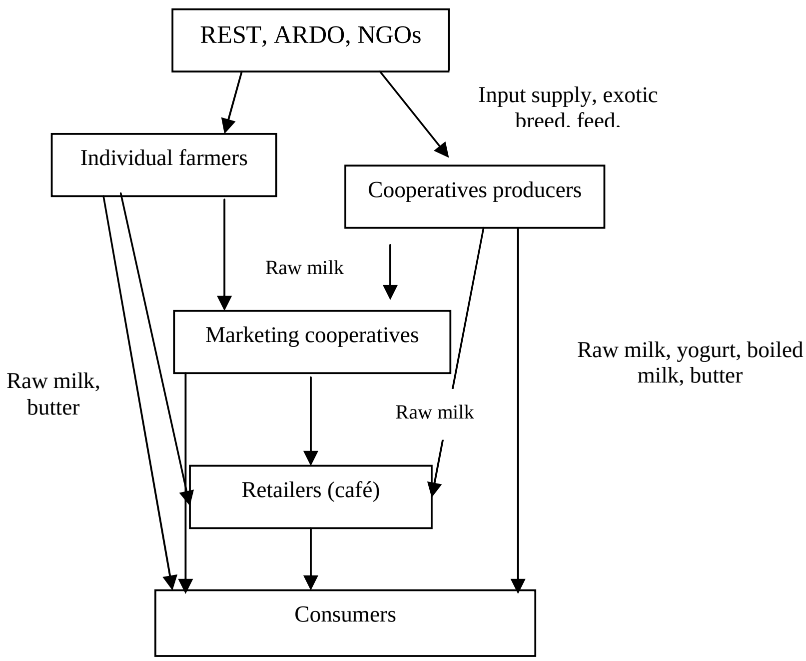
The survey revealed that traders mainly got supply of fresh milk from the smallholder farmers who produce milk at the household level. One cooperative at Atsibi (Jiegen) containing 10 members produces fresh milk at cooperative level. Many of the smallholder farmers produce and distribute fresh milk and butter through the open market and contract. Marketing cooperatives are also serving as a selling point to the smallholder producers.

Producers acquire exotic breed and other inputs mainly from the district agricultural and rural development office. Further more, Relief Society of Tigray (REST), religious institutions (Catholic Church and the Ethiopian Orthodox Tewahido church) are supplying inputs to cooperatives and individual farmers.

As far as traders are concerned, the main traders are cafés and snack bars that sell boiled milk, yoghurt, and butter to consumers. These cafés constitute the lion's share of dairy traders. No processor was operating in the region. There were also collectors who collect and distribute to these cafés and snack bars. Dairy marketing cooperatives also distribute to cafés and other snack bars. Such cooperatives also directly sell various dairy products to consumers. Consumers can also directly buy fresh milk and other dairy products from producers or cooperative shops. Consumers buy boiled milk, yoghurt and other forms mainly from cafés and snack bars. Hence the chain is organized as depicted on Figure 2.

- Inputs are from REST[1], ARDO[2] and other NGOs that supply hybrid dairy cows, processing equipment, lactometer, and other required inputs (the input chain)
- Milk is produced at individual farmer level or through cooperative producers. (cooperative chain, and producer chain)
- The cooperative chain is also coordinated in contracts with smallholder producers,
- There are no processing industries except traders and cooperatives that make little value addition and supply it to their customers (consumers).
- The trader chain gets supply from small holder producers, cooperatives or collectors, and it is dominantly coordinated in contract.

Figure 2: Dairy supply chain



[1] REST is Relief Society of Tigray, local NGO operating in the region.
[2] ARDO stand for Agricultural and Rural Development Office

The common channels of distribution for dairy products are the spot market, the marketing cooperatives and contracting. In all the research sites cafés and marketing cooperatives are operating. The main traders of dairy products are those retailers such as pastry houses, and snack bars. These traders get their fresh milk through contracts from cooperatives and individual producers. However, a large number of producers is still relying on spot markets that are selling their products by their own. Marketing cooperatives were used as a selling point and they are doing better as responded by the administrators and their chair person except for problem of market. They are performing better due to meeting buyers' requirements, better quality as they have quality control mechanism, versatility of products, trust from the buyers, supplying medicine and feed to their members and less wastage of milk. Individual producers and marketing cooperatives supply milk to other retailers through contracting.

4.2 Survey results

Dairy traders rely mainly on farmers as their supply source as milk production rests on farmers who meet the requirements of suppliers with respect to quality and quantity and delivering it to the place where traders need it. Hence, transportation and transaction costs of traders are minimized. Besides, some of the traders integrate milk production with processing and distribution and fill their deficit of milk requirement from producers (farmers).

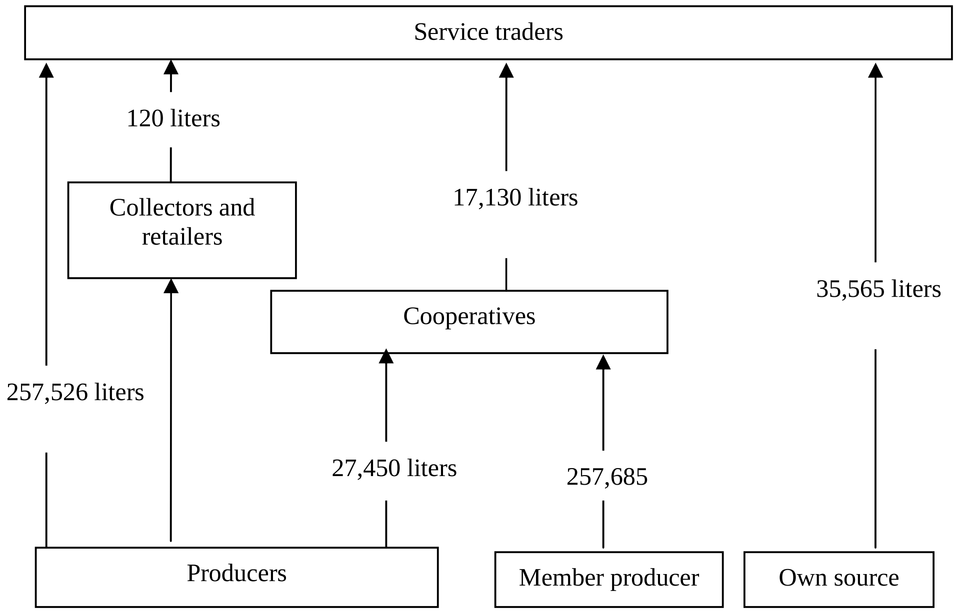
As depicted in Figure 2, traders employed several sources to get milk but the lion's share was supplied by small holder farmers/producers surrounding the towns. To this end, the gathered data from the various buyers have shown that own source, farmers and cooperatives are sources of milk and milk products in Tigray. Fifty four per cent of the fresh milk supply was from farmers.

The downstream dairy supply chain consists of those traders whose business activities are interlinked with milk and milk products; and they are:

1. Service traders (cafés, snack bars, and other fast food selling businesses)
2. Retailers like small shops that collect and sell milk and other milk products.
3. Cooperatives that collect milk from their members and other producers.

These traders get their major share of fresh milk from the smallholder producers. Moreover, cooperatives and retailers supply milk to the service traders. The amount of milk purchased in the study areas and the chain they employed based on the data collected is presented below:

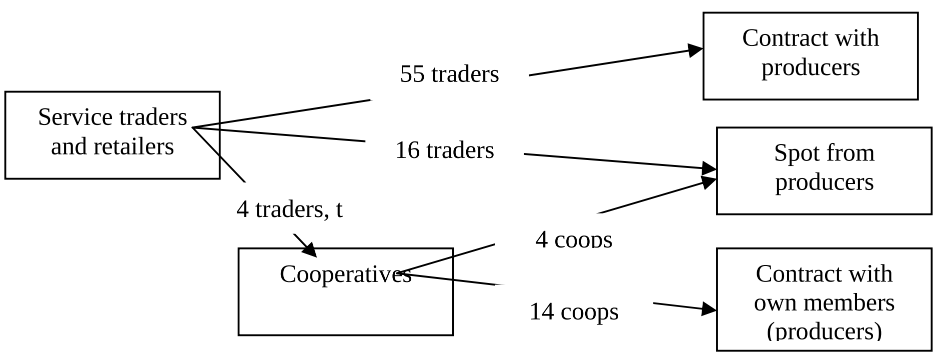
Figure 3: Downstream supply chain and amount of fresh milk supplied in January 2008-Januray 2009



Source: Survey, 2009

As shows in the above diagram, the chains include producer, cooperative and own source. These chains are organized around spot market, contract and vertical integration. The coordination mechanism and the number of traders involved are depicted in the following diagram:

Figure 4: Method of VC



Source: Survey 2009

4.3. Descriptive statistics

As far as traders are concerned, 60% of the respondents were male headed traders and the rest 40% were female headed traders. The average level of education was eight years of schooling. For selected explanatory variables the summary of the descriptive statistics is presented below:

Table 2: Statistical summary of variables

Variable	Number of Observation	Mean	Std. Dev.	Min	Max
Proportion of contract purchase	90	.74	.42	0	1
Starting Capital	90	14690.44	28256.39	300	160000
Difficulty of Market information	90	1.9	.52	1	3
Credit payment	90	.42	.49	0	1
Sales Volume	90	6790.15	9955.29	48	54750
Frequency of transaction	90	436.93	211.66	0	900
Desire to risk quality	90	.38	.49	0	1
Number of sellers	90	2.78	1.04	0	4
Café	90	.71	.46	0	1
Zonal Capital	90	.5	.50	0	1

Source: Survey 2009

Moreover, 76.67 % of the traders rely on contract and their average annual purchase in contract was 6734.2 liters of milk. The average business experience of the responding traders was 4.5 years. Contracting traders were exposed to a couple of transaction cost components such as searching market information, finding buyers and monitoring milk quality as it is easy for adulteration. The labor involved in searching market information was on the average 1.49 man hours in each transaction. Problem of quality in buying milk was a regular incidence as replied by 67.8% of the responding traders. Due to lack of standardizing institutions and any other quality control mechanisms, buyers of dairy products often encountered quality related problems. Major quality related problems were adulteration (mixing milk with water) and substandard milk that was mainly due to lack of care in milking cows, poor storage and improper container used while keeping and carrying fresh milk for sale.

Due to persistent quality problems, buyers used a variety of mechanisms in order to detect and control quality. A few of the buyers had lactometer that was supplied by Relief Society of Tigray (REST) mainly for dairy cooperatives. However, traders used observation (29%), test (20%), combination (39%), and 10 % of them use lactometer.

Traders relied on spot checking irrespective of the commitment they had over the supplier.

In contractual agreements, 57.97 % of the transportation was committed by the sellers and the remaining was by the suppliers. The average transportation cost was birr 1.84/transaction and 2.9 % ***of*** the respondents find organizing transport as a problem. Such transportation advantages could encourage traders to contract with the suppliers. Regarding price terms in contractual agreements, 55.07% replied that their agreement was flexible adjusted during fasting periods; 30.43% agreed on fixed prices. Thirty two per cent of the traders found that side selling was one of the problems they encountered in their contractual agreements.

From among contracting traders, 53.62% settled payment at the end of the month and 30% made immediate payment. None of the respondents provided inputs and technology to the supplier as a means of payment. The remaining 4.35 % settled payments in advance. The majority of respondents (75.36%) replied that they offered no support to suppliers. A few 10.14% provided credit support to their suppliers.

The frequency of purchase was on the average 1.58 transactions a day, on the average 436.93 transactions a year, with a total average volume of 8393.6 liters per annum. Volume of purchase in a unit transaction was on the average 21.11 liters which was worth on the average Birr 100.27.

4.4. Model results

Seventy seven per cent of the traders purchased all or part of fresh milk on contractual basis and the rest got fresh milk either from open markets or from their own source or members. We predicted the determinants of contract purchase using the Tobit model considering proportion of contract as a dependent variable with values ranging from 0 to 100 per cent. Hence, we applied the lower limit Tobit model. The coefficient of all the explanatory variables is found different from 0 as it is determined by the Likelihood Ratio where the $\chi^2 = 51.68$ that is statistically significant at 0 .001 significance level implying the failure to accept the null hypothesis.

Therefore, variables related to transaction costs, quality, credit, size, location and type of firms were included in the model and the result of the empirical model is presented in Table 3. Interpretations of the model can be classified into several categories. The first category is related to the perceived impact of market information availability and number of sellers in the market that has to do with transaction costs.

The model result revealed that those who perceived information was hard to find preferred contracts and bought more on contract. If there were few sellers in the market, traders would buy more on contract to minimize market risk.

The second category is whether contracts are driven by financing need of traders. The empirical model revealed that those traders who needed to pay on account would buy more on contract as it provided them working capital.

The third category is the volume of sales used to indicate the size of the firm on contract purchase. The model result revealed that firms with large sales volume bought more on contract since they might need reliable supply and quality. Location of traders was also included to measure the spatial impact on contract purchase. Hence, traders in zonal capital preferred to buy more on contractual agreements. Moreover, the persistent adulteration in milk quality was considered if it derives traders to operate more on contracts. Hence, the result of the model revealed that the desire to guard milk quality while buying tends to drive traders to adopt contractual purchase.

Table 3: Tobit Model Result

Explanatory variables	Parameter Coefficient	Robust Std. Err.	t-value
Starting capital	0.0132	0.0387	0.34
Difficulty of getting mkt info.	0.1751*	0.1039	1.68
Credit payment	0.4200***	0.0855	4.91
Sales volume	0.0666*	0.0397	1.68
Frequency of transaction	0.0001	0.0002	0.60
Desire to risk poor quality	0.3290***	0.1016	3.24
Number of sellers	0.0779*	0.0434	1.80
Café	-0.0217	0.1086	-0.20
Location (Zone towns)	0.3253***	0.0968	3.36
Constant	-1.0057	0.6310	-1.59
Number of observation	89		
LR Chi2(9)	51.62***		
Pseudo R2	0.3390		

*Note: *,**,***, significance at the 10, 5, and 1 per cent significant levels*

4. Discussion

The dairy supply chain consists of producers, cooperatives, cafeterias, retailers and consumers. A large amount of milk supply is from smallholder farmers. Farmers used to obtain exotic breed and other inputs mainly from government sources. Contract based coordination is popular in the dairy supply chain. Determinants for contract base coordination were found to be information asymmetry, opportunistic behavior, resource requirements, size and location of firms and quality problems. Contracts relieved traders from searching suppliers, market information and price information as it is used as sources of information. Lack of milk quality checking system in fresh milk supply chain exposes the traders to face persistent quality problem. It drives traders to adopt contractual arrangements to build trust and confidence on the supplier.

Contractual arrangements are also driven by the financial need of traders or suppliers. Dairy traders regarded contractual arrangements as sources of working capital as payments are differed to some period in their agreement.

Larger firms need secure market for their fresh milk requirement. If they rely on open markets comprising of smallholder suppliers, the searching cost and quality inspection time will get costly. Hence, contractual agreements would guarantee them reliable quality and supply. Location of firms is found determinant in adopting contract purchase. Zonal towns are with better institutions and less conservative users of dairy products. Therefore, monitoring costs of contract failure will get lower and irregularity of demand won’t be high and requires traders to arrange sustainable supply through contractual arrangements.

6. Conclusions and implications

Traditional spot marketing systems are increasingly replaced by contract agreements by retailing and supermarket traders due to the changes in consumers’ preferences and requirements in quality. Contracting becomes a major coordinating mechanism for dairy products for traders to get supply of fresh milk.

Contracting helped traders reduce quality risk due to lack of institutions to determine and certify quality. None of the respondents had quality certificates. Thus, traders assure quality by establishing long-term contracts with their suppliers as a warranty for quality and consistent quantity delivery. The support relationship traders practiced with suppliers has contributed affirmatively to close coordination in the form of contract. Policy makers are advised to consider traders as strategic partners for upgrading the supply chain that will contribute to the improvement of production and quality of dairy products.

Concerned government organizations operating on rural development need to consider traders as partners for development and facilitate coordination between producers and traders so that they can resolve problems of input and credit supply; they can also facilitate technology transfer to improve quality and quantity of milk production. Furthermore, strengthening marketing cooperatives that deal with the marketing of milk to satisfy the quality and quantity requirements of traders minimizes transaction costs for the traders.

Strengthening traders with better processing devices will enable them to improve the shelf life of dairy products and improve proportion of merchandise and sales. Development and financial institutions need to consider building the capacity of these traders so as to strengthen and upgrade the dairy supply chain in the region. This will play an important role in improving the gains of traders and producers from the subsector and better living standards to the rural households.

Understanding and investigating the impacts of various coordination mechanisms in mitigating the transaction costs and improving profitability of traders and the livelihood of farmers should also be conducted to determine the intervention areas in improving the performance of the dairy supply chain in the region. Improving the productivity of supply chains will improve not only the marketing of agrifood products but also supply of inputs, credits and technologies to the producers that will help facilitate productivity and household livelihood.

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CLASS-BIAS IN TECHNOLOGY ADOPTION: STAGNATION AND TRANSFORMATION OF SUBSISTENCE AGRICULTURE IN THE ETHIOPIAN NORTHERN HIGHLANDS

Luca Mantovan*

1. Brief historical background

This study inquires into the persistence of subsistence agriculture in the Ethiopian Northern Highlands. More specifically, it inquires into the unsuccessful attempts of transforming it through modern agricultural packages. In fact, chemical fertilizers and improved seeds are today registering some good rates of adoption around certain cities and highways. However, while those positive experiences should be not disregarded, they should be also considered against the negative ones. And it is a matter of fact that, although in the 1960s smallholders readily adopted agricultural packages (Hoben 2001, p. 21), today subsistence farming remains by far the dominating form of agriculture, where most peasants are reluctant to change technology; where the majority lacks resources to till land; and where the food security of entire communities is under threat (Befekadu et al. 2002, pp. 53-7; Belay 2003; Dejene 2003; Devereux 2000; Devereux and Sharp 2006; EEA 2009, pp. 64-9).

The form of agriculture that today persists in the region emerged after the reform of 1975. In reaction to the last developments of the empire, that reform redistributed land among the peasantry with egalitarian ideals, somehow presenting in a new vest some aspects of the traditional system of land tenure (Calchi Novati 1994, ch. 4-5; Crummey 2000, pp. 8-12; Dessalegn 1984; Hoben 1973; Hoben 2001; Mesfin 1984).

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Ideally, by taking into account the prevailing technical conditions of production and the differentiation of soil and household's size, the reform allotted to each peasant household the inheritable but unmarketable usufruct right to specific plots of land according to two general principles. On the one hand, that land had to be large enough to allow for the economic reproduction of peasant's household. On the other, it had to be small enough to permit direct cultivation by means of peasant's self-labour (Mesfin 1991, pp. 12-3; Aspen 1993, p. 31). Given that today the land tenure system still rests on the same right to land, it might be expected that the observed variation in holding size can be explained substantially by the variation in household's size. Nevertheless, this is not the case: there is a significant residue, while a consistent negative correlation is observed between household's size and land per person. This situation appears somewhat paradoxical, in so far as the households that result poorer in terms of land, labour and other typical indicators of wealth, tend to be better off in terms of land per person[1] (Ege 2002a, pp. 1443-4). So the question we want to rise is: why?

Figure 1: Negative Correlation between household size and land per person

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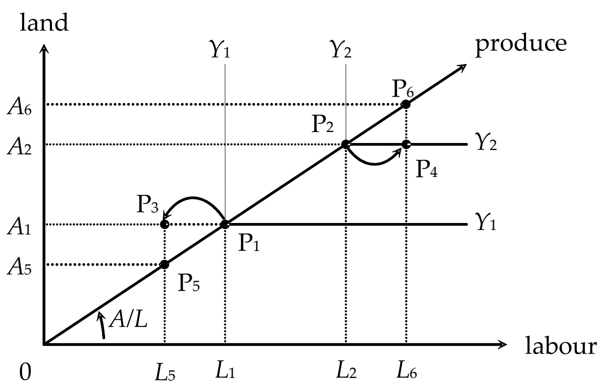

Figure 1 synthesizes the question. Let the traditional technique of production persisting in the region be characterized by the fixed product-land and land-**labour**

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[1] For instance, Ege 2002a refers to a case study where the Gini index of the land distribution per person is 0.30. The same index is virtually equal for the land distribution per household, namely 0.31. Correspondingly, the correlation between household size and holding size is +0.49, while the one between land per person and household size is –0.41.

ratios Y/A and A/L[2]. Consider then two households, respectively of size L_1 and L_2 with $L_1 < L_2$. Assume a null dependency ratio for both, so that the size of each household identifies also its labour force. Ideally, being the two households in the condition to provide directly the labour forces L_1 and L_2, they were assigned of the amounts of land A_1 and A_2 respectively such that $A_1 < A_2$ and $A_1/L_1 = A_2/L_2 = A/L$, and such that the two productive capacities Y_1 and Y_2 were enough to ensure their economic reproduction. Hence, the situation entailed by the reform should be the one captured by the points P_1 and P_2. However, the observed situation seems to be closer to the points P_3 and P_4, where the land-labour ratio of the household of smaller size is significantly greater than the one of the household of greater size. Why?

The reform of 1975 focused mainly on land, but in fact this was of a somewhat narrow perspective, because land, household's composition, draught power and annual advances of agricultural product are all equally necessary to agricultural production and household's economic reproduction. Thus, although the reform was successful in correcting inequality in the social distribution of land, a significant residual inequality was left in all the other sectors of the economy (Dessalegn 1984, pp. 49-53). Correspondingly, sharecropping emerged as a widespread practice with the relative status of the lessor and lessee of land typically reversed: while sharecropped land tends to belong to smaller households supplying labour force, lessees are typically larger households hiring labour force. In some cases, lessors seem to lack draught power, and therefore to be compelled to hire it in exchange for labour or agricultural product[3] (Aspen 1993; Yared 2003). In some other cases, they seem to lack male labour for ploughing, or to be unable to feed their draught animals, and therefore to be compelled to hire out the latter in exchange for agricultural product (Ege 2002a and 2006). Yet, in many other cases, the agricultural and pastoral sectors of the economy seem to be interlocked in a far more complex manner mediated also by market-based exchange relations, so that no definite pattern seems to emerge (Ege

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[2] This assumption can be justified as follows. The Amharic noun *timmad* customarily designates a local unit of measure for land fertility (Mesfin 1991, 12-13). Nevertheless, the noun derives from the verb *temede* – to yoke – and identifies a yoke of two oxen and the land the latter can plough in one day (Aspen 1993, 31). Thus, there is an apparent ambiguity in interpretation. A Leontieff-type of production function solves it by providing the conversion rule $Y/A = Y/K \times K/A$, where Y/A stands for land productivity, Y/K for the productivity of the draught power of two oxen, and K/A for the draught power of two oxen required by a unit of land. Interestingly, this logic underlies the traditional units of measure of land all over the country, the world and history (Kula 1986, ch. VI; Bhaduri 1973, p. 124). It is exactly this logic, which is often extended up to include also human labour, that allowed to put into practice the two general principle followed in land redistributions.

[3] Draught power can be exchanged under different kinds of arrangements, whose names may vary from place to place. However, in the case studied by Aspen 1993 for instance, *mekenajo* allows two households with one ox each to share their oxen. *Igni* allows to hire two oxen for one day in exchange for two days of labour, while *arso* in exchange for ploughing the land of the lender and rearing the animals. *Ribi* typically concerns female animals and their offspring, but it also allows to hire oxen in exchange for agricultural produce. For these and the other production relations mentioned in the following notes refer always to Aspen 1993.

2002b). Nevertheless, below this apparently protean situation, there is an important recurrent fact: land tends to be supplied along with labour force by households unable to survive only of the product of their land. Even with the different forms of support they receive from their communities[4], those households are typically not in the condition of advancing all the agricultural product required by their economic reproduction – advances of agricultural product that include household's food needs, but also seed, fodder, and any other annual requirement of the production process accordingly with its specific organization. Consequently, they are typically compelled to hire out labour in exchange for agricultural product[5] while sharecropping leased-out land they are unable to cultivate on their own.

It is worth starting analysing these production relations in terms of Figure 1. Let the difference $L_1 – L_5$ stand for the amount of labour force supplied by the household of smaller size L_1. Thus, L_5 stands for the residual amount of labour force self-employed in the direct cultivation of the amount of land A_5, while the difference $A_1 – A_5$ stands for the amount of land the household supplies. Correspondingly, the differences $L_6 – L_2$ and $A_6 – A_2$ stand for the amounts of land and labour demanded by the household of greater size L_2. Note that land and labour are supplied so as to maintain the land-labour ratio of the smaller household at the technical level A/L. If the supplies of labour and land of the smaller household are fully met by the respective demands of the larger household, it holds $L_1 – L_5 = L_6 – L_2$ and $A_1 – A_5 = A_6 – A_2$. The first household cultivates directly only the amount of land A_5, while the second one cultivates the operational holding of overall size A_6 by means of both self-employed and hired labour, in overall amount L_6. The effective situation entailed by the prevailing production relations corresponds therefore to the points P_5 and P_6. Nevertheless, despite those interlocked transactions of labour and land, in practice the situation observed in data collection should still correspond to the points P_1 and P_2. Hence, again the question is: why is the observed situation captured by the points P_3 and P_4?

In order to reply, we finally have to consider (properly) households' demographic cycles, which in turn allow us to abandon the assumption of full employment and of full land cultivation. In the first period of household's life cycle, a newly married couple typically tills a small amount of land, which is typically limited to an anticipation of inheritance, and which can be directly cultivated by the couple's labour force[6]. With

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[4] For instance, the community provides support also through *maheber* and *senbete* – Copt feasts that may involve, along with other similar occasions, up to one third of the calendar, and that are sponsored by the richest participants, who supply food in turns.
[5] *Wenfel* allows to hire labour in exchange for food. *Debo* is a working group hosted in exchange for food. Households hosting *debo* tend to gather a number of people slightly exceeding the number of *debo* they take part to, which is a sign of the existence of a weak but net supply of labour also in working groups.
[6] *Gulma* is an advance of land inheritance given to sons when they become capable of ploughing and managing land on their own. The produce of *gulma*, along with the gifts received for the marriage, and the

the passage of time, while the household grows in size, its land holding tends to increase through full inheritance, leaving the land per person ratio substantially unaltered[7]. But then, how can an expanding household in search for additional land gain access to it? Before the reform of 1975, the prevailing land tenure system (the rist) was based on a fundamental contradiction: the distinction between peasant's right to land and his effective holdings. Thank to that contradiction, the customary practice was the one of claiming land on the basis of own rights in a court, in front of judge and witnesses[8] (Hoben 1973, ch. 8). The reform however put an end to the contradiction, so that today the main (if not only) way left to increase household's holding size beyond inherited land is by leasing land[9] (Hoben 2001, pp. 6-7). But from whom was the land claimed in the past, and from whom is the land leased today? Today as in the past, there is a conflict among peasant households for the control of land. Before the reform, that conflict was explicit, and used to find expression inside judges' courts. Today, it is only less apparent, because mediated by sharecropping. Nevertheless, today as in the past, that conflict tends to result in a reallocation of land from households that are not in the material condition of cultivating it to households that are[10]. On the one hand, the lessees of today (like the successful claimants of the past) are larger households disposing of a surplus of labour with respect to their inherited holding because in the full of their demographic cycles and because of their enlarged families. On the other hand, lessors are typically smaller households in deficit of labour force because some of their able members left because they were adopted by richer households as ploughboys or assistants; or because they emigrated to seek food; or because they died prematurely; or because they divorced[11]. It is both this deficit and surplus of labour force that might finally explain the negative correlation observed between household size and land per person (Aspen 1993; Ege 2002a and 2006; Hoben 1973, pp. 62-3; Hoben 2001, p. 5; Yared 2003).

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support received during the two-year starting period spent in the groom's parental homestead, allows the new couple to build the agricultural capital necessary to establish a new independent household.

[7] In deterministic terms, this would be true only if demographic growth was nil homogenously; if there was no overlap between the *n*th and the (*n* + 2)th generation; and if the gender distribution within the household was homogeneous (in spite of gender-neutral rules, in practice inheritance tends to show a gender-bias).

[8] In some cases, grazing or free lands were put under cultivation. In some other cases, land litigations involved entire descent corporations. Nevertheless, in most cases, litigations involved directly only two households (Hoben 1973).

[9] The subsequent waves of land redivisions that redistributed land until 1996, with an average frequency of up to one redistribution every four years, represent another important element of continuity between the two systems of tenure (Hoben 2001, in particular pp. 13 and 18).

[10] When considering demographic cycles in land-bounded communities, it is important to take into account that where there is an expanding household, there is also a contracting one: the game is a zero-sum one (Hoben 1973). Moreover, it is worth emphasizing that although land and labour reallocations are typically judged in terms of economic efficiency, the problem here is different and a more substantial one: efficacy (Hoben 2001, p. 23; Ege 2002b, p. 1452).

[11] Also divorce may be the result of economic distress – for instance, think of the consequences of permanent emigration – especially in a context where infra-household relationships appear of such a strong economic nature (Hoben 1973 and 2001; Ege 2002b, p. 1452).

Turn back to Figure 1. The points P_3 and P_4 might capture the extreme situation where the surplus labour of the lessee in the full of its demographic cycle cultivates all sharecropped land, while all the labour force supplied by the lessor remains unemployed. L_6 stands for the household size of the lessee. The difference $L_6 - L_2$ stands for its surplus of labour with respect to the inherited holding of size A_2. The difference $A_1 - A_5 = A_6 - A_2$ stands for sharecropped land. The difference $L_1 - L_5$ stands for the labour force of the lessor left unemployed, and therefore compelled to emigrate and leave behind a household of residual labour force L_5, which in turn cultivates directly the residual amount of land A_5. Alternatively, the points P_3 and P_4 might capture another extreme situation where the surplus labour of the lessee is attributable to a ploughboy adopted from the lessor, while all the residual labour force of the latter remains unemployed. In this second case, L_6 stands for the household size of the lessee, which includes the ploughboy. The difference $L_6 - L_2 = L_1 - L_5$ stands for the labour force of that ploughboy, in surplus with respect to the holding of size A_2 inherited by the lessee. The difference $A_1 - A_5 = A_6 - A_2$ stands for sharecropped land. L_5 stands for the residual labour force of the lessor left unemployed, and therefore in part compelled to emigrate and in part surviving of the rent from sharecropping. Finally, A_5 stands for land left uncultivated. Both these situations that may be captured by the points P_3 and P_4 are somewhat extreme cases, and the reality will probably be an intermediate situation lying somewhere in the around. Nevertheless one fact should be clear: if the lessee is typically a larger household disposing of a surplus of labour because of natural reproduction or adoptions, the lessor is typically a smaller household in deficit of labour force because of adoptions, emigration, premature deaths, or divorce[12].

The peculiar mode of production – which is namely defined by the interlocked exchange relations of labour and land analyzed so far – is commonly termed in the literature subsistence agriculture. This terminology is appropriate only in so far as it emphasizes that the primary economic objective of a peasant household is the direct production of its means of subsistence. However, there is also a risk of misinterpretation: peasant households are not an undifferentiated mass of autarchic units of production and consumption reproducing on a scale of bare subsistence. First, their household's economies produce a surplus of product that today as in the

[12] In other terms, it is not that ox-deficient households are poor – as wanted by the so-called ox-argument – but the other way round: poor peasants are those who do not dispose of enough agricultural produce to feed their draught animals, or to hire draught power. The same causality applies also to labour force: it is not that labour-deficient households are poor, but poor households lack labour force as a result of poverty. Of course, poverty is a self-reinforcing process resulting from interactions, but the fundamental deficit seems to be in the capacity of advancing agricultural produce. It is the latter that seems to unify the protean situation observed in the countryside (Ege 2002b, p. 1453).

past allows for the existence of non-farming classes[13]. Second, that product circulates also among peasants themselves through specific (interlocked) exchange relations involving labour and land. In view of the following analysis, it is worth underlining that those exchange relations are characterized by at least two important aspects.

