# Ethiopian Economics Association

# (EEA)

## PROCEEDINGS OF THE SIXTH REGIONAL CONFERENCE ON THE TIGRAY REGIONAL STATE ECONOMIC DEVELOPMENT

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# FOREWORD

The Ethiopian Economic Association (EEA) and its Mekelle Chapter are happy to issue the proceeding of the Sixth Annual Conference on the Tigray Regional State Economic Development which was organized on June 30, 2018 at Axum International Hotel Conference Hall, Mekelle. EEA organized this important regional conference as one of its objectives of broadening its activities and coverage at regional level so as to contribute to the economic advancement of regional state through enhancing economic policy formulation capability; the dissemination of economic research findings; promotion of dialogue on critical socio-economic issues; promotion of education in economics in higher learning institutions; enhancing national, continental and global networks of professionals and institutions; and advancement of the professional interests of its members.

The Annual Regional Conferences that the Association has organized in collaboration with its Mekelle Chapter has created important forums for presenting and discussing development issues that are highly relevant to the Regional Socio-economy. These forums have also provided incentives for researchers to conduct research and present their findings on regular basis. Indeed, the Annual Regional conferences were organized in an interdisciplinary fashion, thereby widening the interactive coverage involving both economists living here in the region and those living outside the region and non- economists who are working and experiences on the region. The Sixth Annual Regional Conference on Tigray Regional State Economic Development has contributed towards a deeper understanding of the regional economy and the complex challenges it faces. It attracted about 80 participants including higher officials from Tigray Regional State council office and expertise from Tigray Regional State Bureau of Plan and Finance, Mekelle City Administration, Tigray Agriculture Research Institute, different Banks, Universities of Mekelle, Adigrat, Raya and Axum, NGOs, private sector representative and EEA members in the Region. The participants of the conference expressed their satisfaction on the organization of the conference and the content of the papers presented. They reflected that the papers largely focused on local issue that can contribute to the development of the region.

They also recommended that the issues raised in the discussion are critical that need due attention by policy makers and implementing organs of the region.

In this publication, all papers which were presented at the Sixth Annual Conference reviewed by external reviewers and comments and suggestions including editorial comments were communicated to authors for improvement. Finally, those papers which passed all the review and editorial process published in the Proceeding of the Tigray Regional State Economic Development.

At this juncture, I would like to take this opportunity to express my heartfelt gratitude, on my own behalf and on behalf of the Ethiopian Economic Association, to the many people and organizations that made the conference resounding success. First and foremost, I thank the authors of the papers and the audience whose active participations made the Conference meaningful. The staffs of the Economics Department of the Mekelle University which runs the EEA Mekelle Chapter, participants and the staff of EEA Secretariat deserve a special recognition for their passion and perseverance in managing the conference from inception to completion. Mekelle University also deserves appreciation for hosting EEA Chapter by providing office.

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

Finally, I would like to extend my sincere gratitude to officials of the regions and Mekelle University who spared their busy schedule and participated in the conference.

Tadele Ferede (PhD)
President of the Ethiopian Economics Association

# Technical, Allocative and Economic Efficiencies and Sources of Inefficiencies among Large-scale Sesame Producers in Kafta Humera District, Western Zone of Tigray, Ethiopia: Non-parametric approach

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***Abstract***

*This study analyzed production efficiency and sources of inefficiency differentials of sesame in Kafta Humera district of Tigray region, Ethiopia. It was specifically aimed to address level of efficiency and lower productivity gap on which its determinant factors were not identified; by measuring technical, allocative and economic efficiencies and their sources of inefficiency differentials of sesame in Kafta Humera District. For addressing these objectives this study used primary and secondary data obtained from field survey and desk review. Multistage random sampling technique was used to draw 126 large-scale sesame producers. Applying the Cobb-Douglas functional form the average technical, allocative and economic efficiencies found were 71%, 90% and 64% for large-scale producers. Regarding these producers; education level, frequency of farm visit(number of farms follow up), experience in sesame production, type of road and credited amount obtained were significant sources of technical, allocative and economic inefficiencies. Distance of farm from residence, ownership of living home and livestock and cooperative membership were also significant sources of technical and economic inefficiencies. Depending on the results found, this study recommend strengthening the introduction of improved seed, mechanized labor substituting technologies and fertility enhancing inputs for improving production level. For improving sesame production efficiency this study recommends; capacitating large-scale producers through strengthening education, strengthening the credit access at affordable interest rate, nearby sesame farm follow up and frequently visiting of their farm with effective farm management will be better. For improving the farm level efficiency of large-scale producers, it is also important to initiate producers to hire certified experts, strengthening the productive utilization of their livestock and their house to earn cash.*

**Key words:** Cobb-Douglas function, Efficiency, Inefficiency sources, Kafta Humera, Large-Scale, Production and Sesame

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# 1. Introduction

Agriculture is the most important sector of Ethiopia's economy where about 95% of total arable area is cultivated by small-scale that produce more than 95% of total output obtained from the sector [22], [44], [58], [48]. It has contributed to livelihoods of about 85%, employing about 85% labor force, accounts about 45% of GDP and for foreign exchange currency of about 86% [26]. Accordingly, the government of Ethiopia has taken initiatives that can assure by improving efficiency through reducing losses and improving market performance.

Sesame is one of the important oilseed crops adapted to semi-arid tropical regions that best performs on well drained, moderately fertile soils with temperature between 20-35°C [65]. Sesame is one of the six priority crops in the AGP of Ethiopia [56]. In Ethiopia, sesame is being produced as cash crop by small-scale who cultivate 0.42 million ha and produce 0.29 million tone and by large-scale who cultivate 0.28 million ha and produced more than 0.22 million tones [22]. Nationally, sesame accounts for 3.35% of total area and 1.1% of total grain production [22]. It is produced in North Gondar and Western Tigray lowlands, Wellega, Benishangul Gumuz and South-Omo; which North Gondar and Western Tigray contributed more than 68% to the national production [22].

Over the past years, sesame production has shown greater increase in area and production but decreasing in yield. Looking at its trend, nationally sesame covered 0.14 million ha area where 0.12 million tons was produced in 2004/5 [42] increased to 0.29 million tone production on 0.42 million ha in 2014/15 [42]. But, its productivity declined from 8.47 Qt/ha in 2004/5 [42] to 7.35 Qt/ha in 2013/14 [21] and to 6.87 Qt/ha in 2014/15 [22].

