Gender Differentials and Determinants of Female- Male Holders Revenue Efficiency during the implementation of the GTP plan in Ethiopia: A Panel Data Study

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INTRODUCTION

When the "Agriculture in Africa Today-Telling Facts from Myths" initiative was launched in 2015, researchers in the agricultural international development field were challenged to revisit the conventional wisdom about Africa's agricultural sector. The fact that Africa is facing a rapid economic growth with high food prices could have changed the conventional knowledge about agriculture in Africa that commonly drives policy.

Two conventional ideas hold that Sub-Saharan farmers, especially women, use few modern inputs, and that the usage of these inputs is efficient. This paper offers a new insight on these conventional ideas in Ethiopia, which is one of the Sub-Saharan Africa countries that has the highest rate of poverty, and where major structural changes are taking place through the implementation of an economic growth plan.

In Ethiopia, the participation of women in agriculture is high; they head about 22 percent of rural families, and account for 30 to 40 percent of the agricultural labor force (Eshete, 2000). In addition, women farmers provide around 50 percent of the total labor time required for crop production in most parts of the country according to Ahmed, 2013, Tiruneh et al., 2001, and according to our data in 2013, in rural areas, about 48 percent of females engaged in agricultural activities. Even though, the presence of the women in the agriculture sector in Ethiopia is very significant in numbers, a 2014 World Bank report affirms that female farmers benefit less from economic growth because they are less productive than their male counter parts. According to the report, the gender productivity gap in Ethiopia is one of the highest in sub-Sahara Africa (World Bank 2014).

From the (LSMSIS) survey, we found that female-headed farms in Ethiopia own less land and have fewer hours to allocate to agricultural production than male-headed households have. Also, in Ethiopia a holder is about four times more likely to be a male than a female, and female holders

manage, on average about 0.66 hectares of land as compared to 1.19 hectares for male landholders (Kasa et. 2015) all of which contributes significantly to lower levels of productivity.

In addition, there is evidence from the work of Javed and Asif (2011) that the number of households headed by females are growing rapidly. In Ethiopia, these households are at a higher risk of living in poverty than male-headed households are because these households have fewer assets and lower earning capacity than male-headed households do. There is the need to have a closer look to the agricultural female-headed households, to locate the sources of inefficiency in hopes to contribute to the alleviation of the poverty conditions that the country faces by improved economic performance.

As of now, many studies have tried to find the gender gap in Ethiopia (World Bank, 2014; Quisumbing, 1996; Javed et al., 2011; Solomon et al., 2015) but very few focus have analyzing gender differences in efficiency taking into account most geographic regions of the country, considering most of the crops produced in the country, and under structural changes. This study will consider all three of the mentioned aspects, and will focus on the efficiency analysis of male and female holders that are responsible for the production of cereal and non-cereal crops during the period when the GTP plan was implemented. First, we analyzed female and male holders instead of head of the households because holders are the primary decision makers about the resources they manage, and the basic socioeconomic and agricultural variables that were collected in the survey are at the holder's level. Second, we conducted the efficiency analysis for crops that are cereals, pulse crops, oilseeds, root crops, vegetables and spices. We choose cereals because this is a dominant crop in Ethiopia, and these cereals account for about 70 percent of the total area cultivated during 2012-2013 (LSMS-ISA). In terms of consumption, cereals are the main source of staple food in the nation and they provide more than 60 percent of the national average per capital daily calorie intake (Kara et al., 2015; Dorosh and Rashid, 2012). Given the importance of cereals in the production and consumption in Ethiopia, understanding the role of gender in the production of cereals is relevant. Also, we considered other crops cultivated in Ethiopia like pulse crops (chickpeas, lentils), or oilseeds because females tend to be more involved in the production of these crops, since they required relatively less labor, are located near residential areas, and do not require complex management. By using these two different groups of crops (cereals and non-cereals), the role of women in agriculture can be better analyzed. Third, we included six of the nine regions in Ethiopia since the country has strong differences between its regions, and counting for those differences can clarify the determinants of the gender efficiency in the agricultural sector. Last, taking advantage of the extensive information that the (LSMS-ISA) survey provides before and after a

significant structural change such as the implementation of the GTP, will allow to understand how the new policies that favor the agricultural sector improve the production efficiency of females and males, and then helps to reduce the gender gap that exists. Furthermore, the detailed information provided by the (LSMS-ISA) survey permits to perform a multi-output, and multi-input analysis that can be done using the efficiency revenue approach, which it is rare in the literature.

This study uses the revenue efficiency approach to assess the agricultural producers' efficiency in Ethiopia. The main objective of the study is to examine the differences in revenue efficiency between male and female holder in Ethiopia, to investigate the factors that influence production efficiency differences in male and female holder farms while controlling for holder characteristics, and farm characteristics. The second objective is to observe how planned structural changes in the agricultural sector translate into the improvement or diminishment of the gender gap. Lastly, the study will add some evidence to the debate proposed in 2015 on the conventional wisdom about Africa's agricultural sector, more specifically in the belief that farmers, especially women use few modern inputs, and that the usage of these inputs is efficient.

The results are expected to be of interest to those involve in the evaluation of the GTP, and those in the discussion on "Agriculture in Africa Today-Telling Facts from Myths" initiative, because it gives insights on where the policy priority for female farmers in agriculture should be directed as for now this is not so clear-cut, and it is a big challenge (World Bank, 2015).

The paper is organized as follows. The next section outlines the theoretical framework and the methodology employed. Section three describes the data, variables, and descriptive analysis. Section four discusses the results of the efficiency analysis and the regression analysis followed by the concluding comments in the final section.

SIGNIFICANCE OF THE STUDY AND LIMITATIONS

The ability of a farmer (regardless of the gender) to achieve sustainable food crop production depends on their level of technical efficiency. In particular, technical efficiency and scale efficiency in developing countries is important because it represents a source of productivity and economic growth (Al-hassan 2008). Also, an investigation of farm specific technical efficiency and its factors can help determine the level to which female holder farmers are using the existing technology, and how this determines affect the technical efficiency scores.

Due to the limited data on factors of production (e.g., price of seed, fertilizer), an extension of the analysis to consider allocative and cost efficiency measures was not possible. Further efficiency

analysis (e.g., calculating allocative, and overall efficiency scores) can be done if prices of the inputs are derived from information on valuation of each of the mentioned inputs. In spite of these data limitations, this research provides insight into the technical and scale efficiency of female-headed household in Ethiopia as well as factors that are correlated with these efficiency scores.