(*a*) Freedom and necessity. While human needs might not have an upper limit, in any culture there is quite a clear definition of the lower one. By referring to those basic needs, peasant households can be meaningfully grouped into two economic classes, ultimately distinguished by the motivations and calculations underlying their behaviour. On the one hand there are deficit producers, who are compelled by the necessity of attaining their subsistence to supply labour and land in exchange for agricultural product. On the other hand there are surplus producers, who are able to supply the latter to command labour and land and maintain, if not improve, their status. The asymmetry observed in peasant exchange relations reflects this different capability of advancing product, and therefore these two systems of rationality (Cipolla 1962, ch. II; Keynes 1963, part II ; Robinson 1970, ch. II-III; Kula 1980, ch. III; Bhaduri 1983, ch. I-III).

(*b*) *Conflict and integration*. Land and labour are not simply the economic basis of peasant life. They are the natural environment and the human substance of society. If traditionally they never entered the domain of commerce at par with commodities, today they are still mainly exchanged within the peasant community under the principles of reciprocity and redistribution. These, along with house-holding, are the dominant organizational principles of social production. Correspondingly, peasant terms of exchange are not determined by impersonal market forces, but are typically fixed at certain customary levels that somehow sustain all the members of society. In the light of peasant longstanding conflict for the control of land, those customary terms of exchange ultimately represent the way society absorbs conflict to remain integrated (Weber 1922; Polanyi 1944, ch. IV-VI; Godelier 1984, ch. V; Harris-White 2003).

Starting from these preliminary observations, the rest of this paper attempts to address our initial and main question: technological stagnation. In order to do that, the next section of the paper abandons the static point of view of this first section to analyze, in precise formal terms, the dynamics of reproduction of a corn economy with two representative producers – a deficit and a surplus one – exchanging land

[13] Surplus extraction is another important element of the situation. Nevertheless, the notion of tributarism seems to be of some relevance for the past rather than for today (Berhanu 2005). Furthermore, commercial capital is likely to play an important role. Finally, although the assumption of a homogeneous peasantry is useful when analyzing state-peasant relationship, yet it is empirically untenable. It is necessary to analyze it properly when discussing the impact of a new land policy, otherwise important misinterpretations may follow (with this respect, see also note 32).

and labour in an interlocked manner[14]. The third section analyses the consequences of a positive shock on production in the form of chemical fertilizer, to show how in this economy unintended outcomes like technological stagnation rather than agricultural growth might emerge. The last section finally concludes with some consideration about the more general significance of the analysis.

2. The model

Consider a closed economy where two peasants produce a homogeneous commodity – say corn – by means of the same technique of production, under which land and labour are to be mixed in fixed proportion. Assume that the production process lasts one period, and that the next period starts with the new harvest. Suppose that each peasant owns an amount of land that requires exactly his self-labour to be tilled, and that that land can produce a positive surplus with respect to peasant's subsistence needs. Nevertheless, for some historical reason, suppose also that the effective production of one of the two peasants is in deficit with respect to his subsistence needs, so that he is compelled, in order to cover that deficit, to supply a first part of his labour to the other peasant (who conversely is a surplus producer) in exchange for a wage to be advanced along the cropping year in terms of corn. Hence, it is only the second and residual part of the deficit producer's labour to be self-employed in direct production. And correspondingly, it is only a first part of his overall land to be cultivated directly by himself, while the other part is rented out to the surplus producer in exchange for a share of the harvest of the year after. Lastly, assume that at the ruling unit rent and wage rate, both the land and labour supplied by the deficit producer are fully demanded by the surplus producer. Note that such exchanges are interlocked: had not the one to supply labour, he would neither supply land; and did not he supply land, the other would not demand labour[15].

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[14] The precise link existing between the static analysis of this section and the dynamic one of the following two sections is found in the last paragraph of the next section.

[15] Maybe, it is worth adding few other observations in comment to the assumptions of the model. First, recall that the reason underlying the deficit producer's labour disposal is the necessity of survival discussed in the previous section. Second, recall also that the assumption of fixed coefficients of production is justified by referring to the traditional unit of measure of land in note 2. Third, smaller peasants might adopt more labour-intensive techniques; similarly, land fertility, labour effort and skills might be differentiated. However, it will be realised later that these are marginal details unnecessary to the argument. Fourth, note that peasant interlocked exchanges can be reduced substantially to a pure reciprocal exchange of labour, the one of the deficit producer being repaid by a wage advance, the one of the surplus producer by a share of the harvest of the year after. However, from the disaggregate point of view, the individual deficit producer may supply labour and land to a variable number of different surplus producers. Last, note that the model is oversimplified for many reasons. In particular, it avoids to analyze the role of commercial capital in the external market for produce, which in practice may involve a relatively limited share of production (for instance, around 15% in the case studied by Mesfin 1991).

Under these assumptions, the deficit producer's balance of corn B_t for the year $t > 0$ amounts to the algebraic sum of four flows

$$B_t = Y_t + R_t + W_t - X_t. \qquad (1)$$

Y_t stands for the direct product, R_t for the rent, W_t for the wage, and X_t for the circulating capital advanced on an annual basis to reproduce the production process. Let $L > 0$ be the deficit producer's labour, and let $\lambda_t \in [0, 1]$ be the fraction of it hired out in the year t, so that the complementary fraction $1-\lambda_t$ is deployed in direct production. If $Y > 0$ stands for the overall product of the deficit producer's land, then the direct product Y_t amounts only to a fraction $1-\lambda_{t-1}$ of it[16]:

$$Y_t = Y(1-\lambda_{t-1}). \qquad (2)$$

Instead, the complementary share of that product $Y\lambda_{t-1}$ is produced under sharecropping, and the rent R_t amounts to a fraction $\sigma_S \in [0, 1]$ of it, σ_S being the ruling unit rent:

$$R_t = \sigma_S Y\lambda_{t-1}. \qquad (3)$$

The wage W_t amounts to the corn repaying the hired-out labour $L\lambda_t$ at the ruling wage rate $w_S > 0$:

$$W_t = w_S L\lambda_t. \qquad (4)$$

Finally, it is convenient to reduce the annual advance X_t to only household's subsistence needs, assumed to be equal to the constant value $X > 0$[17]:

$$X_t = X. \qquad (5)$$

[16] Let the production function be $Y_t = min\{(Y/A)A_{t-1}, (Y/L)L_{t-1}\}$. Y_t stands for the corn harvested at the beginning of the year t after having cultivated during the year $t-1$ the amount of land A_{t-1} by means of the labour force L_{t-1}. Y/A and Y/L stand for land and labour productivities. According to the assumptions of the model, Y can be read as the productive capacity of the producer, A as his holding size, and L as his labour force. Thus, it follows that $L_{t-1} \le L$, $A_{t-1} \le A$, and $Y_t = Y \times min\{A_{t-1}/A, L_{t-1}/L\}$. Expression (2) is obtained after setting $A_{t-1}/L_{t-1} = A/L$ and $L_{t-1}/L = 1 - \lambda_{t-1}$.

[17] The first definition of surplus of the earliest classical thought (Physiocracy) includes as circulating capital also seed, fodder, fixed capital amortization, etc. That definition fits a context where house-holding is the prevailing mode of production, while later definitions of surplus (Ricardo's and Marx's) may accommodate different modes of production (Bhaduri 1983, ch. I). Given the peculiarity of the Ethiopian system of land tenure, it would be convenient to include also tax payment into the outflow of advances X_t, in so far as it ensures peasant access to land. In fact, there are also other kinds of obligations, like the progressive agricultural income tax, but most households may be registered below the threshold above which income is to be taxed on a progressive basis (Aspen 1993, pp. 85-90).

From (1)-(5), the corn balance of the deficit producer can be expressed as

$$B_t = (Y–X) – (1–\sigma_S)Y\lambda_{t–1} + w_S L\lambda_t \qquad (6)$$

with λ_t, $\lambda_{t–1} \in [0, 1]$. Note that according to the assumptions of the model the constant term in (6) satisfies the accounting condition

$$Y–X > 0. \qquad (7)$$

This condition says that if the deficit producer did not hire out labour, so that in (6) it holds $\lambda_{t–1} = \lambda_t = 0$, then his corn balance B_t would amount to the entire surplus product of his land $Y–X$, which is positive according to the assumptions of the model.

Given that in the economy land and labour are fully employed, the aggregate balance of corn is constant, amounting to the surplus product of the overall land. Consequently, the corn balance of the surplus producer – amounting to the surplus of his land plus the profit realized by tilling rented land by means of hired labour – is of an expression similar to (6), but with the signs of the terms proportional to $\lambda_{t–1}$ and λ_t reversed, and with the constant term redefined as the surplus product of his land. Hence, while the aggregate surplus is constant, the social distribution of the latter varies according to the labour disposal of the deficit producer. The latter supplies labour only if forced by necessity. If his availability of corn $Y_t + R_t$ for the year t was enough to cover his subsistence needs X_t, that is $Y_t + R_t – X_t \geq 0$, then his supply of labour of that year would be nil. Nevertheless, this is not the case. He faces a deficit $X_t – Y_t – R_t > 0$, and consequently he is compelled to hire out labour in order to cover such a deficit. Therefore, until the following boundary condition holds

$$(Y–X)/(1–\sigma_S)Y < \lambda_{t–1} \leq 1, \qquad (8)$$

the labour disposal of the deficit producer is bound to satisfy the null-balance condition

$$W_t = X_t – Y_t – R_t. \qquad (9)$$

This, along with (2)-(5), gives the first-order difference equation

$$w_S L\lambda_t = (1–\sigma_S)Y\lambda_{t–1} – (Y–X). \qquad (10)$$

Note that the deficit producer's labour supply is of a forced nature: according to (10), the labour supplied $L\lambda_t$ is negatively correlated to the wage rate w_S. Given the deficit on the right hand side of (10), which depends on the labour disposal of the year t–1, and which according to (8) is positive, the higher the wage rate, the lower the labour that in the year t the producer is compelled to hire out to cover that deficit and meet his subsistence needs. The general solution of (10) is

$$\lambda_t = (1+\pi_S)^t(\lambda_0-\lambda_S)+\lambda_S, \qquad (11)$$

where λ_0 is an arbitrary initial value, and π_S and λ_S are defined by

$$(1+\pi_S) = (1-\sigma_S)Y/w_SL \qquad (12)$$

$$\lambda_S = (Y-X)/[(1-\sigma_S)Y-w_SL]. \qquad (13)$$

π_S is the prevailing rate of profit, while λ_S is the value of the only constant sequence satisfying (10)[18]. (11)-(13) exhibit how the time-path of reproduction followed by the deficit producer – and therefore by the overall economy – may be of three types, depending on the values of the parameters λ_0, $1+\pi_S$ and λ_S.

(*a*) *Enlarged reproduction and autarchy*. If the initial condition is $\lambda_0 < \lambda_S$, which in view of (13) can be written as[19]

$$w_SL+\sigma_SY > Y-(Y-X)/\lambda_0, \qquad (14)$$

then the time-path followed by (11) negatively diverges and overcomes in a finite time the lower extreme of (8). Correspondingly, the economy reaches a stationary state where the deficit producer has the full control of his labour and land, and of their product. In other terms[20], if the prevailing terms of exchange (σ_S, w_S) are sufficiently

[18] The general solution of (10) is (11) only if $(1+\pi_S)\neq1$, which implies $\sum_{0\leq n\leq t-1}(1+\pi_S)^n=[1-(1+\pi_S)^t]/[1-(1+\pi_S)]$. Conversely, if $(1+\pi_S)=1$, then $\sum_{0\leq n\leq t-1}(1+\pi_S)^n=t$, and the general solution is

(11-bis) $\lambda_t = \lambda_0-t(Y-X)/w_SL$.

[19] From an analytical viewpoint, enlarged reproduction accounts for four different sub-cases. Refer to (11)-(13). First, if

(14a) $Y < w_SL+\sigma_SY$,

then $1+\pi_S <1$, $\lambda_S <0$, and independently from the initial value $\lambda_0\in [0, 1]$, the time-path tends to converge to the negative stationary value λ_S. Second, if

(14b) $Y = w_SL+\sigma_SY$,

then $1+\pi_S=1$, and the time-path negatively diverges (recall note 18). Third, if

(14c) $X < w_SL+\sigma_SY < Y$,

then $1+\pi_S > 1$, $\lambda_S >1$, and again the time-path negatively diverges. Last, if

(14d) $Y-(Y-X)/\lambda_0 < w_SL+\sigma_SY \leq X$,

then $1+\pi_S >1$, $\lambda_m < \lambda_0 < \lambda_S \leq1$, where $\lambda_m = (Y-X)/(1-\sigma_S)Y$ is the lower extreme of (8), and once more the time-path negatively diverges. Note that according to (7), the term on the left-hand side of (14a) exceeds the one of (14c), which in turn exceeds the one of (14d). Note also that the time-path of enlarged reproduction overcomes in a finite time the lower extreme λ_m: if $1+\pi_S\neq1$, then $\lambda_t < \lambda_m$ iff $t > \log_{1+\pi S}[(\lambda_S-\lambda_m)/(\lambda_S-\lambda_0)]$; if $1+\pi_S=1$, then $\lambda_t < \lambda_m$ iff $t > w_SL(\lambda_0-\lambda_m)/(Y-X)]$. Last, note that if τ is the critical year, then $\lambda_t = 0$ $\forall t \geq \tau$.

[20] Note that condition (14) can be easily written as $\lambda_0[(1-\sigma_S)Y-w_SL]< Y-X$.

high that in the initial year the amount of corn extracted by the surplus producer as profit, that is $\lambda_0[(1–\sigma_S)Y–w_S L]$, does not exhaust the entire surplus product of land, that is $Y–X$, then, starting from the subsequent year, the deficit producer is able to satisfy his subsistence needs by reducing his supply of labour and land in favour of direct production. In this way, year after year, he gradually emancipates himself from any form of economic dependency, being finally able to gain and maintain the full control of his resources. From the point of view of the overall economy, the enlarged reproduction of the deficit producer leads to a new class configuration – say autarchy – where the two producers share the same status of independent surplus producers.

(*b*) *Simple reproduction and stagnation*. If the initial condition is $\lambda_0 = \lambda_S$, then the inequality (14) turns into an equality, and the time-path followed by (11) is constantly equal to λ_S given by (13). Correspondingly, the economy stagnates in a stationary state where a fraction $(1 – \lambda_S)$ of the deficit producer's labour and land are under his direct control, while the complementary fraction λ_S is commanded by the surplus producer. In other terms, when the surplus producer extracts as profit the entire surplus product of land, the deficit producer is left in a state of simple reproduction, where he is just able to reach subsistence and maintain a partial control of his labour and land. From the point of view of the overall economy, the simple reproduction of the deficit producer corresponds to a stagnating class configuration where the status of the two producers is only relatively differentiated, both producers being to some extent direct producers.

(*c*) *Contracted reproduction and polarization*. If the initial condition is $\lambda_0 > \lambda_S$, then in (14) the sign of inequality is reversed, and the time path followed by (11) positively diverges and reaches in a finite time the upper extreme of (8). Correspondingly, the economy reaches a state where the surplus producer has no more direct control of labour and land[21]. In other terms, when in the initial year the surplus producer extracts as profit more than the surplus product of land, the deficit producer is compelled since the year after to augment his supply of labour and land at the expense of direct production. In this way, year after year, he is gradually evicted, being finally forced to depend completely on the surplus producer's support. From the point of view of the overall economy, the contracted reproduction of the deficit producer leads to a new class configuration – say polarization – where the difference between the status of the two producers is maximum.

Before turning to the problem of technological change, it is worth concluding this section by referring once more to Figure 1. The condition allowing for the deficit

[21] Refer to (11)-(13), and recall note 19. If the sign of inequality of (14) is reversed, then $1+\pi_S > 1$, $\lambda_m < \lambda_S < \lambda_0 < 1$, and the time-path positively diverges, overcoming in a finite time the upper extreme of (8): $\lambda_t < 1$ iff $t > \log_{1+\pi S}[(1–\lambda_S)/(\lambda_0–\lambda_S)]$, where $\lambda_S < \lambda_0 < 1$. Note also that if τ stands for the critical year, then $\lambda_t = 1 \ \forall t \geq \tau$.

producer's simple reproduction identifies one point on the line characterized by the fixed land-labour ratio of technology A/L. For instance, let such a point be P_5. Thus, its coordinates satisfy the condition $1–\lambda_0 = L_5/L_1 = A_5/A_1$, where $A_1 = (A/L)L_1$ and where L_1 stands for L above. The point P_5 identifies the first (unstable) equilibrium of the model – stagnation. The second (stable) equilibrium – autarchy – is captured by the point P_1. It is the final result of the process of enlarged reproduction, and corresponds to a situation where the deficit producer's land and labour are both fully employed in direct production. Finally, the deficit producer's eviction, which is the situation resulting from the process of contracted reproduction, is captured by the origin of the axis, where the deficit producer's labour and land are both entirely supplied to the surplus producer. Note that such a situation is not an equilibrium: under the conditions of contracted reproduction the deficit producer cannot survive of the only wage and rent. Nevertheless, if emigration, ploughboys adoption, or any other factor that may finally reduce the deficit producer's labour force are allowed for, then the last (stable) equilibrium of the model – polarization – is captured by the point P_3. The interpretation of the latter has been already given in the first section: while the difference $L_1 – L_5$ stands for hired labour force, L_5 now stands for labour force compelled to emigrate. Correspondingly, while the difference $A_1 – A_5$ stands for rented land, A_5 now stands for land supplied but left uncultivated. In fact, the land of the evicted deficit producer might remain fully cultivated if the wage rate and unit rent adjusted to allow for his subsistence. More realistically, it would be enough to assume that the surplus producer disposed also of surplus labour. Nevertheless, although this last assumption may be of some descriptive relevance, it is analytically unnecessary when turning to the problem of technological change[22]. As the next section shows, it is the underlying conflict for the control of land that plays the key role in such an issue.

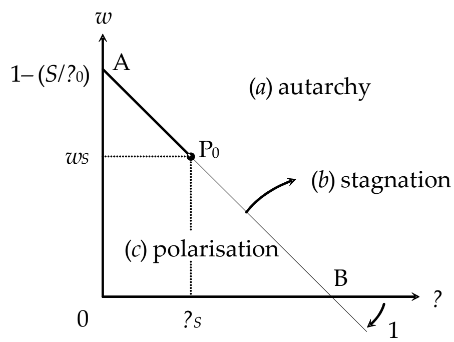
3. The transformation

Figure 2 synthesizes the model of the previous section. The two axes report the values of the ruling wage rate w and unit rent σ respectively. To economize in notation, set $S = Y–X$ and normalize L and Y to the unit. Given the initial state λ_0, the segment AB is the graph of (14) with the sign of equality. It is the locus of all the terms of exchange (σ, w) that are compatible with the deficit producer's simple reproduction. The terms of exchange left at northeast of AB are conversely compatible with his enlarged reproduction, while the rest with his contracted

[22] However, it is important to observe that, under that assumption, the loss of productive labour due to the partial emigration of the deficit producer's labour force tends to be compensated by the absorption of the surplus labour of the surplus producer. Thus, emigration tends to correspond both to a reallocation of resources and, from the point of view of the overall economy, to an extraction of surplus labour, so that aggregate production tends to stagnate.

reproduction. Starting from the initial state λ_0, and depending on the ruling conditions of production (σ, w), the dynamics of reproduction of the economy may lead to three stationary states: (*a*) autarchy; (*b*) stagnation; (*c*) polarization. What discriminates among these three situations is the class structure of society, which is a reflection of the underlying social distribution of labor, land, and their produce.

Figure2: Condition of production and class structure



Consider a situation like the one corresponding to the point P_0 of Figure 2. Given the initial state λ_0, let the prevailing conditions of production (σ_S, w_S) satisfy (14) with the sign of equality, so that $\lambda_0 = \lambda_S$. In other terms, let the deficit producer be in a stationary state of simple reproduction, with a partial control of his labour and land. Starting from this initial situation, what follows analyzes the consequences of a positive shock on production in the form of chemical fertilizer. Assume that the latter has to be mixed with land in fixed proportion; that it leaves the previous land-labour proportion unaffected; that it requires an advance of corn; and that it improves land productivity[23]. In particular, suppose that if in the year t–1 the deficit producer

[23] Maybe, it is worth adding few other observations also in comment to this second set of assumptions. First, given that this study does not analyze the market for produce, it does not analyze the market for fertilizer as well. Second, it will be realised that a change in the land-labour ratio (as claimed for instance in EEA 2009, p. 64) would not affect the essence of the analysis. Third, the argument substantially applies to any other technology. In fact, also the morphology of terrain and the fragmentation and small size of peasant plots might contribute to explain the lack of *private* investments on land and mechanized technology. Conversely, the insecurity of land tenure entailed by the recurrent redivisions experienced until the most recent past (which is the explanation for technological stagnation prevailing in the literature, see for instance the Hoben 2001; Berhanu et al. 2003; Berhanu 2005) fails to explain permanent crops, tree-planting (Crummey 2003), and reluctance towards agricultural packages (in this respect, recall note 10, and the fact that in the 1960s peasants readily adopted agricultural packages; moreover, notice that the benefits of the latter are limited to only one agricultural season). Last, it might be wondered why credit is not included in the picture. For a comment on this refer to note 29.

advances the corn necessary to cover the subsistence needs X and to adopt the fertilizer to be mixed with the self-labor $L(1–\lambda_{t–1})$, that is

$$X_{t–1} = X + xL(1–\lambda_{t–1}), \quad (15)$$

then, the year after, he harvests the corn

$$Y_t = (1+\delta)Y(1–\lambda_{t–1}). \quad (16)$$

In (16) x stands for the corn advanced for fertilizer per unit of labour, while δ for the corresponding relative improvement of labour productivity. Both x and δ are positive and satisfy the accounting condition[24]

$$\delta Y–xL > 0. \quad (17)$$

Note that according to (7) and (17), the surplus product of land improves. However, whether this enhancement is enough to benefit the deficit producer or not crucially depends on how the change of technology interacts with the pre-existing conditions of production (σ_S, w_S) and transforms the parameters λ_0, $1+\pi_S$ and λ_S governing the dynamics of reproduction (11).

In the adoption year $t = 0$, the deficit producer's availability of corn is $Y_0 + R_0$, where Y_0 and R_0 are the direct product and rent given by (2) and (3) for $\lambda_{t–1} = \lambda_S$. Hence, according to (9) and (15), if he advances corn for fertilizer, he is compelled to hire out a fraction of labour λ_{0T} satisfying the initial condition

$$\lambda_{0T} = (x+w_S\lambda_0)/(x+w_0). \quad (18)$$

In (18), $\lambda_0 = \lambda_S$ is the fraction of labour that he would hire out if he did not adopt fertilizer, while w_0 is the wage rate ruling in the year of adoption. Since the labour supply is of a forced nature, according to (18) the hired-out labour $L\lambda_{0T}$ is correlated positively to the unit advance x, but negatively to the wage rate w_0: given the availability of corn Y_0+R_0, the higher the wage rate, the lower the labour the producer is forced to supply in order to match subsistence and adopt fertilizer[25]. For simplicity,

[24] It might be argued that in order to represent an improvement, the new technology should entail a lower unit cost of production, so that condition (17) should be replaced by the more binding one $\delta Y > (Y/X)(xL)$, where $Y/X > 1$ according to (7). Nevertheless, in the model there is no possibility for agricultural extension, so that the surplus cannot be reinvested on new lands by applying the traditional technique.

[25] More precisely, this is true only if $\lambda_{0T} \leq 1$, that is $w_0 \geq w_S\lambda_S$, which implies $d\lambda_{0T}/dx = (w_0–w_S\lambda_S)/(x+w_0)^2 \geq 0$. Otherwise, at the ruling wage rate w_0, the full labour supply L would be not enough to reach subsistence. Note that if $w_0 = w_S$, as assumed later, then $\lambda_{0T} < 1$.

assume that the initial condition is $w_0 = w_S$[26]. According to (18), the labour $L\lambda_{0T}$ hired out in the year of adoption clearly exceeds the pre-transformation one $L\lambda_0 = L\lambda_S$[27]. In economic terms, when the producer is in a state of simple reproduction, he cannot substitute the corn satisfying his subsistence needs for the one he advances for fertilizer. He is compelled to hire out labour he used to self-employ. If he disposed of a surplus to advance, indeed the cost of adoption would amount to the required advance $xL(1–\lambda_S)$ given by (15), and condition (17) would ensure him a benefit. However, he does not dispose of such a surplus. Thus, although according to (16) labour productivity improves, yet self-labor contracts, and his cost of adoption amounts to the loss entailed by that contraction. Therefore, *the comparative cost determined by his relative class position may exclude the deficit producer from the change of technology*.

To prove this, let (σ_T, w_T) be the terms of exchange ruling after the transformation. From (3), (4), (9), (15) and (16), the two parameters (12) and (13) are transformed into

$$(1+\pi_T) = (1-\sigma_T)Y/(w_TL+xL) \qquad (19)$$

$$\lambda_T = [(1+\delta)Y-X-xL]/[(1+\delta)Y-\sigma_TY-w_TL-xL]. \qquad (20)$$

Thus, from (11), the transformation pushes the deficit producer onto a time-path of enlarged reproduction only if the initial condition is $\lambda_{0T} < \lambda_T$. In view of (18)-(20), this becomes

$$w_TL+\sigma_TY > Y+(\delta Y-xL)-[(Y-X)+(\delta Y-xL)]/\lambda_{0T}. \qquad (21)$$

In such a case, the stationary state that prevails after the transformation is the one of autarchy. Compare (21) and (14). If the change of technology satisfies the accounting condition

$$(Y-X)(\lambda_{0T}-\lambda_0)/\lambda_0\lambda_{0T} - (\delta Y-xL)(1-\lambda_{0T})/\lambda_{0T} > 0, \qquad (22)$$

then the enlarged reproduction of the deficit producer requires that the post-transformation terms of exchange (σ_T, w_T) dominate those that before the transformation were compatible with his simple reproduction, that is (σ_S, w_S). Note that (22) captures a net cost: the second addendum captures the absolute improvement of the surplus product of land (17), while the first one captures the initial

[26] Note that if $w_0 < w_S$ the argument would be even stronger.
[27] By substituting $x = x\lambda_0+x(1-\lambda_0)$ into the numerator of (18), it follows $\lambda_{0T} = \lambda_0+x(1-\lambda_0)/(x+w_0) > \lambda_0 = \lambda_S$.

cost of adoption specific to the deficit producer, which is due to the initial contraction corresponding to (18), and which is positive according also to (7)[28]. Consider then a change of technology satisfying (22). Coherently with (21), the deficit producer would benefit from the improved technology only if he could prevail on the other producer, and make the post-transformation terms of exchange (σ_T, w_T) dominate the pre-transformation ones (σ_S, w_S) so much to absorb the net initial cost captured by (22). However, he is in a relatively weak position with respect to the surplus producer, because the rent and wage paid by the latter are necessary to his survival. Thus, he cannot turn those customary conditions of production to his own advantage, and his class-determined comparative disadvantage may finally exclude him from the benefit[29].

Although the deficit producer might not adopt fertilizer, it might be argued that it is the surplus producer that should do it on the share of land he commands. After all, if he disposes of enough surplus to advance fertilizer on his own land, he may do the same on sharecropped land, and in such a case he does not encounter the cost specific to the other producer[30]. Hence, let the deficit producer be in the stationary state $\lambda_0 = \lambda_S$, and suppose that indeed the surplus producer is able to advance the corn required by the fertilizer to be mixed with the hired labour $\lambda_S L$. Note that if in the generic year t–1 the surplus producer adopts fertilizer, then the deficit producer's rent of the year t turns into

$$R_t = (1+\delta)\sigma_T Y \lambda_{t-1}, \qquad (23)$$

where σ_T is the unit rent prevailing after the transformation. From (2), (4), (5) (9) and (23), the two parameters (12) and (13) governing the time-path (11) are transformed into

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[28] By recalling (12), (13) and (18), note that condition (22) can be conveniently rewritten as

(22-bis) $\pi_S w_S L(\lambda_{0T}-\lambda_0) - (\delta Y - xL)(1-\lambda_{0T}) > 0.$

The first addendum is the increase of the profit extracted by the surplus producer due to the initial expansion of sharecropping $\lambda_{0T}-\lambda_0$. The second addendum is the improvement of the surplus produced by cultivating directly the initial fraction of land $1-\lambda_{0T}$. Hence, their positive difference is the initial net cost of adoption specific to the deficit producer.

[29] The deterministic nature of the argument might lead to the deduction that credit would solve the *impasse*. Nevertheless, if stochastic harvest fluctuations are included in the analysis (which can be done easily), then crop-failure – and therefore contracted reproduction and eviction – is an event of small but *positive* probability. Hence, the (compounded) loss entailed by the latter may be so high that the sign of the final expected outcome may result to be negative. The fact that crop failure is an issue for credit-based agricultural extension programmes is a matter of experience (Belay 2003, p. 39; Dejene 2003, p. 197).

[30] If surplus labour is allowed, then, because of self-consumption, the surplus product left to the surplus producer would be little, if not nil. Hence, it might be even argued that the latter might not have the capacity of adopting fertilizer on its own land. Nevertheless, the important point here is that while the surplus producer may have some interest in increasing the productivity of his own land, this is not the case with respect to sharecropped land.

$$(1+\pi_T) = [1-(1+\delta)\sigma_T]Y/w_T L \quad (24)$$

$$\lambda_T = (Y-X)/\{[1-(1+\delta)\sigma_T]Y-w_T L\}. \quad (25)$$

Thus, according to (11), (18), (24) and (25), the transformation pushes the deficit producer onto enlarged reproduction if it holds the initial condition $\lambda_S < \lambda_T$, that is

$$w_T L+\sigma_T(1+\delta)Y > Y +Y-(Y-X)/\lambda_0 \quad (26)$$

with $\lambda_0 = \lambda_S$. Compare (26) and (14). If the post-transformation terms of exchange (σ_T, w_T) are dominated by those that before the transformation were compatible with the simple reproduction of the deficit producer, that is (σ_S, w_S), then they bring to autarchy – and therefore, to the surplus producer's loss of command of the other's labour and land. In economic terms, if the surplus producer adopts the fertilizer under fixed terms of exchange, he exerts on the income path of the other producer the positive externality

$$\sigma_S \delta Y \lambda_0 > 0. \quad (27)$$

This additional inflow, which originates from the rent, activates the deficit producer's enlarged reproduction, and compromises the surplus producer's relative status. Consider then a change of technology. Coherently with (26), the surplus producer benefits from it only if he could prevail on the other producer, and make the post-transformation terms of exchange (σ_T, w_T) dominated by the pre-transformation ones (σ_S, w_S) so much to internalize the externality (27) and seize the entire improvement of the product of land. However, also his position is relatively weak, because the system of land tenure protects the deficit producer's right to land. Thus, he cannot turn those customary conditions of production to his own advantage, and it can be concluded that the positive externality exerted through the rent on the income path of the deficit producer gives the surplus producer a disincentive to change technology on sharecropped land.

Figure 3: Technological change and conflict of interests

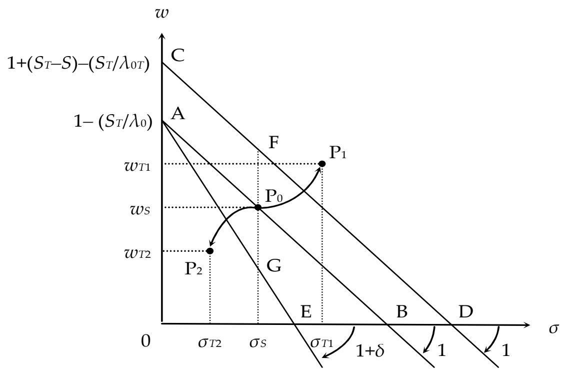

Figure 3 summarizes the overall argument. Again, the two axes report the values of the wage rate w and unit rent σ respectively, $S = Y–X$, $S_T=(1+\delta)Y–X–xL$, and $L=Y=1$. Recall the situation prevailing before the transformation. The segment AB is the graph of (14) with the sign of equality, and is the locus of the terms of exchange that are compatible with the simple reproduction of the deficit producer. The region left at northeast identifies the terms of exchange that are compatible with his enlarged reproduction, while the region OAB those compatible with his contracted reproduction. Turn now to the situation arising after the transformation. The segment CD refers to a change of technology satisfying (22), and is the graph of (21) with the sign of equality. It is the transformation of the locus AB due to the adoption by the deficit producer. Note that CD is parallel to AB, and that their constant vertical distance – measured by the length of the segment AC – is equal to the deficit producer's net cost of adoption (22). Similarly, the segment AE is the graph of (26) with the sign of equality, and represents the transformation of the locus AB due to the adoption by the surplus producer. Note that AE and AB are of equal intercept but different slope, so that their variable vertical distance is indeed equal to the positive externality (27) per unit of sharecropped produce. CD and AE divide the plan into three regions: the one at northeast of CD, OAE, and the critical one ACDE.