In Tigray region, about 176,030 small-scale [22] and about 1130 large-scale [41] were engaged in sesame production that supplied 88.7% of their production [21]. According to [21], Tigray region ranked second in area and production. Western zone took the lion share in the region's sesame area

(76.33%) and total production (76%) for the average productivity of 7 Qt/ha [22].

Given agriculture as backbone of the nation's food security and as sesame is the second agricultural product that earns foreign exchange; it is imperative to conduct study on measuring production efficiency and inefficiency; so, large-scale producers in the study area were fail to earn profit. Similarly, sesame suffers lower productivity than the FAO estimated potential [65]. Also, through farmer's practice productivity ranges from 2 to 13.75 Qt/ha [67], [31] which shows wider gap. So, this study was aimed to measure production efficiency and inefficiency sources. Achievements of these objectives have significance contributions on making an informed decision for optimum input allocation and providing scientific information for decision makers, planners, policy makers, input suppliers, supporting institutions, and other actors. This study would also help as reference for other studies.

## 2. Methodology

**Description of the Study Area:** The study was conducted in Kafta-Humera district, Ethiopia; bordered by Eritrea, Sudan, Tsegedie district, Welkayt district and North western zone in the north, west, South, East and north east, respectively. The study area has 24 kebeles with total population of 103,692 having 26,352 households covering 4,542.33Km2with 396,852ha cultivable land [39]. There are also 1,130 large-scale producers who cultivate sesame [41]. The study area is known for cultivation of sesame and sorghum [39],[31] that obtains annual rainfall ranging from 400-650 mm in the months from June to September [29].

**Data Types, Sources and Methods of Data Collection:** Both primary and secondary data types were collected for this study where primary data sources were collected using semi-structured questionnaires of formal survey procedures from large-scale producers in four kebeles. Secondary data sources are also collected from office of agriculture and rural development, HuARC, different books and published and unpublished reports.

**Sampling Procedure and Sample Size:** This study used multi-stage sampling technique for selecting sample producers. First, large-scale producers in the district were selected purposively. Secondly, four kebeles (Mai Cadra, Baeker, Adebay and Rawyian) were selected randomly. Then depending on probability proportional to size of large-scale producers from each sample kebeles, specified numbers of respondents were obtained based on the formula developed by [69] considering confidence level of 90% and accepting the error (e) of 9%,

$$n = \frac{N}{1 + N(e^2)} \quad (3.1)$$

Where n = sample size, N= total large-scale household equal to 1,130. Based on the calculation, 126 large-scale sesame producers were sampled using random sampling technique (Table 1).

**Table 1: Number of sampled producers from each kebele**

| Kebele | Total pop. | Sample |
|---|---|---|
| Adebay | 98 | 16 |
| Baeker | 149 | 25 |
| Mai Cadra | 409 | 68 |
| Rawyian | 107 | 17 |
| Total | | 126 |

Source: [40]

## 3. Methods of Data Analysis

**Production Efficiency and Sources of Inefficiency Differentials**

In estimating technical, allocative and economic efficiencies and inefficiencies, SFA of Cobb-Douglas function was applied; because, it allows segregating of external effects from inefficiency. From [6], [47], SPF in Cobb-Douglas form is defined as:

$$\ln Y_i = \beta_0 + \ln \sum_{j=1}^{k} \beta_j x_{ij} + \varepsilon_i \quad (3.2)$$

$$\varepsilon_i = V_i - u_i \quad (3.3)$$

Where j= 1… k inputs; i= ith producer; Yi= sesame yield, Xij= jth input used, βi= vector of unknown parameters, εi= disturbance term composed of vi (error) and ui (inefficiency).

Production function could be either Cobb-Douglas or translog that requires specification by likelihood ratio test. As it was developed by [14] Cobb-Douglass production function of dual cost used to specify cost function with its inefficiency where cost function represents dual approach [18]. The stochastic nature of cost frontier would still imply the theoretically minimum cost frontier; stochastic in nature, given as:

$$C = C\left(P, Y^*, \alpha\right) \quad (3.4)$$

Or,

$$\ln c_i = \alpha_0 + \left(\sum_{j=1}^{k} p_{ij}, \alpha_i\right), + \alpha_j Y_i^* \quad (3.5)$$

Where i = ith household; Ci = minimum cost; j= 1…k, inputs used; Pij= input price; Yi* = farm revenue adjusted for noise vi, and α's= parameters to be estimated.

**Variables of sesame production efficiency:** These variables are inputs in sesame production efficiency which could be production or cost inputs that combined to determine the overall production efficiency.

**Production function:** This uses the Cobb-Douglas form that shows the relation of dependent variable with its inputs. The dependent variable is given by the following equation.

$$\ln Y_i = \beta_0 + \beta_i \ln ld_i + \beta_i \ln sd_i + \beta_i \ln lb_i + \beta_i \ln pw_i + \beta_i \ln fq_i + (v_i - u_i) \quad (3.6)$$

Where ld= land, sd = seed, lb= Labor, pw = Oxen/tractor power, fq = fertilizer
Estimation of cost functions for sesame production

This refers to production cost incurred by producer's calculated taking price of inputs give as follows:

$$\ln c_j = \partial_{0j} + \partial_{1j}\ln cld_{j1} + \partial_{2j}\ln csd_{j2} + \partial_{3j}\ln clb_{3j} + \partial_{4j}\ln cft_{4j} + \partial_{5j}\ln cpw_{5j} + \partial_{6j}\ln cmt_{6j} + \partial_{7j}\ln cop_{7j} + (v_j - u_j) \quad (3.7)$$

Where j= jth producer; cj = actual cost; i=1…7, ith input cost; βj= coefficients to be determined; v-u = error; cld= land cost; csd= seed cost; clb= wage; cft= fertilizer cost; cpw= plough cost; cmt= material cost and cop= operation cost. The minimum cost input equation can be expressed as:

$$\Delta c_i / \Delta p_i = x_{ie}\left(p_i, Y_i^*, \alpha\right) \quad (3.8)$$

So, optimization profit principle is to minimize cost subject to optimum output. Minimum cost is derived using the methodology used in [10], [52], [70] and [24]. Given input oriented function, the efficient cost function is written as:

$$Min \sum C = \sum_{j=i}^{k} \left(x_j, p_j\right) \quad (3.9)$$

Subject to

$$Y_i^* = \hat{A} \prod Xj^{\beta j} \quad (3.10)$$

$$\hat{A} = Exp\, \beta_0 \quad (3.11)$$

By substituting the expenditure function and the adjusted yield for stochastic error in to the above minimization function to derive the following:

$$C\left(Y_i^*, Y_i\right) = H \; Y_i^{*u} \prod_i P_i^{\alpha j} \quad (3.12)$$

According to [60], the explained cost measures enable to estimate AE and further EE.