REVIEW OF METHODS

Production efficiency is a popular method to compare the performance of economic entities in similar industries. Farrell in 1957 started the discussion of efficiency, as well as indicated that the efficiency of a firm consist of two components: the technical efficiency and allocative efficiency. The allocative efficiency includes cost minimization, revenue maximization and profit maximization. We will consider the allocative efficiency, and more specifically the revenue maximization approach. The allocative efficiency firm is the one that uses the optimal amount of inputs to produces an optimal amount of outputs given prices and production technology. Also, the way to measure the ability of a firm to get the maximum possible revenue at a given level of input or set of inputs is call revenue efficiency. Thus, all productive units that are consider allocative efficient, are operating on a production frontier that represents maximum revenue attainable from each input level. All other feasible points that are below the frontier are considered technically inefficient points. The optimization rationale of farmers in Ethiopia can be argued that is based on the revenue maximization principal, assuming all farmers are acting as rational subjects, and so input should be treated as exogenous.

The empirical work on efficiency of small production units like those similar to smallholder farmers in Ethiopia have been influenced by the poor-but the efficiency hypothesis of Schultz (1964), in which it is established that small units in the agricultural sector are poor but efficient in utilizing the inputs they have. Thus, any variation of the production frontier (push it outwards, or inwards) will require new inputs and technology, or as Zenebe (2005) pointed, there is a possibility to enhance productivity through more efficient use of farmers' inputs for a given technology.

The importance of estimating the production frontier is relevant because it provides insights on production efficiency of smallholder female and male-headed households in Ethiopia. There exist two methods for analyzing technical efficiency, allocative efficiency, and cost efficiency and their principal determinants: the parametric frontier (stochastic frontier approach), and the non-parametric approach frontier (Data Envelopment Analysis).

The parametric frontier uses econometric methods to estimate the parameters of both the production frontier and the model that captures the determinants of efficiency/inefficiency. Even though the stochastic approach allows stochastic random noises that are out of the control of the farmer, it imposes an explicit functional form and distributional assumptions on the data.

The non-parametric approach (DEA) does not focus on the estimation of an average technology production function used by all units analyzed, but identifies the best operational units. The best-practice production frontier is constructed and all units of analysis are related to this frontier. DEA has several advantages: it does not require an assumed functional form for the production frontier, it can handle multiple outputs and inputs and it is possible to identify the best practice for every unit. Furthermore, this approach does not require assuming a distributional assumption of the inefficiency terms (Coelli et al. 2005). Although this approach has been criticized for not allowing the possible random shocks due to measurement errors and other noise from the data (Coelli 1995), others have found that this mathematical programming approach appears to be robust procedure for efficient frontier estimation (Forsund, 1991). As a result, this study will employ the non-parametric approach.

Data Envelopment Analysis (DEA)

Data envelopment analysis (DEA) is a non-parametric approach method that was proposed by Farrell in 1957 and then improved by Charnes et al. (1978) and Banker et al. (1984). This analysis is a mathematical programming method to measure the relative efficiency of decision-making units (DMU) using multiple inputs and outputs.

In the efficiency analysis under a DEA method, there are three alternatives, variable returns to scale (VRS), constant returns to scale (CRS), and non-increasing return to scale (NIRS). The CRS assumption is appropriate when all DMU's are operating at an optimal scale (Coelli, 1996). Since all male and female holders considered in the analysis are most probably facing financial constraints, market failure for inputs, market access difficulties, etc., these farms are not operating at an optimal scale, thus VRS is the assumed assumption. Also, there is the option of input-oriented models or output-oriented models under DEA, the latest two methods identify inefficiencies as a proportional reduction of inputs usage, or proportional increase of output respectively. One common goal in agriculture is to produce the highest amount of output, having relatively more control of the inputs that are used. This suggests that VRS input-oriented models are suitable to be used in the evaluation on the performance of the DMUs in this study.

Revenue Efficiency

In order to derive the revenue efficiency of the farms, it is necessary to find the maximum revenue, given output prices, input levels, output level and technology:

Let us consider n DMUs, each of them has m inputs and s outputs. There is a column vector of inputs of the *j*-th DMU as $X_j = (x_{1j}, x_{2j}, \dots, x_{mj})^{\mathrm{T}}$, and a column vector of outputs as $Y_j = (y_{1j}, y_{2j}, \dots, y_{sj})^{\mathrm{T}}$. Also, let us suppose that $P_j = (p_1, p_2, \dots, p_s)^{\mathrm{T}}$ is a known vector of prices of outputs. The model for the maximization of the total revenue of DMUo under the assumption of given input $\mathbf{X_o}$ is as follows:

Maximize

$$\psi = \sum_{r=1}^{s} p_r y_r,$$

Subject to:

$$\begin{aligned} \sum_{j=1}^{n} \lambda_j x_{ij} &\le x_{io}, & i &= 1,2,\dots,m. \\ \sum_{j=1}^{n} \lambda_j y_{rj} &\le y_r, & r &= 1,2,\dots,s, \\ \lambda_j &\ge 0, & j &= 1,2,\dots,n. \end{aligned} \qquad (1)$$

where $\lambda = (\lambda_1, \lambda_2, \dots, \lambda_n)$ is a vector of weights of the DMUs. Also, $y_r, r = 1,2,\dots,s$, are the variables of model (1), which express the amount of outputs produced by the given amount of inputs. Base on the optimal solution ψ^* the overall revenue efficiency (RE) given by the standard DEA model of DMUo is then solved by the following calculation:

$$RE_i = \frac{\psi^*}{P^T \mathbf{Y}_o} \ge 1$$

Which is DMUo's relative ability to allocate the inputs in a revenue-maximizing way, given the estimated technology. The revenue efficiency score for each DMU is calculated by dividing the maximum revenue over the actual revenue of the DMU.

Tobit Panel Analysis

In regression models, where range of the dependent variable is restricted, the variables that take values in a limited range are defined as "censored". In this study, we calculate inefficiency scores from the TE that resulted from the DEA analysis, by subtracting 1 to each TEt. Since the dependent

variables (inefficiency scores) is limited to [0,1], and the independent variables that correspond to 1 or 0 can be observed, the dependent variable has a censored structure.

When estimating a model with censored dependent variable using OLS methods is feasible and recommended by some (Banker and Natarajan, 2008; McDonald, 2009), but can lead to biased and inconsistent results according to others (Greene 2003). For these reasons, Tobit Panel regression with the MLE method for parameter estimation is used in the present study.