Given the initial state λ_0, suppose that before the transformation the ruling conditions of production are those corresponding to the point $P_0 = (\sigma_S, w_S)$, which lies on AB in the critical region ACDE. Starting from this initial situation, where the deficit producer has partial control of his labour and land, consider the transformation. If the deficit producer could absorb his class-determined cost – measured by the length of the segment P_0F – by means of post-transformation conditions of production lying in the region at northeast of CD, like the point $P_1 = (\sigma_{T1}, w_{T1})$, he would change technology. In such a case, the stationary state prevailing after the transformation would be autarchy. Conversely, if it was the surplus producer to internalize the inter-class externality – measured by the length of the segment P_0G – by means of post-transformation conditions of production lying in the region OAE, like the point P_2 = (σ_{T2}, w_{T2}), he would be the one to change technology. In this second case, the prevailing stationary state would be polarization. Nevertheless, each producer is in a relatively weak position with respect to the other. The wage and rent paid by the one are necessary to the other's survival, while the latter's right to land is ensured by the system of land tenure. Therefore, neither one can prevail in turning the customary conditions of production to his own advantage outside the critical region ACDE. In this case, the change of technology benefits no one, and the conflict of interest results in stagnation. The latter is the only equilibrium where the best response when the other does not adopt is not adopting as well.

4. Significance of the result

In the specific historical situation considered by this paper, class-differentiation is neither a question of holding size nor of ox-ownership, but is forced by the necessity of survival of deficit producers[31]. This attributes a differentiated response to price and market mechanisms that may be termed rationality dictated by *class-determined comparative costs*. The latter reflects the longstanding conflict for the control of land that before the agrarian reform of 1975 used to find explicit expression in the customary practice of peasants of claiming land in courts, and that after the reform has became somehow less apparent because mediated mainly by sharecropping. Today as in the past, that conflict tends to reallocate land from contracting households that cannot cultivate it to enlarging households that can[32]. This is an important element of continuity between the pre-reform system of land tenure and the

[31] It is worth emphasizing that the economic notion of class is not incompatible with the typical weak sense of community, or with the fact that peasant households are not enduring entities with strong kinship ties. Indeed, there is little (if no) room for the social notion of class consciousness (Hoben 1973; Ege 2002a). However, as long as there is evidence for different modes of organizing household production, it is the economic (and logic) notion of class that allows to discriminate between them. In fact, deficit and surplus producers are to some degree both direct producers, so that the logic distinction between the two classes is of a fuzzy nature. Nevertheless, when considering their economic motivations, any ambiguity is ruled out: the surplus producer is free to pursue his interests, while the deficit producer is forced to follow his necessity of survival. Neither the notion of class is incompatible with the one of class mobility (Berhanu 2005, p. 308). The latter remains beyond the scope of this analysis, but it is worth observing that it is an important open question whether the factors that before the reform used to grant a high degree of mobility (Hoben 1973), are still operating today, and in what direction. For instance, in the past, the adoption of poor ploughboys by richer households, and the gifts they received for marriage in the form of fixed and circulating capital, used to contribute to a great extent to their sustenance: but are today this and other similar practices still common today?

[32] This enduring aspect of peasant agriculture is of overwhelming relevance when analyzing the impact of a new land policy (recall note 13). Virtually any peasant – land lessors included – will asserts that he would never sell his land if he had the right to do it (Berhanu et al. 2003). However, this does not mean that he would never do it if compelled by his actual conditions and his necessity of survival. What peasant would like to do in theory, and what they eventully do in practice, may not coincide.

post-reform one. Nevertheless, there is also an important difference. While in the past successful claimants gained full control over additional land, today that control is only partial. The post-reform system of land tenure guarantees the right to land to any peasant, and enlarging households must pay a rent on additional land. It is this new fact that might explain why today peasants are so reluctant towards agricultural packages while in the 1960s they were not. Notwithstanding its historical specificity, this situation assumes a more general significance in so far as it exemplifies the consequences of a reform that addressed only one sector of the economy, while neglecting the other interlocked ones. Inequality is a multidimensional phenomenon, and to correct it only in one dimension may result counterproductive. In analogy with the second-best argument, when equality pertains only to one sector, the free adjustment of the other sectors may lead to counterintuitive outcomes, like technological stagnation rather than agrarian growth[33].

The argument is developed in two steps. The first step shows why, under the ruling social conditions of production, both deficit and surplus producers may be reluctant to change technology. Deficit producers tend to be excluded from the change by the cost of adoption specific to their relative class position. They cannot substitute corn satisfying their subsistence needs with corn advanced for fertilizer, for their consumption cannot be contracted any further. Instead, they would be forced to hire out labour they self-employ, therefore contracting direct production and meeting a loss. On the other hand, surplus producers may have an interest in changing technology on their own land, but they tend to avoid the change on sharecropped land because of the positive externality they would exert on the other producers. The economic function of rent is reversed in so far as it is an integral component of deficit producers' income. This entails a positive externality in the sense that, if surplus producers improved technology, the benefit would be felt also by the income-path of deficit producers, with the result of compromising the former's command over the latter's resources. In both cases a change in technology would require a major change also in the ruling social conditions of production, to favour one class at the expense of the other. And should it take place, it would transform the class structure of society in two opposite directions.

Hence, the second part of the argument abandons the notion of allocative efficiency of price response, and evaluates instead how peasant exchange relations resolve that conflict of interest to sustain all the members of society. The final result argues that the interaction between technology and mode of production may oppose innovation – a result that has its precedents in the analytical traditions of semi-

[33] This situation might be of a more general interest also because, with due care (Ege 2002b, p. 17), it shows strong similarities with other historical realities. At least one of them received special attention (Cox 1979 and 1984).

feudalism (Bhaduri 1973) and of the early classical thought (Vaggi 1985). As long as it requires a change in the ruling social conditions of production, technological change tends to depend on its interaction with the class structure of society. If deficit producers were in the position to turn those conditions to their own advantage, technological change would promote the mitigation of differentiation within society. Conversely, were surplus producers in such a position, technological change would exacerbate differentiation. However, if no class can impose itself on the other because of necessary economic dependencies and common cultural values embodied into law, technological stagnation tends to emerge as the only resolution of the conflict of interest, and the existing class configuration of society is preserved. Therefore, judged from this point of view, peasant exchange relations are relatively efficient in maintaining society integrated[34], if not in favouring technological dynamism. What set and timing of interlocked interventions would be more efficient in promoting both social integration and agrarian growth does remain an open question.

[34] There is both clear evidence and widespread agreement on the fact that, in comparison to other historical realities, in Ethiopia emigration from rural areas is still contained and mainly directed towards other rural areas (Getnet 2010).

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THE IMPACT OF AGRICULTURAL WATER MANAGEMENT TECHNOLOGIES ON POVERTY, IN ETHIOPIA

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Abstract

The main focus of this paper is to explore whether access to selected AWMTs, such as deep and shallow wells, ponds, river diversions and small dams, has led to significant reduction in poverty and, if they did so, to identify which technologies have higher impacts. In measuring impact we followed different approaches: separation tests, propensity score matching and poverty analysis. The study used a dataset from a representative sample of 1517 households from 30 Peasant Associations (Kebeles) in four regions of Ethiopia. Findings indicated that the estimated average treatment effect on per capita income was significant and amounted to USD 82 per season. Moreover, there was 22% less poverty incidence among users of AWMTs compared to non-users. Deep wells, river diversions and micro dams have led to 50, 32 and 25 percent reduction in poverty incidence compared to rain-fed system. Finally, our study identified the most important determinants of poverty on the basis of which we made policy recommendations: i) build assets (AWMT, livestock, etc); ii) human resource development; and iii) improve the functioning of labor markets and access to these (input or output) markets for enhanced impact of AWMT on poverty.

Key words: water management, income, consumption expenditure, propensity score matching, poverty analysis, Ethiopia

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1. Introduction

Farmers in rural Ethiopia live in climate-related risk-prone environment. The major source of climate risk is the persistent fluctuation in the amount and distribution of rainfall (Awulachew, 2006; Namara et al., 2006). The dependence on highly variable rainfall increases farmers' vulnerability to shocks while also constraining farmers'' to use yield-enhancing modern inputs. This exacerbates household's vulnerability to poverty and food insecurity. Poverty in Ethiopia is, in fact, mainly rural. Small-scale farmers are the largest group of poor people in Ethiopia (MoFED, 2006). As a response, the government of Ethiopia has embarked on massive investment in low cost Agricultural water management technologies (AWMTs). Lately the focus has been on development of small-scale micro water harvesting schemes. This wide range of technologies collectively referred to as "smallholder water and land management systems," attempts to create opportunities for the poor and small landholders in accessing water, rain or ground water, which in turn leads to increased production and income. These technologies are reported to be particularly suited to small, poor and even landless households as the costs self-select the poor and have a strong land and water-augmentation effects (Hussain et al. 2001).

In this line, thousands of shallow wells and dozens of deep wells have been developed since 2002/2003 in Ethiopia. In Amhara and Tigray Regional states alone a total of approximately 70,000 ponds and tanks were constructed in one fiscal year (Rämi, 2003). There are currently an estimated 56,032 ha of modern small scale irrigation schemes in Ethiopia, comprising micro dams and river diversions (Awulachew et al. 2007) and larger percentage areas are under traditional irrigation. The development of these systems has required huge financial input from the government, whose food security budget has increased from year to year, a major chunk of which is used to promote different types of small scale water and land management systems (FDRE, 2004). Despite these huge investments, their impact remains hardly understood, save the anecdotal evidences gathered here and there (Rämi, 2003).

The Comprehensive Assessment of Water Management in Agriculture (IWMI, 2007) states that "improving access to water and productivity in its use can contribute to greater food security, nutrition, health status, income and resilience in income and consumption patterns. In turn, this can contribute to other improvements in financial, human, physical and social capital simultaneously alleviating multiple dimensions of poverty" (P.149). FAO (2008) also argued that well-targeted, local interventions in water can contribute to rapid improvements in livelihoods of the rural poor in SSA and help attain the Millennium Development Goals of eradicating extreme poverty and hunger. In fact, FAO (2008) identified better management of soil moisture and investment in water harvesting and small storage as two promising interventions in view of their poverty-reduction potential.

Evidence on the impact of irrigation on poverty from Asia, be it from large or small systems, is plenty (Hussain, et. al.2001; Hussain, et. al.2006; Hussain, 2005; Hussain, 2007; Huang, et al., 2006; Namara, et al., 2007b) and the research findings consistently indicate that irrigation development alleviates poverty in rural areas of developing countries (Hussain and Hanjra, 2003). Hussain and Hanjra (2004) reported that irrigation is productivity enhancing, growth promoting, and poverty reducing. The poverty impact of AWMTs in Asia is viewed in the same positive light. Of the many studies that documented the poverty reduction impacts of micro-irrigation in Asia, Namara et al., (2007a) and Narayanamoorthy (2007), both from India, reported that micro-irrigation technologies result in a significant productivity and economic gains. Shah et al. (2000) reported that treadle pump technology has had a tremendous impact in improving the livelihoods of the poor in Bangladesh, eastern India, and the Nepal Terai, South Asia’s so-called “poverty square.”

As far as sub-Saharan Africa is concerned, although there are specific country evidences that support the poverty reduction impacts of irrigation development (Van Koppen et al., 2005; Namara et al., 2007; Tesfaye et al., 2008; FAO, 2008), a report by AfDB, FAO, IFAD, IWMI, and the World Bank (2007) documented that irrigated cropping in the region continues to be characterized by low productivity and hence low profitability with serious implications for poverty reduction and growth.

There is an emerging literature, although still very scanty compared to the evidence in Asia, on the impact of small scale agricultural water management technologies on poverty in Africa. Just to mention few: evidences from Tanzania, suggest that acquisition of treadle pump enabled households to double their income (Van Koppen et al., 2005). Similarly, adoption of treadle pumps by farmers in Niger has resulted in significant positive impacts, in terms of improvement of labor efficiency, increase in area under cultivation, cropping intensity and production volume, and increase in farm income. The same study also showed that in Nigeria, the use of low cost petrol pumps had a positive effect on its direct beneficiaries and slightly improved their situation in terms of income derived from irrigated fadama farming (Van Koppen et al., 2005). Adeoti, et al., (2007), exploring the impact of use of treadle pump in Ghana, West Africa, found that adoption of treadle pumps reduced poverty as measured by household income with positive impacts on human capital, i.e. children schooling and health.

The current study also aims to contribute to the emerging global literature by measuring the poverty impacts of selected agricultural water management technologies in Ethiopia. This study has at least four novel features compared to earlier studies in the field. First, it makes a systematic documentation of the so-called promising technologies/practices in Ethiopia before measuring their poverty impacts. The paper quantified the effect on poverty of successfully adopting selected AWMT. In doing so, welfare indicators such as per capita income and expenditure per adult equivalent were used to measure these improvements. Second, the study considered all aspects of agricultural water management technologies ranging from in-situ to ex-situ AWM technologies and practices while also considering the different suits used to control, withdraw, convey and apply water. Third, to explore the impact of adoption of AWMT on poverty we used a variety of simple and complex statistical techniques (to test robustness of results) ranging from separation tests, to standard poverty analysis techniques, and the estimation of average treatment effects using propensity score matching. As part of explaining the role of access to AWMTs on poverty, we also identified correlates of poverty using a multivariate regression model.

2. Data and study site description

This study is part of a comprehensive study on Agricultural Water Management Technologies in Ethiopia. The study includes inventory of Agricultural Water Management Technologies and Practices in Ethiopia and assessment of the poverty impacts of most promising technologies, the focus of this study being on the latter[66]. The socio-economic survey data, on which this study is based, is gathered from a total sample of 1517 households from 30 Peasant Associations[67] (Kebele) in four Regional states (see Fig. 1). This selection was based first on the identification of promising technologies through key informant interviews (see Loulseged et al., 2008). Then households from each peasant association (PA) were selected randomly, once the households in each PA were stratified into those with access and without access, following a non-proportional sampling approach. Details of the sample households by type of technologies from the four regions are given below in table 1. The data was collected for the 2006/2007 cropping season.

[66] The study was conducted during October - December 2007 and was implemented by the International Water Management Institute (IWMI) with support from USAID.
[67] A Kebele on average covers 800ha of land and is the lowest rural administrative unit in Ethiopia. It is also known as a peasant association.

Figure 1: Location of the study sites

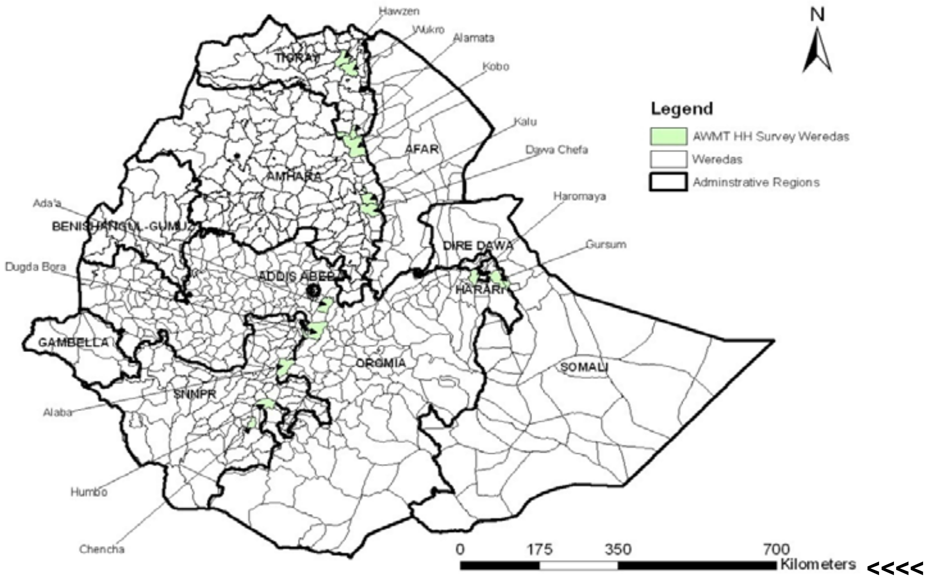


Table 1: Summary of sample households

Region	River diversion					
	Purely rainfed	**Pond**	**Shallow wells**	**Deep wells**	**River Diversion**	**Micro dams**	**others**
Amhara	281	8	45	10	28	13	5
Oromia	219	12	23	68	68	1	2
SNNPR	217	68	55	0	14	25	0
Tigray	143	47	91	1	40	35	18
Total			688			829	

3. Analytical approaches

Here below we present the analytical approaches used in the paper to measure impact.

Propensity score matching

One of the problems of assessing impact is to find comparable groups of treated and control groups, i.e. users and non-users of AWMT. Matching econometrics provides a promising tool to do just that while estimating the average treatment effects (Ravallion, 2004).

Matching is a method widely used in the estimation of the average treatment effects of a binary treatment on a continuous scalar outcome. It uses non-parametric regression methods to construct the counterfactual under an assumption of selection on observables. We think of having access to AWM technologies as a binary treatment, income per capita as an outcome, and households having these technologies as treatment group and non-user households as control group. Matching estimators aim to combine (match) treated and control group households that are similar in terms of their observable characteristics in order to estimate the effect of participation as the difference in the mean value of an outcome variable. In this case, we used observable household characteristics (such as characteristics of household head, land, livestock and labour endowment, access to credit, etc.) and village level covariates that may influence choice of participation in the intervention (e.g. choice of AWMTs) but not necessarily influenced by the intervention.

Let Y_1 is the per capita income when household i is subject to treatment $(C=1)$ and Y_0 the same variable when a household is a member of the control group $(C=0)$. The observed outcome is then

$$Y = CY_1 + (1-C)Y_0 \qquad \textbf{(1)}$$

When $C=1$ we observe Y_1; when $C=0$ we observe Y_0. Our goal is to identify the average effect of treatment (using AWMT) on the treated (those households who have access to the technologies) (ATT). It is defined as

$$ATT = E(Y_1 - Y_0 | C=1) = E(Y_1 | C=1) - E(Y_0 | C=1) \qquad \textbf{(2)}$$

The evaluation problem is that we can only observe $E(Y_1 | C=1)$; however, $E(Y_0 | C=1)$ does not exist in the data, since it is not observed. A solution to this problem is to create the counterfactual $E(Y_0 | C=1)$ (what would have been the income of households with access had they not had access to AWMT (or the converse)), by matching treatment and control households. As discussed by Heckman (1998) a critical assumption in the evaluation literature is that no-treatment state approximates the no program state[68]. For matching to be valid certain assumptions must hold. The primary assumption underlying matching estimators is

[68] Here the assumption of no contamination bias or general equilibrium effect is important.

the Conditional Independence Assumption (CIA). CIA stated that the decision to adopt is random conditional on observed covariates X. In notation,

$$(Y_1, Y_0) \perp C \mid X \quad \textbf{(3)}$$

This assumption imply that the counterfactual outcome in the treated group is the same as the observed outcomes for non-treated group

$$E(Y_0 \mid X, C=1) = E(Y_0 \mid X, C=1) = E(Y_o \mid X) \quad \textbf{(4)}$$

This assumption rules out selection into the program on the basis of unobservables gains from access. The CIA requires that the set of X's should contain all the variables that jointly influence the outcome with no-treatment as well as the selection into treatment. Under the CIA, ATT can be computed as follow:

$$ATT = E(Y_1 - Y_0 \mid X, C=1) = E(Y_1 \mid X, C=1) - E(Y_0 \mid C=1) \quad \textbf{(5)}$$

Matching households based on observed covariates might not be desirable or even feasible when the dimensions of the covariates are many. To overcome the curse of dimensionality, Rosenbaum and Rubin (1983) show that instead of matching along X, one can match along $P(X)$, a single index variable that summarizes covariates. This index is known as propensity score (response probability). It is the conditional probability that household i adopts AWMT given covariates:

$$p(X) = pr(C=1) \mid X \quad \textbf{(6)}$$

The ATT in equation (5) can then be written as

$$ATT = E(Y_1 \mid P(X), C=1) - E(Y_0 \mid P(X), C=1) \quad \textbf{(7)}$$

The intuition is that two households with the same probability of adoption will show up in the treated and untreated samples in equal proportions. The propensity score (pscore) is estimated by a simple binary choice model; in this paper a binary[69] logit model is used. Once the pscore is estimated, the data is split into equally spaced

69 Probit and logit have different assumptions about the distribution of the error term but have similar results (Verbeek, 2000).

intervals (also called common support) of the pscore. Within each of these intervals the mean pscore and of each covariate do not differ between treated and control plots. This is called the balancing property. For detail algorithm of pscore matching see Dehejia and Wahba (2002). If the balancing property is not satisfied higher order and interaction terms of covariates can be considered until it is satisfied. Since pscore is a continuous variable exact matches will rarely be achieved and a certain distance between treated and untreated households has to be accepted. To solve this problem, treated and control households are matched on the basis of their scores using nearest neighbor, kernel and stratification matching estimators. These methods identify for each household the closest propensity score in the opposite technological status; then it computes investment effect as the mean difference of household's income between each pair of matched households. For details of these methods we refer to Becker and Ichino (2002) who also provide the STATA software code we use in this paper. One limitation of the matching based on observables is that endogenous program placement due to purposive targeting based on unobservables will leave bias (Ravallion, 2001). However, there is hardly any reason to believe that these interventions are purposively placed as the feasibility of the technologies is conditioned more by natural factors (e.g. availability of water, topography, etc.) than by socio-economic preconditions.

Poverty analysis

When estimating poverty following the money metric approach to measurement of poverty, one may have a choice between using income or consumption as the indicator of well-being. Most analysts argue that, provided the information on consumption obtained from a household survey is detailed enough, consumption will be a better indicator of poverty measurement than income for many reasons [70](Coudouel et al. 2002). Hence, in this paper we estimate poverty profiles using expenditure adjusted for differences in household characteristics. We also used the Foster-Greer-Thorbecke (FGT) class of poverty measures to calculate poverty indices (Foster et al., 1984). The FGT class of poverty measures have some desirable properties (such as additive decomposability), and they include some widely used poverty indices (such as the head-count and the poverty gap measures). The poverty line acts as a threshold, with households falling below the poverty line considered poor and those above the poverty line considered non-poor.

We used an inflation-adjusted poverty line of 1096.03 per person per year as absolute food poverty line based on the corresponding 1995/96 official food poverty

Households may be more able, or willing, to recall what they have spent rather than what they earned. Expenditure can be easily related to welfare.

line. These lines were chosen to enable meaningful comparison of poverty levels in Ethiopia between various groups and over time (in reference to earlier studies).

Following Araar and Duclos (2006), we also calculated the relevant values of α are 0, 1 and 2 where at α=0 measures poverty incidence or the head count ratio, at α=1 the equation measures depth of poverty (poverty gap) and at $\alpha = 2$ the equation measures poverty severity or squared poverty gap. This takes into account not only the distance separating the poor from the poverty line (the poverty gap), but also the inequality among the poor.

We constructed poverty profiles showing how poverty varies over population subgroups (example users Vs non-users) or by other characteristics of the household (for example, level of education, age, asset holding, location, etc.). The poverty profiling is particularly important as what matters most to policymakers is not so much the precise location of the poverty line, but the implied poverty comparison across subgroups or across time. We calculated these indices using STATA 9.0 and tested for difference between poverty profiles between groups following approaches suggested by Kwakani (1993) and Davidson and Duclos (1998).

Dominance tests

Poverty comparisons can, however, be sensitive to the choice of the poverty line. The important issue in poverty analysis is that the poverty line yields consistent comparisons (Ravallion, 1994). Stochastic tests used to check the robustness of ordinal poverty comparisons prove to be useful in poverty analysis (Atkinson, 1987). The idea of standard welfare dominance is to compare distributions of welfare indicators in order to make ordinal judgment on how poverty changes (spatially, inter-temporally or between groups) for a class of poverty measures over a range of poverty lines (Ravallion, 1994; Davidson and Duclos, 2000). Hence, we need to undertake ordinal poverty comparisons using stochastic dominance tests and check the robustness of the poverty orderings. The idea here is to make ordinal judgments on how poverty changes for a wide class of poverty measures over a range of poverty lines.

Determinants of poverty

An analysis of poverty will not be complete without explaining why people are poor and remain poor over time. Within a micro-economic context, the simplest way to analyze the correlates of poverty consists in using a regression analysis against household and demographic factors, specific individual/household head characteristics, asset holdings, village level factors, and access to services (markets, credit, AWM technologies, extension, etc). Let the welfare indicator W_i be given as:

$$W_i = Y_i / Z \quad (8)$$

where Z is the poverty line and Y_i is the consumption expenditure per adult equivalent. Denoting by X_i the vector of independent variables, the following regression

$$LogW_i = \beta' X_i + \varepsilon_i \quad (9)$$

could be estimated by ordinary least squares (OLS). In this regression, the logarithm of consumption expenditure (divided by the poverty line) is used as the left-hand variable. The right hand variables in the regressions include: (a) household head characteristics, including sex, level of education (using five tiered categories), primary occupation of the household (farming vs. non-farming) and consumer worker ratio; (b); asset holding: oxen holding, livestock size (in TLU[71]) and farm size, adult labor (by sex) all in per adult equivalent terms; c) access to different services and markets: credit, non-farm employment, access to market proxied by distance to input markets, seasonal and all weather roads, distance to major urban markets; and d) village level characteristics mainly agro-ecology.

The β coefficients in equation (9) are the partial correlation coefficients that reflect the degree of association between the variables and levels of welfare and not necessarily their causal relationship. The parameter estimates could be interpreted as returns of poverty to a given characteristics (Coudouel et al., 2002; Wodon, 1999) while controlling for other covariates, the so-called ceteris paribus condition. We used regression techniques to account for the stratified sampling technique and, hence, adjust the standard errors to both stratification and clustering effects (Deaton; 1997; Wooldrige, 2002) and thereby to deal with the problem of heteroskedasticity. We also tested for other possible misspecifications (e.g. multicollinearity) using routine diagnostic measures.

[71] We used livestock less oxen in tropical livestock units.

4. Results and discussions

In this section, we report the results of the statistical summary of important variables for users and non-users, including their test statistics, matching estimates of the average treatment effects, poverty profiles of users and non-users and decomposition by various socio-economic variables to identify who the poor are and results of the dominance tests and correlates of poverty.

Summary statistics and separation tests

This statistical test result could serve as some indicative measure of the differences in important variables between users and non-users. Accordingly, we found statistically significant difference in mean values of important variables (Table 2).

Table 2: Separation tests of some important variables of households with access and without access to AWMT

Variable name	Non-user of AWMT (n= 641)	User AWMT (n= 876)	p-value*
	Mean (SE)	Mean (SE)	
Value of fertilizer used	274.9 (27.0)	399.5 (32.7)	0.0053
Value of seed used	272.1 (31.1)	698.1 (204.1)	0.0762
Value of labor used	600.9 (34.7)	1114.3 (67.6)	0.0000
Value of insecticide used	19.6 (3.1)	75.4 (19.7)	0.0161
Loan size (cash)	1293.4 (108.0)	1688.9 (102.5)	0.0083
Crop income	302.3 (16.4)	682.5 (57.0)	0.0000
Livestock income	51.6 (5.37)	67.3 (4.25)	0.0201
Agricultural income	352.9 (7.2)	749.7 (57.2)	0.0000
Non-farm income	63.7 (4.36)	67.0 (4.95)	0.6276
Consumption expenditure per adult equivalent (monthly)	39.2 (4.46)	40.8 (3.71)	0.7739
Face food shortage	0.373 (0.019)	0.354 (0.016)	0.4475
Market share	0.07 (0.01)	0.15 (0 .012)	0.0000
Oxen units	1.18 (0.047)	1.71 (0.055)	0.0000
Livestock units (in TLU)	3.27 (0.113)	4.64 (0.15)	0.0000
Land holding in (timad)	5.12 (0.163)	7.143 (0.19)	0.0000
Labor endowment (adult labor)	2.961 (0.059)	3.054 (0.051)	0.2340
Labor endowment (Adult male)	1.4456 (0.039)	1.568 (0.035)	0.0209
Labor endowment (Adult female)	1.496 (0.037)	1.476 (0.029)	0.6650

* Two-sided test of equality of means

As could be seen from the separation test, there is statistically significant difference ($p \leq 0.000$) in agricultural income (both crop and livestock) among users and non-users of AWMT. Those with access to AWMT were found to use higher farm inputs and have significantly higher share of their produce supplied to the market ($p \leq 0.000$)

implying increased market participation. Accordingly, the value of fertilizer, seed, labor and insecticide used and the size of loan received from micro-finance institutions were significantly higher for users of AWMT compared with non-users. This may imply that because of access to AWMT, there is increased intensification of agriculture. This is expected to have wider effects on the economy e.g. on input and factor markets. Not surprisingly, users were also found to have significantly higher asset endowments such as male adult labor, oxen, livestock (in TLU) and land holding, which may imply that those with access to AWMT have managed to build assets. On the other hand, it may also mean that households with better resource endowments may be targeted by the program (or due to self-selection) secured access AWMT, an issue we may not be able to tell in the absence of baseline data. However, the separation test indicated that there is no significant difference in mean consumption expenditure per adult equivalent, incidence of food shortage and size of non-farm income between those with access to AWMT and those without access.

Average treatment effects

The problem with such separation tests is non-comparability of the two sub-samples and that we did not control for the effect of other covariates. Hence, we will systematically analyze if access to AWMT has led to significant effects on income and poverty using matching (by creating comparable groups) and standard poverty analysis techniques respectively in the subsequent sections.

Table 3: Results of matching method to measure impact of AWMT on household income (bootstrapped standard errors)

Kernel Matching method			
Treatment (n)	**Control (n)**	**ATT**	**t-test**
699	394	788.674 (218.78)	3.605***
Nearest Neighbor Matching method			
699	247	760.048 (255.73)	2.972***
Stratification method			
699	394	785.326 (227.53)	3.451***

*, **, *** significant at 10, 5 and 1 percent level of significance.

The matching estimates where the treated and control households were matched on the basis of their scores using nearest neighbor, kernel methods and stratification matching estimators, show that there is a significant effect on household income from owning AWMTs. Important to note is that out of the 1517 households only about 947 are comparable (see Table 3). The estimated average treatment effect for the treated (ATT) is also positive in all the cases and is about ETB 780 per season (equivalent to USD 82). This indicated that access to AWMT technologies has led to significant increase in per capita income. We now turn to poverty analysis using consumption expenditure per adult equivalent.

Poverty profiles and decomposition

Using the absolute overall poverty line of ETB 1821.05, about 48 percent of the individuals in user households have been identified as poor. On the other hand, about 62 percent of the individuals in non-users were identified as poor. The test results also show that there is a significant difference in poverty levels between users and non users. Our calculation shows that there is about 22% less poverty incidence among users compared to non-users. In other words, individuals with access to AWMT are in a better position to meet their consumption requirements, food and non-food. There is also significant difference in poverty gap and severity of poverty among users and non-users, implying that access to AWMT are effective instruments to narrow the poverty gap and inequality (see Table 4).