Generally from the above explained concepts TE can be defined in the ratio of observed outputs (Yi) to the corresponding frontier output (Yi*).

$$TE_i = Y_i / Y_i^* = \sum_i x_{it}, P_i / \sum_i x_i, P_{ip} \quad (3.13)$$

Also economic efficiency (EE) is the ratio of the minimum costs adjusted or expenditure (C*) to the actual total production cost or expenditure (C).

$$EE = c_i^* / c = \sum x_{ie} P_i / \sum x_i P_i \quad (3.14)$$

From these two equations the AE can be derived as the ratio of EE to TE.

$$AE = EE / TE = \sum x_{ie} P_i / \sum x_{it} P_i \quad (3.15)$$

**Sources of sesame production inefficiency**

After measuring TE, AE, and EE, it is important to identify the major sources of inefficiency derived from different variables. Following the adoption of [14] for analysis inefficiency using Cobb Douglas functional form, estimation of inefficiency is specified as:

$$U_i = \sigma_0 + \sigma_{1i} w_{1i} + \sigma_{2i} w_{2i} + \sigma_{3i} w_{3i} + \ldots + \sigma_{15i} w_{15i} \quad (3.16)$$

Where Ui= inefficiency of ith producer; w1-w15= inefficiency variables.

**Estimation of best production function**

Selecting the best function relative to other functions is based on tests of fitness to the data generated. In specifying the best production function this study conducted hypothesis tests for the parameters of SFA using likelihood ratio statistic defined by Equation 3.17, that H0 is for Cobb-Douglas and H1 is for translog.

**Likelihood ratio test:** This is used to compare the goodness of fit of two hypotheses given as in eq. 3.17.

$$LR = \lambda = -2 \ln\left[L(H_0) / L(H_1)\right] = -2\left[\ln L(H_0) - \ln L(H_1)\right] \quad (3.17)$$

Where, L[Ho] is value of H0, L[H1] is value of H1. This also enables to detect either there is error or not; through comparison of χ2 by obtaining λ, γ and δ2.

$$\lambda = \delta_u^2 / \delta_v^2 ...or.... \delta_u / \delta_v, \quad (3.18) \qquad \gamma = \delta_u^{\;2} / \delta^{\;2} \quad (3.\ 19)$$

$$\delta^2 = \delta_u^2 + \delta_v^2 \quad (3.\ 20)$$

Given the specification of SFA, inefficiency is present is defined by Ha:$\gamma \neq 0$. In selecting the best fitting model; so further the level of TE, AE and EE and inefficiencies, the studies conducted by [20], [3], [30], [11], [28], [15], [17] and [24], similarly used likelihood ratio test.

## 4. Results and Discussion

### Demographic Features and Availability of Production Resources

On average there were six persons in each family with the composition of three by three for male and female members (Table 2).

**Table 2: Household characteristics of large-scale sesame producers**

| Variables | Mean |
|---|---|
| Age (years) | 48.4 |
| Experience (years) | 19.8 |
| Family size (No) | 6.50 |
| Male members (No) | 3.30 |
| Female members (No) | 3.20 |
| Active family (No) | 3.90 |
| Non-active family (No) | 2.50 |
| Dependency ratio | 0.38 |
| Education level (years of school) | 4.88 |
| Extension contact (No) | 1.34 |
| Training obtained (No) | 0.91 |
| TLU | 12.73 |
| Off-sesame income (Birr) | 61,361.27 |
| Borrowed money (Birr) | 347,960.30 |
| Own income (Birr) | 192,245.10 |
| Labor hired /ha | 23.17 |
| Total land | 159.86 |
| Sesame land | 128.60 |

Source: Survey result, 2016

The sampled sesame producers used hired labor at different production activities that were 23 man-days/year per-ha owning the average land holding size of 159.86 ha (Table 2). 98.67% of the sesame produced in 2015/16 production year was sold (Table 3).

**Table 3: Amount of sesame allocated for different purposes**

| Purpose | Mean (Qt.) | % |
|---|---|---|
| Sold | 295.91 | 98.67 |
| Seed | 3.6 | 1.2 |
| Consumption | 0.38 | 0.13 |

Source: Survey result, 2016

**Summary Statistics of Sesame Production Inputs and Costs**

The average sesame produced by the sampled producers was 299.43 Qt/household with cost of birr 854469.84 (Table 4).

**Table 4.Summary of total production inputs and costs**

| Variable | Unit | Mean |
|---|---|---|
| Sesame produced | Qt | 299.43 |
| Production cost | Birr | 854469.84 |
| Labor used | No | 2979.44 |
| Labor cost | Birr | 445387.67 |
| Land size | Ha | 128.59 |
| Land cost | Birr | 178981.01 |
| Plough power hour | Hr | 64.30 |
| Plough cost | Birr | 63530.04 |
| Operating cost | Birr | 53458.69 |
| Material cost | Birr | 7657.32 |
| Seed amount | Kg | 436.98 |
| Seed cost | Birr | 12681.64 |
| Fertilizer cost | Birr | 92773.63 |
| Fertilizer used | Qt | 72.24 |
| Average sesame yield | Qt/ha | 2.46 |
| Average production cost/ha | Birr/ha | 6644.43 |

Source: Survey result, 2016

**Estimation of Production Function parameters**

**Specification tests:** Different types of tests were applied for model validity checking such as multi-collinearity, heteroskedasticity, and adjusted R-square. Multicollinearity test using VIF for all variables was less than ten (i.e., 5.21), indicating no severe problem (Table 5). Heteroskedasticity test using the Breusch-Pagan test also show that there is no heteroskedasticity problem (Table 5). Adjusted R-squared also was 0.92 indicating the variables explain 92% of the variability in sesame output (Table 5).