The study used two panels, one for males and one for females, composed of 98 observations for females, and 709 for males, for two periods. In this context, the basic formula of Panel Tobit used in the study is presented below:

$$y_{it}^{*} = \beta' X_{it} + \varepsilon_{it}$$

$$y_{it} = \begin{cases} y_{it}^{*}, & if\, y_{it}^{*} < 1 \\ 1, & otherwise \end{cases}$$

Where *i* defines the household and *t* defines the time. X_{it} is the matrix 1 x k that holds the explanatory variables, and β is the parameter vector on dimension k x 1 (Baltagi 2008). The error term $\varepsilon_{it} = \lambda_t + u_{it}$ where the λ_i is the unobservable individual effects and the μ_i is the individual and random effects. The individual effects, are addressed in two different ways: if λ_i is assumed fixed for each *i*, then it is referred as "Fixed-Effect" estimator; if is considered to be at random from a probability distribution then it should be referred as "Random-Effect" estimator (Thomas 2007) . The Random-Effects Tobit model (RE) was used to model the panel data, since the Tobit model is non-linear and Fixed Effects could cause incidental parameter problems, and result in biased estimators.

The analysis of the data used in the study requires three stages: 1) revenue efficiency estimation, 2) calculation of inefficiency scores, and 3) the estimation of determinants of the inefficiency scores using a Tobit panel regression of the inefficiency scores on several socio-economic factors affecting revenue efficiency. Stata was used to estimate the Tobit model, and GAMS was used to estimate revenue efficiency scores.

DATA AND VARIABLES

This study was conducted utilizing one section of the unique, recently collected, nationally representative, agriculturally intensive, and cross-country comparable Living Standard Measurement Study-Integrated Surveys (LSMS-ISA) that were implemented in six Sub-Saharan countries. The

section of the data studied was collected in Ethiopia from 2011-2012, and from 2013-2014, focusing in male and female farm holders.

The period of time that the study comprehends is very unique as a consequence of the significant structural changes that The (GTP I) produced once implemented in 2011.One of the objectives of the GTP was maintaining the agriculture sector as a major source of economic growth, while promoting gender and youth empowerment (GTP 2011/-2014/15). Even though the plan strategy clearly specifies the importance of a more inclusive sector, the country's numerous male-smallholders dominate Ethiopia's agricultural sector. The (LSMS-ISA) survey showed that a holder is about four times more likely to be a male than a female and that even though after 2011 major efforts have taken place through the Growth and Transformation Plan (GTP), that pays special attention to benefit women and youths, only 20 percent of the holders are women. In all regions the distribution of farmers that are female and males are almost the same with slightly higher numbers of male farmers in Amhara region and higher numbers of females' farmers in Oromia region.

In general, about 80 percent of smallholder's farms are dedicated to both, crops and livestock, but the major agricultural activity is crop agriculture, which mainly produces cereals. At the country level, female cereal production is on average lower than male production. One possible reason is that cereal production dominates in terms of agricultural land usage and rural labor employment since cereals are consider a field crop, and they require the preparation of the land, weeding, and the labor to harvest the crop. Therefore, holders that have land or labor constraints are less likely to cultivate cereal crops, which in the case of Ethiopia the majority of those are females. In economic terms, the fact that women farmers have relatively less opportunity to produce cereals could decrease their revenues, as well as the food security of the household because cereals are by far the leading crop in Ethiopia in terms of production and consumption. In the (LSMS-ISA) survey over 90 percent of all households report consuming one of these cereal items almost daily: wheat, teff, rice, barley, corn, and sorghum.

As regards to the usage of modern inputs such as chemical fertilizer, improved seeds, or irrigation, the GTP economic growth plan has put emphasis on the extension packages that can facilitate the access of this modern inputs to both female and male farmers, but the survey shows that only a small proportion of holders use those inputs. In addition, female holders that applied chemical fertilizer are about 8 percent less than their male counterpart. Moreover, chemical fertilizer usage is more intense in female holders than male holders (Kasa 2015). Despite the fact that the adoption of modern inputs has not reached the GTP plan's objective, and that there was less labor and land

utilized, surprisingly in 2011-2012 there was an increased in the average production of agricultural output in all regions of the country. This possibly indicates an increase in the production efficiency of farmers, this reinforces the belief that farmers use the basic inputs in an efficient manner.

With an increase in the production of crops combined with the higher output prices, farmers in average experienced higher revenues according to the(LSMS-ISA) survey. But then again, more males have the higher revenue over females. Female holders captured only 10 percent of the highest revenues, whereas among the farmers that had the lowest revenues, women represented 30 percent.

As can be seen, the circumstance that women face in the agriculture sector in Ethiopia are less favorable compare to those of men's in terms of revenue, production, and utilization of inputs. In addition, there is evidence from the work of Javed and Asif (2011) that the number of households headed by females is growing rapidly, and that these are at a higher risk of living in poverty than male-headed households are because female-headed households have fewer assets and lower earning capacity than male-headed households do. Under those situations, there is a need to have a closer look at the agricultural female holders, trying to locate the sources of inefficiency in hopes of contributing to the alleviation of the poverty conditions that the country faces by improving the economic performance.

A sub-sample of the data was selected for the analysis. The farmers that we considered for the study were those that claimed to be holders of the plots, and had information on kilos of seeds used, number of hectares used, number of post-harvest & post-planting labor used, and revenue for the two periods that the survey took place. A holder, in the context of the surveys, is a person who exercises management control over the operations of the agricultural holdings and makes the major decisions regarding the utilization of the available resources. That person has technical and economic responsibility for the holding. In addition, the person may operate the holding directly as an owner or as a manager. The total number of observations that are in the sub-sample are 594, 518 males and 76 females. This sub-sample is a good representative of the total sample since the proportion of population share per region, and gender are similar to those found in the sample (see table 1). We want to acknowledge the loss of prediction power because of working with a sub-sample rather than the sample. The total number of observation (594 observations) came from merging various modules of post-planting and post-harvesting data of Ethiopian Rural Socioeconomic Survey (ERSS).

Table1: Population and sub-sample share by region

In the sub-sample data, almost all holders are also household heads, but in the case where there were more holders in the household, each holder in the household got an agricultural questionnaire.

	Population Share	Population share from the sub-sample	Difference in percent points
National	100%		
Regions			
Tigray	6.60%	12%	+5%
Afar	1.70%	-	-
Amhara	26.60%	33%	+6%
Oromia	37.60%	22%	-16%
Somali	4.50%	-	-
Benishangul	1%	5%	+4%
SNNP	20.80%	25%	+4%
Gambela	0.40%	-	-
Harari	0.30%	1.68%	+1.38%
Dire Dawa	0.50%	-	-

The holders are located in 5 different regions of the country (Amarah, Oromia, SNNP, Tigray, and Benishangul Gumuz). In the sub-sample 34 percent of female holders are located in SNNP region, and 34 percent of male holders are located in Amarah region (see Table 2). The average age of female holders and male holders is around 43 years old and 46 years old respectively.