Table 4. The effect of irrigation on incidence, depth and severity of poverty (poverty line = ETB 1821.05)

Category	Incidence ($\alpha = 0$)		Depth ($\alpha = 1$)		Severity ($\alpha = 2$)	
	Value	SE	Value	SE	Value	SE
Access to AWMT						
Users (n= 876)	0.478	0.017	0.198	0.009	0.1110	0.007
Non-users (n= 641)	0.623	0.018	0.282	0.011	0.167	0.009
z-statistic*	-484.2***		-381.6***		-282.0***	
Types AWMT[72]						
Pond (n= 196)	0.561	0.035	0.218	0.017	0.107	0.011
z-statistic[73]	-193.5***		-170.8***		-146.2***	
Shallow wells (n= 251)	0.565	0.031	0.266	0.019	0.168	0.016
z-statistic	-233.0***		-172.3***		122.1***	
Deep wells (n=93)	0.312	0.048	0.113	0.021	0.0550	0.013
z-statistic	-109.2***		-107.8***		-98.0***	
River diversion (n= 291)	0.403	0.029	0.1440	0.013	0.071	0.009
z-statistic	-258.0***		-235.5***		-189.0***	
Micro-dams (n= 63)	0.484	0.063	0.1910	0.032	0.101	0.022
z-statistic	-71.6***		-63.0***		-53.3***	
In-situ technologies						
Users (n= 368)	0.614	0.025	0.253	0.014	0.141	0.0110
Non-users (n= 373)	0.521	0.0148	0.2300	0.008	0.134	0.007
z-statistic	-296.2***		-220.9***		-150.5***	
Water application technologies[74]						
Flooding (n= 533)	0.429	0.021	0.159	0.010	0.079	0.007
Manual (n= 284)	0.567	0.029	0.274	0.018	0.171	0.015
Water withdrawal						
Treadle pump (n=101)	0.524	0.049	0.183	0.023	0.088	0.014
z-statistic	-111.0***		-103.4***		-63.4***	
Motor pump (n=127)	0.228	0.037	0.068	0.0135	0.027	0.007
z-statistic	-155.7***		-172.7***		-171.0***	
Water input						
Supplementary (n= 270)	0.56	0.030	0.262	0.18	0.16	0.15
z-statistic	-245.0***		-24.5***		-17.4***	
Full irrigation (n= 579)	0.437	0.020	0.16	0.009	0.077	0.006
z-statistic	-322.7***		-287.0***		-231.7***	

*, **, *** significant at 10, 5 and 1 percent level of significance.

*The z-statistic is derived using Kwakani's (1993) formulae to test for equality of poverty measures. The critical value for the test statistic is 1.96 (applicable for all tests in Tables 4-6) at 5% level of significance.

[72] We compared those using different AWMT against non-users.

[74] We compared those using different water application technologies against non-users.

We disaggregated users by the type of AWMT to measure the poverty impact of specific technologies. As could be seen from the reported results, all ex-situ technologies considered in this study were found to have significant poverty reducing impacts. However, deep wells, river diversions and micro dams seem to have higher poverty impacts compared to ponds and shallow wells perhaps largely due to scale benefits. In this case, deep wells, river diversions and micro dams have led to 50, 32 and 25 percent reduction in poverty incidences compared to the reference, i.e. rain fed system. On the other hand, use of in-situ AWMT was found to have no significant poverty reducing impacts. On the contrary, those using in-situ AWMT are found to have higher poverty levels in terms of the head count, poverty gap and severity of poverty indices. However, we did not check households that use in-situ technologies vis-à-vis those who do not use.

We do not have any a priori reason for this seemingly counter intuitive result. However, it may be mentioned that in-situ technologies have been used as mere soil conservation measures with little immediate impact on productivity growth; and at the same time they may divert labor from direct agricultural crop production.

We also considered disaggregating poverty levels by type of water withdrawal and application technologies. The most common withdrawal and application mechanisms include gravity flooding (63.3 %), manual (33.7 %), treadle pump (6.7%), and motor pump (8.4%). Sprinkler (0.20 %) and drip (0.20%) are hardly practiced although there are signs of households picking up these technologies gradually. Accordingly, those using motor pumps were found to have significantly lower poverty incidence, compared to treadle pump users. In fact, as a result of using motorized pumps, there is more than 50 percent reduction in the incidence of poverty mainly due increased water availability and scale benefits. As far as, water application technologies are concerned, households using gravity were found to have significantly lower poverty incidence compared to those using manual (using cans) applications. Furthermore, we disaggregated poverty by the type of water use that is whether water is used for supplementary or full irrigation. Our results show that those who use AWMT for full irrigation have significantly lower poverty incidence compared to those using supplementary and non-users. This implies that supplementary irrigation could contribute to poverty reduction; a significant contribution comes, however, from full irrigation. System reliability and scale benefits seem to be the most important drivers of poverty reduction. This will have an important implication on technology choice for an effective poverty reduction.

We also estimated poverty profiles using an absolute food poverty line of ETB 1096.02. Accordingly, 23 percent of the users and 34 percent of the non-users respectively are identified as food poor. These indices could be taken as food security indices. This implies that the level of food security has increased compared to 38% in 2004/05 (MoFED, 2006; p. 27) calculated based on poverty line of ETB 647.8.

Table 5: The effect of irrigation on incidence, depth and severity of poverty (poverty line = ETB 1096.02)

Category	Incidence ($\alpha = 0$)		Depth ($\alpha = 1$)		Severity ($\alpha = 2$)	
	value	SE	Value	SE	Value	SE
Access to AWMT						
Users (n= 876)	0.2340	0.015	0.086	0.007	0.049	0.005
Non-users (n= 641)	0.349	0.018	0.137	0.009	0.081	0.007
z-statistic*	-286.4***		-231.3***		-181.8***	
Types AWMT						
Pond (n= 196)	0.275	0.032	0.071	0.011	0.028	0.006
z-statistic[75]	-116.2***		0.00		-144.9***	
Shallow wells (n= 251)	0.311	0.029	0.143	0.017	0.094	0.014
z-statistic	-137.0***		0.0		-69.7***	
Deep wells (n= 93)	0.151	0.037	0.0380	0.0130	0.017	0.008
z-statistic	-3.8***		0.0		-73.2***	
River diversion (n= 291)	0.158	0.021	0.047	0.008	0.023	0.006
z-statistic	-179.6***		0.0		-128.9***	
Micro-dams (n= 63)	0.234	0.053	0.081	0.022	0.039	0.014
z-statistic	-47.0***		0.0		-39.7***	
In-situ technologies						
Users (n= 368)	0.302	0.024	0.111	0.012	0.062	0.009
Non-users (n= 373)	0.279	0.013	0.109	0.007	0.064	0.005
z-statistic	-156.7***		-117.2***		-85.1***	
Water application technologies						
Flooding (n= 533)	0.176	0.016	0.056	0.006	0.027	0.005
Manual (n= 284)	0.341	0.028	0.144	0.015	0.091	0.0128
Water Withdrawal technologies						
Treadle pump (n=101)	0.227	0.042	0.062	0.013	0.020	0.005
z-statistic	-490.7***		0.1		-104.6***	
Motor pump (n= 127)	0.0470	0.019	0.014	0.007	0.006	0.003
z-statistic	-490.8***		0.0		-149.3***	
Water input						
Supplementary (n= 270)	0.333	0.028	0.138	0.016	0.086	0.013
z-statistic	-496.6***		0.1		-75.8***	
Full irrigation (n= 579)	0.174	0.0158	0.053	0.006	0.025	0.004
z-statistic	-490.7***		0.1		-155.8***	

*, **, *** significant at 10, 5 and 1 percent level of significance.

When disaggregated by type of AWMT, as in the case of overall poverty, deep wells, river diversion and micro dams have relatively higher impact on reducing food poverty. Ponds and wells, although have led to significant reduction (compared to

* Critical statistics

[75] We compared those using different AWMT against non-users.

non-users), they have relatively lower poverty reducing impacts. However, in-situ AWMT have not led to significant reduction to food insecurity. On the contrary, those using in-situ AWMT are found to have higher poverty levels in terms of the head count, poverty gap and severity of poverty indices.

Furthermore, households using AWMT for full irrigation have relatively lower food poverty compared to those using water for supplementary irrigation. We also conclude that the mentioned comparative advantages are linked to reliability and adequacy of water supply as well as availability of labor for water management.

Who are the poor?

We tried to gain additional insights into the question of who the poor are by decomposing poverty profiles of households by other socio-economic variables. We used variables such as sex of the household head, education status of the head, asset holding (mainly labor, farm and oxen holding) and access to services like formal credit and location dummies (in this case regions). We tested for differences in poverty across socio-economic groups using statistical tests. The results are reported in Table 6.

The regional decomposition of poverty shows that users of AWMT in Oromia and Amhara have significantly lower poverty levels in incidence, depth and severity of poverty compared to users in Tigray and SNNPR. This may show the successful use of AWMT in Oromia and Amhara having significant impact on poverty reduction. Not surprisingly, poverty seems to be closely related to asset holding, most importantly land holding. Households with operated farm holding greater than the mean holding, depicted lower poverty levels than those having farm holding less than the mean. On the other hand, households with oxen holding greater or equal to the mean holding (1.5 oxen units) displayed significantly higher poverty levels, perhaps indicating owning more than two oxen may not contribute to poverty reduction. Perhaps it makes no sense to keep more than two oxen in mixed crop-livestock system. Female-headed households have apparently higher poverty levels in terms of the incidence, depth and severity of poverty.

Table 6: Poverty decomposition by other socio-economic variables (users only and poverty line = ETB 1821.05)

Variables	Incidence ($\alpha = 0$)		Depth ($\alpha = 1$)		Severity ($\alpha = 2$)	
	Value	SE	Value	SE	Value	SE
Tigray region (n= 244)	0.606	0.031	0.215	0.015	0.102	0.009
z-statistic	-230.5***		-202.0***		-179.3***	
Amahra region (n= 273)	0.329	0.028	0.117	0.012	0.056	0.008
z-statistic	-258.7***		-2.42.8***		-198.9***	
Oromia region (n= 190)	0.258	0.032	0.081	0.012	0.036	0.007
z-statistic	-205.2***		-216.0***		-193.4***	
SNNPR region (n= 169)	0.810	0.030	0.446	0.026	0.301	0.023
z-statistic	-205.6***		-115.4***		-78.6***	
Female-headed (n= 81)	0.568	0.055	0.205	0.028	0.107	0.020
Male-headed (n= 768)	0.463	0.018	0.191	0.009	0.106	0.007
z-statistic	-67.9***		-55.4***		42.8***	
Education level of head						
Illiterate (n= 787)	0.59	0.175	0.27	0.011	0.162	0.008
Informal education (n= 239)	0.47	0.03	0.174	0.015	0.085	0.009
z-statistic	-56.9***		-127.4***		-0.2***	
Primary complete (n= 327)	0.49	0.027	0.203	0.015	0.119	0.012
z-statistic	-62.8***		-165.9***		-125.3***	
Junior complete (n= 119)	0.48	0.046	0.20	0.024	0.106	0.017
z-statistic	-45.3***		-76.9***		-57.3***	
10 & above complete (n= 29)	0.44	0.094	0.187	0.055	0.121	0.046
z-statistic	-18.0***		-17.4***		-13.7***	
Primary occupation						
Farming (n= 834)	0.48	0.017	0.195	0.009	0.11	0.006
Non-farming (n= 33)	0.57	0.087	0.28	0.049	0.158	0.034
z-statistic	-35.7***		-31.5***		-25.7***	
Land holding						
Below average (n= 1054)	0.55	0.15	0.247	0.009	0.147	0.002
Above average (n= 463)	0.52	0.02	0.212	0.012	0.113	0.009
z-statistic	-93.1***		-253.7***		-235.3***	
Oxen holding						
Below average (n= 691)	0.48	0.02	0.18	0.009	0.092	0.006
Above average (n= 826)	0.59	0.17	0.28	0.011	0.174	0.008
z-statistic	-89.6***		-390.3***		-343.4***	
Labor holding (male)						
Below average (n= 568)	0.64	0.02	0.29	0.012	0.175	0.010
Above average (n= 949)	0.48	0.016	0.202	0.008	0.113	0.006
z-statistic	-352.5***		-264.2***		-183.8***	
Credit access						
With access (n= 447)	0.52	0.023	0.226	0.003	0.131	0.010
Without access (n= 1070)	0.55	0.015	0.240	0.008	0.139	0.006
z-statistic	-355.1***		-620.8***		-211.6***	

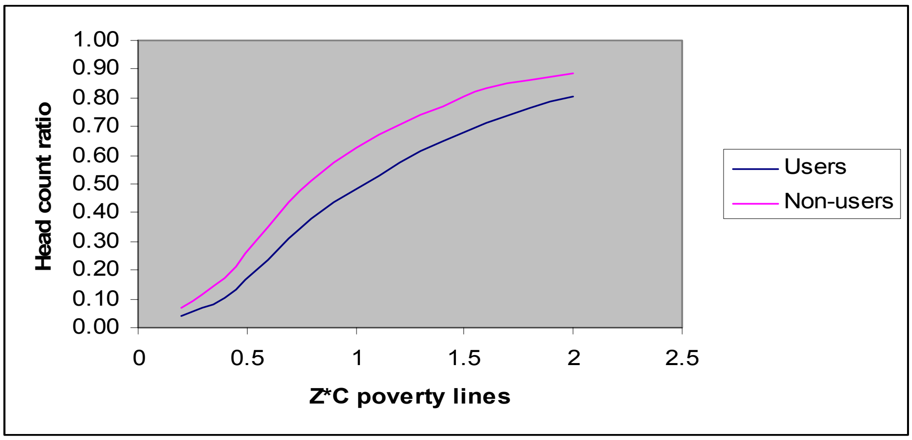
*, **, *** significant at 10, 5 and 1 percent level of significance.

Education was also found to have significant effect on poverty levels of users. Accordingly, households with heads that have informal training or higher educational attainment have lower poverty levels compared to illiterate heads. There is also a significant difference in incidence, depth and severity of poverty depending on whether households have access to formal credit. This may have to do with the fact that households with access to AWMT may use credit to purchase farm inputs. Perhaps surprisingly, households whose primary occupation is farming have significantly lower poverty in terms of the incidence, depth and severity of poverty compared to those having non-farming as their primary occupation, which signifies agriculture is the most paying occupation in rural Ethiopia. The later group mainly constitutes landless farmers who make a living mainly from off/non-farm employment though they are also engaged in agricultural by renting in/sharecropping in land.

Dominance test results

Comparing the head count ratios between users and non-users of AWMT, the different orders of stochastic dominance tests established unambiguously that poverty is significantly lower among users compared to the non-users (Figure 2). This confirms that the incidence of poverty is significantly lower among users compared with non-users.

Figure 2: First-order stochastic dominance



Similarly, in terms of the depth and severity of poverty, the second and third order stochastic dominance tests showed that there is a significant difference in poverty gap and severity between users and non-users (see Figures 2 and 3). The results are robust for the different poverty lines considered. Hence, we could conclude that access to AWMT has led to significant reduction in poverty. More interestingly, AWMT are not only poverty reducing but also inequality reducing, as could be seen from the third order stochastic dominance.

Figure 3: Second-order stochastic dominance

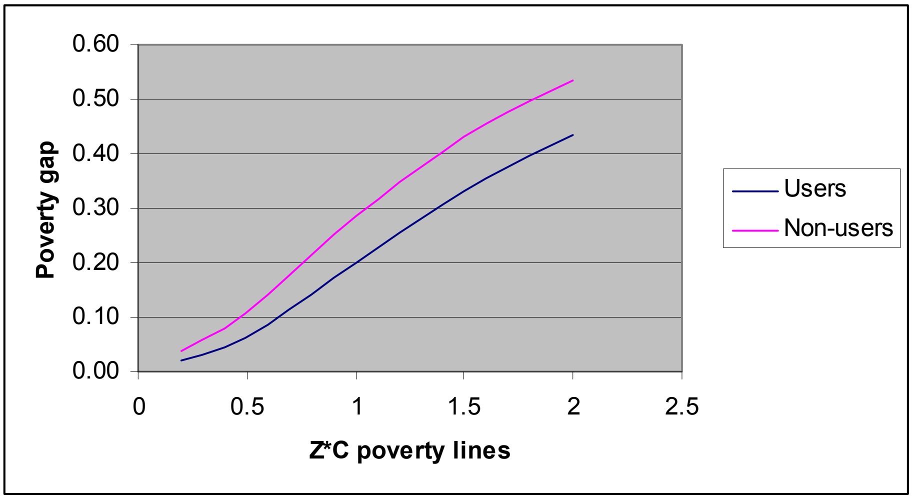
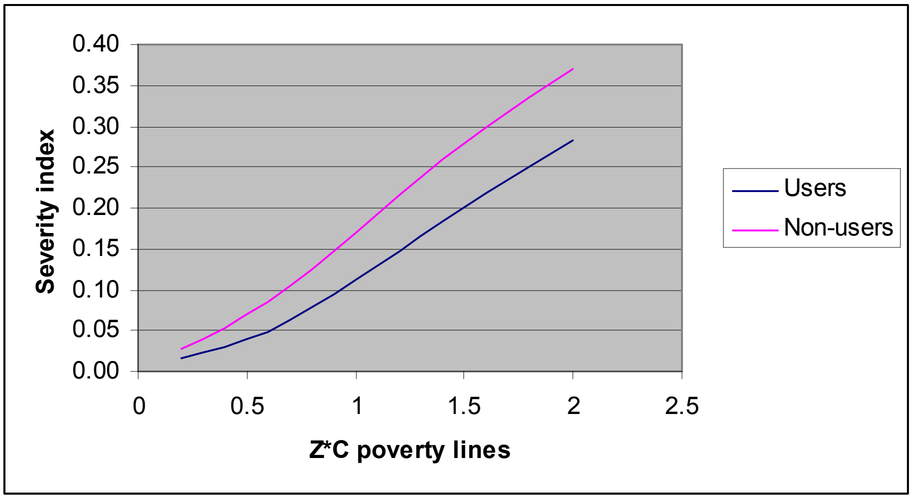


Figure 4: Third-order stochastic dominance



Poverty correlates

The results of the regression analysis on correlates of poverty are reported below. The F-test results indicate that the hypothesis of no significant β coefficient (except the intercept) is rejected (p ≤ = 0.000); the coefficients are jointly significantly different from zero. As could be seen from the results in Table 7, most of the coefficients are significantly different from zero. The goodness of fit measure indicates that about 25 percent of the variation in the model is explained by the chosen model. Given the data used is survey data, this measure is not atypical.
Reporting on the significant variables, water input from AWMT has a significant effect on household welfare. Particularly, households that use AWMT as supplementary or full irrigation have significantly better wellbeing compared with those who depend on rainfed agriculture. This result corroborates the evidence we found earlier on the positive and poverty reducing impact of AWMT in Ethiopia.

While controlling for all other variables, households with more asset holdings are found to have significantly higher wellbeing (i.e. less poverty). This is particularly true with oxen holding and other forms of livestock holding. On the other hand, households with more adult labor endowment, both male and female, are found to have significantly lower wellbeing. This could be indicative of the high level of rural unemployment prevalent in Ethiopia and the poor functioning of the labor market. Grown-up children may be enrolled in education and may be less active in employment.

Access to services is also found to have significant effect on household wellbeing. In this line, distance to input (fertilizer and seed) markets have a significant negative (at 1 percent level of significance) effect on household wellbeing while controlling for all other factors. Distance to water source has also a negative and significant effect on household welfare which may imply that those with access to water closely to home are better off. This underlines the fact that access to water for productive and consumptive uses, poverty reduction and sustainable livelihoods for rural people are all intimately linked (IWMI, 2007). Accesses to credit markets also have a significantly positive effect on household welfare, albeit at 10 percent level of significance. On the other hand, households distance to all weather roads has a significant and positive effect on wellbeing. The result is counter intuitive; one possible explanation could be households who are able to produce for the market, transport their produce to distant but more attractive markets (Hagos et al., 2007).

Few household level covariates and agro-ecology (a village level covariate) were also found significant in explaining household wellbeing ceteris paribus. Accordingly, age of the household head has a negative effect on household welfare and the marginal effect decreases with age as we could see from the non-linear age coefficient. Our results also show that households with more dependents (compared to producers), i.e. higher consumer-worker ratio, are worse off. Education attainment of the household head has also a positive and significant effect on household welfare. Accordingly, compared to illiterate household heads, household with informal education (church and literacy program) and primary complete have a significantly positive effect on household wellbeing. The coefficients for junior high and high school complete have also the expected positive sign but were not significantly different from zero. Contrary to usual expectation, we did not find a significant difference between male-headed and female-headed in terms of welfare while controlling for all other relevant factors. Agroecology, which could be a good proxy of the agricultural potential of geographical area, was found to have a significant effect on poverty. Accordingly, households located in highland (dega) were found to have higher poverty compared to lowlands. This could be indicative of the suitability of AWMT in relatively low land compared to highlands.

Table 7: Determinants of poverty (Regression with robust standard errors)

Dependent variable: log(welfare)			
Variable name	**Coefficient**	**Standard error**	**t-value**
Household characteristics			
sex of head (Male-headed)	-0.045	0.077	-0.59
Age of head	-0.025	0.009	-2.81***
Age squared	0.0002	0.0001	2.48***
Informal education (reference illiterate)	0.162	0.056	2.90***
Primary complete(reference illiterate)	0.111	0.063	1.77*
Junior high complete (reference illiterate)	0.119	0.108	1.10
Secondary and above (reference illiterate)	0.195	0.198	0.99
Framing (reference non-farming)	-0.063	0.129	-0.49
Consumer-worker ratio	-0.096	0.031	-3.14***
Asset holding			
Number of male Adult labor	-0.077	0.030	-2.54***
Number of female Adult labor	-0.148	0.032	-4.63***
Land holding per adult equivalent	-0.0002	0.035	-0.01
Oxen per adult equivalent	0.160	0.079	2.02**
Other forms of livestock per adult equivalent (in TLU)	0.118	0.038	3.10***
Agricultural water management technologies (reference= rain fed)			
Supplementary irrigation	0.171	0.074	2.31**
Full irrigation	0.281	0.050	5.59***
Other uses (livestock and domestic)	-0.120	0.127	-0.95
Access to factor markets			
Off-farm employment	-0.048	0.049	-0.99
Credit access	0.088	0.051	1.71*
Distance to input distribution center	-0.002	0.001	-3.17***
Distance to all weather road	0.002	0.001	2.55***
Distance to local wereda center	0.001	0.001	1.28
Distance to water source	-0.003	0.001	-4.81***
Village level factors			
Agro-ecology (Weina Dega)	-0.058	0.047	-1.23
Agro-ecology (Dega)	-0.700	0.116	-6.05***
_cons	1.114351	0.273	4.07***

Number of obs = 1421
F(25, 1420) = 15.45
Prob > F = 0.0000
R-squared = 0.2517
Number of clusters = 1421

*, **, *** significant at 10, 5 and 1 percent level of significance.

5. Conclusions and recommendations

AWMT have been identified as important tools to mitigate adverse effects of climatic variability and to reduce poverty. Huge resources are being allocated to develop and promote diverse low cost technologies in many developing countries including Ethiopia. In the last few years, thousands of low cost AWMTs have been developed for use by smallholders. In spite of these huge investments, their impacts remain unknown. The main objective of this paper was, hence, to explore whether adoption of selected AWMTs has led to significant reduction in poverty and if so identify which technologies have relatively higher impact.

Our results show that there was significant reduction in poverty due to adoption and use of AWMTs. In fact, our calculations show that there is about 22% less poverty incidence among users compared to non-users of AWMT. We found the poverty orderings between users and non-users are statistically robust. Furthermore, from the poverty analysis (severity indices), we have found that AWMT are not only effectively poverty-reducing but also equity-enhancing technologies. Equitable development is good for the poor and for better performance of the economy (Ravallion, 2005).

The magnitude of poverty reduction is found to be technology specific. Accordingly, deep wells, river diversions and micro dams have led to 50, 32 and 25 percent reduction in poverty incidences compared to the reference, i.e. rain fed system. This may imply that there is a need to promote more micro deep wells, river diversions and small dams for higher impact on poverty. Use of modern water withdrawal technologies (treadle pumps and motorized pumps) were also found to have strong poverty reducing potential. Households using of motorized pumps were found to have led to more than 50 percent reduction in the incidence of poverty. Similarly, households using gravity irrigation were found to have significantly lower poverty levels compared to those using manual (using cans) applications because of scale benefits. This implies that promotion of modern water withdrawal and application technologies could enhance poverty reduction.

While poverty analysis techniques do not have in-built mechanisms of creating comparable groups, and hence, could lead to attribution bias[76], our results from the propensity score matching, however, indicated that the average treatment effect of using AWMT is significant and has led to an increase in per capita income which amounts to average income of USD 82 per season.

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[76] The baseline situation of users and non-users is not known, one could argue that the difference in estimated poverty levels may have to do with differences in initial conditions.

While access to AWMT seems to unambiguously reduce poverty, our study also indicated that there are a host of factors that could enhance this impact. The most important determinants include asset holdings, educational attainment, underutilization of family labor and poor access to services and markets. To enhance the contribution of AWMT to poverty reduction, there is, hence, a need to: i) build assets; ii) human resource development; and iii) improve the functioning of labor markets and access to markets (input or output markets). These areas could provide entry points for policy interventions to complement improved access to AWMT in Ethiopia. Moreover, care is needed in choice and promotion of technologies that are not only reliable and have scale benefits but are also financially viable and resilient to climate change and variability.

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FACTORS INFLUENCING FARMERS' DECISION TO JOIN AGRICULTURAL CO-OPERATIVE IN RURAL ETHIOPIA

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Abstract

Lack of access to markets is among the serious impediments that Ethiopian smallholder- subsistent farmers face in order to produce marketable surplus. Agricultural cooperatives try to address the problem of market access and input supply by mobilizing the resources and products of their members. One of the factors for co-operatives to achieve their objective is a broad membership base, which is also a goal set by the different development strategies of the government of Ethiopia. This study tries to identify the factors that affect the decision of farmers to be members of cooperatives. The study used a survey data that covers 1117 households from eight Weredas within seven regions. We employed the probit model and identified several characteristics of the household head and the household itself to affect probability of cooperative membership. Accordingly, it is found that sex and education level of the household head, possession of radio, access to cooperatives within the kebele and access to market are significant factors that determine households' membership in a cooperative.

1. Introduction

The Ethiopian agricultural sector is characterized by smallholder subsistence farming. According to CSA (2009) about 33 percent of farming households in the country hold less than 0.5 hectare and about 84 percent hold less than 2 hectares. Although there are various structural problems that inhibit farmers from producing surplus, lack of access to market is among the serious impediments they face. In the face of market failures and high transaction costs, the participation of small holder farmers in the market and the extent to which they benefit from their participation are very low (Bernard *et. al.* 2008). Individual farmers find it difficult to market their surpluses as a result of high risks and associated costs. They usually also have lower bargaining power than most of their potential buyers.

Agricultural co-operatives, also known as farmers' co-op, are associations where farmers pool their resources so as to perform activities in a more effective or efficient way than otherwise. A broad typology of agricultural co-operatives distinguishes between agricultural service co-operatives, which provide various services to their individuall farming members, and agricultural production co-operatives, where production resources (land, machinery, etc.) are pooled and members farm jointly (Cobia 1989; as cited on Karki 2005). The main interest of this paper is the former.

Agricultural co-operatives are known to exist in Ethiopia as early as the imperial era[77] (Bernard et al. 2007). According to Couture *et al.* (2002) in Kodama (2007), the co-operative organizations were first established in Ethiopia in the 1950s. During this period there were only few co-operatives operating in both the rural and urban parts of the country. Co-operatives were not also given a crucial part in the development process. Although some co-operatives actually existed, they were established primarily for promoting crop export, which excluded smallholders. During the *Derg*[78] regime, co-operatives were given a higher role and mission. However, due to the high level of government intervention and involuntary membership, co-operatives were not seen positively by the society. Excessive government intervention and too much dependence on communal traditions of cooperation have contributed to the unpopularity of co-operatives (see Tsujimura (1999) in Kodama (2007)). As a result of the unhealthy experience related to the practice of co-operatives during the socialist regime, co-operatives were abolished in 1991 following the overthrow of the *Derg* regime.

[77] This is the time that Ethiopia was under an imperial rule that came to an end in 1974

[78] A military rule that took over power from the imperial government and ruled the country between the years 1974 and 1991

In 1994 co-operatives were reinstated to play their role in a free market system, free from governmental intervention (FDRE 1994). The main objective for this action was 'to make conditions convenient so that Ethiopian peasants living in the rural areas in scattered manner can be organized on their own free will and may be able to solve jointly the economic and social problems facing them'(*ibid.*). This was further made firm by the Plan for Accelerated and Sustained Development to End Poverty (PASDEP) in which cooperatives are given a central role in the development of agriculture. The Federal Co-operatives Commission (now the Federal Co-operatives Agency) was established in 2002 to augment the participation and role of co-operatives towards the development process. The five-year development plan of the agency aspires to have co-operatives in each *Kebele* and provide co-operative services to 70 percent of the population (Bernard *et*. *al*. 2007; Bernard *et*. *al*. 2010). According to Spielman et al. (2008) there are around 23,084 co-operatives operating in both the urban and rural parts of the country. The number of co-operatives in the rural areas has been increasing over the years. However the plan to make 70 percent of the rural population a co-operative member is still far from being achieved. The proportion of households that are members of any form of co-operative is estimated to be only 4.5 million. Although membership in co-operatives is voluntary and non-discriminatory, membership still remains to be very low (Bernard *et*. *al* 2007).

The role of these co-operatives is not only to provide access to market for small-holder farmers but also offer credit and supply modern agricultural inputs to their members. The success or failure of a co-operative is reflected by the impact that it brings on its members. This is why several authors (see for example Prakash 2000) stress that co-operatives should focus on their members than themselves. Particularly in Ethiopia, co-operatives have limited coverage as compared to the target set by the government (Bernard and Spielman 2009). Since membership is voluntary, individual characteristics of farmers and their socio-economic conditions determine whether they want to be members of a given co-operative or not. The purpose of this study is, therefore, to identify demographic and socio-economic factors that affect individual choices for cooperative membership to understand the underlying causes of the considerably low membership level. Attempting to fill this knowledge gap will benefit co-operatives themselves, policy makers and all other stakeholders. Such knowledge is an important player in the design of policies to achieve the government's plan to bring seventy percent of the rural population under co-operative membership.

The remaining part of this paper is organized as follows. The second section of the paper presents review of relevant literatures, followed by methodology in section three which discusses about data sources, descriptive statistics and model specification. The fourth section presents the empirical findings and discussion of results. The final section presents conclusions and policy implications. .

2. The role of co-operatives in agricultural development

Co-operatives are believed to play a key role in promoting economic and social development (RSA, 2005b:2 in Ortmann & King 2007). As member-owned businesses, they aggregate the market power of people who are not able to achieve much on their own, and provide ways out of poverty. By supplying production inputs, co-operatives further meet producers' supply needs. The effectiveness of co-operatives influences the input cost of producers and consequently their profitability. Likewise, the marketing functions that co-operatives perform influence farmers' ability to market their commodities and directly affect the profitability of producers' operations (McNamara et al. 2001). Another aspect of co-operative operations is their presence in the local economy as a source of local employment, income, as well as source of goods and services to non-agricultural rural residents. In other words, co-operatives function as a critical element in sustaining a community's economic base (*ibid.*).

Theoretically the role of co-operatives in fostering agricultural development is mainly allowing members to get better access to market their outputs and acquire inputs. Most co-operatives are established with a two-fold objective: of obtaining inputs at a lower cost, and marketing their products at better prices or in markets that they did not have access to (Barton 2000). Such groups are solutions for market imperfections which include high transaction costs and imperfect and asymmetric information (Thorp *et. al.* 2003). In the African context, the traditional role of agricultural co-operatives has been limited to agricultural marketing. With the emergence of market liberalization, their role as input package distributers has been dropped in most cases.

Subsistence farmers are believed to benefit from an improved bargaining power and hence better prices, if they sell their output through co-operatives. In this aspect, agricultural co-operatives have achieved a great deal in terms of transforming farmers who basically produced for their own consumption to commercialize their outputs. However, the role of co-operatives in fostering agricultural marketing will be effective to the extent that they are able to build a strong membership base; especially the membership of those subsistence farmers who otherwise would not be able to market their products on their own or who do not benefit from marketing their products due to lower bargaining power or lack of access to markets. If co-operatives are only attracting farmers with better resource endowment leaving out the poorer ones, then their effectiveness could be seriously curtailed. Moreover, the leadership quality and efficiency of management also plays a crucial role in the effectiveness of co-operatives in achieving their goals.