**Table 5: SFA parameter coefficient for sesame production by large-scale producers**

| Ln sesame production | unit | Coefficients | P>\|t\| |
|---|---|---|---|
| Ln land | Ha | -1.15*** | 0.007 |
| Ln fertilizer | Qt | 0.024 | 0.276 |
| Ln labor | Man day | 0.021 | 0.352 |
| Ln plow power | Tractor hr | 2.31*** | 0.00 |
| Ln seed | Kg | -0.279** | 0.025 |
| Total (elasticity) | | 0.926 | |
| Constant | | 3.60*** | 0.00 |
| Wald chi2 (5 ) | | 2746.57 | P= 0.00 |
| Sigma_U | | 0.482 | P= 0.00 |
| Sigma_V | | 0.117 | P= 0.00 |
| gamma(γ) | | 0.944 | |
| sigma2 | | 0.246 | |
| MLR | | -24.32 | |
| Adj. R-squared | | 0.9156 | |
| hettest. Prob. > chi2 | | 0.217 | |
| VIF | | 5.21 | |

*, **, ***, significant at 10%, 5% and 1%, significance level respectively

The study indicated that variables such as land size and plough power were significant at 1%; while improved seed at 5% for determining large-scale sesame production; however, variables such as fertilizer and labor become insignificant (Table 5). The studies conducted by [13], [35], [64],[17] and [24] found farm size was significant in determining production. Moreover, , [55], [70], [4], 0, [27], [35], [64], [15] and [24] found seed as significant variable. So, it is observable that the result found by this study is similar with the results obtained by the listed former studies. The inverse relationship between farm size and yield was similar with the results of [19], [45], [68] and [15]. The coefficients in Table 5 could be interpreted that, one percent increment in sesame land size leads to 1.15% decline in yield. Similarly one percent increment in seed results to 0.28% reduction of total production. However, one percent increase in plough power hour leads to 2.31% increment of production.

**Elasticity of sesame production:** The summation of production inputs' coefficients was 0.93 (Table 5), indicating the one percent increase in inputs simultaneously leads to 0.93% increment of production. This has consistency with the result of [51], [35]and [24] found the scale ranging from 0.84 to 1.2105%.

**Cost efficiency:** This study found that both error terms (u and v) for sesame producers were statistically significant at 1% (Table 7). Further, value of gamma ($\gamma=\delta u2 / (\delta\ u2 + \delta\ v2)$); is $\gamma = 0.9257$ that implies 92.57% variability is contributed by differences in decision maker's inefficiencies (Table 6). Regarding the cost function inputs, all variables have statistically significant with positive sign; except operation and material costs that were insignificant (Table 7).

**Table 6:Tests of cost function model validity**

| Null hypothesis | LR value calculated | Critical value (5%) | decision |
|---|---|---|---|
| H0: $\gamma=0$ | 92.57 | 11.07 | Reject H0 |
| H0: $\delta 1 = ... \delta 10=0$ | 77.27 | 9.39 | Reject H0 |

Source: STATA.13, output

Material cost includes cost of agricultural materials, sack, harvesting and threshing materials and tractor material and tools. Whereas operating cost includes cost of; fuel and lubricants, tractor repairing, medical service and feed expense for draft animals, transportation and loan. This study shares similarities on cost parameters with the formerly conducted studies by [50], [15] and [24], in which cost efficiency inputs were wage, seed cost, agrochemical costs, and amount produced. But also, cost of farm tools by [50] and land rental cost by [15] in addition to the above explained once.

**Table 7: Sesame production cost parameters**

| Total sesame Production cost | Coefficient | P>\|z\| |
|---|---|---|
| Ln Operation cost | 0.006 | 0.44 |
| Ln seed cost | 0.033** | 0.023 |
| Ln fertilizer cost | 0.007*** | 0.001 |
| Ln material cost | -0.009 | 0.471 |
| Ln plough cost | 0.039*** | 0.006 |
| Ln labor cost | 0.242*** | 0.00 |
| Ln land cost | 0.083*** | 0.004 |
| Ln production | 0.62*** | 0.00 |
| Elasticity | 1.0155 | |
| Constant | 5.22*** | |
| MLR | 127.98 | |
| Sigma_v | 0.0395*** | |
| Sigma_u | 0.1393*** | |
| Sigma2 | 0.021*** | |
| gamma (γ) | 0.9257 | |

*, **, *** significance at 10%, 5%, and 1%, respectively

**Estimation of technical, allocative and economic efficiencies of large-scale sesame producers**

**Technical efficiency:** The mean TE level found in this study was 71.46% (25.6 - 96.03) (Table 8). This implies that if the average producer wants to achieve the TE of his/her most efficient counterpart, he/she could realize 25.59% input saving [i.e., 1-(71.46/96.03) x100]. Similar the most inefficient farmer reveals cost saving of about 73.34% [i.e., 1-(25.6/96.03) x100]. The mean level of TE shows that there is an opportunity to increase efficiency on average by 28.64% if inputs allocated properly.

**Table 8: Category of sampled sesame producers based on their TE**

| Category | Number of respondents | Percent |
|---|---|---|
| TE<20 | 0 | 0.00 |
| 20<TE<30 | 2 | 1.59 |
| 30<TE<40 | 5 | 3.97 |
| 40<TE<50 | 9 | 7.143 |
| 50<TE<60 | 15 | 11.9 |
| 60<TE<70 | 20 | 15.87 |
| 70<TE<80 | 24 | 19.05 |
| 80<TE<90 | 37 | 29.37 |
| TE>90 | 14 | 11.11 |
| Mean TE | 71.46 | |

Source: Survey results, 2016

The average and range of TE in this study is consistent with the result of [34], [8], [20], 0, [23], [28], [25], [27], [33], [64], [17] and [24]; ranging in 34-77%.