The majority of holders, females and males, they have both livestock and crops in the fields, and about 55 percent of male farmers do not participate in extension programs whereas 80 percent of women do not participate in extension programs. Around 67 percent of male holders and 70 percent of female holders did not access to credit. Almost the same percentage of female and male farmers have advisory services, this is 70 percent. Men utilized in average more oxen than female farmers did, but female farmers in average used double the chemical fertilizer than males.

Table2: Summary of variables that are included in the Tobit Panel model.

	Male Holders	Female Holders

		Units[b]	Mean (Mode)[a]	Sd (%freq)[a]	Min	Max	Mean (Mode)a	Sd (%freq)a	Min	Max
DEMOGRAPHICS										
Age		years	43	14.05	18	85	46	12.5	22	75
School	Do you have at least one year of formal education?	0= Y 1=N	1	55%			1	56%		
Region	There are 5 regions		Amhara	34%		13	SNNP	34%		7
FARM CHARACT.										
Oxen	How many oxen did you use?	# of oxen used	1.4	1.12	0	10	0.97	0.92	0	3
Rotation	Exercise crop rotation on the land holding?	1=Y 2=N	1	92.6%			1	93%		
Type of Farm	What type of farm you have?	1=crop 2=livestock 3=both	3	95%			3	93%		
MANAGERIAL CHARACT.										
Access to credit	Do you have access to credit?	1= Y 2=N	2	67%			2	70%		
Advisory	Do you get advisory services?	1=Y 2=N	1	77.63			1	78%		
Extension	Do you participate in the extension program?	1=Y 2=N	2	55%			2	81%		
		N=581						**N=74**		

[a] The mean and standard deviations are not reported for the dummy variables, instead, the mode and the percentage of frequency is reported

.[b] Y stands for yes, and N for no when the variable is a dummy variable.

To calculate the revenue of all holders, we imputed the prices of the crops per region. To calculate prices of crops per region, we took the information on revenue and quantities in kilos of crops

sold from farmers who reported they have sold their crops. The harvested quantities from year one were reported in kilos and grams, but the harvested quantities from year two were reported in numerous units. The survey used a conversion rate that converted all quantities into kilos but not grams, thus the output quantities we used to calculate revenue are in kilograms only. We imputed the prices of 36 different crops in different regions of the country.

The measurement of the land in the survey was done either using GPS system or a cord. All the holders in the study had their land measured by a GPS system, and we converted the squared meters that were reported into hectares (10000 sqm = 1 hectare).

The information on fertilizer was obtained by adding DPA and UREA quantities applied in each holder's field. The information for the first year came in kilograms and the second year the survey provided kilograms and grams.

All labor that a holder used in the post-planting and post-harvest seasons was added. The labor variable included hired labor, household labor (up to the 6th household member), and other labor. Male, female and children labor was taken into account. The labor was reported in days, weeks, and number of people. We assumed a labor day consisted of eight hours. The unit of labor used in the study is days*number of workers. A summary of the descriptive statistics on inputs and outputs per year is presented in table 2.

The statistics of the variables that were used to calculate the efficiency scores using the DEA are in the table below (Table 3). The summary for the output shows that in 2011 an average male holder's total crop value1 of cereals was 799 ETB (Ethiopian Birr) while for the female the total value of the crops was less at 534 ETB. The total value of the crops for both male and female increased for the period 2013-2014. The non-cereals' total value are lower than the total value for both the cereal for about 100 ETB for both female and male. In the production process, on average, 65.45 kg of fertilizer were used and male holders used 82kg of seed. The amount of fertilizer used by female is slightly higher than males. Moreover, the mean size of land in square meters is about 15990 for both females and males, but males have slightly larger farms.

Table3: Summary of Model variables

	Units	Description	Mean	Std Deviation	Min	Max

[1] The information used to obtain the crop value came from a post-planting harvest question: what was the total value of [CROP) sold? (BIRR).

*All costs are given in Ethiopian Birrs. They were estimated from the information provided in the survey and all holders who did report total cost of inputs were considered for the figures presented.

**Cost of Labor is per person per day

Inputs	**labor1**	Days*#workers	Days of work include all non-hired and hired labor in days. It excludes child labor due to missing values for all holders.	133.7	611.6	0.5	6378.2
	labor2			90.3	111.4	0.3	1343.2
	land1	Hectares	Fields were measured with GPS and reported in square meters. Holders with zero or missing values were dropped	1.5	2.4	0	46.4
	land2			1.7	5.4	0	115.5
	fertilizer1	Kg	Fertilizer is measured as total Kg applied. Includes DPA and Urea quantities	64.7	115.8	0	1335
	fertilizer2			59.7	224.9	0	6325
	seed1	Kg	The total amount of seed used in the planting period, whether was purchased, donated, kept from previous years	81.4	103.6	0	1165.2
	seed2			80	109.6	0	915
Output	**revenue1**	Birrs (ETB)	Aggrerage sales in ETB produced during the post-harvest period by holder. Observation with no sales used imputed prices	3031.1	4479.7	8.7	43144.8
	revenue2			5219.75	3989.9	13.4	15974.7

1 refers to period 2011-2012. 2 refers to 2013-2014.

During the time of analysis, some macroeconomic and microeconomic changes were observed due, perhaps, to the implementation of the GTP economic plan which policy was designed based on the first wave results. For instance, the average output prices indicate an increment of almost 2 percent, which could be the cause of high average revenues in 2013-2014. In addition, the average holder has very small piece of land which is the equivalent of approximate 15600 square meters for the first year, and this average increased to 17400 square meters during the second year when land reforms in some regions of the country started taken place in due to the GTP economic plan. Some holders did not use any type of fertilizer in any of the two years even though it was stablished in the economic plan that increasing the amount of fertilizer available to farmers was an objective.

We considered five of the nine region for the study. We omitted the observation from the Somali region because the labor and revenue information were oddly high. Also, these observations represented 0.3 percent of the observations (only 2), and also the Somali region the main agricultural activity is pastoral. The other region omitted is the Harari region. The number of observation from this region represented 0.6 percent (4 observations), and the values for revenue and labor were also considered outliers given its high values. In addition, the Harari region is the smallest region in Ethiopia, and is not representative of the nation.