Although groups such as agricultural cooperatives may be fundamental in bringing about better economic, social and political outcomes and members could be enabled to reach their goals easily, a somehow defective group dynamics and limited inclusiveness of such groups may curtail their effectiveness. For instance, Thorp *et, al.* (2003) find that the chronically poor are disadvantaged in group formation. Such exclusion, though not necessarily by design, may curtail the co-operatives from achieving their goals. Similar findings are also indicated by a study by Weinberger and Jütting (2000) in analyzing membership and participation in local development groups. Their empirical findings show an obvious exclusion of the majority of the poor from such groups. This is especially true for women.

In the Ethiopian context, a study by Bernard and Spielman (2009) found that only 9 percent of all smallholders were members of such co-operatives, only 40 percent of households have access to a co-operative in their *kebele*[79] and even where co-operatives do exist, only 17 percent of the local households are, in fact, members, as of 2005. According to the same study, the dominant determinants of household participation in co-operatives are education and landholding. Similarly, a study by Bernard *et al*. (2007) examined the impact of co-operatives on smallholder commercialization of cereals, by considering *kebeles* that have co-operatives. According to the study households' decision to participate in a co-operative in any given *kebele* is likely to be driven by the expected benefit from the organization. The study identified different household characteristics to be determinants of households' membership in co-operatives. Although these studies that were done in rural Ethiopia, that shed light on the determinants of co-operative membership, related works using different data sets will further enrich the understanding in the area.

3. Methodology

a. Data

The data used for this study is collected from a household survey that was undertaken jointly by the Ethiopian Economics Association (EEA) and the International Food Policy Research Institute (IFPRI)[80]. The survey was conducted in eight selected *Weredas*[81] in seven regions of Ethiopia. It includes 1117 households residing in 4 *Kebeles* randomly selected from each of the eight *Weredas*. The data collection took place in 2009. The household questionnaires administered to both household heads and spouses included questions related to membership in co-operatives and details related to the workings of the co-operatives in which they are members. A separate questionnaire was also administered to agricultural co-

[79] A *kebele* is the smallest administrative unit in Ethiopia
[80] EEA-IFPRI data henceforth
[81] *Wereda* is an administrative unit that is immediately above *kebele* in rural areas

operatives in all the *Kebeles* of the selected *Weredas* of the seven regions. This data provides an in-depth understanding into the workings of the agricultural co-operatives in the respective *Kebeles* and the services they provide to their members. Table 1 below summarizes the distribution of sample size among the seven regions.

Table 1: Regional distribution of respondents

Region	Freq.	Percent
Afar	138	12.35
Amhara	280	25.07
Benishangul-Gumuz	139	12.44
Gambella	140	12.53
Oromia	140	12.53
SNNP	140	12.53
Tigray	140	12.53
Total	1,117	100

Source: Own computation using EEA-IFPRI data

b. Descriptive Statistics

There are a total of seventy eight co-operatives in all the eight *Weredas* selected from the seven regions. The establishment of these 78 co-operatives took place between the years 1978 and 2007. The years 1996 and 2005 experienced exceptionally higher number of co-operatives formation, where 12 (16 percent) of the co-operatives were formed in 1996 and 21 (about 27percent) of them were formed in 2005. There were only less than five co-operative formation per year during the remaining years.

Ideally co-operatives are member-driven and member-managed organizations. However, in most rural communities co-operative formation is mainly initiated by *Wereda* bureaus. The Initiative for the formation of the majority (about 63 percent) of these co-operatives was taken by the *Wereda* administration. Following *Weredas*, the *Kebele* administration played the second most important role in terms of taking initiative in forming co-operatives. Member-initiated co-operatives account only for 13 percent of these co-operatives. The remaining 6 percent were established by the initiatives taken by non-government organizations (NGOs), proclamation of the *Derg*, *Kebele* dwellers and others. Although the initiatives to form the co-operatives may be made by local administration, membership is still voluntary and farmers make individual decisions as to whether they want to join the co-operatives or not.

These co-operatives had, on average, 159 members during formation. The average number of members a co-operative has during the survey was about 422 while the highest and the lowest number of members are 1700 and 15 respectively. Membership in co-operatives is mostly dominated by men. Although the contribution of women in agriculture is very significant, their participation in co-operatives is very minimal. Moreover, even if they manage to become members of a given co-operative their role is limited to being a simple member. No official position or responsibility is given to them. On average only about 27 percent of co-operative members are female. All but one co-operative are currently accepting new members. New members who wish to join a co-operative are expected to pay a one-time membership fee in 76 of the 78 co-operatives. This payment is around 11 birr on average but it is in the range of 1 and 170 birr with a standard deviation of 24. Members of 25 of the 78 *kebeles* are from more than one *kebele* while that of the remaining 53, which is about 68 percent of the co-operatives, are only from single *kebele* each. Thirty four co-operatives themselves, on the other hand, are members of co-operative unions, which are bigger umbrella organizations that have several co-operatives as members.

Although the co-operatives interviewed are taken from all the *kebeles* in the eight selected *weredas*, the households interviewed were only from the 32 *kebeles* that were randomly selected from the eight *weredas*. Out of a total of 32 *Kebeles* included in the household survey, only 14 *Kebeles* have agricultural co-operatives within their boundaries. Only 21 percent of the respondents indicated that they were a member of at least one co-operative. The most prominent type of co-operative, about 57 percent of co-operative members indicated their membership in, is multi-purpose agricultural co-operative followed by various agricultural processing co-operatives. The most important service co-operative members indicated that they get by being members of co-operatives are access to credit followed by easier access to agricultural inputs. However, about 18 percent of the respondents feel that they see no benefit in becoming a member of a co-operative. On the other hand, the most pronounced challenges that co-operative members face are high input prices followed by inefficiency in the co-operative management and lack of transparency.

In an attempt of understanding the factors that determine the decisions of farmers to join co-operatives, we included demographic variables like age, sex, educational level and household variables in our empirical analysis. The summary of these variables is presented in Table 2 below.

Table 2: Mean values of main household characteristics by membership status

	Non members	Members	Difference
Age	42.673	45.612	2.939***
Gender (1=male, 0=Female)	0.739	0.931	0.192***
Education	1.493	2.819	1.326***
household size	5.388	6.759	1.371***
pack animals	0.295	0.364	0.068**
Radio	0.281	0.448	0.167***
land size	1.839	3.479	1.640***
Distance from main road (in minutes)	56.322	51.280	-1.942*
Cooperative exists in the *kebele*	0.369	0.703	0.333***
Total Sample	**875**	**232**	

Source: Own computation using EEA-IFPRI data
Note: Coefficients are significant at *10 percent, ** 5 percent and *** 1 percent.

As can be clearly seen from the descriptive statistics presented above, there is a significance difference in almost all of the identified characteristics between member and non-member households. Co-operative members have a relatively better level of education than non-members. Land size and ownership of pack animals is also significantly higher for member households. The mean value in the number of minutes it takes to reach the nearest roads is lower for co-operative members implying a relatively better access of these households to markets. In terms of ownership of radio and land size, co-operative members are also better off from their non-member counterparts.

c. Model Specification

The dependent variable in this study is that whether the respondent is a member of a farmers' co-operative or not. In this case membership is reported as one and non-membership as zero. Since the dependent variable is binary with outcomes 0 and 1, we employed the *probit* model recognizing the discrete choice nature of the response variable.

Let the observed outcome be y_i. The underlying latent variable y_i^*, which is the unobserved threshold level that marks between being a member or not in a co-operative, is a function of observed personal and socio-economic factors, say x_i, and unobserved characteristics, say ε_i, for respondent i. This can be expressed in equation form as:

$$y_i^* = x_i '\beta + \varepsilon_i , \quad \varepsilon_i \sim NID(0,1) \qquad (1)$$

f this threshold level is set to zero, without loss of generality, then the *probit* model can be fully described as:

$$y_i^* = x_i '\beta + \varepsilon_i , \quad \varepsilon_i \sim NID(0,1) \qquad (2)$$

$$y_i = \begin{cases} 1 & if\ y_i^* > 0 \\ 0 & if\ y_i^* \leq 0 \end{cases} \qquad (3)$$

The estimation will immediately follow from the above specification by employing the method of the maximum likelihood estimation technique.

4. Empirical Findings

We used several household level and personal characteristics to explain farmers' membership decision into an agricultural co-operative. The household level variables are the size of the household, existence of co-operatives in the *kebele* where the household is located that indicates access to co-operatives, access to road, size of land owned by the household to proxy wealth and possession of radio to control for exposure to information. Personal characteristics of the respondent such as gender, age (both in levels and squared) and educational attainment are also included among the explanatory variables. We also included *wereda* dummies for the six of the *weredas* in order to control the *wereda* effects.

A *probit* model was estimated and the parameter estimates are reported in table 3 below. *Wereda* fixed effects are included in the regression. Observations from Afar region are dropped since there are no households which are members of any cooperative.

The estimation results gave positive relationship between co-operative membership and all the significant variables, with the exception of squared age and distance from the main road. Male headed households are found to me more likely to be co-operative members than the female headed ones. The fact that female headed households are less engaged in agricultural production or the risk-averse behavior of such households could have contributed to this result. As expected, more educated farmers are keen in accepting membership in a co-operative. Age of household head is found to affect co-operative membership positively but the negative sign on the coefficient of its square indicates that after certain age the probability of household heads to join co-operatives would decline.

Table 3: Estimation results

Variables	Coefficient	Marginal Effects
Male	0.586***	0.115***
	(0.165)	(0.026)
Age	0.072***	0.017***
	(0.021)	(0.005)
Age squared	-0.001***	-0.000***
	(0.000)	(0.000)
Education	0.018***	0.004***
	(0.008)	(0.002)
Household size	-0.010	-0.002
	(0.026)	(0.006)
Radio	0.301***	0.075***
	(0.113)	(0.031)
Pack animal	0.023	0.006
	(0.116)	(0.028)
Existence of co-operative in the *kebele*	0.315***	0.076***
	(0.168)	(0.043)
Distance to nearest road	-0.002**	-0.000***
	(0.001)	(0.000)
Intercept	-2.918	
	(0.634)	
Number of obs = 970	Wald $chi^2(14)$ = 1107.15***	Pseudo R^2 = 0.3150

Source: Own computation using EEA-IFPRI data
Notes: Standard errors in parenthesis. Coefficients are significant at *10 percent, ** 5 percent and *** 1 percent.

According to the findings, households with larger land holdings are more likely to be members of co-operatives. Each additional hectare of land increases the probability of the household's participation in a co-operative by 0.14 percent. In line with Bernard *et. al* (2007) the odds of wealthier households to join co-operatives are greater than those otherwise. The results also suggest that possession of radio increases the chance of participation by more than 7 percent.

Existences of co-operatives in the *kebeles* of the households increase the odds of that household's being a member by about 8 percent. Unlike the study by Bernard *et al*. (2007), we tried to examine *kebeles* with co-operatives and without. Although it can be argued that co-operatives are themselves established by members in the first place most of the co-operative members indicated that the initial step in forming most of the co-operatives emanated from local administration units. As indicated earlier, the evidence from the data shows that farmers do not usually take the first step in establishing co-operatives. This could be due to lack of awareness or organizational know-how. Hence examining kebeles with or without co-operatives is important since it helps to identify the importance of access to a co-operative within *kebele* of residence. This, in turn, plays an important role in policy recommendation regarding intervention to improve co-operative participation of farmers.

Better access to information, as indicated by possession of radio, is also a factor that enhances the chances of co-operative membership. Access to market and infrastructure as captured by the variable that indicates the distance to main road in minutes is found to increase the probability of co-operative membership. Other things remaining constant, households with better access to the main road are more likely to be members of co-operatives than those who are relatively distant from the main road. Educational attainment, gender and age of the household head are also among the factors determining decision of farmers to be members in farmers' co-operatives. Male farmers have 12 percent higher chance of being members than female farmers while each additional year of education increases this probability by 0.43 percent. The lower participation of women in such co-operatives could be the society's traditions and norms which normally discourage women from participating in such institutions. The high opportunity cost for women to participate in local organizations or groups could also explain the lower probability for women to become co-operative members. Similarly, educated farmers' have a higher probability of becoming co-operative members than those with lower education, given that other factors remain the same.

5. Conclusion and policy implication

As argued by several authors, agricultural co-operatives should focus on fulfilling the needs of their members in order to succeed in achieving their main objectives of market access and input supply to their members. Knowing this fact, co-operatives themselves and all other stakeholders will benefit from knowing the factors that influence the decision of co-operative membership. Such knowledge, on the other hand, can be an important player in the design of policies to achieve the government's plan to make seventy percent of the rural population members of a co-operative.

The findings of the study suggest that personal characteristics such as gender, age and educational level are significant factors affecting co-operative membership.

Moreover, the land ownership of farmers, distance of households to the main road, capturing access to market and other infrastructure and access to information also affect decision of farm households to join cooperatives.

The findings imply that co-operative membership can be improved by improving the educational level of the society as well as by providing information about the workings and benefits of co-operatives. In addition the improvement of the living standards of the society will also contribute to the membership since better wealth will give farmers the freedom to break out of the routines and make new decisions. Most importantly, making co-operatives accessible to farmers is an area of intervention both for the government as well as other stakeholders. Such stakeholders could encourage the formation and expansion of co-operatives to *kebeles* where there are none. This can be done by playing roles of facilitation and capacity building. Such activities should be carried out cautiously so that they will not cross the line to violate the basic principles of co-operatives, member nature-driven- and the internal democracy.

Interventions in the areas of challenges reported by respondents could also help improve the performance of the co-operatives, hence the participation of farmers in these co-operatives. Among the most important challenges reported were high input prices and management problems such as inefficiency and lack of transparency. Improving the qualification of co-operative staffs through trainings might help alleviate the inefficiency problem that in turn will be reflected in the services rendered by the co-operative. The issue of transparency could also be solved using restructuring and internal regulations.

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DOES IRRIGATION ENHANCE AND FOOD DEFICITS DISCOURAGE FERTILIZER ADOPTION IN A RISKY ENVIRONMENT? EVIDENCE FROM TIGRAY, ETHIOPIA

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Abstract

This paper assesses how rainfall risk, access to irrigation, and food deficits affect the probability and intensity of fertilizer use in the highlands of Tigray Region, Ethiopia. Using a Cragg (Double Hurdle) model, we found that households are more likely to use fertilizer and that they used significantly higher amounts of fertilizer on irrigated plots than on rain-fed plots. The probability and intensity of fertilizer use was significantly higher in areas with higher average rainfall and in areas with lower rainfall variability. Irrigation was significantly more important for fertilizer adoption and fertilizer intensity in lower rainfall areas. Irrigation had a stronger positive effect on intensity of fertilizer use in areas with high rainfall variability. However, among these households, those that decided to use fertilizer used significantly more fertilizer than households that did not have a food deficit.

Keywords: *Tigray, irrigation Average rainfall, Rainfall variability, food deficit, fertilizer use.*

1. Introduction

There have been many studies on the effect of irrigation on fertilizer adoption (Abdoulaye and Sanders, 2005; FAO, 2002; Fox and Rockstrom, 2000; IFA, 2002; Morris *et al.*, 2007 ; Shah and Singh, 2001; Smith, 2004; Wichelns, 2003; Yao and Shively, 2007). Some of these studies suggest strong complementarities between irrigation and fertilizer. For example, Abdoulaye and Sanders (2005) argue that fertilizer and water are issues that need to be handled simultaneously because, when water is a limiting factor, fertilizer may have no positive effect or may indeed have an adverse effect. Shah and Singh (2001) considered irrigation as a major catalyst for agricultural growth through the adoption of Green Revolution technologies in India. FAO (2002) and Morris et al (2007) also argue that households with access to irrigation benefit more because of the complementarities of irrigation and fertilizer. However, irrigation and the Green Revolution have not been nearly as successful in Africa as in Asia (Feder *et al.*, 1985).

Differing from findings from other parts of the world and the expectation of the regional government, previous studies in Tigray (Pender *et al.*, 2002) report that irrigation has an insignificant effect on fertilizer adoption. Furthermore, using Deaton's (1997) approach to correct selection bias, Hagos (2003) finds a negative relationship between irrigation and fertilizer adoption. A more recent work by Pender and Gebremedhin (2007) reports that fertilizer use on irrigated plots is less likely than on plots with stone terraces. Hence, the impact of irrigation on agricultural production was found to be statistically insignificant.

However, these previous studies from Tigray suffer from small sample size for irrigated plots, which constitute only 1% of the sample plots of Hagos (2003) and only 5.6% of that of Pender et al. (2002) and Pender and Gebremedhin (2007). Comparing such a small sample of irrigated plots with a large and heterogeneous sample of rain-fed plots makes it difficult to uncover any causal effect of irrigation. This makes estimation unreliable and more dependent on model specification and spurious correlations, while estimation results are susceptible to bias (Ho *et al.*, 2007). Pender and Gebremedhin (2007) acknowledge this problem and suggest the need for further research. Their paper does not properly control for the effect of bio-physical factors, such as soil type, slope, and land quality. Given that farmers consider environmental and plot characteristics as a basis for their decision to invest in inputs, the omission of such variables may lead to omitted variable bias in the estimated parameters (Sherlund *et al.*, 2002).

The effect of production risk and food deficit on technology adoption in general and fertilizer use in particular is mixed in the literature. The standard theory and view has been that producers' risk aversion leads to low adoption of new technologies (Dercon and Christiaensen, 2007; Feder *et al.*, 1985; Sandmo, 1971). On the other hand, Finkelshtain and Chalfant (1991) and Fafchamps (1992) showed that poor households do not systematically produce less if they think that adoption of the new technology may help them to become more food self-sufficient. Finkelshtain and Chalfant (1991) demonstrated that food-deficit households producing a normal good that they consume have an ambiguous response to higher risk but that higher risk aversion increases the probability that they respond to higher risk by producing more. Our study area and data represent an excellent opportunity to test this.

Different studies have empirically investigated the determinants of fertilizer adoption in Ethiopia. Among others, Kassie et al. (2008) used output variance as a proxy of production risk and found that higher output variance and probability of crop failure were negatively related to the probability and intensity of fertilizer adoption. Consistent with this, they found that farmers' output (return) was positively related to the probability and amount of fertilizer use. Fufa and Hassan (2006), on the other hand, have investigated the factors that affect the probability and intensity of fertilizer use on maize production in the Dadar district in eastern Ethiopia. They found that the age of the farm household's head and fertilizer price were negatively related to the probability and intensity of fertilizer use. On the other hand, farmers' expectation of good rainfall was positively associated with fertilizer use. Demeke et al.(1998) have controlled for the effect of a wide range of factors affecting farm households' fertilizer use in four major crop producing regions (Amhara, Ormiya, SNNPR and Tigray) of Ethiopia. Among other factors, access to fertilizer distribution centers, access to credit and extension services were found to be important in influencing whether farm households in the wereda have used fertilizer. In the same study, teff (a staple crop in Ethiopia) was positively related to fertilizer use. This could be because the cultivated teff area covered the largest proportion of the total cultivated area. However, since growing teff is an endogenous decision of the farm household, the result could be susceptible to a problem of endogeniety. Surprisingly, Demeke et al. (1998) found no significant relationship between average rainfall and fertilizer use.

Despite their importance in informing policy makers, these studies have not adequately examined the role of irrigation in reducing production risk due to adverse climatic conditions and its effect on fertilizer adoption. They have not assessed the effect of average annual rainfall and rainfall variability on fertilizer adoption. This paper attempts to fill some of the gaps by analyzing the effect of production risk and role of irrigation to reduce such production risks and then to enhance fertilizer adoption. We tried to capture production risk through average annual rainfall and rainfall variability. New in this paper is also an examination of the effect of food deficit on fertilizer adoption. Since we lack a good measure of households' risk preference and risk aversion behavior, we could not control for its effect on fertilizer adoption. But the response to food deficit may also give a hint about households' risk preferences. The paper has also attempted to address some of the gaps of the previous studies in Tigray by controlling for the effect of agro-ecological factors on fertilizer use. The analysis is based on plot level data of both irrigated and rain-fed plots using a Cragg (Double Hurdle) model.

The objectives of this paper are to: (1) analyze the effect of production risk due to rainfall scarcity and rainfall variability on fertilizer adoption, (2) investigate the role of irrigation in hedging against production risk and then to stimulate fertilizer adoption, and (3) investigate the effect of food deficit (consumption shocks) on fertilizer adoption.

The rest of the paper is structured as follows. Section 2 presents a review of related literature in relation to production uncertainty and technology adoption. In section 3, we present the analytical framework followed by estimation methods in section 4. In section 5, we give a description of the study area, data collection and descriptive statistics of the data. Results and related discussion are presented in section 6 before we conclude in section 7.

1. Literature review: Risk and technology adoption

Sandmo (1971) shows that a risk averse profit maximizing firm reduces investment in purchased inputs and production, compared to what would be if it were risk neutral and maximizes the expected profit. This implies that firms without perfect insurance under-invest in purchased inputs and hence under-produce. This explanation has attracted attention among economists working on technology adoption. Producers' resistance to risk has been used to explain the failures of farm households to adopt new technologies (Feder *et al.*, 1985). This view has been challenged in the sense that poor households do not systematically under-produce (Fafchamps, 1992; Finkelshtain and Chalfant, 1991). Fafchamps (1992) shows that if people are poor and concerned about their survival, the solution may not be to under-invest and under-produce. They may even adopt risk increasing technologies if they think that it helps them to become food self-sufficient. Finkelshtain and Chalfant (1991) extended the analysis of Sandmo (1971) by assessing the behavior of a producer-consumer household rather than a pure producer, assessing the effect of being a net seller or net buyer producing an inferior or a normal good that is also consumed by the household, and varying the level of risk aversion. They derive an alternative measure of the risk premium, taking into account the covariance between income and price of output and show that the Sandmo result only holds strictly when $\eta > r > 0$, where η is the income elasticity of the household's demand for home-consumption of the farm crop and *r* is the relative risk aversion. They show that a net buyer of food who is risk neutral or slightly risk-averse has the same qualitative response as in the Sandmo model, while a more risk-averse producer increases output with increased risk. Furthermore, an increase in relative risk aversion is associated with increased output for a given level of risk. This suggests that net-selling producers use less inputs and produce less under risk than under certainty, while net-buying households with severe risk aversion increase their input use and production (Finkelshtain and Chalfant, 1991).

There is an agreement that fertilizer adoption, or modern input use in general, is crucial in achieving agricultural productivity growth and ensuring food security, especially in Sub-Saharan Africa, where agriculture is characterized by low use of modern technology and low productivity (Franklin, 2006; Kassie *et al.*, 2008). In the adoption literature, production uncertainty (risk) and risk avoidance behavior of poor people are often associated with low adoption of modern inputs (Franklin, 2006; Hazell, 1988; Kassie et al., 2008; Rosenzweig and Binswanger, 1993). The most common factor for the low adoption of modern inputs is risk and farmers' resistance to technological innovations, which raises both the mean and variability of income (Hagos, 2003; Koundouri *et al.*, 2006). Uncertainty associated with the adoption of modern inputs has two dimensions: the riskiness of farm yield after adoption and price uncertainty related to agricultural production itself (Koundouri et al., 2006).

Hazell (1988) has suggested that, despite the fact that production risk is prevalent everywhere, it is particularly burdensome to smallholder farmers in developing countries. They try to avoid it through different mechanisms, such as diversifying their crops, using traditional farming techniques (avoiding less familiar modern inputs) and using other risk sharing mechanisms such as sharecropping contracts. The types and levels of risk vary with the type of farming system, climate, degree of market integration, policy and institutional characteristics (Ibid 1988). When farmers are constrained by either ex-ante resource constraints or limited by ex-post coping (insurance) mechanisms, they become hesitant to invest in modern technology such as fertilizer (Just and Pope, 1979; Rosenzweig and Binswanger, 1993). This may lead to a risk induced poverty trap, as those who are better endowed with ex-ante resources can self-finance their investment or can easily insure their consumption against ex-post income shocks and thereby take advantage of modern technology. On the other hand, those who are poor and resource constrained are engaged in low risk and low yield activities and may, therefore, be trapped in poverty (Kassie et al., 2008; Rosenzweig and Binswanger, 1993). Since low agricultural productivity causes persistent poverty, interventions that can help poor households to hedge against shocks and then adopt modern inputs might be an effective poverty reduction strategy (Dercon and Christiaensen, 2007).

Market imperfections such as those in labor and credit markets, can substantially influence farmers' technology adoption. This is important in developing countries in general and in sub-Saharan Africa in particular, where rural infrastructures such as roads and communication networks are underdeveloped (Shiferaw *et al.*, 2006). Imperfect markets are characterized by high transactions costs due to asymmetric information and imperfect competition that leads to non-separability of production and consumption decisions of households (de Janvry *et al.*, 1991; Singh *et al.*, 1986). When markets are imperfect, households' resource endowments become important determinants of investment and production decisions (Holden *et al.*, 2001), implying that resource poor households are less likely to adopt purchased inputs. For example, an imperfect labor market leads households to equate their demand for labor with their family labor. Households with larger labor endowments are likely to adopt more labor intensive technologies than labor poor households. For example, Abdoulaye and Sanders (2005) found that fertilizer application also needs high labor input for weeding in Niger, indicating that labor rich farm households are more likely to adopt fertilizer.

An imperfect credit market also affects households' investment and production decisions. For example, fertilizer adoption requires an initial investment. With limited access to credit, poor households may not have the capacity to purchase it. Hence, wealthier households with accumulated savings in the form of cash or capital (such as livestock) are more likely to invest in fertilizer and reap the benefits. For example, Wills (1972) has reported that shortage of financing is a major limiting factor of fertilizer use. However, credit alone may not limit technology adoption, particularly if the technology requires small amount of resources (Feder et al., 1985).

Consumption risk is another important determinant of fertilizer adoption. Production risk is one major source of income fluctuations for rural households, especially in developing countries (Giné and Yang, 2008). This is due to the fact that output variability affects total agricultural output, which influences food security at household level. Households lacking insurance against shocks in food stock are likely to stick to their traditional production techniques. Since ensuring food security is important for subsistence-producing households, farmers may prefer inputs that are stable in output at different moisture levels (Kaliba et al., 2000). This implies that, despite enhancing productivity, the fertilizer also increases income variability. Hence, households experiencing a food deficit may decide not to adopt it, because they are ill-equipped to cope with shocks (Dercon and Christiaensen, 2007; Giné and Yang, 2008). Farm households may make their decision to adopt or not to adopt fertilizer based on its *ex-ante* and *ex-post* consumption plans. In general, food deficiency may affect households' fertilizer use in two dimensions. First, food insecure households may have stocks or savings that partially facilitate consumption smoothing. Second, poor farm households that aim to minimize consumption fluctuations due to covariate shocks (such as drought) may opt for less risky inputs in order to avoid permanent damages (Dercon and Christiaensen, 2007; Giné and Yang, 2008). However, higher returns in good years may help to bridge the deficit in bad years, meaning that risky inputs may be preferred and result in higher food security overall.

In general, output variability causes substantial consumption risk under subsistence production, especially when production depends on rainfall. This is relevant in areas where insurance against production risk is absent and credit markets are imperfect. Dercon and Christiaensen (2007) reported that farmers in a semi-arid district of western Tanzania with limited options to smooth ex-post consumption were found to grow lower return, but safer crops. Gafsi and Roe (1979) report hat poor farmers in Tunisia preferred domestically developed varieties to the imported varieties which are less known to them.

Based on this review of the theoretical and empirical literature, an analytical framework is developed in the next section relating production risk and irrigation to farm households' consumption needs and fertilizer adoption.

2. Analytical framework

The framework focuses on a production environment where rainfall is scarce and erratic, markets are imperfect, peasant households are poor and strive for subsistence, and are net food buyers. With access to irrigation, a farm household produces on its irrigated and rain-fed plots. Assuming that the household i has p plots with $p = n + m$, where n represents irrigated and m represents rain-fed plots, income from agricultural production is specified as:

$$Y_i = \sum_{n=1}^{n} p_q \theta^{(I)} Q_{ip}^{(I)} \left(x_{ip}^{f(I)}, x_{ip}^{nf(I)}; z_h, A_c, \psi_i \right) + \sum_{m=1}^{m} p_q \theta^{(R)} Q_{ip}^{(R)} \left(x_{ip}^{f(R)}, x_{ip}^{nf(R)}; z_h, A_c, \psi_i \right) - p_f \left(\sum_{n=1}^{n} x_{ip}^{f(I)} + \sum_{m=1}^{m} x_{ip}^{f(R)} \right) - p_{nf} \left(\sum_{n=1}^{n} x_{ip}^{nf(I)} + \sum_{m=1}^{m} x_{ip}^{nf(R)} \right) \quad \textbf{(1)}$$

where Y is the stochastic net income (Birr[82]) of household i produced on irrigated and rain-fed plots, Q is a vector of crop production outputs and p_q is a vector of output price. The variable x represents purchased inputs (such as hired labor, oxen, seed, chemicals and pesticides, etc.) used by household i on plot p where the superscripts f and nf represent fertilizer and other inputs, respectively, where p_f is price of fertilizer and p_{nf} is price of other inputs. The superscripts (I) and (R) indicate irrigated and rain-fed agriculture, respectively. Variable z_h represents household-specific characteristics (such as age, gender and education), the household's labor and capital endowments (such as, livestock and oxen) and the household's food stocks. These are included due to market imperfections leading to household-specific shadow prices for these endowment variables. Variable A_c captures plot characteristics, and ψ_i is unobserved household heterogeneity that captures unreported household characteristics, such as farming experience and skills, risk aversion, and other factors that affect households' input use and production decisions in an environment with imperfect markets. Production risk is represented by the random variable θ, which has mean 1 and variance $\theta_{\text{var}} = \sigma_\theta^2$. The distribution of this random variable is exogenous to the farmer's decision. The effect of the random variable (production risk) depends on the type of plot (i.e., whether a plot is irrigated or rain-fed), implying that $\theta_{\text{var}}^{(I)} < \theta_{\text{var}}^{(R)}$.

When rainfall is variable and unpredictable, it affects agricultural production and causes production risk in two ways. First, shocks in weather conditions (θ) cause direct crop failure. On the other hand, if rainfall is unpredictable, the risk of investment in fertilizer becomes high, because when water (i.e., moisture) is not available at the right time and in the right amount, fertilizer use may even have an adverse effect (Abdoulaye and Sanders, 2005), therefore, increasing production risk. Production risk due to adverse weather conditions may also affect prices (Holden and Shiferawl 2004). Self-sufficient households or even surplus producers in normal years may become net buyers in drought years, when food prices tend to be higher because a larger area may face the same problem. In order to meet their food needs, households may have to sell some of their livestock, which creates a downward pressure on livestock prices. The indirect negative effects through changes in crop and livestock prices may be as big as the direct production loss effect (Holden and

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[82] Birr is an Ethiopian currency

Shiferaw, 2004). With access to irrigation, the negative effect of stochastic environment and associated production risk should be lower. This implies that production risk on irrigated plots is less than that on rain-fed plots $\left(\theta^{(I)} < \theta^{(R)}\right)$.