To give a better picture about TE distributions, a frequency distribution is categorized by 10% interval; here, 40.48% of the producers were operating blow mean (Table 8). This imply that in the long run there is a room for improving the existing TE level of sesame producers providing a special attention to introduce best alternative farming practices and improved technologies.

**Allocative efficiency:** The average AE of large-scale sesame producers was 89.88% (56.94 - 98.16) (Table 9). With this deviation, if the average producer wants to operate his/her AE to the most efficient, he/she could obtain cost saving of 8.44% [i.e., 1-(89.88/98.16) x100], however the most allocatively inefficient could save 42% [i.e., 1-(56.94/98.16) x100]. About 38% of the sampled producers were operating below mean AE (Table 9).The result obtained in this study is complementary with the results of [51],[50],[7], [46] and [17] who found AE from 57 to 96%. Generally, AE of large-scale sesame producers in Kafta Humera district show that most of the producers have relatively similar allocation of resources with the unit prices attached to each input, so leads higher AE.

**Table 9: Distribution of AE of sesame producer categories**

| Category | Number of respondents | Percent |
|---|---|---|
| AE< 20 | 0 | 0.00 |
| 20< AE<30 | 0 | 0.00 |
| 30<AE<40 | 0 | 0.00 |
| 40<AE<50 | 0 | 0.00 |
| 50<AE<60 | 1 | 0.79 |
| 60<AE<70 | 0 | 0.00 |
| 70<AE<80 | 8 | 6.35 |
| 80<AE<90 | 43 | 34.13 |
| AE>90 | 74 | 58.73 |
| Mean | 89.88 | |

Source: Survey result, 2016

**Economic efficiency (EE):** Following the relative ratio of actual cost to the hypothetical minimum cost, EE could be obtained which is the multiplication of TE and AE. Applying this procedure this study found mean EE of 64.58 percent (22.37 - 92.76) (Table 10). Taking this range, if the average producer wants to reach his/her EE to the most efficient counterpart, he/she could experience the cost saving of 30.38% ([i.e., 1-(64.58/92.76) x100]. Similarly, the most inefficient producer could save his/her cost by 75.88% [i.e., 1-(22.37/92.76) x100]. The mean EE found in this study is similar with the results of Abu et al. (2012), [49], [30], Abba (2012), [23], [11], [25], [27], [15], [17] and [24].

As presented in Table 10, about 45% of the sampled producers' EE was below mean which is an indication that producers were unfairly efficient; meaning there was greater variability in their achievement.

**Table 10: Distribution of EE by large-scale sesame producers**

| Category | Frequency | Percent |
|---|---|---|
| EE<20 | -- | -- |
| 20<EE<30 | 6 | 7.14 |
| 30<EE<40 | 6 | 7.14 |
| 40<EE<50 | 13 | 15.88 |
| 50<EE<60 | 21 | 16.67 |
| 60<EE<70 | 27 | 28.57 |
| 70<EE<80 | 26 | 19.84 |
| 80<EE<90 | 25 | 3.17 |
| EE>90 | 2 | 1.59 |
| Mean | | 64.58 |

Source: Survey data, 2016

**Sources of technical, allocative and economic inefficiency of large-scale sesame producers**

Having information about TE, AE and EE, identifying the major sources of inefficiency is the next important part of this study. Before using all the proposed socio-economic and institutional variables into the model a test for multi-collinearity using VIF is important. Accordingly, the VIF result of each variable is below ten (i.e., 2.73) (Table 11), indicating no severe multicollinearity problem. Based on the Breusch-Pagan test result of heteroskedasticity also, the null hypothesis could not be rejected (Table 11).
The test for cost inefficiency model validity also indicated the result of VIF for each variable in the model and the mean value of all variables is below 10 (i.e., VIF= 3.59) (Table 11). Based on the Breusch-Pagan test result of heteroskedasticity also, the null hypothesis could not be rejected (Table 11). The adjusted R-squared in both production and cost inefficiency also show the variables explained 69%and 91.46%,respectively (Table 11). As a result all the variables hypothesized are entered in to their respective models. The significant sources of technical, allocative and economic inefficiencies (Table11) are discussed as follows.

**Education level of household head (eduhhd):** The result of this study shows that education level of household head significantly and negatively affect to technical, allocative and economic inefficiency at 1%. If education level in years of schooling becomes one year higher relative to others, one's technical, allocative and economic inefficiency decreases by 1.4%, 0.6% and 1.6%, respectively. This may be, education enables producers to have greater ability to understand, adopt and correlate inputs with lower cost and misuse.

According to [32]and [43], the relationship between education level and efficiency is theoretically justified as education increases performing capacity and so best match of resources; because education is proxy for managerial ability. The result of this study is similar with the results found [62], [54], 0, [27], [33], and [59]; but, in conducted to [4]. The result of allocative and economic inefficiencies obtained in this study is in line with results of [10], [12], [53], [61], [62], [49], [17] and [63].

Experience in sesame production (exp): It is found that experience of sesame producers is significantly and negatively affected to technical, allocative and economic inefficiency of sesame production at 5%, 10% and 5%, respectively. This could be; because experience is a proxy for managerial aspects and improves the skill and technical capacity that enables to best match inputs and in cost saving aspect so attain higher productivity at minimum cost. The relationship implied that, there is a reduction in technical, allocative and economic inefficiencies by 0.6%, 0.37% and 0.5%, respectively as one's experience increases by one year. The technical inefficiency result is consistent with the results of [2], [49], [30], [15]and [24]; but contradicts with result found by [5]. Taking allocative and economic inefficiency the result found is similar with results of [70], [4], [3], [49], [30] and [16]. However, it is in contrast to the result of [23] and [24].

**Membership in cooperatives (memb):** The technical and economic inefficiency of large-scale producers were significantly and positively determined by being a membership in cooperative at 1%. Theoretically, membership in social organizations helps producers in achieving efficiency; but, this unexpected result could be that members might not discuss related to sesame production while meeting and they may spend more time while discussing other issues which compute time of sesame farm operation. Besides, while producers want to take loan from their cooperative it takes more time; so, they did not get their credit on its time, spending of time until getting loan which computed sesame farm operating time. Depending on the result of this study, as sesame producer's become members of cooperative one's technical and economic inefficiencies raises by ten and 10.3%, respectively.