In order to conduct a descriptive analysis variable that account for the changes in input and revenue were created. Thus, we have: changed in revenue (revenue2-revenue1), change in labor (labor

used in period 2- labor used in period 1), change in land ((land used in period 2- land use in period 1), and change in fertilizer ((fertilizer used in period 2- fertilizer used in period 1). Since the standard deviation of revenue, revenue2 and revenue changed was significantly high, observations that were one standard deviation away from the mean of the variable revenue-changed were dropped.

Table 4. Average changed in the use of labor units and hectares by region and gender

	Average of labor changed		Average of land changed		Total Average of labor changed	Total Average of land changed
Row Labels	**Male**	**Female**	**Male**	**Female**		
Tigray	10.480	-14.234	0.682	-0.956	7.695	0.497
Amhara	21.176	22.592	0.211	0.236	21.312	0.213
Orimaya	-63.945	-21.719	-0.023	-0.337	-57.689	-0.069
Benishangui	-75.435	9.063	0.421	1.552	-69.984	0.494
SNNP	-1.062	0.895	0.177	0.128	-0.736	0.169
Harari	-34.800		0.078		-34.800	0.078
Grand Total	**-10.755**	**-1.061**	**0.217**	**-0.048**	**-9.547**	**0.184**

There are other facts from the data that were obtained after the cross tabulation analysis of various variables, and the calculation of the variables above mentioned, these facts are: The majority of the farmers are located in the Amhara region (226). The majority of the farmers did not change crops production. In average the highest revenue changed happened to farmers that changed crops (they could either have gone from cultivated cereal to non-cereal or vice versa). In average the farmer that increased revenue from one year to the next cultivated non-cereal crops, more specifically crops like chickpeas, horse beans, wheat, maize, and lentils. The diversification of the crops that came from planting cereals to non-cereals reported the highest revenue changed.

We also found that holders in all regions reduced the labor utilized in second year except for the Tigray and Amhara region. Male holders in average reduced the use of labor more than female holders. In regions like SNNP and Benishangui, female holders in average used more labor units than male holders. In terms of the change in land used, in average during the second year all holders used

slightly more land than in the first year (0.184 hectares). Female in average reduced the utilization of land by about 0.04 hectares while males increased in average the used of land as an input by 0.271 hectares. In Oromia region, the used of land in the second year in average was reduced by both female and male, we had mentioned before that there was an implementation of a land reform in this region, and this caused all prices of land to increased, thus we can infer that the higher prices of land reduced the demand for this input in that region (Addisfortune 2016).

Graph 1 represents isoquants from wave 1 and 2 using two main inputs: labor and land. The outliers depicted in the graphs that have used higher number of labor units from 2011-2012 and 2013-2014 are located in Amhara region. According to IFPRI, Amhara is one of the regions where hired labor is relatively less important than family labor, thus the higher prices in rural wages that were registered during the period studied did not affect the labor units utilized by farms.

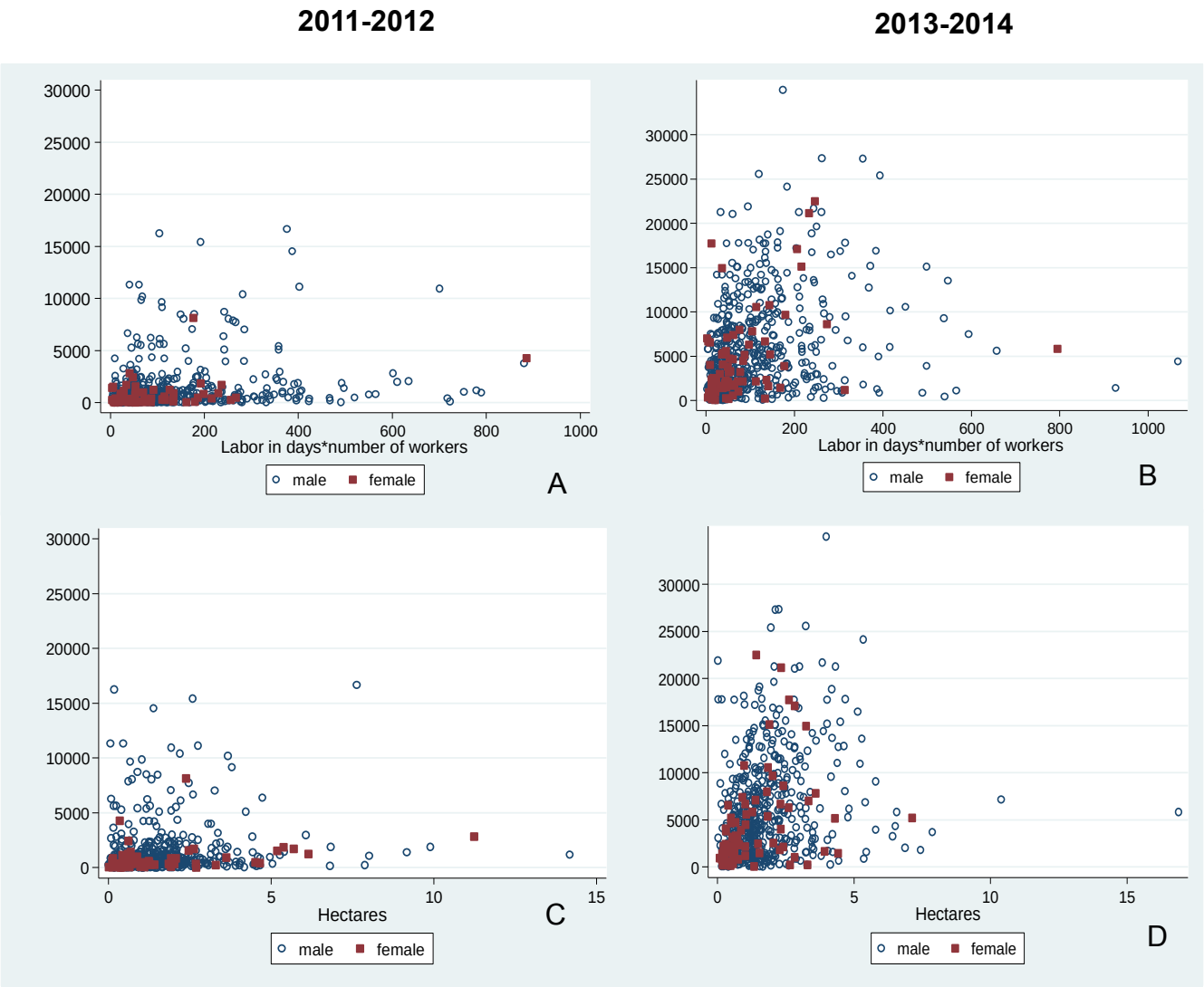
Graph1. Labor Vs. Land by gender

2011-2012 (A) **2013-2014 (B)**

The holders that have used the highest amount of hectares are those that cultivated exclusively cereals and located in Oromia region (graph1 A, B), in this region a land reform took place in 2013. In graph 1 (B), the outliers from the labor are located in the Amhara region, this region is one of the regions where we found the farms with the highest revenues. On the other hand, the holders with the smallest amount of labor hired in (B) are non-cereal producers located in the SNNP region, in this region hired labor is relatively more important than family labor, and with the increased in the wages, it can be inferred that poor farmers could not hired as much labor as needed. For those observations

with very small number of hectares (not even half of a hectare), they were found to be non-cereal producers, or producers that produced both cereal and non-cereals.