We assume that both output and input prices are non-random (i.e., farmers are assumed to be price takers in both markets). Risk-averse farm households maximize the expected utility of gross output specified as follows:

$$\max_{x_{ip}^{f(I)},x_{ip}^{f(R)},x_{ip}^{nf(I)},x_{ip}^{nf(R)}} EU\left[\begin{array}{l}\sum_{n=1}^{n} p_q\theta^{(I)}Q_{ip}^{(I)}\left(x_{ip}^{f(I)},x_{ip}^{nf(I)};z_h,A_c,\psi_i\right)+\sum_{m=1}^{m} p_q\theta^{(R)}Q_{ip}^{(R)}\left(x_{ip}^{f(R)},x_{ip}^{nf(R)};z_h,A_c,\psi_i\right)\\ -\left[p_f\left(\sum_{n=1}^{n}x_{ip}^{f(I)}+\sum_{m=1}^{m}x_{ip}^{f(R)}\right)-p_{nf}\left(\sum_{n=1}^{n}x_{ip}^{nf(I)}+\sum_{m=1}^{m}x_{ip}^{nf(R)}\right)\right]\end{array}\right] \quad (2)$$

where E is the expectation operator and U is a well-behaved concave and non-decreasing utility function of total income. The last term in square bracket of equation (2) represents the costs that include fertilizer and other purchased inputs. Other variables are as explained above. The utility maximization problem of the farm household is subject to a cash constraint specified as:

$$\left[p_f\left(\sum_{n=1}^{n}x_{ip}^{f(I)}+\sum_{m=1}^{m}x_{ip}^{f(R)}\right)+p_{nf}\left(\sum_{n=1}^{n}x_{ip}^{nf(I)}+\sum_{m=1}^{m}x_{ip}^{nf(R)}\right)\right]+p_qQ^D\left(z_h,\psi_i\right)\le\bar{C}\left(z_h,\psi_i\right) \quad \textbf{(3)}$$

where $p_qQ^D\left(z_h,\psi_i\right)$ is household's food consumption deficit and $\bar{C}(.)$ captures the farm household's cash constraint, both of which are conditioned by a household's characteristics, consumption preferences, access to credit and other unobserved household heterogeneities. Therefore, with a binding cash constraint, the maximization problem is specified as follows:

$$\begin{array}{l}\max_{x_{ip}^{f(I)},x_{ip}^{f(R)}} L = EU\left[\begin{array}{l}\sum_{n=1}^{n} p_q\theta^{(I)}Q_{ip}^{(I)}\left(x_{ip}^{f(I)},x_{ip}^{nf(I)};z_h,A_c,\psi_i\right)+\sum_{m=1}^{m} p_q\theta^{(R)}Q_{ip}^{(R)}\left(x_{ip}^{f(R)},x_{ip}^{nf(R)};z_h,A_c,\psi_i\right)\\ -\left[p_f\left(\sum_{n=1}^{n}x_{ip}^{f(I)}+\sum_{m=1}^{m}x_{ip}^{f(R)}\right)-p_{nf}\left(\sum_{n=1}^{n}x_{ip}^{nf(I)}+\sum_{m=1}^{m}x_{ip}^{nf(R)}\right)\right]\end{array}\right] \quad \textbf{(4)}\\ +\lambda\left[\bar{C}\left(z_h,\psi_i\right)-p_f\left(\sum_{n=1}^{n}x_{ip}^{f(I)}+\sum_{m=1}^{m}x_{ip}^{f(R)}\right)-p_{nf}\left(\sum_{n=1}^{n}x_{ip}^{nf(I)}+\sum_{m=1}^{m}x_{ip}^{nf(R)}\right)-p_qQ^D\left(z_h,\psi_i\right)\right]\end{array}$$

Given that $Y = p_q\theta^{(I)}Q^{(I)} + p_q\theta^{(R)}Q^{(R)}$, the first order conditions (FOCs) for x_f^I and x_f^R are:

$$\frac{\partial L}{\partial x^{f(I)}} = \frac{\partial EU}{\partial Y}\left[p_q\theta^{(I)}\frac{\partial Q^{(I)}}{\partial x^{f(I)}} - p_f \right] - \lambda p_f = 0 \tag{5}$$

$$\frac{\partial L}{\partial x^{f(R)}} = \frac{\partial EU}{\partial Y}\left[p_f\theta^{(R)}\frac{\partial Q^{(R)}}{\partial x^{f(R)}} - p_f \right] - \lambda p_f = 0 \tag{6}$$

Equations (5) and (6) show the marginal benefit minus marginal cost of fertilizer used on irrigated and rain-fed plots, respectively. λp_f is the opportunity cost of reducing current consumption due to investment in fertilizer. Variable λ is a markup shadow price of fertilizer. From equations (5) and (6), we see that the marginal cost of production and the opportunity cost of reduction in current consumption are the same in both irrigated and rain-fed agriculture. Given that other inputs including land and fertilizer remain the same, we assume that expected income from irrigated agriculture is greater than rain-fed agriculture, i.e. $E\left(p_q\theta^{(I)}Q^{(I)} - C^{(I)}\right) > E\left(p_q\theta^{(R)}Q^{(R)} - C^{(R)}\right)$. This is due to the fact that the effect of random shocks is less in irrigated agriculture than in rain-fed agriculture $\left(\theta_{\text{var}}^{(I)} < \theta_{\text{var}}^{(R)}\right)$. Accordingly, we expect that

$$\frac{\partial EU}{\partial Y} p_q\theta^{(I)}\frac{\partial Q^{(I)}}{\partial x^{f(I)}} = \frac{\partial EU}{\partial Y} p_q\theta^{(R)}\frac{\partial Q^{(R)}}{\partial x^{f(R)}}, Q^{(I)} > Q^{(R)}, x^{f(I)} > x^{f(R)} \tag{7}$$

Equation (7) implies that the average return to fertilizer used in irrigated agriculture is greater than the average return to fertilizer used in rain-fed agriculture.

$$EU\left(Y \middle| x^f > 0\right) > EU\left(Y \middle| x^f = 0\right) \tag{8}$$

Based on the theory that we review and the theoretical framework, we have developed the following hypotheses for empirical testing:

H1: *Farm households are more likely to use fertilizer on irrigated plots than on rain-fed plots.* Testable implication: the dummy variable plot type (1=irrigated) has a positive and significant effect on the likelihood of household's fertilizer use.

H2: *Access to irrigation enhances fertilizer use*. The implication is that, controlling for the effect of other plot characteristics, farm households use more fertilizer on irrigated plots than rain-fed plots. Therefore, the coefficient of plot type (1=irrigated) is positive and statistically significant in the intensity regression.

H3: *Rainfall risk hypotheses*

H3a: *Lower average rainfall leads to less use of fertilizer.* The implication is that the coefficient of mean rainfall is positive and statistically significant in both the probability and intensity models.

H3b: *Higher rainfall variability leads to lower fertilizer use.* The implication is that the coefficient of rainfall variability is negative and statistically significant in both the probability and intensity regressions.

H4: *Irrigation and rainfall risk interaction hypotheses*

H4a: *Irrigation stimulates greater fertilizer use in low rainfall areas than in high rainfall areas*. The implication is that the interaction effect of irrigation and rainfall (*rainfallirr*) on fertilizer use is negative. Thus, the marginal benefit of irrigation investment is lower in high rainfall areas. Its effect on fertilizer adoption is less there as well.

H4b: *Irrigation stimulates greater fertilizer use in areas with high rainfall variability relative to areas with low rainfall variability.* The implication is that the interaction effect of irrigation and rainfall variability (*cvirr*) on fertilizer use is positive and significant.

H5: *Food deficit impact hypotheses:*

H5a: *The probability of food self-sufficiency is positively associated with fertilizer use.*

H5b: *Households predicted to have a food deficit use less fertilizer than households that do not have a food deficit.* This is because such households are less able to bear *ex-post* consumption fluctuations and fund fertilizer use (Dercon and Christiaensen, 2007). or

H5c: *Food deficit households use more fertilizer than other households in order to reduce their food deficit* (Finkelshtain and Chalfant, 1991).

3. Study area, data and descriptive statistics

4.1. The study area and data

The data used in this paper came from a large rural household sample survey targeting small-scale irrigation projects in the Tigray region, northern Ethiopia. Our study area covers six communities/*tabias*[83], each consisting about four villages. These sites were selected to represent different agro-ecological settings, water typologies (source of irrigation water), irrigation water distribution and management systems.

[83] The tabia is the lowest administrative unit in the structure of the Regional Government of Tigray.

The sample was established through a three-stage stratified random sampling process. First, all *tabias* in the region with irrigation projects were identified based on the type of irrigation technology. Altitude, size of irrigable land and experience (years since irrigation was started) were also used as a basis for stratification. Among the six sites, two use micro-dams, and two use river diversion, as a source of irrigation water. The remaining two use ground water, with one of them using pressurized tube irrigation infrastructure. At the second stage, all farm households in each *tabia* were stratified based on their access to irrigation.

In the final step, we selected 100 sample households from each *tabia*, with the exception of *Kara-Adishawo (in Raya Azebo),* from which we have 113 sample households. The number of households with and without access to irrigation was determined based on the proportion of total farm households that have and have not access to irrigation in each *tabia*. This approach enabled us to have households with and without irrigated plots, with the second group serving as a counterfactual. In this paper, we dropped rented in and rented out plots. Hence, we used 1782 owner-operated plots, of which 1419 and 363 are rain-fed and irrigated, accounting for 79.6 and 20.4%, respectively. A plot is defined as a distinct management unit based on the type of crop planted during 2004/2005 agricultural season.

Data on plot characteristics include soil type, land quality and slope (as perceived by the farm households) and recall data on inputs and output from the past harvest season.[84] Plot size was not physically measured, but farmers were asked to report the size of the plot in the local measurement unit (*tsimdi*[85]). Size was subsequently converted into hectares. Since farmers have land certificates indicating the size and boundaries of their plots, we trust that the size of plots that they reported is quite accurate.

4.2. Descriptive statistics

Table 1 presents a summary of variables used in the regression. We see that about 77% of the sample households are headed by males. Households with access to irrigation have higher shares of female labor. About 62% of pure rain-fed cultivating and 66% of irrigating households have access to credit. The overall average plot size is about 1.2 hectares and the average size of rain-fed and irrigated plot is 1.4 and 0.41 hectares, respectively. On average, about 22, 20, 23 and 35 percent of rain-fed plots, and 17, 33, 27 and 24 percent of irrigated plots are found in Baekel, Walka, Hutsa and Mekayhi soils, respectively (for soil characteristics see Appendix 2). On

[84] Data collection was carried out during October-December, 2005

[85] Four tsimdi is approximately equal to one hectare.

the other hand, about 9% of irrigated and 19% of rain-fed plots are found in plain area, while farmers believe that about 82% of their irrigated and 60% of rain-fed plots are of good quality. Overall, average fertilizer use is about 10.5 Kg/ha, about 18.2 and 8.5 Kg/ha on irrigated and rain-fed plots, respectively. Finally, we see no statistical difference in the village level variables, except that 28% of rain-fed plots and 35% of irrigated plots are found in lowland (Kola) areas.

4. Estimation methods

In order to test the effects of households' food self-sufficiency and actual food deficits on households' fertilizer adoption, we first ran a probit model to predict the probability that households were food self-sufficient. We **had** data whether a farm household had sufficient food at the beginning of the rainy season (June), but this variable was likely to be endogenous and dependent on structural characteristics (such as household wealth, composition and general agro-climatic conditions). It may also be affected by potential community-wide shocks (like droughts) or problem affecting individual households (like health problems affecting the labor force during the production season)..To capture shocks in households' food availability and examine the effect of a food deficit on households' fertilizer use, we used the residual (=dummy for actual food self-sufficiency minus the predicted food self-sufficiency) to generate two dummy variables. The first of these (*D1foodaversi*) was set equal to one if the value of the residual is greater than -0.5 and less than 0. This captures food deficit households that were predicted to be in food deficits. The second (*D2foodaversi*) was set equal to one if the value of the residual is less than -0.5 and captures food deficit households that were predicted to be food self-sufficient. Therefore, their actual food deficit may be attributable to a shock. For a clear exposition of how the two dummy variables were generated, see the following procedure.

	Food availability in June (Y)	
	Yes = 1	**No = 0**
Predicted food availability $\hat{Y}$	Y-yhat = (+)	Y-yhat = (-), D1=1 if 0>D1>-0.5
	Y-yhat = (+)	Y-yhat = (-), D2=1 if D2<-0.5

The more negative the residual is, the less likely that the household is facing a food deficit; i.e., such households are wealthier and subsequently more self-sufficient. We use both variables in the fertilizer adoption models to test whether food deficits are expected to affect farm households' ability to invest in fertilizer as a strategy to become food self-sufficient.

In our sample data, fertilizer use has been reported in about 30% of irrigated and 32% of rain-fed plots (see Table 1). In such conditions, estimating the parameters using OLS regression fails to account for the qualitative difference between zero and continuous observations and leads to biased estimates. This is sometimes referred to as “substantial bias”(Franklin, 2006; Smits, 2003). On the other hand, restricting the analysis to observations where fertilizer has been applied (i.e., $f > 0$) will yield biased and inconsistent parameter estimates. This is known as “heterogeneity bias” (Smits, 2003) because it ignores the process that generated the observed fertilizer use (Yilma and Berger, 2006).

We assessed whether it is appropriate to use a one-shot or two-stage model for fertilizer use by comparing the results of a censored Tobit model and a Cragg (double hurdle) model. In the double hurdle model, we first estimated the probability that the farm household adopts fertilizer. We estimated the intensity of fertilizer use in the second stage. We performed a likelihood ratio test to see whether the censored Tobit model nests the two-stage model. The likelihood ratio test rejected the censored Tobit model in favor of the double hurdle model ($\chi^2_{(22)} = 316.75,\ prob = 0.000$).

Given our two-stage model, there is also a risk of selection bias related to clustering at zero due to selection rather than censoring. A Heckman selection test was used to test for selection bias. We found no significant selection bias in the Heckman selection model and hence present only the results from the Cragg (double hurdle) model.

5. Results and discussion

We found that households with access to irrigation are significantly (at 10% level) more likely to use fertilizer than households without access to irrigation. Our first hypothesis (**H1**) stated that farmers are more likely to use fertilizer on their irrigated plots than on rain-fed plots. We see from Table 2 that farm households were significantly (at 1% level) more likely to use fertilizer on irrigated plots than on rain-fed plots. Furthermore, our second hypothesis (**H2**) stated that access to irrigation enhances fertilizer intensity. We found that farm households use significantly (at 1% level) higher amounts of fertilizer on irrigated plots than on rain-fed plots (see Table 3). Therefore, we are clearly not in a position to reject these hypotheses, contrary to earlier findings in this part of Ethiopia. One possible explanation may be that there is a learning curve in relation to production on irrigated land, as it is a relatively new technology, and the advantages have become stronger in our more recent data. Another explanation is that we have better quality data, allowing us to do a more rigorous test than was possible in earlier studies.

Hypothesis three (**H3a and H3b**) stated that fertilizer adoption is lower in areas with low rainfall and in areas with high rainfall variability. We found that the probability of fertilizer use was significantly (at 1% level) higher in areas with higher average rainfall (*rainfall*) and lower rainfall variability (*cv*), in line with our hypotheses. Similarly, the intensity of fertilizer use is significantly (at 5% level) higher in high rainfall and low rainfall variability areas (see Table 2 and 3). The results imply that rainfall risk is an important constraint to fertilizer adoption in Tigray.

Hypothesis four (**H4a, H4b**) stated that irrigation stimulates greater fertilizer use in low rainfall and high rainfall variability areas relative to areas with high average annual rainfall and low rainfall variability. To test these, we use the interaction effect of irrigation with average annual rainfall (*rainirr*) and rainfall variability (*cvirr*). From Table 2, the sign and significance (1% level) of the first interaction variable indicates that the effect of irrigation on the probability of fertilizer use is higher in low rainfall areas than in high rainfall areas, while the second interaction variable was insignificant. Both interaction variables were significant (at 5 and 10% levels) with negative and positive signs respectively in the intensity model (Table 3). This provides clear evidence of the higher importance of use of irrigation scheme for fertilizer adoption in low rainfall areas and weak evidence of more fertilizer use in areas with more rainfall variability. These findings imply that irrigation is more important for fertilizer adoption in drought-prone areas than in areas with sufficient precipitation. This may have policy implications for where to allocate irrigation investments, but it must be combined with overall cost-benefit analyses where investment costs, crop productivity effects and transportation costs are taken into account.

Hypothesis five (**H5a, H5b, H5c**) stated that food deficits may affect fertilizer adoption positively or negatively and that expected (predicted) food deficits may have a different effect than actual food deficits (e.g., due to shocks). From Table 2, we see that the higher probability of households' being food self-sufficient (*yhat*) was negatively related to the probability of fertilizer adoption (significant at 1% level). This indicates that expected food deficits stimulate fertilizer adoption as a means to reduce the deficit. However, food deficit households predicted to be so (*D1foodaversi*) were significantly (at 1% level) less likely to use fertilizer. This may indicate that particularly poor households experiencing a food deficit may be forced to use scarce resources to buy food to satisfy current consumption, rather than to invest in fertilizer adoption to reduce future food deficits.

On the other hand, the food deficit may not have come as a shock to these households; they may be less liquidity constrained and thus appear to try to reduce future food deficits by using higher levels of fertilizer. We should remember that the sample size here has been restricted to those using fertilizer, meaning that those who were unable to buy fertilizer due to poverty/liquidity constraints have been eliminated from the sample. These finings are in line with the model of Finkelshtain and Chalfant (1991) and Fafchamps (1992), showing that net buyers of food respond differently to risk than net sellers or firms (Sandmo (1971). This adds empirical evidence to the presumed effect of consumption risk on technology adoption in general and fertilizer, in particular.

There are some additional observations that we can make in Tables 2 and 3. Households with more livestock (oxen and other livestock) and households with more literate members were significantly more likely to use fertilizer, demonstrating significant market imperfections causing wealth to affect production decisions. Households with older household heads were significantly less likely to use fertilizer. This could have several explanations. Old age could imply lower working capacity, less capacity to access fertilizer, poorer knowledge about the use of fertilizer and more skepticism towards fertilizer use. This is in line with findings in Malawi (Franklin, 2006). We see also that female-headed households were significantly (at 1% level) less likely to use fertilizer than male-headed households. This can be related to cultural norms that female labor in Ethiopia is not used for cultivation, except for weeding and harvesting. Moreover, female-headed households are among the poor households (Croppenstedt *et al.*, 2003) that lack access to resources to invest in fertilizer.

6. Conclusion

We used a simple theoretical framework based on relevant theory for behavior of producer-consumer households that produce for their own consumption and may be net sellers or net buyers of food. We used theory to derive relevant hypotheses to test the effects of investment in irrigation, rainfall and rainfall variability and food self-sufficiency and food deficits on adoption and intensity of fertilizer use on irrigated and rain-fed land.

We found strong positive effects for adoption and intensity of fertilizer use on irrigated land, contrasting with earlier studies that did not find such positive effects of irrigation. Our study is based on more solid data, and we think that these new results provide evidence of significant positive effects of irrigation investment on fertilizer use.

We found that production risk due to adverse climatic conditions (rainfall scarcity and variability) is an important determinant of farmers' fertilizer adoption. We also found that predicted food self-sufficiency was negatively related to fertilizer adoption, indicating that expected food deficits had a positive effect on fertilizer adoption. This is contrary to the prediction of the pure producer model of Sandmo (1971), but it is in line with the predictions of the producer-consumer household model of Finkelshtain and Chalfant (1991), indicating that risk averse net buyers of food may respond to higher risk by producing more (through use of more inputs). We also assessed the effects of actual food deficits, whether they were expected or not, and found a contrasting effect on adoption of fertilizer vis-a-vis intensity of fertilizer use. Food deficit households predicted to be in food deficits were less likely to use fertilizer, possibly due to liquidity constraints and the need to buy food to meet urgent food needs rather than reducing future food deficits. However, when assessing the fertilizer use of those households that still managed to buy fertilizer, we found that they used significantly more fertilizer than other households. These households are likely to be less cash constrained and, therefore, more able and willing to use fertilizer to reduce future expected food deficits, a sign of their high relative risk aversion (Finkelshtain and Chalfant 1991). Overall, we may conclude that liquidity or credit constraints may inhibit fertilizer adoption of food deficit households. However, the covariance between income and price risk may cause the risk premium to be negative for food deficit households and induce them to adopt and use more fertilizer to reduce their future food deficits. In general, therefore, both investment in irrigation and provision of credit can be important policy instruments to enhance food security in semi-arid and drought-prone areas like the one in our study, where fertilizer can enhance food self-sufficiency.

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Table 1: Summary statistics of variables

variable	Description	Total owner operating households	Households that have no access to irrigation	Households that have access to Irrigation	*t-test*
	Household level Variables				
Jnenough	Household has enough food in June (1=yes)	0.436 (0.021)	0.4160 (0.030)	0.455 (0.030)	-0.897
Hhage	Household age	46.813 (0.657)	46.814 (0.928)	46.811 (0.933)	0.002
Hheadsex	Household sex (1=male)	0.765 (0.018)	0.766 (0.026)	0.764 (0.026)	0.059
Litrate	Literate household members	1.375 (0.062)	1.223 (0.079)	1.524 (0.096)	-2.418**
Femwl	Household member female labor	1.585 (0.039)	1.561 (0.054)	1.607 (0.058)	-0.582
Mamwl	Household member male labor	1.426 (0.044)	1.431 (0.064)	1.422 (0.062)	0.106
Oxen	Oxen ownership	1.246 (0.045)	1.197 (0.067)	1.295 (0.061)	-1.079
Totaltlu	Livestock ownership (tlu)	3.131 (0.143)	3.002 (0.227)	3.257 (0.176)	-0.887
Farasso	Household's access to credit (1=yes)	0.638 (0.021)	0.617 (0.030)	0.658 (0.029)	-0.996
Adueqcoworo	Adult equivalent consumer worker ratio	1.561 (0.039)	1.508 (0.055)	1.613 (0.054)	-1.369
Farmzpadu	Owner operated land holding per adult equivalent (ha)	1.125 (0.038)	1.318 (0.061)	0.936 (0.042)	5.195***
Obs.	Number of households	544	269	275	
	Plot level variables	**Total plots**	**Rain-fed plots**	**Irrigated plots**	
Plottype	Plot type (1=irrigated)	0.204 (0.010)	----	----	-----
Plotsize	Plot size in ha.	1.198 (0.025)	1.400 (0.029)	0.409 (0.008)	19.545***
Yhat	Predicted	0.464	.469 (0.005)	0.443	3.256***

D1foodaveresi	Food deficit households predicted to be so	0.384 (0.012)	.384 (0.013)	0.383 (0.026)	0.180
D2foodaveresi	Food deficit households predicted to be food self-sufficient	0.144 (0.008)	.145 (0.009)	0.140 (0.018)	-0.668
Baekel	Soil type, 1=baekel)	0.210 (0.010)	0.222 (0.011)	0.165 (0.020)	3.481***
Walka	Soil type (1=walka)	0.224 (0.010)	0.198 (0.011)	0.325 (0.025)	-4.598***
Hutsa	Soil type (1=hutsa)	0.240 (0.010)	0.233 (0.011)	0.270 (0.023)	-2.896***
Mekayhi	Soil type (1=mekayhi)	0.325 (0.011)	0.347 (0.013)	0.240 (0.022)	3.808***
Slope1	Slope of plot (1=plain)	0.168 (0.009)	0.189 (0.010)	0.088 (0.015)	4.805***
Landqual1	Plot quality (1=good, 0=poor)	0.646 (0.011)	0.601 (0.013)	0.824 (0.020)	-7.985***
Ferzuse	Fertilizer has bee applied (1=yes)	0.311 (0.011)	0.315 (0.012)	0.298 (0.024)	0.059
Fertzperha	Fertilizer used (Kg/hectare)	10.476 (0.565)	8.513 (0.475)	18.152 (2.016)	-8.542***

	Variables				
Mktwalkdis	Walking distance to all weather roads	0.935 (0.006)	0.937 (0.006)	0.926 (0.014)	
Popdensi	Population density (Km^2)	104.514 (1.058)	105.296 (1.220)	101.455 (2.049)	0.852
Degua	Agro-ecology, 1=highland, 0=otherwise	0.221 (0.010)	0.228 (0.011)	0.190 (0.021)	1.209
Wdegua	Agro-ecology, 1=mid-altitude, 0=otherwise	0.488 (0.012)	0.495 (0.013)	0.463 (0.026)	0.897
Kola	Agro-ecology, 1=lowland, 0=otherwise	0.291 (0.011)	0.277 (0.012)	0.347 (0.025)	-2.064**
Rainfall	Average annual rainfall (mm)	779.535 (2.972)	781.150 (3.349)	773.223 (6.436)	0.920
Cv	Coefficient of rainfall variability	0.334 (0.003)	0.334 (0.004)	0.331 (0.007)	-0.287
Rainirri	Rainfall-irrigation interaction	141.226 (6.799)	0 (0)	693.290 (7.691)	-20.028***
cvirri	Rainfall variability-irrigation interaction	0.068 (0.003)	0 (0)	.331 (0.007)	-18.599***
loca1	Tabia (1=Adis Alem)	0.1765 (0.016)	0.160 (0.022)	0.193 (0.024)	-1.005
Loca2	Tabia (1=Kara-Adishawo)	0.175 (0.016)	0.234 (0.026)	0.116 (0.019)	3.657***
loca3	Tabia (1=Laelay Agulae)	0.127 (0.014)	0.052 (0.014)	0.2 (0.024)	-5.308***
loca4	Tabia (1=Adi-Ha)	0.175 (0.016)	0.1450 (0.022)	0.204 (0.024)	-1.804*
loca5	Tabia (1=Adidedena)	0.182 (0.017)	0.227 (0.026)	0.138 (0.021)	2.690***
loca6	Tabia (1=Maiadrasha)	0.165 (0.016)	0.182 (0.024)	0.1491 (0.022)	1.037
popdensi	Population density (people/Km^2)	100.118 (1.821)	96.539 (2.725)	103.619 (2.410)	-1.949*
Obs.	Number of plots	1419	363	1782	

* Significance level is 10%, ** significance level is 5%, *** significance level is 1%, Figures in parenthesis are standard errors.

Table 2: Probability of fertilize use

Variable	Variable description	Coefficient	Std. Error
hhaccirr	Household has access to irrigation (1=yes)	0.118*	0.070
plottype	Plot type (1=irrigated)	2.101***	0.450
hhage	Household age	-0.018***	0.004
hheadsex	Household sex (1=male)	0.822***	0.128
litrate	Literate household members	0.080***	0.025
femwl	Household member female labor	0.044	0.042
mamwl	Household member male labor	0.031	0.035
oxen	Oxen ownership	0.163**	0.066
totaltlu	Livestock ownership (tlu)	0.050*	0.027
farasso	Household's access to credit (1=yes)	-0.048	0.097
plotsize	Plot size (ha)	0.077*	0.046
farmzpadu	Owner operated land holding per adult equivalent (ha)	0.033	0.060
yhat	Predicted probability of food availability in June	-2.875***	0.959
D1foodaversi	Food deficit households predicted to be so	-0.290***	0.091
D2foodaversi	Food deficit households predicted to be food self-sufficient	-0.066	0.103
landqual1	Plot quality (1=good, 0=poor)	0.080	0.081
slope1	Slope of plot (1=plain)	-0.220**	0.101
Baekel	Soil type, 1=baekel)	-0.302**	0.120
Walka	Soil type (1=walka)	-0.038	0.124
Hutsa	Soil type (1=hutsa)	-0.093	0.124
rainfall	Average annual rainfall (mm)	0.026***	0.003
cv	Coefficient of rainfall variability	-14.711***	1.874
rainirri	Rainfall-irrigation interaction	-0.002***	0.001
cvirri	Rainfall variability-irrigation interaction	-1.114	0.758
Degua	Agro-ecology, 1=highland, 0=otherwise	4.133***	0.425
Wdegua	Agro-ecology, 1=mid-altitude, 0=otherwise	1.346***	0.193
mktwalkdis	Walking distance to all weather roads	-0.059	0.149
cons	Constant	-16.390***	1.499
	Number of observation	1782	
	Log likelihood	-859.800	
	Wald chi2(27)	1257.790	
	Prob > chi2	0.000	
	Pseudo R2	0.222	

Table 3: Intensity of Fertilize use

Variable	Variable description	Coefficient	Std. Error
Hhaccirr	Household has access to irrigation (1=yes)	8.517	8.246
Plottype	Plot type (1=irrigated)	163.562***	60.259
Hhage	Household age	0.824	0.563
Hheadsex	Household sex (1=male)	-9.795	13.736
Litrate	Literate household members	0.102	2.844
Femwl	Household member female labor	1.068	4.669
Mamwl	Household member male labor	5.193	3.515
Oxen	Oxen ownership	-11.969	8.369
Totaltlu	Livestock ownership (tlu)	-0.073	3.246
farasso	Household's access to credit (1=yes)	-12.054	12.181
Plotsize	Plot size (ha)	-64.328***	12.220
farmzpadu	Owner operated land holding per adult equivalent (ha)	-17.430**	7.878
Yhat	Predicted probability of food availability in June	120.973	117.566
D1foodaversi	Food deficit households predicted to be so	43.402***	12.930
D2foodaversi	Food deficit households predicted to be food self-sufficient	14.178	8.727
landqual1	Plot quality (1=good, 0=poor)	13.851	8.512
Slope1	Slope of plot (1=plain)	-17.063	12.598
Baekel	Soil type, 1=baekel)	1.050	12.174
Walka	Soil type (1=walka)	-18.946*	10.291
Hutsa	Soil type (1=hutsa)	-13.093	11.023
Rainfall	Average annual rainfall (mm)	0.860**	0.368
Cv	Coefficient of rainfall variability	-592.664**	246.848
Rainirri	Rainfall-irrigation interaction	-0.228**	0.104
Cvirri	Rainfall variability-irrigation interaction	147.986*	88.269
Degua	Agro-ecology, 1=highland, 0=otherwise	112.454**	54.475
Wdegua	Agro-ecology, 1=mid-altitude, 0=otherwise	12.659	25.451
Mktwalkdis	Walking distance to all weather roads	4.970	17.206
Cons	Constant	-571.251***	217.913
	Number of observation	555	
	Log likelihood	-2396.732	
	Wald chi2(27)	85.400	
	Prob > chi2	0.000	

Appendix 1: Probability of food availability in June (Probit model)

Variable	Variable description	Coefficient	Std. Error
hhage	Household age	-0.010**	0.004
hheadsex	Household sex (1=male)	0.184	0.154
litrate	Literate household members	-0.010	0.046
femwl	Household member female labor	0.036	0.067
mamwl	Household member male labor	-0.039	0.067
oxen	Oxen ownership	0.111	0.078
totaltlu	Livestock ownership (tlu)	0.069**	0.027
farasso	Household's access to credit (1=yes)	-0.163	0.122
adueqcoworo	Consumer worker ratio (adult equivalent)	-0.060	0.083
farmzpadu	Owner operated land holding per adult equivalent (ha)	0.076	0.074
loca1	Tabia (1=Adis Alem)	-0.030	0.205
loca3	Tabia (1=Laelay Agulae)	-0.987*	0.599
loca4	Tabia (1=Adi-Ha)	-0.584	0.550
loca5	Tabia (1=Adidedena)	0.279	0.201
loca6	Tabia (1=Maiadrasha)	-1.041	1.178
popdensi	Population density (people/Km^2)	0.013	0.011
cons	Constant	-1.012	0.754
	Number of observation	544	
	Log likelihood	-344.833	
	Wald chi2(16	47.950	
	Prob > chi2	0.000	
	Pseudo R2	0.074	

Appendix 2: Classification of soils in Tigray

Local name	Scientific name	General characteristics
Baekel	Cambisol	• Normally found in moderately steep slope, good drainage, poor fertility, low compaction, Easy to plough (good workability)
Walka	Vertisol	• Normally found in valley bottom, good soil depth, rich in chemical soil minerals, poor drainage, difficult to plough (tough workability)
Hutsa	Leptosol	• Extremely poor soil fertility, found in steep slope (susceptible to erosion), high drainage, low water absorbing capacity, shallow soil depth and easy to plough.
Mekayhi	Luvisol	• Found in moderate slope, deep soil, well drained, moderate fertility, easy to plough (good workability)

Source: (Nyssen *et al.*, 2007)[86]

[86] Additional information was used based on informal discussion with a soil scientist, who is familiar to the region.