**Distance of sesame farm from residence (distfh):** It is found that farm distance is significant and negatively related to technical and economic inefficiencies at 1% and 5%. Accordingly, as farm distance increases by 01Km, their technical and economic inefficiencies decreases by 0.3%and 0.2%, respectively. This relation may be because there is high probability of family members or manager to live in production site; so, whole day follow up is observed that enables to better manage farms which lead to better efficiency achievement.

**Frequency of sesame farm visit (freqgo):** It is found that this variable significantly and negatively determines technical, allocative and economic inefficiencies at 1%, 10% and 1%, respectively. So, according to the study result as large-scale sesame producer increases his/her farm visit by one time, his/her technical, allocative and economic inefficiencies decrease by 0.4%, 0.6% and 0.4%, respectively. Theoretically, the relation could be interlinked, as there is nearby farm follow up that enables understanding of real happening so solutions could be emanated.

**Ownership of standardized home (ownhom):** It is found that this variable significantly and negatively determined technical and economic inefficiencies of large-scale sesame producers at 1%. According to the result found, as large-scale producer owns standard home that could hold as collateral their technical and economic inefficiencies decreases by 23% and 22% relative to the one who did not own. This may be as producers had their own house, they do not pay house rent rather they may allocate the money for sesame production. Also it can be used as collateral for obtaining loan. Thus, improves their efficiency. This result matches with the result of [37].

**Ownership of livestock (ownliv):** This study found that TLU significantly and negatively affected to technical and economic inefficiencies of the sampled producers at 10%. This relationship implies that as large-scale producer's TLU increases by one, one's technical and economic inefficiencies decreases by 5.1% and 0.56%, respectively. This could be as livestock enables to obtain off-sesame farm income. Regarding, the relationship of TLU and

TE, the result in this study is similar with the result of [64], but in contradiction with the result revealed by [66]. In relation of TLU and EE the result found is similar with the reports of Amos et al. (2007), [36], [53], [61], [17] and [63].

**Table 11: Sources of technical, allocative and economic inefficiencies**

| Variables | Technical inefficiency | Allocative inefficiency | Economic inefficiency | VIF production function | VIF cost function |
|---|---|---|---|---|---|
| Age household head (years) | 0.001 | -0.001 | 0.001 | 1.99 | 2.40 |
| Education level (schooling years) | -0.014*** | -0.006*** | -0.016*** | 1.69 | 1.92 |
| Experience (years) | -0.006** | -0.0037* | -0.005** | 1.67 | 2.08 |
| Dependency ratio (No) | 0.004 | 0.004 | 0.006 | 1.9 | 2.06 |
| Distance of farm (Km) | -0.003*** | 0.0002 | -0.002** | 1.88 | 2.03 |
| No of extension contact (No) | -0.01 | 0.005 | -0.007 | 2.09 | 2.84 |
| Frequency farm visit (No) | -0.004*** | -0.006* | -0.004*** | 1.93 | 2.21 |
| Home ownership (Dummy) | -0.23*** | -0.022 | -0.22*** | 1.68 | 2.44 |
| Livestock ownership (TLU) | -0.051* | -0.017 | -0.056* | 1.90 | 2.29 |
| Number of training obtained (No) | -0.003 | 0.001 | -0.001 | 1.76 | 1.75 |
| cooperative member (Dummy) | 0.10*** | 0.0204 | 0.103*** | 1.92 | 2.07 |
| Road type (Dummy) | -0.033*** | -0.008** | -0.033*** | 1.48 | 1.95 |
| Ln Off sesame income (Birr) | 0.003 | 0.0027 | 0.004 | 2.48 | 2.48 |
| Ln loan obtained (Birr) | 0.011* | 0.003* | 0.01** | 1.53 | 2.25 |
| Constant | -0.6*** | -0.87*** | -0.54*** | | |
| Mean | | 2.73 | | 3.59 | |
| Adjusted R2 | | 0.91 | | 0.69 | |
| Chi2 | | P(X2 = 0.19)=0.12 | | P(X2 = 0.78)=0.38 | |

*, **, *** significance at 10%, 5%, and 1% respectively

**Amount of credit obtained for sesame production (loan):** It is significantly and positively related to technical, allocative and economic inefficiencies of large-scale producers at 10%, 10% and 5%, respectively. According to this result, as one obtains one percent of the amount he/she expected and invested at sesame production one's technical, allocative and economic inefficiencies increases by 0.011, 0.003 and 0.01%, respectively. This may be that they spent the loan obtained in payment of laborers and fertilizer purchase which did not have significance contribution in TE achievement. It may also due to as loan is obtained from informal money lenders, who were most familiar in the area that requires higher interest rate.

**Availability of road facility from farm to home (road):** It is also found that road facility is significantly and negatively related to technical, allocative and economic inefficiencies of large-scale producers at 1%, 5% and 1%, respectively. This is implying that as large-scale producer obtained access to normal road, one's technical, allocative and economic inefficiencies decreases by 0.033%, 0.008% and 0.033%, respectively. It is because accessible road enables to timely reach so manage farm activities timely and reduced amount of grain loss while transporting.

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# Comparative Analysis of Technical Efficiency of Row Plantation Technology and Traditional Sowing Technology in Barley Production in Eastern Zone of Tigray

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***Abstract***

*Ethiopian GDP highly depends on the production and productivity of agriculture. Agricultural productivity is seen as one of the major contributors to the development process. It is, therefore, essential to study the performance of existing plantation technology systems in order to become informed about this development process. This study examined the factors influencing technical efficiency in barley farming in eastern zone of Tigray using a stochastic frontier production function in which technical inefficiency effects were assumed to be functions of both socioeconomic characteristics of the farmer and farm-specific characteristics of the two seed plantation technologies; namely row plantation system and traditional plantation system. In this research work paper the researchers select randomly 300 farmers comprising 155 row planters and 145 traditional planter farmers. The result from the descriptive statistics indicates that the farmers who use traditional plantation technology are producing on a lower production frontier than the farmers who practice row plantation technology and the result is also statistically significant at one percent in a two tail sample t test. The results also revealed existence of high levels of technical inefficiencies in barley production, especially among the traditional sowing farmers. The study found that the magnitude of technical efficiency varied from one farmer to another and ranged from 42.4% to 75.4%, with a mean of 68.2%. Consequently, due to technical inefficiency farmers have lost close to 32% of the potential output. The main factors that influenced the degree of inefficiency were age of the household head, family size, livestock quantity, row plantation technology, access to irrigation and cooperative membership. Based on the findings from this study, the researchers recommend that farmers should have to get*