Graph 2. Revenue vs. Land/labor by gender



The plots above are frontiers where revenue is plotted in the Y-axis and land or labor is the X-axis. The revenue/labor frontier for 2011-2012 shows many observations that have used relatively high units of labor and obtained low revenue (Graph 2 a). Those observations in year one are in the regions of Amhara and Oromia, and farmers produced mostly cereal or a combination of cereal and pulse crops. According to Graph2, those farms whose holders had high revenues in small units of land were mostly cultivating non-cereal crops, or both (cereal and non-cereal) as opposed to only cereal. It was known that in the GTP economic growth plan, horticulture was particularly

targeted, due to its potential to boost export earnings and job creation; however, the issue of land availability and distribution was identified as a major bottleneck for the expansion of horticulture.

The graph for 2013-2014 (Graph 2B, 2D), less labor and land were used and higher revenues were obtained, for both female and male farmers. A possible explanation to this trend, is the higher level of output prices observed in 2014 compared to 2011, and the higher cost of hire agricultural labor in comparison to 2011 (IFPRI 2016). In addition, from the data, we observed an increasing quantity produced in all crops. In addition, the majority of our data comes from the Oromia region, where a land reform started in 2013 and it caused an increased in all the land prices. This might be the explanation of why less land has been used during the second period of the study.

RESULTS

Results from DEA model

The input-oriented DEA analysis across all male and female holders was estimated under the VRS assumption. Only VRS coefficients are consider in the analysis. The holder's revenue efficiency scores for the two periods were obtained using total value of the crop as an output, and four inputs. Table 5 shows the revenue efficiency (RE) scores for the two periods evaluated for each farm.

Table 5. Revenue Efficiency scores female and male holders in Ethiopia from 2011-2014

Revenue Efficiency scores

	2011-2012		2013-2014	
	Female RE	Male RE	Female RE	Male RE
	VRS	VRS	VRS	VRS
1	20.27%	4.44%	24.32%	6.37%
0.9-0.999		0.39%	1.35%	0.77%
0.8-0.899	2.70%	0.39%	9.46%	3.09%
0.7-0.799		0.39%	4.05%	2.70%
0.6-0.699	2.70%	1.35%	5.41%	5.41%
0.5-0.599		1.16%	8.11%	7.53%
0.4-0.499	6.76%	2.70%	9.46%	8.49%
0.3-0.399	9.46%	3.67%	12.16%	10.81%
0.2-0.2999	16.22%	5.21%	6.76%	16.99%
0.01-0.019	41.89%	80.31%	18.92%	37.84%
Mean	39%	15%	56%	34%
Min	0	0	0	0

Max	1	1	1	1
Sd	0.35	0.23	0.34	0.27
DMU	74	518	74	518
%Males	87			
% Females	13			

The results were obtained by separate estimations, one from 2011-2012, and the other from 2013-2014. Assessing the distribution of farms based on revenue scores, the mean estimates for RE for female holders is higher (39 percent) than the male holders (15 percent) in both years, indicating that female holder farms are more revenue efficient than male holder farms. During the two periods of the study, there was a decreasing in the minimum RE estimates for both female and male. For 2011-2012, 41 percent of female holder farms were less than 2 percent efficient; this percentage of female holder farms was reduced to 18.92 percent of the female holders being less than 2 percent revenue efficient in 2014. For the male holder farms, about 80 percent of those farms were 2 percent or less efficient, in 2014 the percentage of male holder farms that were 2 percent or less efficient dropped to only being 37 percent of the farms. This indicates an improvement in revenue efficiency from one period to the other, regardless of the gender. It is important to note that this improvement did not necessarily mean that the number of fully revenue efficient firms grew considerably, since the all-efficient firms are less than 7 percent for female and male holder farms of the sub-sample. This increase in revenue efficiency improved the middle efficient firms that became more revenue efficient, but not totally efficient. Still only 25 percent of the female holder farms are fully revenue efficient compare to 6.5 percent of male holder farms. The results obtained indicate that all farms regardless of the gender of the holder are losing an opportunity to receive more revenue given the same amount of resources. In the case of the female farmer they are losing the opportunity to receive 46 percent of revenue, in the case of the male could receive 66 percent more of what they are earning, with the same resources they were using in 2014.

There was significant difference between male and female holder farms in revenue efficiency scores based on the t-test results. Also, the Chow test was performed, and there is statistically evidence that the data cannot be pooled.

Results from Panel Tobit model

Assuming that the inefficiency scores of each of the farms obtained from the DEA are dependent variables, panel Tobit analysis was applied in the second stage to examine the determinant sources of revenue inefficiency (RES) for male and female holders. The model that we considered is the following:

$$RES_{it}^{*} = \beta_1 age_{it} + \beta_2 region_{it} + \beta_3 rotation_{it} + \beta_4 extension_{it} + \beta_5 credit = \beta_6 oxen_{it} + \beta_7 education + \beta_8 advisory_{it} + \varepsilon_{it}$$

Separate regressions of the panel Tobit were performed: for female and male. Results are shown in the table below. The contribution of some selected farmers' personal characteristics, farms' characteristics, and managerial characteristics were studied. These include farmers' age, region (Tigray being region1), rotation, credit, number of oxen used, education, participation in extension services, and advisory services.

The determinants of revenue inefficiency for the female and male holders were calculated and are shown in table 5. In the results, six of the eight variables are statistical significant, and have significant impact on female holder farmer's efficiency. These factors are: age, region, rotation, credit, education, advisory. For males, the significant factor that influences revenue efficiency is the region they are located. Being from the Tigray region increases the probability to get a higher efficiency score, regardless of the gender.

For female farmers, age influences efficiency scores. Being older contributes to increase the probability to be revenue inefficient. Also, this result is probably reflective of older producers who use traditional farming methods and are less willing to adopt innovative, alter-crop mix activities, chemical fertilizer, improved seeds, etc. The coefficients of age are significant at the 5 percent level.