DETERMINANTS OF TECHNOLOGY ADOPTION AND INCOME DIVERSIFICATION: THE CASE OF NORTHERN PART OF ETHIOPIA

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1. Introduction

Ethiopia has an area of 1.12 million square kilometers and is the ninth largest country in Africa. About 66% of the total land is potentially arable out of which only 22% is currently under cultivation and only 4% of the land suitable for irrigation is currently utilized (Beyene, 2008). The irrigation potential of the country is over 3.5 million ha (Legesse, 1998). With regard to its livestock population, Ethiopia stands first in Africa and tenth in the world (ibid). During 1960 to 2000 the amount of arable land under cultivation has risen marginally, but the population of households engaged in agriculture has tripled, resulting in a steady decline in the land-to–person ratio, from 0.508 ha (1960-69) to 0. 252 ha arable land per person (Jayne eat al, 2005). During the same period food crop productivity has remained stagnant, with an average productivity falling below 1 ton per hectare, while the population was growing at about 2.6 % per year. As a result real agriculture GDP per capita declined from its Birr 700 in 1962 to birr 500 in 2004 (Ministry of Finance and Economic Development -MoFED, 2002). Ethiopia is one of the oldest nations where agriculture has been practiced for more than 11, 000 years (Abate, 2007).It belongs to one of early civilizations where crop and livestock have first been domesticated and used by mankind. Agricultural extension service in Ethiopia is said to have started during 1900-1910, where rubber and eucalyptus trees were introduced and irrigation based modern commercial farms were established (ibid).

Why then this long-term stagnation amidst all sorts of natural resources endowments and long history of farming experience. Five key challenges to promoting agricultural growth can be identified: a geographical and infrastructure challenge, serious environmental degradation, frequent exposure to risk and vulnerability, the challenge of providing appropriate and profitable technologies for a highly heterogeneous sector and low labor mobility and the very small size of the rural non-farm sector (Delgado, 1995; Byerlee et al, 2005). All these problems can be summarized, as luck of proper economic policy in general and rural and agricultural development policy in particular.

Especially beginning 1950s, various extension intervention programs have begun either in the form of fully fledged programs or as pilot projects. Unfortunately, the impacts of all of these development interventions were not that much significant. There were only few changes such as the introduction of artificial fertilizer and the use of improved seeds and animals. But in general productivity per unit area was not significantly improved over the traditional (Abate, 2007). Whatever effort done, was focused only on staple crops, as if agriculture is solely crop production, marginalizing the other agricultural commodities, let alone to consider non-farm income sources. A new extension program called Participatory Demonstration and Training Extension System (PADETS), then after *package approach* was introduced in 2003. The extension program, for the first time tried to provide services ranging from crop production, livestock development and non-farm income generating interventions.

Until recently, the rural non-farm sector was the wrongly understood component of the rural economy; by policy makers and planners in the developing world. In the 1950s and 1960s during the heyday of import substitution and industrialization, a common view was that rural non-farm employment is a low productivity sector producing low quality goods and services that would wither away as a country develops and income rises (Lanjouw and Lanjouw P. 2001; Islam N., 1997)

To some extent, opinion has changed over the last three decades. Rural non-or off rural sector or household income diversification as research area and policy intervention has attracted the attention of researchers and policy makers (Barrett et al., 2006). The main reasons are basically two. The first reason is that the failure of the two dominant sectors amidst high expectations: the agriculture sector to reduce poverty in the rural areas and the urban based industrial sector to absorb the migrant rural labor force. The second reason is the late recognition of the important role non-farm income is making, to rural household livelihoods; and emergence of arguments which favors the promotion of rural nonfarm sector (See Islam, 1997).

It seems, with the understanding of the above historical context of the agriculture sector's performance and convinced by the non-farm favoring argument, the Ethiopian Government adopted an agricultural extension service that tries to combine a service support system to address both farm and non-farm based activities in 2003.

The *package approach the type of extension practiced in Tigray Region,* is based on the principle of providing farmers a list of technology package choices (dairy, fattening, poultry, apiculture, petty trade support credit facilities, etc), and farmers are encouraged to pick the type of technology that fits their situations (Gebremedhin et al, 2006). Farmers given their own resource endowments and other external factors are made to reveal their choice package and get credit service and technical support by a village based extension workers. Accordingly, until the end of 2008, the program has covered more than 90% of the total 800, 000 farming household, in the region. (Tigray Bureau of Rural and Agricultural development -TBORAD, 2008). In view of the technical capacity and logistical support available at the grassroots level the coverage as well as the pace is very ambitious.

Various studies have been conducted in the areas of income diversification; mainly focusing on non-farm income diversification: characterization, determinants of income generation strategies, poverty analysis and different policy recommendations have been documented (Reardon, 1997; Ellis, 1998; Joshi et al., 2002; Ersado, 2003; Minot et al., 2006). Impact assessments have also been done to see the effect of agricultural extension systems (Feder et al., 1985; Evenson and Bindlish, 1993; Evenson and Bindlish, 1997). However, we did not come across a literature that focused on an area, such as the package approach and how it conditioned technology choices and the income diversification capabilities of the people. Hence, the study have tried to uncover, how the package approach is influencing the technology adoption behavior of beneficiary rural households, factors explaining households participation in the extension program, what choices participants made and the variables explaining the choices; and based on the findings some policy recommendations are outlined.

2. Description of the study area

The Regional State of Tigray is located in northernmost part of Ethiopia and is one of the nine federal states with an estimated area of 51560 km^2 (TBORAD, 2008). The altitudes in the region lie between 300 meters above sea level (masl) in the east to above 3000 masl in the north and central part. Hence, it covers three agro-climatic zones: lowland (*kolla*) which falls below 1500 m.a.s.l; medium highland (*woina dega*) 1500 to 2300 m.a.s.l and upper highland (*douga*) 2300 to 3200 m.as.l.

The regional population, according to 2007 census, is 4.6 million with an average annual growth rate of above 2.6%. (CSA, 2008). The mean annual rainfall in the region varies from 200 mm in the extreme east bordering Danakil Depression to over 1900 in the South western part of the region (TBORAD, 2008). The mixed faming, subsistence oxen plough single cropping cereal crop dominated (productivity below 1 ton per ha) combined with livestock rearing production is the typical farming system. According to the agricultural sample census report (ibid), the average farm size of holder in the region ranges from 0.6 in the Eastern part to 1.2 in the western part of the region, and generally average land holding decreases with altitude and vise versa. As a result the farm produce is not in a position to support for more than 6 months a household of 5- 6 family size.

3. Technology adoption and the income diversification concept

To understand how technology adoption is contributing to income diversification at the household level, the two basic concepts: technology adoption and income diversification should be reviewed. Hence, in this section a review of relevant conceptual and theoretical foundations of the two concepts will be presented

3.1 Technology Adoption

The issues of adoption of technological innovations and adoptions in agriculture have attracted considerable attention among development economists because the majority of the population of less developed countries derives its livelihood from agricultural production. In view of the growing food demand new technologies hoped to offer an opportunity to increase production and income (Feder et al, 1985). The basic concepts in the theoretical framework of technology adoption are innovation, adoption and diffusion.

According to Rogers, the four main elements that affect the adoption rate are: the innovation, communication channels, time and the social system. Moreover, seven innovation attributes were identified which affect the adoption intensity. These are relative advantage, communicability, compatibility, complexity, trialability, divisibility and observability of the technology (Tornnatzky and Klein, 1982; Rogers, 1962). Some tried to explain the adoption rate of a given innovation, to increase as the degree of uncertainty and imperfect information is reduced (Hiebert, 1974); communication improved (Feder, 1985); positive relationship between better physical environment and adoption (Nelson and Phelps, 1966; and Welch, 1970; in Feder, 1985); better physical features such as soil quality and the human capital endowment of the household (Fischer and Lindner 1980). In another work, Lindner (1980) showed the positive relationship between technology adoption (information acquisition) and farm size. Many studies tried to stress the role of communication and attempted to drive analytically an S- shaped diffusion path by assuming that the driving force of the diffusion process is imitation (Griliches, 1957; Rogers, 1962; Mansfield, 1961; Lekvall and Wahlbin, 1973; Hernes, 1976; Lerviks, 1976).

The discussion of adoption behavior and the determinants of technology adoption can be broadly grouped into three paradigms. The paradigms are: the innovation-diffusion model, the adoption perception and the economic constraint models (Uaiene, et al; 2009).

The underlying assumption of the innovation-diffusion model is that the technology is technically and culturally appropriate but the problem of adoption is one of asymmetric information and very high search cost (Feder and Slade, 1984; Smale et al., 1994). The second paradigm, the adopters' perception paradigm, on the other hand, suggests that the perceived attributes of the technology condition adoption behavior of farmers. This means that, even with full farm household information, farmers may subjectively evaluate the technology differently than scientists (Kivlin and Fliegel, 1967; Ashby and Sperling, 1992). Thus, understanding farmers' perception of a given technology is crucial in the generation and diffusion of new technologies and farm household information dissemination. The economic constraint model contends that input fixity in the short run, such as access to credit, land, labor or other critical inputs limits production flexibility and conditions technology adoption decisions (Smale et al., 1994).

In this study, we adopted the three paradigms approach to understand farmers behavior in joining the extension service system, as each of the elements do have a role in influencing in the adoption decision processes. This is consistent with some of the recent studies in the area (Gemeda et al., 2001, in Uaiene, et al; 2009).

3.2 Income Diversification

It is important to note that income diversification is not synonymous with livelihood diversification. The latter is a process by which households construct a diverse portfolio of activities and social support capabilities in order to improve their living standard and manage risk. Income diversification is one of components of livelihood strategies (Ellis, 1998, Ersado, 2003). The term "income diversification" has been used by different authors to describe four distinct but related concepts (Minot et al., 2006).

The first definition of income diversification refers to an increase in the number of sources of income or the balance among the different sources. Hence, a household with two income sources is more diversified than one source or a household with two income sources each contributing half of the total is more diversified than a household with two sources, one that accounts for 90 percent of the total (Joshi et al., 2003; Ersado, 2003; Minot et al., 2006; Dercon, 1998). A second definition of income diversification concerns the switch from subsistence food production to the commercial agriculture. Such type of diversification is changing the subsistence oriented production into cash crop production (Delgado and Siamwalla, 1997). Third, income diversification is used to describe expansion in the importance of non-crop or non-farm income. Here, non-farm includes both off-farm wage labor and non-farm self-employment (Reardon, 1997; Escobal, 2001). Finally, income diversification can be defined as the process of switching from low-value crop production to high-value crops, livestock, and non-farm activities (Minot et al., 2006).

The main objective of our study is, first, to see whether the adoption and technology choice decisions are done simultaneously or not. Second, which factors of the household capitals: human, locational, financial, natural and social are influencing the response variable? And third, to see if the extension program contributing towards household income diversification.

Hence, as the first definition is consistent with the stated objective of the research, with some fine tuning will adopt the first income diversification definition. Accordingly, the study has adopted two broad income categories: farm and non-farm. Farm income includes crop and animal resource income sources. Non-farm-income is made to include wage, business; migration and transfer income. Crop income includes all income coming from cereals, oil seeds, and fruits and vegetables. Livestock income refers any income generated by the household from livestock by-product, livestock sells, or rental services (such as ox or pack animal rental services). Wage income refers to all types of income derived from both agricultural and non-agricultural wage employment, around some one's homestead. Migration income consists of send back and brings back income by migrant labor, but nationally. Any income received by the household in the form of transfer from governments, non-governments (food aid, cash or in kind), friends and relatives is classified as transfer income. Business income includes any income generated from business activities run and owned by the family located in their home or nearby towns. Finally, in this study household is conceived as the social group which resides in the same place, shares the same meals, and makes joint or coordinated decisions over resource allocation and income pooling (Meillassoux, 1981; in Ellis, 1998).

Given the above conceptual framework, the following hypothesis are hypothesized and tested. First, extension participation and technology choice decisions are made in two-steps. First the households decide to participate in the extension program and then select the package types (cropping, dairy, sheep and goats, and others) they want to adopt. Second, consistent with the human theory, education and age are expected to positively and negatively influence technology adoption process respectively. Third, household wealth (land and livestock holdings) status promotes the adoption of modern technologies. Fourth, locational variables are expected to have some mixed results on the technology adoption and selection decision. While distance to market is expected to have an inverse relationship with cropping (which includes improved seed, fertilizers and irrigation related technologies) but distance through its locational attributes such as access to grazing will have a positive relationship with livestock related technologies. Finally, given the nature of the non-farm income job opportunities of the research sites, extension program participants' households are less diversified than non-participants households

4. Data and methodology

The research site is located in the Geba catchment with in Tigray[87] region. The site covers 4600 km^2 area, 10 Woredas and 168 Tabias. To reflect the contrasting agro-climatic zones of the catchment four Woredas; one from lowland, one from highland and two from Middle highland were selected. Two Tabias were selected from each Woreda.

Households were assigned again to each Tabia based on population size and the number of farmers' participation rate in the agricultural extension service. Accordingly, 389 participants and 346 non-participants household were administered. Questionnaires were tested and validated before survey work. Simple statistical description, multinomial logit, and OLS/Tobit models are used to answer the research questions, test hypothesis and drive some conclusion on the income diversification strategies of the rural communities in the research areas. The variables used for the analysis are indicated in Table.1

Table 1. Description of the explanatory variables

Variables	**Description**	***Nature of the Variable***
Malehhh	Sex of the head of the household (1 male 0 female)	Dummy
AgeHHhead	Age of the head (continuous)	Continuous
Hhhedulevel	Educational level of the head of the household	Continuous
Fsize	Family size	Continuous
Oxquantity	Number of ox a household own	Continuous
Lnlag Livestock(2003)	*Lag Livestock resource holding of the household*	*Continuous*
lnFixedasset	Fixed asset (farm equipments, tools etc…)	*Continuous*
Lnlag Landsize(2003)	Lag Land holding size in 1996(2003/2004) i.e., before the launching of the extension program	Continuous
Land*livestock	An interaction variable of landsize and livestock	continuous
landsize	Household land in tsemad(1ha=4 tsemad)	Continuous
Edirmembership	1If the hh is a member of edir 2 otherwise	Dummy
Tabiadismekelle	Tabia distance to Mekelle market	Continuous
TabiaDisWoreda	Tabia distance to Woreda market	Continuous
Tnonfarmincome	Total nonfarm income of the household	Continuous
Transferincome	1 If the household had any transfer income and 0 otherwise	Dummy
Ownbusiness	1 if the Household has business 0 otherwise	Dummy
Accesswage	1 if any member of the household worked for wage and 0 otherwise	Dummy
Migrantmember	1 if the household had any migrant member 0 otherwise	Dummy
Extenp01	1 participant hh in agricultural extension 0 otherwise	Dummy
TPackcost	Total package cost	Continuous

[87] Region is an administration territory equivalent to Province. Woreda is the next administration strata and equivalent to County. Tabia is the lowest government unit.

5. Results and Discussions

5.1 Description of the Extension Participation and Package Choices.

The descriptive statistics summary results (Table. 2) for participants and non-participants measured in terms of household characteristics, wealth indicators and access to non-farm employment opportunities show some differences. The household characteristics includes: male/female household headship, age (a proxy for agricultural experience), household head educational level and family size. Except in schooling variable, participants showed relatively better human capital ownership compared to non-participants. Accordingly, 34 % of the nonparticipants compared to 20% of participants are headed by female, younger by 2 years, and do have small family size and more or less the same household head educational status. The better human capital could be the driving force for the wealth difference observed between the two groups as well as the outcome of program participation.

In terms of real property indicator variables, participants do own 1 tsemad land, Birr 310 worth livestock, Birr 1978 worth of fixed assets, more than non-participants; showing the wealth superiority of participants over non-participants. With regard to locational and distance to markets, more or less participants and non-participants did not show significant differences. Access to non-farm income opportunities (access to wage employment, income transfer, participation in business and migrant member in the household), except in the transfer income where the non-participants showed 10 percent higher opportunities than participants, the participant households revealed marginal advantage over the non-participant households. This is mainly attributed to the differences in human, physical and natural capitals observed between the two groups; and better opportunity of participants to safety net public work program, so as to encourage participation in the extension program and to ensure the repayment of the credit of the extension program.

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Table.2 Descriptive statistics of the explanatory variables of the technology adoption and income diversifications

	Participants (obs=388)		Non-participants (obs=346)		
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**	**t-statistics**
AgeHHhead	44.93299	12.88453	42.81214	16.25831	-2.0827**
Malehhh	.7989691	.4012886	.6618497	.4737651	-4.2922***
Hhhedulevel	.9458763	1.462594	.8208092	1.390329	-1.3564*
Fsize	6.03866	2.121881	4.635838	2.201525	-1.1075
Landsize	4.895206	3.425594	3.804644	3.216831	-4.4433***
lagLandhol(2003)	4.167191	3.217567	3.075578	3.108495	-4.4984***
lagLivetock(2003)	1612.871	1052.551	1310.688	1580.049	0.9570
Oxquantity	1.244845	.9668133	1.127168	1.038958	-1.7778**
Edirmembership	.2912371	.4549192	.1618497	.3688463	-4.1711***
Fixedasset	12446.33	20475.34	10648.63	30507.86	-1.0483
Tabiadismekelle	72.1134	30.90333	68.07225	28.07997	-1.7554**
Tabiadisworeda	13.13144	8.999684	11.34538	8.954309	-2.6531***
Tnonfarmincome	2414.124	3392.86	1976.172	2055.955	-2.1042**
Accesswage	.7525773	.4320716	.7109827	.4539625	-1.190
Ownbusiness	.2164948	.4123871	.265896	.442449	1.641*
Transferincome	.2293814	.4209779	.3468208	.4766474	3.612***
Migrantmember	.1391753	.3465762	.1271676	.3336431	-0.4199
Land*livestock	7013.899	7759.754	5425.728	10557.76	-2.195**
Tpackcost	2565.262	1277.351			

Finally, in terms income diversification index, participant households do revealed higher level (though marginal) levels of 0.43 index compared to 0.41 for non-participants.

5.2 Determinants of Extension Participation/Choices and Income Diversification

Model Design

Numerous empirical studies have examined farmers' participation behavior using logit models (Adeogum et al, 2008; D'Souza et al, 1993). Multinomial logit to understand the determinants of different technology choices (Zepeda, 1990). These studies, however, are criticized for their assumption that the conditioning variables influence the adoption decision and the technology choice decisions in the same way (Lin and Schmidt, 1984). This means, a variable that increases (decreases) the probability of adoption also increases (decreases) the probability of choosing all types of the technology choices for farmers who participate in the package program. However, this assumption may not hold at some cases. For example, farmers who are skeptical and less risk averse may not pick costly technologies, despite their participation.

In this paper, we will consider two estimation models: a conventional one-step model, which assumes that the participation decisions are made simultaneously with the technology type selection; and a two-step model, which assumes that the technology selections are made conditional on the adoption decision.

One-step Model In the one-step model, the adoption decision is modeled jointly with type decision, in the sense that the same variables (×j) affect both decisions. Hence, the two decisions becomes the standard multinomial logit/probit model. With the strong assumption about the distribution of the error terms, that they are independently and identically distributed (IID), the multinomial logit model which is appropriate for unordered response of more than two outcomes (Long, 1997; Wooldridge, 2002), can be written as:

$$\Pr(Y_i = m / X_i) = \frac{\exp(X_i \beta_m)}{\sum_{j=0}^{J} \exp(X_i \beta_j)} \quad m=0, 1, 2, 3, 4 \qquad (1)$$

Where m_i=0 farmer choices of no adoption, m_i=1 cropping choice, m_i=2 sheep/goats choice and m_i=3 dairy choice and m_i=4 others (which includes poultry, bee hives and petty trade). To identify the above model, we must impose constraints on the $\beta's$ by setting one of the $\beta's$ equal to 0, such as β_0=0 or β_j (Long, 1997). Adding this constraint to the model results in the probability equation:

$$\Pr(Y_i = m / X_i) = \frac{\exp(X_i \beta_m)}{\sum_{j=1}^{J} \exp(X \beta_{j_i})} \quad \text{Where } \beta_0=0 \qquad (2)$$

Since exp ($X_i\beta_0$= exp(X_i0)=1, the model is commonly written as

$$\Pr(Y_i = 0 \mid X_i) = \frac{1}{1 + \sum_{j=1}^{J} \exp(X_i \beta_j)} \qquad (3)$$

$$\Pr(Y_i = m \mid X_i) = \frac{\exp(X_i \beta_m)}{1 + \sum_{j=1}^{J} \exp(X \beta_{j_i})} \quad \text{For } m>0 \tag{4}$$

Two-step model The two-step estimation model presented in this paper (Table.3), considers package type selection decision, conditional on the participation decision. The farmer first decides whether to participate in the package program and then chooses the package type that optimizes his utility. The logit model, which is based on cumulative logistic probability function is computationally easier to use than other types of model and is also has the advantage to predict the probability of farmers technology adoption. The decision to participate or not responses are discrete (mutually exclusive and exhaustive) and therefore, a binary logit model can be specified as follows:

$$\Pr(Y_i = 1 \mid X_i) = \frac{\exp(\beta Xi)}{[1 + \sum \exp(Xi\beta)]} \tag{5}$$

And the multinomial logit model

$$\Pr(Y_i = j \mid X_i) = \frac{\exp(Xi\beta)}{[1 + \sum \exp(Xi\beta)]} \quad , j=0,1,2,\ldots 4 \tag{6}$$

The separate estimation of the logit model was expected to show different variables that influence the adoption decision than the technology selection decision. In implementing the two-step model, we first estimated the probability of participation and then estimated the truncated multinomial logit model using the same variables plus the predicted outcome of participation and cost of technology variable.[88] As expected consistent with the two-step hypothesis theoretical construct, we found that predicted probability of participation significantly influences the technology choices. Finally, to see how extension service participation influencing households' income diversification level, OLS and Tobit models are used.

5.3 Model Results

The model results[89] did not support the households' one-step decision process hypothesis; and alternatively the two-step decision is accepted. In the adoption decision model almost all the variables, except the locational and cost of technology variables were found to be significant to influence the adoption decision of the household. The human capital: age, and education level of head of the household,

[88] . these two variables were not part of the logit estimation
[89] See detail under model design section

family size; lag land size lag livestock ownership; and edir (a sort of social capital) positively influence the adoption decision, which is consistent with our apriori hypothesis. The only variable which is significant and negatively influencing the household adoption decision is the interaction variable, landlivestock.

5.4 Discussions

Participation and Technology Selection Decision. Following the conceptual framework and hypothesis formulated logit and multinomial logit models are used to identify the determinants of household adoption decision and factors that conditioning the different technology choices. However, before we proceed to the interpretation of model results, brief highlights regarding the overall fitness of the model and relevant tests run is in order.

First, the likelihood ratio (χ2) value of 95.44 is greater than the critical chi-square values ($\chi^2_{0.01,36}$) of 89.343 at the 1% level of significance. This test confirms that all the slope coefficients are significantly different from zero. Hence, the alternative hypothesis is thus accepted at these levels of significances. Second, as the multinomial logit model has a strong assumption of independence of irrelevant alternatives, therefore we carried out Hausman test which revealed the assumptions of IIA has not being violated. To examine the outcomes are distinguishable, we carried out Wald test which suggested that we cannot combine any package choice and the outcomes are distinguishable (Long, 2006).

Finally, to deal with endogeneity, variables which are less prone to endogeneity problem have been selected. For instance, most of the demographic characteristics sex, age, and education level of the head of the household and family size are clearly variables less likely to change following the decision to participate in the extension program. More over for the same reason wealth indicators, such land and livestock their lag form of the respective variable are used. Edir membership is a variable which is believed to have less change after extension participation. Locational variables are still less prone to endogeneity problems.

The results of the parameter estimates of the MNL provide only the direction of the effects and level of significance, not the actual magnitude of influence or probabilities change of the dependent by the independent parameter. Thus, to facilitate the understanding and analysis, the marginal effects from the MNL are estimated (Table .3). The set of explanatory variables varies across the choices in terms of the level significance and signs. For the cropping choice the only insignificant variables are: locational and cost of technology.

The coefficient for age, consistent with the human capital and inconsistent with the adoption theories is positive through out. According to the adoption theory, younger farmers have a longer planning horizon and are most of the time less risk averse than older, established farmers. If a household head is over 44 years old, it increases the probability of adoption by 2.2% compared to non-participants and 2.6 percent, 9.1 percent and 0.6 percent more likely to adopt cropping, dairy and others packages respectively as compared to the sheep/goats categories. This is inconsistent with the results of previous technology adoption studies (D'Souza et al, 1993; Zepeda, 1990; Gebremedhin, et al., 2009) but consistent with previous studies (Adesina and Baidu-Forson, 1995; Teklewold et al., 2006). Household head education is significant at 1% level and is positively related to adoption. Suggesting that the literate farmers are more likely to participate in the extension program than the illiterate farmers. This result corroborates Chianu and Tsujii, 2004; Alene and Manyong, 2007; Alene et al., 2000. Education is significant only on the adoption of crop package. This is mainly, as the average educational attainment in the research site is very low which is below first grade level, education as a variable could not have the power to explain the differences technology choices.

The coefficient for family size is positive and statistically significant at the 10 % and 5% level for cropping and dairy but not for other category. The result is consistent with labor intensive nature of the packages. Households with more adult labor force size are more likely to be adopters than families with lower family. Accordingly, households having a family size above 6 persons unit are more likely to have 3.7 %, and 11.7% probability to adopt cropping, and dairy and than sheep/goats. The family size, which includes also dependents are not pure dependents. In rural areas like the research sites, livestock herding, fetching of fuel wood and water for the domestic services; and even the main agricultural activities are done using child labor. As a result, the larger family size, is an asset for the household, in dairy and sheep/goats rearing activities.

As anticipated expected, lag land size and lag livestock holding, it increases the probability of participation in the extension program. Accordingly, each additional unit of land above the mean value is likely to increase the probability of program participation by 15.7% (compared to non-participants) and dairy technology selection compared to the base category (sheep/goats). On the other hand, the livestock variable increase the probability of participation by 2.4 % and farmers' preference for cropping, dairy and other technology by 5.2%, 6.4% and 2.5% respectively. This shows the interdependence of livestock and farm size resources via feed and animal power need of agricultural activities.

Edir[90], a social capital, is positive and significant for all the technology types. To reduce uncertainty and risks, early adopters must acquire and process a better quality and a larger quantity of information than followers and late adopters. In rural context, agricultural extension service and other social net work such as Edir are the most relevant sources of information. Accordingly, Edir members are 10.96%, 1%, and 7.9% more likely to adopt cropping, sheep/goats and dairy packages compared to non-members, respectively.

Locational variables, which include distance to main market (the regional capital city – Mekelle) though not significant in the adoption model, it is still significant in the choice model. Hence, it reduced the probability of farmers' selecting cropping and other technology categories compared to the base technology choice. The negative and significant (with marginal effects of 0.13%) relationship of cropping and other (which includes petty trade, poultry etc.,) package supports the notion that farmers with superior access to markets are in a better position to adopt and produce for market (Abdulai and CroleRees, 2001). Whereas, the positive and significant (with marginal effects of 3%) relationship with sheep/goats and dairy (though not significant) packages shows, access to grazing (which is positively related with distance) is more important than market access to engage in the diary package.

Finally, the coefficients for total nor-farm income is positive but insignificant effect on the participation decision, which indicates the *stress-push* nature of the diversification and limited opportunities for employment in the study areas and families rely heavily on farm income to acquire many of the required inputs. Whatever amount earned is used for immediate consumption of the household. This is consistent with Alene et al., (2000) in contrast of earlier findings (Stampini, et al 2008). According to these studies, they found that farm households with non-farm income spend significantly more on seeds, services, hired labor and livestock inputs.

[90] Edir is a community –based institution established on mutual interest of members and its primary objective is to support members during the time of crises such as death of family members.

Note * indicates 10% , ** 5% and ***1% level of significance and β and γ are coefficients and marginal effects respectively

Variables	Logit		Multinomial logit model for technology choices					
			Cropping		Dairy		Others	
	β	γ	B	γ	β	γ	β	γ
AgeHHhead	.0876749**	.022021	.5327186*	.02588	.5799462**	.0908169	.2333034	-.0201368
agesqr	-.0009332**	-.0002335	-.0053354*	-.0002342	-.0061662**	-.0009963	-.0023534	.0002224
Hhhedulevel	.20909***	.0506864	1.34793**	.0599902	1.383308***	.1784512	1.072067*	.014891
Fsize	.1777011***	.0425182	.8872876*	.037292	.9235424**	.1171034	.7613709	.0159658
Lnlaglandsize(2003)	.6465067***	.1566596	2.862795	.030103	4.246306***	.6805528	2.584911	-.0130596
Lnlaglivestock(2003)	.0993467***	.0241284	.8610356***	.0515936	.6846471***	.0639788	.7031281**	.0244883
Land*livestock	-.000037***	-8.99e-06	-.0002451**	-.0000113	-.0002542***	-.0000346	-.0001717	3.74e-07
Edirmembership	.6528282***	.1558212	5.060884***	.2516114	4.400337***	.308489	3.44542*	-.0162098
Tabiadisworeda	-.003839	-.0011164	-.1104866***	-.0134594	.0002026	.0112963	-.0571135**	-.0045952
Tnonfarmincome	.0000416	.0000106	.0002038*	8.67e-06	.0002126**	.0000274	.0001688	2.88e-06
Tpackcost			-.0001336	-.0000186	.0000568	.0000318	-.0001358	-.0000175
PrAdoption			-26.74085**	-1.003092	-29.30732***	-3.838478	-23.77071*	-.4908179
_cons	-4.257146***	.8587162	-11.34479*		-11.93814**		-4.507263	

Logit	MNLM
Number of obs = 734	Number of obs = 364
LR chi2(10) = 125.96	LR chi2(36) = 119.43
Prob > chi2 = 0.0000	Prob > chi2 = 0.0000
Log likelihood = -444.58846	Log likelihood = -419.65339
Pseudo R2 = 0.1241	Pseudo R2 = 0.1246

Levels of Income Diversification. Based on the theoretical framework and hypothesis formulated Tobit and OLS models are used to identify the factors that conditioning the degree of income diversification at the household level. To estimate the determinants of household income diversification, conditional on adoption, we used OLS and Tobit models (Table.4). However, before we proceed to the interpretation of model results, establishing the grounds to conclude that the estimates we obtained have the desired statistical properties, and the specified model is not going to lead us towards misleading inference; brief highlight regarding the situations of the basic assumptions of the model and relevant tests run is in order. Running a regression model is based, among other things, on four basic assumptions: *linearity*, *orthogonality*, *homoscedasticity* and *normality*. When these assumptions are not met the results my not be trustworthy, resulting in over or under-estimation significance or effect size(s). Following the statistical tests and making the necessary corrective measures the overall model fitness and reliability of results have substantially improved. Another common statistical goodness of fit is the R^2. A high value of R^2 suggests that the regression model explains the variation in the dependent variable well. The value R^2 0.3167 (OLS) though not a high one, it is characteristics of many cross-sectional studies that use household data, at a given point in time (Griffiths, et al, 1993). A low R^2 means low predictive capacity of the model, but it does not necessarily mean that the coefficients cannot be reliably estimated. Finally, all coefficients (except fixed assets) are having the expected signs and most of the variables are statistically significant.

When we compare the results of OLS and Tobit models we notice that the coefficients are very close to each other. This is because, few observations are hitting the upper or lower limits for the Simpson index of diversity (SID). Thus, when few observations are hitting these limits, OLS regression analysis will give us unbiased and efficient coefficient estimates. As a result, OLS coefficients are used for our analysis.

We can broadly classify the significant variables into household characteristics (sex and level of education of the head of the household), natural capital (land size) access to non-farm income (transfer, wage, migration and own business,), household wealth indicators (livestock and fixed asset) and locational variables (distance to Woreda market).