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*trainings on how to plant seeds, on the use of better techniques and application of fertilizer and other capital equipment. Moreover, the regional government should have to develop small scale irrigation schemes to enhance the productivity of row plantation technology. Last but not the least, though the result from the Tobit model and t test statistics are significant, row plantation technology user farmers are on higher frontier than their counterparts. Thus integrating those who use traditional cultivation method can lead to more viable production and productivity in using this technology.*

**Key words:** Productivity, technical efficiency, stochastic frontier function, two limit tobit model, and barley farming in Eastern zone of Tigray

## 1. Background and Justification

Agriculture is the backbone of the Ethiopian economy. This particular sector determines the growth of all other sectors and consequently, the whole national economy. On average, crop production makes up 60 percent of the sector's outputs, whereas livestock accounts for 27 percent, and other areas contribute 13 percent of the total agricultural value added. The sector is dominated by small-scale farmers who practice rain-fed mixed farming by employing traditional technology, adopting a low input and low output production system. The land tilled by the Ethiopian small-scale farmer accounts for 95 percent of the total area under agricultural use and these farmers are responsible for more than 90 percent of the total agricultural output (GTP, 2010).

Agriculture is the mainstay of the Ethiopian economy and underpins its development process. It is a sector with great potential for stimulating growth and employment and eradicating poverty. Because of its importance to national food security and poverty reduction, the government has, within the Growth and Transformation Plan (GTP), articulated a clear vision for the sector, placing it at the center of the country's transformation agenda. The initiatives that underlie the agriculture policy and plan aim to stimulate investment and productivity of the sector to promote household and national food security and to rally development partners to deliver effective development aid to the sector. Transformation of the Ethiopia's agricultural sector requires scaling up efforts to increase agricultural production and productivity by among others promoting domestic and foreign investment through agricultural commercialization, increasing public investment in agricultural infrastructure, promoting technology transfer and adoption, ensuring efficient use of land, labor, technology and other inputs, and specifically raising the productivity of smallholder farmers (GTP, 2010). Among thus, row planning is one agricultural technology where high emphasis is given for improving the productivity of small holder farmers in the Growth and Transformation Plan of Ethiopia.

Beyond these investments and interventions, the introduction of new technologies through a strengthened extension system has been a major area of effort for the Transformation Agenda. The efforts in extending the Tef, Improved Seed Variety, Row Planting, Reduced Seed Rate (TIRR) technology package is an illustration of the significant yield increases that can be realized from seemingly simple technologies.

The core "TIRR" technology package (Tef, Improved seed, Reduced seed rate, and Row planting) prioritized for tef farmers by the agricultural extension system 2013, led to significant increases in crop yields across the country. Detailed analysis of the 2013 TIRR package, with a sample of 1,300 farmers, showed average yield increases of 44% the control group and 72% the experiment group (MoA, 2014/15).

During the GTP period, government aims to double the production of smallholder farmers by implementing measures to raise and sustain high agricultural productivity. The scope to increase production through area expansion is continuously diminishing as land for agriculture gets exhausted, making this approach less sustainable in the long term. In Ethiopia, agricultural productivity among smallholder farmers is as low as 1.25 tons per hectare for tef, there is also great variability in productivity across farmers with the most productive farmer producing 3.66 tons per hectare compared to the average yield of 1.83 per hectare for cereals (MoA, 2014/15).

One crucial element in the process of crop production is land preparation, as it is decisive in obtaining a good harvest. Establishing a good crop, increasing yield per hectare, reducing weed pressure, and improving soil moisture

retention all depend on good land preparation (tillage). Farmland is prepared using the traditional ploughing instruments. Row planting is not easy for the farmers as it needs more labor than broadcasting; therefore, many apply the latter alternative. These and other activities, like weeding and soil fertility management, are highly labor-intensive (Atsbaha G. and Tessema B. 2010).
There are many constraints to agricultural inefficiency including the small and diminishing size of farm lands; inadequate extension services and follow-ups by the respective office of agriculture; soil infertility; outdated modes of production; and a lack of correct agricultural information.

This shows that there is great potential to increase production by raising yields per hectare for all smallholder farmers to that of the most productive (model) farmer. Significant productivity differences also exist across agro-ecological zones. These differences provide additional prospects for increasing production and productivity by providing incentives that induce farmers to optimally exploit zonal specific advantages to enhance returns from agricultural investment. Doing so will not only increase agricultural production through specialization and commercialization of agricultural production but will help to raise agricultural household income and employment, and ultimately contribute to poverty reduction in the rural sector.

**Table 1: Tradition and row plantation technologies**

| Woreda | Tradition sowing plantation technology | | | Row plantation technology | | |
|---|---|---|---|---|---|---|
| | Target | Actual | % | Target | Actual | % |
| Atsbi Wenberta | 6868 | 8810 | 128.28 | 5976 | 3620 | 60.576 |
| K/Awlaelo | 11556 | 13634 | 118 | 8020 | 4253.5 | 53 |
| Hawzen | 7007 | 10761 | 153.6 | 9305 | 3488 | 37.5 |
| S/T/Emba | 13262 | 14752 | 111.2 | 6538.5 | 4427 | 67.7 |
| G/Afeshum | 6910 | 5441 | 78.7 | 3613 | 4503 | 124.6 |
| G/Mukada | 7205.5 | 6551 | 90.9 | 3998.5 | 4653.3 | 116.4 |
| Erob | 634 | 909 | 143.4 | 566 | 200.96 | 35.5 |
| Total | 53442 | 60858 | 113.9 | 38017 | 25146 | 66.1 |

Source: Zonal BOARD 2015

In addition to the lack of agricultural technologies, the problem of low productivity on smallholder farms is inadequate knowledge, skills and resources (inputs such as fertilizer, labor, equipment, seeds and water) to enable them adopt and efficiently utilize existing technologies to enhance production and earning from farming. Thus, researches are necessary to identify the low agricultural productivity. Thus, the existence of steady economic inefficiency for decades in the nation and the prevalence of production differences using different agricultural technologies in the region, inadequate knowledge, and absence of scientific research carried out to assess the socio- economic determinants of economic inefficiency are the major factors influencing this research to be realized.