Even though rotation is essential to increase efficiency because help control many of the crop-disease, and increase crop yields by improving soil conditions, during the time of the analysis and for the sub-sample that we are analyzing, rotation did not contribute to an improvement of revenue efficiency. If female farmer rotates crops, the probability to become inefficient is higher than if the farmer does not rotate crops. A possible explanation is that the highest revenues from 2013-2014 were observed in farmers that rotated from cereal crops to horticulture crops, since female farmers in average cultivate more of the horticulture crops than cereal crops. Those female farmers that answered in the surveyed

that have rotated crops perhaps went from horticulture crops to cereal in which case, due to the decline in the prices of cereals, they experienced lower revenue and that affected their efficiency scores.

Table 6. Panel Tobit Analysis of revenue efficiency in Ethiopia from 2011-2013

Explanatory Variable	FEMALE HOLDERS Revenue Inefficiency	MALE HOLDERS Revenue Inefficiency
Age	.00596633***	.00198
	(.00063)	(.0017)
Region Tigray	-.07230523**	-.1477187**
	(.0347)	(.07490)
Rotation	.4194077***	-.04567
	(.0351)	(.1380)
Extension	-.0009	.0416
	(.024)	(.0531)
Credi	.04475329*	.0518
	(.02527)	(.0556)
Oxen	-.0051	.0141
	(.00899)	(.0237)
Education	.08297658**	.050394
	(.0220)	(.0503)
Advisory	.07318754**	.1024
	(.03069)	(.0633)

Note: *,**, *** denote significance at the 10%, 5% and 1% level, respectively coefficient

Advisory services for female resulted to be significant at a 5 percent level of significance. According to table 6, taking part of advisory programs contribute to the revenue inefficiency. As counterintuitive as it might sound, some studies have revealed that due to low literacy levels, domestic obligations, distance, lack of awareness and lack of facilities where the educational training is held are some of the significant barriers that women face to be successfully part of these type of services. In addition, the adequacy of the knowledge farmers would get from the advisory sessions has a significant in the improvement of the revenue efficiency. An appropriate and relevant information on

prices, and markets, or access to sale center can contribute to the revenue efficiency of female farmers. Perhaps, the information obtained from the advisory services focuses more in production and usage of technology rather than marketing. Both are equally relevant in improving the revenue efficiency of both female and male farmers.

In contrast to the priori expectation coefficient, having access to credit increases the probability to become revenue inefficient, and having some education over having non-education increases the inefficiencies in the study.

Conclusions

This study used a two-stage performance assessment across female and male holders from 2011 to 2012, and from 2013 to 2014. In the first stage of the study, the revenue efficiency scores of female and male holders were calculated by using different DEA for the two years. Once all revenue efficiency scores were obtained, they were transformed into inefficiency scores calculated as one minus the efficiency score. Then, a panel Tobit analysis was estimated on the farms' inefficiency by including variables related to the farmer's personal characteristics, farms' characteristics, and managerial characteristics.

The study corroborates the two conventional ideas that women use few modern inputs, and the usage of these inputs is more revenue efficient relative to the male's usage of the inputs. From the descriptive analysis, we found that even with the emphasis that the GTP economic plan has put in the extension packages to increase the usage of the modern inputs such as chemical fertilizer and improved seeds, the survey shows that only small portion of female and male farmers used those inputs. In addition, female holders tend to use in a more intense way fertilizer than male counterpart. When measuring the percentage of females using basic inputs such as land, labor and oxen, the descriptive analysis results show that men utilized more oxen than females, males have slightly larger farms, and females in average reduced the utilization of the land while males increased in average the used of it. The contrary happened to the usage of the labor input where male holders in average reduced the use of labor more than female holders.

In terms of financial services, both female and male indicated not have access to credits. However, the situation is different for the advisory and extension services where the gender disparities are evident. In average, a higher percentage of women do not participate in the extension program in comparison to male farmers. This is especially critical since extension services have the objective of provide kits and technical support of modern inputs to the farmer; this would give them access to new

technologies, and let them improve their technical efficiency. In terms of advisory services, a high percentage of male and female have this service.

The descriptive analysis indicated that the total value of crops for male and females increased from 2011-2014, but in average the total value of crops for females is lower than the total values of males. In terms of revenue, the farmers that diversified, and increased the number of crops cultivated were those with higher revenues.

From the first stage of the study, we found there was substantial amount of inefficiency in revenue during the study period for male holders. The mean revenue efficiencies of the male holders was 15 percent, whereas female mean was 39 percent for the first year. What this means is that the average male farm receives only 15 percent and female farm receives 39 percent of the maximum possible revenue, giving the resources the farms have. For the second year, the scores improved radically to 34 percent for males and 56 percent for females during 2013 to 2014. Thus, we conclude that the policy intervention that occurred during 2013-2014 because of the GTP economic plan increased the efficiency scores for both female and male, but male efficiency scores increased more than the female efficiency scores.

Special attention should be paid to the most efficient male holders. The percentage of male holders that are completely efficient increased, but this increment was only 1.93 perceptual points, and female holders that became 100 percent efficient incremented around four perceptual points. Still, the policies should be aimed to make more farmers become fully efficient, and being on the efficiency frontier. On the other hand, the reduction in the percentage of the least efficient farmers was very significant for both males and female farmers; the percentage reduction was 43.47 percentage points, and 22.97 percentage points respectively.

In the second stage of the study, panel Tobit analysis was used to obtain consistent and unbiased estimators since the dependent variable obtained by DEA is censored. Region is the common factor that affects efficiency to both female and male holders. Holders that are located on Tigray region have a higher probability to become more revenue efficient than if they were located in other regions. The Tigray region is more likely to favors efficiency over the other regions. Thus, we conclude that there is a structural inequality persisting in the country that make holders from other regions to have a lower probability to increased efficiency.

The female holder results indicated that the age, rotation, education, advisory, and credit of the holder increases inefficiency scores. With respect to age, it can be argued that the older a holder is they

are more likely to become economic inefficient regardless of the gender because those innovative agricultural methods, are less likely to be adopted by them. The results that are coming from the extension and advisory services can be explained by the fact that some this services need to consider the low literacy levels of the farmers, especially females, the domestic obligations that impose a constraint restriction on the female farmer, the distance from the farms, among others. A more in depth analysis of the effect of education, and access to credit on efficiency scores is warranted since the theory would indicate the contrary.

Lastly, there is evidence in the paper that structural planned changes in agriculture can be diminishment of the gender gap in this sector in terms of efficiency. It also shows that a gender inclusive policy benefits all farmers, and not only female farmers.