Male headed households positively increase their level of diversification[91] by 4.1% and is significant at 5% compared with female headed households. Level of schooling of the Head of the household is inversely related to dependent variable, the type of

[91] The Simpson index of diversity (SID) is defined as:

SID=1- $\sum V_i 2$; Where V_i is the proportion of income coming from source i. the value of SID always falls between 0 and 1. If the household dependes just on one source of income, Vi=1, so SID=0. As the number of sources increases, the shares (Vi) decline, as does the sum of the squared shares, so that SID approaches 1 (Minot, et al, 2006 alternative sources of income, such as non-farm employment opportunities are not attractive to literate heads of households. Fixed asset and lag livestock holding, including quantity oxen (oxquantity) do influence household income diversification positively and significantly. Accordingly, 1.3% increases in fixed asset increases the level of income diversification index by 1 unit. All the variables indicating access to non-farm income (transfer, wage employment, income from migrant labor member and own business) were found to be positive and significant at 1 %, indicating the importance of the meager non-farm income towards household income diversification. Accordingly a household with access to wage, have own business, reported to have transfer income and migrant household member increases level of income diversification by 19.2, 11.33, 2.8 and 4.6 the level of household diversification index respectively.

Finally, the predicted probability of participation in the extension service positively and significantly influenced the level of diversification of the households.

Table 4. OLS and Tobit estimates of determinants of income diversity (SID)

Variables	Logit estimate		Tobit estimate		OLS estimate	
Variables	Extenp01		SID		SID	
	β	SE	β	SE	β	SE
AgeHHhead	.0031203	.006575	-.0001185	.0005813	-.0001329	.0005562
Malehhh	-.1210714	.2096433	.0408338**	.0185297	.04104**	.0177734
Hhhedulevel	.2093574***	.0675614	-.0086832	.0056364	-.0089763*	.0054117
Fsize	.2456843***	.0456035	-.004125	.0052904	-.0036673	.0050699
Landsize			-.0100568***	.0028771	-.010525***	.0027665
Lnlglandsize(2003)	.5250133***	.1587285				
Lnlaglivestock(2003)	.1202202***	.0343459				
Land*livestock	-.0000479***	.0000149				
Oxquantity			.0017341	.008468	.00177	.0081338
Edirmembership	.8911843***	.2085413				
lnFixedasset			.0139032**	.006243	.0129944**	.0059945
Tabiadismekelle	.0116039***	.0033542	-.0004702	.0003467	-.0004824	.0003329
Tabiadisworeda			-.002901***	.000939	-.0029733***	.0009009
Tnonfarmincome	.0000626*	.0000364				
Accesswage			.2094486***	.0171614	.1921791***	.0163196
Ownbusiness			.1190671***	.0161643	.1133156***	.0155475
Transferincome			.0310028*	.0159085	.0283982*	.0152795
Migrantmember			.0488527***	.0179374	.0463449***	.0172642
Inversemill			.1977503***	.0582109	.1888496***	.0559052
Constant	-3.671257***	.5041687	.1117323	.0685434	.146108**	.0656389

sigma	.1819959	.0049564

6. Summary and conclusions

In this paper, we have examined how farm characteristics affect extension participation decisions. We develop and estimate econometrics models in which decisions about technology choice type are conditional on their adoption decision. The model results of technology choice type decisions conditional on, rather than jointly with, the adoption decision leads to the conclusion that the variables influencing the adoption are different from technology choices. However, the different household capitals are instrumental in adoption and technology selection decisions, though with different intensity and sign.

Moreover, in the household income diversification index analysis, against our expectation, it was found that participant households (though marginal) were more diversified than non-participants. This can be attributed to the better access given to participants in the public work called 'Safety net program". But to sustain farmers' interest in the extension program and bring long lasting impact on rural households future efforts should be directed; to diversify the type and quality of technologies supplied to farmers as the current list and supply capacity is not up to the farmers need; and creating more sustainable non-farm employment opportunities and reduce the excessive dependency on safety net public works.

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THE ECONOMIC IMPACT OF IRRIGATION EXPANSION IN ETHIOPIA: A CGE ANALYSIS

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1. INTRODUCTION

In Ethiopia rain-fed agriculture is the backbone of the country's economy and rural livelihoods. Virtually all food crops in Ethiopia come from rain-fed agriculture with the irrigation sub-sector accounting for only about 3% of the land (FAO, 2008).

The dependency of most of the farmers on rain fed agriculture has made the country's agricultural economy extremely vulnerable to the adversities of weather and climate. Agriculture in the country is exposed to the effect of failure of rains or occurrence of successive dry spells during the growing season, which could lead to food shortage. Though food shortages resulting from adverse weather conditions are not new in this country, they have increased in severity and there have been shortages every two years since 1950. (CEEPA, 2006)

Water development for agriculture is a priority, but poorly designed and planned irrigation undermines efforts to improve livelihoods and exposes people and environment to risks. There are several factors that contribute to water scarcity: average annual precipitation may be low, or it may be highly variable, population growth and an increasing consumption of water per capita (Alvaro Calzadilla, et al, 2003)

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During conditions of very variable rainfall and recurrent droughts, heavy reliance on rain fed agriculture affects agriculture and hence, has adverse effects on the economy of Ethiopia. Enhancing public and private investment in irrigation development has been identified as one of the core strategies to delink economic performance from rainfall and to enable sustainable growth and development (World Bank 2006; MOWR 2006).

In Ethiopia, under the prevalent rain fed agricultural production system, the progressive degradation of the natural resource base, which is caused by factors such as population pressure and small farm sizes, land tenure insecurity, limited access to credit, limited education, especially in highly vulnerable areas of the highlands coupled with climate variability have aggravated the incidence of poverty and food insecurity. Water resources management for agriculture includes both support for sustainable production in rain-fed agriculture and irrigation (Awulachew et al. 2005).

In the past 15 years, the Ethiopian government has responded to drought and famine through various efforts to expand irrigation in the country. The country's Agricultural Development Led Industrialization (ADLI) Strategy considers irrigation development as a key input for increasing agricultural production. In line with the ADLI objective, during the first phase of Sustainable Development and Poverty Reduction Program (2000-2005), significant steps were taken towards improving overall water resource management of the country by formulating the National Water Resources Management Policy, the National Water Sector Strategy, the National Water Sector Development Program (WSDP) and Nile Basin Initiative.

The total area under irrigation in 2006 was reported to be 603,359 hectares of which traditional irrigation accounts for 479,049 hectares while 124,569 hectares of land was developed through medium and large scale irrigation schemes (MoFED, 2007). Despite the efforts of the government to expand irrigation, the country has still not achieved sufficient irrigated agriculture to overcome the problem of endemic food insecurity and poverty in Ethiopia.

Hence, the purpose of this study is to capture the impact of the new irrigation plan of the government on macro economic variables and welfare of households in Ethiopia; specifically (i) understand the broader implications for the economy; (ii) compare effectiveness of expansion of irrigation infrastructure in drought-prone areas only with that throughout the country without discrimination under two different scenarios i.e. Scenario 1-irrigation expansion in the whole country without favoring by agro ecological zone and Scenario 2-expansion of irrigation in drought prone area of the country based on MoARD's irrigation plan for 2010/11. For drought-prone, where the majority of the chronically food insecure population live, the strategy particularly underlines the need for generation and dissemination of small scale irrigation technologies as key strategic elements for diversifying into high value crop production. Apparently, small scale irrigation is considered a good alternative to improve the livelihoods of farming households at little investment cost.

2. Review of Literature

2.1. Views on the contribution of irrigation to an economy

Studies on the impact of irrigation on agricultural performance, household income and poverty have mixed findings. Some of the studies argue that expansion of irrigation is a cause for a number of environmental problems such as land degradation, loss of natural habitat, possibly inducing problems of water logging and salinity problems which hit primarily the poor first, consequently perpetuating rural poverty.

Rosegrant and Everson (1992) found that they were unable to establish a positive link between irrigation investment and productivity in India. Similarly, study done by Jin et al. (2002) also did not find a link between irrigation and the total factor productivity growth of any major grain crop in China between 1981 and 1995. Empirical study conducted by Berhanu and Pender (2002) in Tigray Region, Ethiopia, showed that the impacts of irrigation development on input use and the productivity of farming practices controlling all other factors were insignificant. They indicted that irrigation has limited impact on the use of fertilizer and improved seed leading to less gain productivity from irrigation. However, they suggested the reason why irrigation failed to improve productivity of farming practices, deserved further and careful study on the technical, institutional, governance and managerial aspects.

On the other hand, there are a number of studies in different countries that show evidence irrigation has served as the key driver behind growth in agricultural productivity and in increasing household income and alleviation of rural poverty. Lipton et al. (2004, p.10) for instance highlight the various ways how irrigation would have an impact on poverty. They stated that there are four interrelated mechanisms by which irrigated agriculture can reduce poverty:

- Increasing production and income, and reduction of food price, that helps very poor households meet the basic needs and associated with improvements in household overall economic and welfare,
- Protecting against risks of crop loss due to erratic, unreliable or insufficient rainwater supplies,
- Promoting greater use of yield enhancing farm inputs.
- Creation of additional employment, which together enables people to move out of the poverty cycle.

A study undertaken by Narayanamoorthy (2001 p: 349-362) in India using state-wise cross-section data covering the period 1970 to 1994 for fourteen major states of India, showed that besides increasing the cropping intensity and productivity of crops, the intensive cultivation of crops due to timely access to irrigation increased the demand for agricultural laborers and hence wage rates for those who lived below the poverty line.

He concluded that improvement in access to irrigation and investing in human capital development are the two most important factors for agricultural growth and rural poverty reduction in India. Moreover, a study made by Fan et al. (1999) examining the linkages between government spending, growth and poverty in rural India, using state level data from 1970 to 1993 which showed that government spending on productivity enhancing investments, such as irrigation, research and development in agriculture, rural infrastructure (including roads, electricity, and education) which target the rural poor have all contributed directly to the reduction of rural poverty. They found that irrigation development, in addition to raising agricultural productivity, also encourages private investment into those regions. Empirical evidence from Australia showed that a dollar worth of output generated in irrigated agriculture generates more than five dollars worth of value to the regional economy, which suggested irrigation development has a strong multiplier effect on other sectors of the economy (Ali and Pernia 2003).

Datt and Ravallion (1997) also found that improvement in agricultural productivity and rural poverty reduction in India have moved together, and that irrigation and other infrastructure development have played an important role. They describe that states with better initial stocks of human resources, physical infrastructure and irrigation intensity have achieved a higher growth in agricultural productivity, which in turn helped to reduce rural poverty.

2.2 A Historical Perspective on Irrigation Infrastructure Development in Ethiopia

Irrigation is one means by which agricultural production can be increased to meet the growing demands in Ethiopia (Awulachew et al. 2005). A study also indicated that one of the best alternatives to be considered for reliable and sustainable food security development is expanding irrigation development on various scales, through river diversion, constructing micro dams, water harvesting structures, etc. (Robel et al 2005).

Irrigation is practiced in Ethiopia since ancient times producing subsistence food crops. However, modern irrigation systems were started in the 1960s with the objective of producing industrial crops in Awash Valley. Private concessionaires who operated farms for growing commercial crops such as cotton, sugarcane and horticultural crops started the first formal irrigation schemes in the late 1950s in the upper and lower Awash Valley. In the 1960s, irrigated agriculture was expanded in all parts of the Awash Valley and in the Lower Rift Valley. The Awash Valley saw the biggest expansion in view of the water regulation afforded by the construction of the Koka dam and reservoir that regulated flows with benefits of flood control, hydropower and assured irrigation water supply. In addition, the construction of the tarmac Addis-Assab road opened the Awash Valley to ready markets in the hinterland as well as for export (MCE 2004). Although, certain aspects of the development during the pre-Derg era have wrong doings in terms of property and land rights, there has been a remarkable emergence of irrigation development and establishment of agro-industrial centers.

Currently, the government is giving more emphasis to the sub-sector by way of enhancing the food security situation in the country. Efforts are being made to involve farmers progressively in various aspects of management of small-scale irrigation systems, starting from planning, implementation and management aspects, particularly, in water distribution and operation and maintenance to improve the performance of irrigated agriculture. Ethiopia has a significant irrigation potential identified from both available land and water resources. The country has developed irrigation schemes in many parts of the country at different scales. Data and information are not uniformly available to accurately know the existing irrigation schemes. While it is possible to capture the medium and large schemes data accurately, it is difficult to account for the small-scale irrigation development, particularly, the traditional irrigation development and the privately developed household-based irrigation schemes which use traditional diversions, water harvesting and ground water development (Awulachew et al 2007).

2.3 Irrigation Potential

Ethiopia is endowed with a substantial amount of water resources with an estimated irrigation potential of 3.5 million hectares (Awulachew et al. 2007b). During 2005/2006 the total estimated area of irrigated agriculture in the country was 625,819 ha, which, in total, constitutes about 18% of the potential (MoWR 2006). It is planned to expand irrigation development in the country by an additional 528,686 ha by the year 2010 (Atnafu 2007; MoWR 2006; MoFED 2006), which will constitute about 33% of the potential.

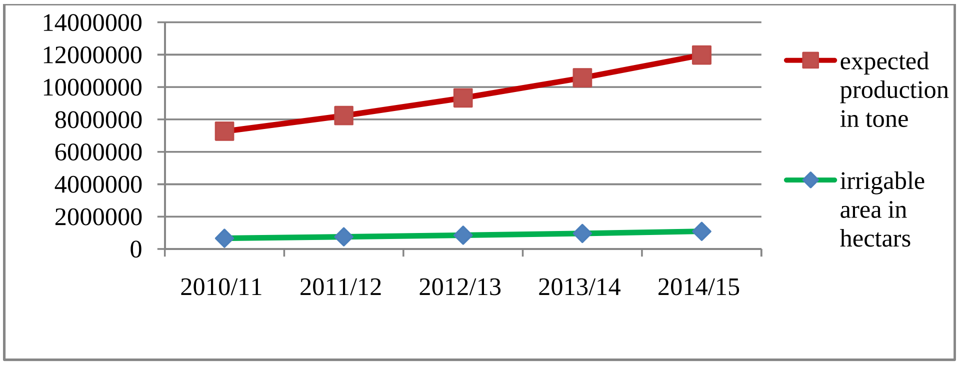
The surface water resource potential is impressive, but little developed. The country possesses twelve major river basins, which form four major drainage systems. Due to lack of water storage capacity and large spatial and temporal variations in rainfall, there is not enough water for most farmers to produce more than one crop per year. Crop failures due to dry wells and droughts are frequent. Ethiopia has many small, medium, and large reservoir dams constructed for hydropower generation, irrigation, and drinking water supply. Small dams are less than 15m and have a capacity of less than 3 million m^3. The height of the medium and large dams in Ethiopia is 15-50m and their capacity ranges from 4 to 1,900 million m^3. In total, there are nine medium and large dams with a total capacity of almost 3.5 km^3. Two large dams are used for hydropower generation only, one dam is used both for hydropower generation and irrigation supply, two dams are used for irrigation supply only and the remaining four for water supply to the city of Addis Ababa and the town of Gondar. Small dams (micro-dams) constructed for irrigation supply are concentrated in the Amhara and Tigray regional states. (FAO, 2008 and Awulachew et al. 2007b).

3. Planned Small Scale Irrigation for the Next Five Years (2010/11-2014/15)

The major source of growth for Ethiopia is still conceived to be the agriculture sector, as it is expected to be insulated from drought shocks through enhanced utilization of the water resource potential of the country, (through development of small-scale irrigation, water harvesting, and on-farm diversification) coupled with strengthened linkages between agriculture and industry (agro-industry), thereby creating a demand for agricultural output (MoFED 2006).

Irrigation development is getting importance under the current government, particularly, since 2004. According to MoARD with respect to irrigation development, within the program period of PASDEP 2010/11-2014/15, irrigation expansion will be carried out for 661000 hectares in 2010/11 to 1089000 hectares in 2014/15. . This implies that further development will extend the small scale irrigated area to cover approximately 65% of the total land area. These plans are used for future irrigation development and valuing the future contribution of irrigation to the national economy. The irrigation expansion plan of MoARD for the next five years is expected to bring more production.

Figure 1. Small Scale Irrigation expansion plan for five years



4. The Model and the Macroeconomic Closures

The paper uses the IFPRI standard CGE model and the 2005/06 EDRI Social Accounting Matrix (SAM). The standard CGE model explains all of the payments recorded in the SAM. The model therefore follows the SAM disaggregation of factors, activities, commodities, and institutions. It is written as a set of simultaneous equations, many of which are nonlinear. There is no objective function. The equations define the behavior of the different actors. In part, this behavior follows simple rules captured by fixed coefficients (for example, ad valorem tax rates). For production and consumption decisions, behavior is captured by nonlinear, first-order optimality conditions. That is, production and consumption decisions are driven by the maximization of profits and utility, respectively. The equations also include a set of constraints that have to be satisfied by the system as a whole but are not necessarily considered by any individual actor. These constraints cover markets (for factors and commodities) and macroeconomic aggregates (balances for savings investment, the government, and the current account of the rest of the world) (Lofgren et al 2002).

The model captures production linkages by explicitly defining a set of nested constant elasticity of substitution (CES) production functions. Producers in each region supply their products to a central market and that a national price adjusts to equate demand and supply at the national as well as regional level.

The 2005/06 Ethiopian SAM is disaggregated in 99 activities, 91 commodities, 25 factors,14 households, 17 tax (8 indirect commodity tax and 9 direct tax) accounts. But for this study this SAM is aggregated into 18 activities and 15 commodities, 4 factors, 4 households, and 3 tax accounts for the first scenario and in to 22 activities and 15 commodities,6 factors, 6 households, and 3 tax accounts for the second scenario. We disaggregated the drought prone area from the SAM for our analysis in the second scenario. The SAM also has government, saving-investment, inventory and rest of the world account.

The closure rules determine how the macro economy and the factor markets work. For this paper, government savings are flexible; direct tax rate is fixed implying the government finances its deficit through borrowing and constrained in raising taxes to cover additional public spending. Savings-driven investment closure is adopted in which investment adjusts endogenously to the availability of loanable funds. The level of foreign savings is fixed and exchange rate is flexible which implies during shortage of foreign savings the real exchange rate adjusts by simultaneously reducing spending on imports and increasing earnings from export. Furthermore, land and capital is fully employed & activity-specific while labor is assumed to be fully employed and mobile across sectors.

5. The Simulations

We simulate the model by increasing total factor productivity (TFP) α_a^{va} (alphava) due to irrigation expansion as shown in the following aggregate value added production function. Total Factor Productivity (TFP) is the portion of output not explained by the amount of inputs used in production. As such, its level is determined by how efficiently and intensely the inputs are utilized in production. Because of the irrigation plan in 2010/11 the TFP is assumed to increase so that alphava which is the shift parameter for CES activity production function is shocked.

$$QVA_a = \alpha_a^{va} \cdot \left(\sum_{f \varepsilon F} \delta_{fa}^{Va} . QF_{fa}^{-\rho_a^{va}} \right)^{\frac{1}{\rho_a^{va}}}$$

$$\begin{bmatrix} quantity\ aggregate \\ value\ added \end{bmatrix} = CES \begin{bmatrix} factor \\ inputs \end{bmatrix}$$

Where

$f \varepsilon F\ (= F\ ')$ = a set of factors,

α_a^{va} = efficiency parameter in the CES value-added function,

$\delta_{f\alpha}^{v\alpha}$ = CES value-added function share parameter for factor f in activity a,

$QF_{f\alpha}$ = quantity demanded of factor f from activity a,

$p_{\alpha}^{v\alpha}$ = CES value-added function exponent,

The equation states that, for each activity, the quantity of value-added is a CES function of disaggregated factor quantities.

For our analysis the simulation assumes two scenarios. The first scenario assumes irrigation expansion in the country without favoring any agro ecological zone. That is total factor productivity (alphava) for maize, wheat, barley and sorghum is shocked by 7%, 2%, 4% and 4% respectively. We choose maize, wheat, barley and sorghum as major irrigated crops based on the amount of irrigation area covered by the crops and their respective irrigated production. The simulated yield is calculated assuming that the yield per hectare of the crops will double due to irrigation. Then, the percentage change from the base yield to the simulated yield is used for the shock. On the other hand, the second scenario assumes irrigation expansion only favoring drought prone areas for the major irrigated crops. The SAM disaggregates agricultural activities, land and rural households geographically by agro-ecological zone (AEZ). The five AEZs distinguished in the SAM differ in terms of climate, moisture regime and land use. The drought prone areas are classified as Zone 4 in the SAM and cover a considerable proportion of the total land area. As compared to other areas, the drought prone tracts are more vulnerable to ecological degradation, leading to an increasing economic dependency and social deprivation.

In drought prone areas there is rainfall inadequacy and variability, declining agricultural productivity and environmental limiting factors so that our simulation is based on our assumption of irrigation investment in drought prone area will bring an improvement in agricultural productivity. This time the total factor productivity (alphava) is shocked by 20%, 9%, 10% and 16% for maize, wheat, barley and sorghum respectively. The TFP shock in this scenario is due to an assumption of doubling yield as a result of additional irrigable area in drought prone areas only. The drought prone areas are included in the first scenario as part of the total irrigable land in the whole country. The additional area planned to be irrigated is distributed to each major crop based on their irrigated area coverage in 2007/08. The two scenarios are means to analyze the effect of irrigation in the country without considering the agro ecology and by considering the agro ecology (i.e. drought prone area) and to identify which is the best alternative.

Different Literatures indicated that improved irrigation has the ability to double yield. Park (2001) states that output from the irrigated land is more than double from the land not irrigated. Food production, particularly in many developing countries, can often be increased only by improving or rehabilitating existing irrigation. Bjorn Lomborg (2001) in his book explains about the success of Eritrea in doubling production as a result of improved seed grain, the correct use of fertilizers and improved irrigation. According to FAO (2008) irrigation may double or even triple yields, it increase water availability and controls when and where water is available.

Based to these and other similar literatures we take the percentages for the shock by the assumption of an increase in the area of irrigation for each major crop will double their yield per hectare. In the two scenarios MoARD's irrigation plan for 2010/11 is used for the shock.

6. The Results

6.1 The Impact of Irrigation expansion on Production and Output Prices

Irrigation expansion in all regions causes the production of maize, wheat, sorghum and barley improve at the national level. On the other hand, the expansion of irrigation in drought prone areas only has resulted in a big increment of production of the crops in the drought prone zone causing production in other areas decline.

Table 1.Percentage change in Production

Irrigated crop	Scenario 1_Irrigation at national level	Scenario 2 irrigation only in drought prone area		
	National	Drought prone area (Zone 4)	Other zones	National
Maize	6.37	47.5	-7.6	26.9
Wheat	2.39	19.8	-2.8	13.1
Sorghum	3.6	29.7	-11.7	18.2
Barley	3.63	21.1	-3.7	6.9

The increase in production of the crops due to irrigation in both scenarios has led to a decline in their respective prices (see table 2). The decline in output prices is more in scenario one due to the reason that there is no shift in the supply curve of the production function in contrast to the second scenario in which there is a shift in the supply curve causing the price increment smaller.

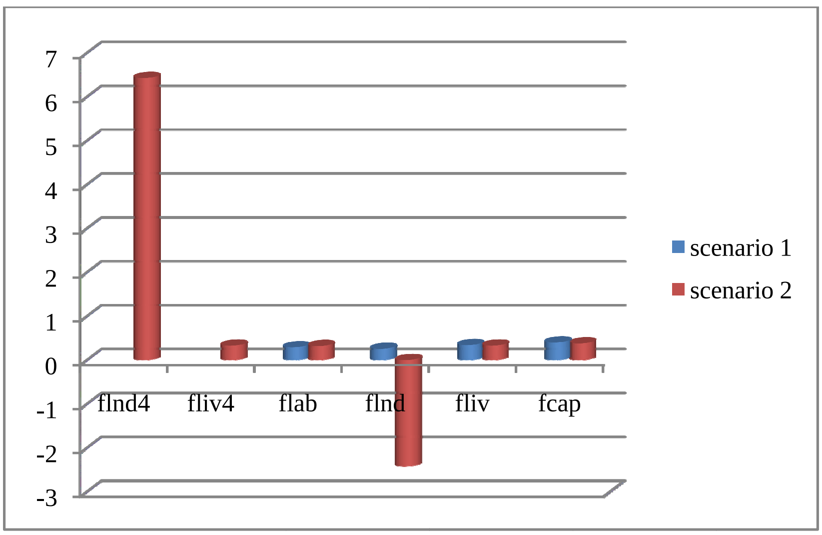
Table 2. Percentage Change in Output Price

Irrigated crop	Scenario 1_Irrigation at national level	Scenario 2 irrigation only in drought prone area
Maize	-5.94	-4.441
Wheat	-1.29	-1.717
Sorghum	-3.6	-6.931
Barley	-3.34	-2.261

6.2 The Effect of the Shock on Factor Income

The income from labor, land and livestock has improved by 0.29%, 0.25% & 0.34% respectively as a result of the first scenario i.e. irrigation expansion in all areas in the country without favoring agro ecological zones. When we come to the second scenario i.e. drought prone area favored irrigation expansion, factor income from land has gone up by 6.43% causing the return from land in other areas to decline by 2.42%. The income from livestock in the drought prone areas has almost the same increment as in the first scenario. Labor is not disaggregated for the second scenario since it is assumed to be fully employed and mobile across sectors in the model closures.

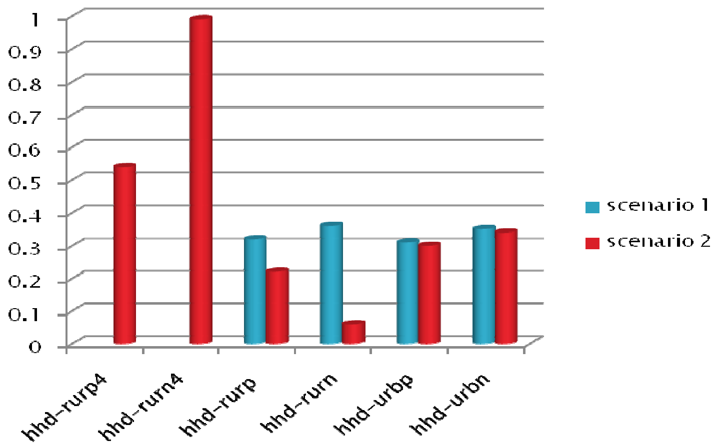
Figure 2. Percentage change on the effect of irrigation expansion on factor income



6.3 The impact of the Shock on Household Income

Household's income has increased in all the rural and urban areas during irrigation expansion in all regions. In the second case where the irrigation expansion is entirely in drought prone areas, the income of household's in drought prone areas has shown a big increase and is more than the income of households out of the drought prone areas.

Figure 3. Percentage changes on the effect of irrigation expansion on household income



6.4 Macroeconomic Effects of the Irrigation Improvement

For both scenarios the total absorption has increased by 0.4% and consumer price index (CPI) has lowered by 0.1%.The increase in household income and the decline in prices resulted in an increment of household consumption by 0.5%. The nominal and real exchange rates have depreciated in both scenarios as shown in table 3.

Table 3. Percentage change on the macro variables

	Scenario 1 Irrigation at national level	Scenario 2 irrigation only in drought prone area
ABSORPTION	0.4	0.4
HH CONSUMPTION	0.5	0.5
REAL EXCHANGE RATE	0.3	0.3
NOMINAL EXCHANGE RATE	0.4	0.3
CONSUMER PRICE INDEX	-0.1	-0.1

6.5 The Effect of the Shock on GDP, Import and Export

During national level irrigation expansion GDP at factor cost has grown up by 0.46%. On the other hand when irrigation is favored to drought prone regions the GDP at factor cost rose to 0.51% and this is higher than the rise during economy wide irrigation expansion. Export and import values have increased slightly in the first scenario but declined in the second scenario. The decline in export despite the depreciation of the real exchange rate is due to the rise in domestic price of most of the export commodities which is greater than the rise in their respective export prices.

Table 4. The impact of irrigation on GDP at factor cost, import and export(Percentage change)

	Scenario 1 Irrigation at National Level	Scenario 2 irrigation only in drought prone area
ABSORPTION	0.35	0.364
PRIVATE CONSUMPTION	0.5	0.5168
EXPORTS	0.03	-0.0838
IMPORTS	0.01	-0.0302
GDP at market prices	0.43	0.4429
GDP at factor cost	0.46	0.5095

7. Summary

In this paper, we have used the IFPRI standard CGE model based on MoARD’s irrigation expansion plan for 2010/11.Different results have shown how irrigation affects the economy whether it’s expanded at the national level or at drought prone zone only. Irrigation investment causes production to go up and prices to go down. The increase in production and decline in price during irrigation in drought prone areas is more than the increase at a country level. During irrigation at drought prone areas, Profitability of land in drought prone areas has increased causing the return from land at other areas to decline. Household’s income has increased in all the rural and urban areas. When the irrigation investment is entirely at the drought prone zone, household’s income has increased in drought prone areas more than the increment in other areas.

The nominal and real exchange rate have depreciated.GDP at factor cost has grown up because of the increase in productivity. Export and import values have increased slightly during economy wide irrigation. Export and import values declined during drought prone area irrigation. The decline in export despite the depreciation of the real exchange rate is due to the rise in domestic price of most of the export commodities which is greater than the rise in their respective export prices.

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Annex 1. Total Irrigated and Non-Irrigated Area from 2004/05-2007/08

		Area in hectare	
Year	Crop Type	Irrigated	Non-irrigated
2004/05	Barley	7212	1,088,224.00
	Wheat	4614	1,343,601.00
	Maize	29407	1,313,509.00
	Sorghum	9756	1,243,864.00
2005/06	Barley	7441	990427
	Wheat	6116	1453424
	Maize	35586	1484697
	Sorghum	15596	1449585
2006/07	Barley	5032	1014282
	Wheat	5604	1468313
	Maize	41060	1647620
	Sorghum	9241	1452188
2007/08	Barley	12156	972787
	Wheat	7681	1417038
	Maize	39674	1727715
	Sorghum	18195	1515342

Source CSA Agricultural Sample Survey, Report on farm management practices

Annex 2:- Total irrigated production from 2004/05-2007/08

	Year			
Crop Type	2004/05	2005/06	2006/07	2007/08
Barley	757,467.53	67,942.18	631,327.68	1,530,895.22
Wheat	470,321.19	87,413.94	927,163.22	1,149,773.74
Maize	3,940,050.63	713,712.90	9,496,925.18	9,520,958.58
Sorghum	1,032,131.12	208,906.73	1,623,521.59	3,250,752.27

Source CSA Agricultural Sample Survey, Report on farm management practices

Annex 3:- Irrigated area in hectare and yield per hectare by agro ecological zone

Agroecological zone	major crop	area in hectare	yeild
moisture reliable_cereal	BARLEY	8377.8	12.1
	MAIZE	10041.6	34.6
	SORGHUM	4582.3	18.0
	WHEAT	3494.6	15.2
moisture reliable-enset	BARLEY	69.0	8.6
	MAIZE	7460.5	13.8
	SORGHUM	720.8	13.8
	WHEAT	221.3	20.1
humid moisture reliable and lowland	BARLEY	-	-
	MAIZE	1251.4	10.5
	SORGHUM	321.3	10.5
	WHEAT	74.1	14.4
pastoralist	BARLEY	-	-
	MAIZE	12845.1	25.4
	SORGHUM	1615.2	14.5
	WHEAT	21.1	7.7
droughtpron	BARLEY	3709.0	11.3
	MAIZE	8075.3	15.3
	SORGHUM	10955.9	14.3
	WHEAT	3869.9	14.2

Source CSA Agricultural Sample Survey, Report on farm management practices

Annex 4:- Total area and production from 2004/05-2007/08

Year	crop	Area in hectare	Production in Quintal
2004/05	Barley	1,095,436	13,280,520
	Wheat	1,348,215	21,766,030
	Maize	1,342,916	23,941,622
	Sorghum	1,253,620	17,159,543
2005/06	Barley	997,868	12,706,798
	Wheat	1,459,540	22,190,754
	Maize	1,520,283	33,367,952
	Sorghum	1,465,181	21,735,987
2006/07	Barley	1,019,314	1,351,480
	Wheat	1,473,917	24,630,639
	Maize	1,694,523	37,764,397
	Sorghum	1,464,318	23,160,409
2007/08	Barley	984,943	13,548,071
	Wheat	1,424,719	23,144,885
	Maize	1,767,389	37,497,491
	Sorghum	1,533,537	26,591,292

Source CSA Agricultural Sample Survey, Report on area and production for major crops.

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