References

Ahmed, M.E. "Poverty and livelihood strategies of female-headed households in rural Ethiopia: the case of Libo Kemkem Woreda, South Gondar." (2013):

Aigner, D., C.K. Lovell, and P. Schmidt "Formulation and estimation of stochastic frontier production function models." *Journal of Econometrics* 6 (1977):21-37.

Al-Hassan, S. *Technical efficiency of rice farmers in Northern Ghana* (2008):

Alemu, B.A., E. Nuppenau, and H. Boland "Technical efficiency of farming systems across agro-ecological zones in Ethiopia: An application of stochastic frontier analysis." (2008):

Baltagi, B. *Econometric analysis of panel data*. John Wiley & Sons, 2008.

Banker, R.D., A. Charnes, and W.W. Cooper "Some models for estimating technical and scale inefficiencies in data envelopment analysis." *Management science* 30 (1984):1078-92.

Banker, R.D., and R. Natarajan "Evaluating contextual variables affecting productivity using data envelopment analysis." *Operations research* 56 (2008):48-58.

Berihun, K. *Assessment of Factors Affecting Agricultural Production: Evidence from Smallholder Farmers of Southern Tigray, Northern Ethiopia* (2014):

Block, S.A. "The recovery of agricultural productivity in sub-Saharan Africa." *Food Policy* 20 (1995):385-405.

Charnes, A., W.W. Cooper, and E. Rhodes "Measuring the efficiency of decision making units." *European Journal of Operational Research* 2 (1978):429-44.

Coelli, T. "Estimators and hypothesis tests for a stochastic frontier function: a Monte Carlo analysis." *Journal of productivity analysis* 6 (1995):247-68.

Coelli, T.J. *A guide to FRONTIER version 4.1: a computer program for stochastic frontier production and cost function estimation* (1996):

Coelli, T.J., D.S.P. Rao, C.J. O'Donnell, and G.E. Battese *An introduction to efficiency and productivity analysis*Springer Science & Business Media, 2005.

Debebe, S., J. Haji, D. Goshu, and A. Edriss "Technical, allocative, and economic efficiency among smallholder maize farmers in Southwestern Ethiopia: Parametric approach." *Journal of Development and Agricultural Economics* 7 (2015):283-92.

Dercon, S. "Ethiopia: Poverty assessment study." *Department of Economics, Oxford University, http://www.economics.ox.ac.uk/members/stefan.dercon/IFAD1.pdf* (1999):

Dorosh, Paul, and Shahidur Rashid, eds. *Food and agriculture in Ethiopia: Progress and policy challenges*. University of Pennsylvania Press, 2013.

Ellis, F. *Peasant economics: Farm households in agrarian development*. Cambridge University Press, 1993.

Eshete, A. *Why is gender a development issue? In: (Eds.), Ethiopian Agricultural Research Organization (EARO), Addis Ababa, Ethiopia.*, Addis Abeba, Ethiopia ed.2000.

Farrell, M.J. "The measurement of productive efficiency." *Journal of the Royal Statistical Society.Series A (General)* (1957):253-90.

Featherstone, A.M., M.R. Langemeier, and M. Ismet "A nonparametric analysis of efficiency for a sample of Kansas beef cow farms." *Journal of Agricultural and Applied Economics* 29 (1997):175-84.

Førsund F.R., and E.S. Jansen "Technical efficiency of Norwegian banks: The non-parametric approach to efficiency measurement." *Journal of Productivity Analysis* 2 (1991):127-42

Greene, W.H. *Econometric analysis*Pearson Education India, 2003.

Hailu, B.K. "Econometric Analysis of Access to Agricultural Extension Workers' Service and its Implication on Crop Yield in Tigray Region, Ethiopia." *International Journal of Agricultural Science, Research and Technology in Extension and Education Systems* 4 (2014):25-36.

Javed, Z.H., and A. Asif "Female households and poverty: A case study of Faisalabad District." *International Journal of Peace and Development Studies* 2 (2011):37-44.

Kasa, Leulsegged, James Warner, and Caitlin Kieran. *"Patterns of agricultural production among male and female holders: Evidence from agricultural sample surveys in Ethiopia"*. Intl Food Policy Res Inst, 2015.

McDonald, J. "Using least squares and tobit in second stage DEA efficiency analyses." *European Journal of Operational Research* 197 (2009):792-8.

Mekonnen, E., E. Geta, and B. Legesse "Production Efficiency Of Sesame In Selamago District Of South Omo Zone, Southern Ethiopia." *Current Research in Agricultural Sciences* 2 (2015):8-21.

Palacios-Lopez, Amparo, Luc Christiaensen, and Talip Kilic. "How much of the labor in African agriculture is provided by women?." *World Bank Policy Research Working Paper* 7282 (2015).

Ogato, G., E. Boon, and J. Subramani "Gender roles in crop production and management practices: a case study of three rural communities in Ambo district, Ethiopia." *Journal of human ecology* 27 (2009):1-20.

Quisumbing, A.R. "Male-female differences in agricultural productivity: Methodological issues and empirical evidence." *World Development* 24 (1996):1579.

Schultz, T.W. "Transforming traditional agriculture." *Transforming traditional agriculture.* (1964):

Seguino, S., and M. Were *Gender, Development, And Economic Growth In Sub--Saharan Africa* 2012.

Solomon, T., M. Yami, and B. Begna "Gender Differentials in Scale and Technical Efficiencies among Improved Wheat Variety Growers in Wheat Belt Areas of Ethiopia: A Data Envelopment Analysis (DEA)." *Journal of Economics and Sustainable Development* 6 (2015):91-100.

Tesfay, G. *Agriculture, resource management and institutions: a socioeconomic analysis of households in Tigray, Ethiopia* Wageningen University and Research Centre, 2006.

Tiruneh, A., T. Tesfaye, W. Mwangi, and H. Verkuijl *Gender differentials in agricultural production and decision-making among smallholders in Ada, Lume, and Gimbichu Woredas of the Central Highlands of Ethiopia*Cimmyt, (2001).

Szirtes, T. *Applied dimensional analysis and modeling* Butterworth-Heinemann, (2007).

World Bank (WB) (2011). W*orld development report 2012: Gender equality and development.* Washington, DC: The World Bank. Retrieved from: http://siteresources.worldbank.org/INTWDR2012/Resources/7778105-1299699968583/7786210-1315936222006/Complete-Report.pdf.

Zenebe, G., A. Oskam, and W. Tasew "Technical Efficiency of Peasant Farmers in Northern Ethiopia: A Stochastic Frontier Approach." (2005):