However, unlike the remarkable achievements in the agricultural sector, there are still gaps in the areas of household production and economic efficiency that require further development, involvements of the government and other development agents to share the fate of sustainable development. In addition, most of the research works done on agricultural technologies focuses on the impact of these technologies on livelihood of households. Thus, they never relate with production and economic efficiency. This calls for the realization of this research work to fill such gaps and provide scientific evidence on the socio economic variables that determine economic inefficiencies.

Even though the interventions, the introduction of new technologies through a strengthened extension system has been given a major area of effort for the Transformation Agenda, however; studies on assessing the economic efficiency of row plantation in comparison to traditional sow plantation is not done yet. And to the best of the researchers understanding there were not researches so far conducted systematically in this region where this study is proposed to be conducted. For this reason, the study aims to compare production and economic efficiency of row plantation system with the traditional plantation system in cereal production using appropriate methods of data analysis.

## 2. Objective of the Study:

**General Objective:**

The general objective of the study is to compare production and economic efficiency of row plantation system with the traditional plantation system in cereal production.

**Specific Objectives:**

- To compare the production efficiency (technical efficiency) of row plantation production system with the conventional one
- To analyze the socioeconomic variables that may explain the differences in the estimated levels of technical inefficiency

## 3. Methodology of the Study

**Methodology**

This study employed a mixed approach with an emphasis given to quantitative household survey supplemented by the qualitative research method. The quantitative research approach is to compare the production and technical inefficiency of row plantation production system with the conventional one and to analyze the socioeconomic variables that may explain the differences in the estimated levels of technical inefficiency. In line with this, to capture some variables which are non-quantifiable (either methodologically or due to other reasons), qualitative methods of data analysis will also be used to describe the cropping patterns of the two production systems.

**Research Process**

Based on the objectives, the research process with in this study was divided into five stages. In the first stage, review of relevant secondary sources was conducted which, in fact, served as the background for understanding the research problem and hence set a research problem with in the ongoing dialogue in the literature.

In the second stage, the random selection of the study woredas was done from the seven woredas of eastern zone of Tigray based on the implementation of the two production systems.

Thirdly, selection of *tabias* from different agro ecological zones was undertaken to ensure diversity in the study and hence equal sample of respondents was drawn using a systematic random sampling. In the fourth stage, household survey using structured questionnaire and focused group discussions was under taken. Lastly, since the purpose of the research is to produce findings and the process of data collection is not an end by itself, data analysis, interpretation and presentation of findings was conducted.

Therefore, a total of 300 households were selected from three agro ecological zones from four *tabias* by using systematic random sampling method individual household for questionnaire survey was selected.

**Method of Data Analysis**

As part of quantitative research methods, primary data was collected by means of survey questionnaire. In the sample survey, in-depth information regarding the social and demographic characteristic, different agricultural inputs, livestock ownership and institutional variables were collected. All these data were considered during the analysis to compare production and technical efficiency of row plantation system with the traditional plantation system in cereal production.

As part of quantitative data analysis, an econometric model was also used to compare production and economic efficiency of row plantation system with the traditional plantation system in cereal production.

**Econometric Model specification**

To compare production and economic efficiency of row plantation system with the traditional plantation system in cereal production, a Stochastic Frontier Analysis and two limit tobit model was employed in this study. Frontier economic programming (version 4.1) software was used for estimating the farm specific economic efficiency scores of cereals producers in the study area. Following that the efficiency score is taken as a dependent variable and is then regressed against farmer specific, demographic, socioeconomic and institutional factors.

Boris et al. (1997) described that Cobb- Douglas functional form is used to specify the stochastic production frontier, which is the basis for deriving the cost frontier and the related efficiency measures. The specific Cobb- Douglas production model estimated is given by:

$$Yi = \beta 0 * \prod_{i=1}^{n} Xi^{\beta i} * e^{vi-ui}$$

By Transforming this in to double log linear model:

$$lnYi = ln\beta 0 * \beta 1 \prod_{i=1}^{6} lnXi \quad + (vi - ui)$$

**Where** Yi represents cereal yield harvested and Xi represents cereal production inputs by i[th] farmer. Whereas, $\beta 0,\ \beta 1,\ \beta 2,\ \beta 3,\ \beta 4,\ \beta 5\ and\ \beta 6$ are regression parameters to be estimated. From the error term component $(vi - ui)$, $vi$ is a two sided $(-\infty < v < \infty)$ normally distributed random error (v˜N [0, $\sigma^2 v$]) that represents the stochastic effects outside the farmer's control (e.g whether, natural disaster,…), measurement error and other statistical noise. While Ui is a one sided (Ui≥0) efficiency component which is independent of Vi and is normally distributed with zero mean and constant variance $(\sigma^2 u)$ allowing the actual production to fall below the frontier but without attributing all short falls in output from the frontier as inefficiency.

*Two limit tobit model with maximum likelihood estimation*

Following Amemiya (1981), Waluse (2011) Essa et al (2011) and Endrias et al. (2013) the two limit tobit model is defined as:

$$yi * TE = \sigma 0 + \sum_{j=1}^{12} \sigma j Zij + ui$$

Where $yi*$ is the latent variable representing the efficiency scores, $\sigma 0, \sigma 1, \dots, \sigma 12$ are parameters to be estimated, and TE (technical efficiency) and of the ith farmer. Zi is demographic, socio economic and institutional factors that affect efficiency level. And Ui is an error term that is independently and normally distributed with mean zero and variance $\sigma 2$ (Ui˜IN (0, $\sigma 2$)). Farm specific efficiency scores for the smallholder cereal producers range between zero and one. Therefore, two limit tobit model can be presented as follows:

Yi= 1 if Yi*≥1
Yi= Yi* if 0 < Yi*<1
Yi= 0 if Yi*≤ 0

Two limit tobit model allows for censoring in both tails of the distribution (Green, 2003). The log- likelihood that is based on the doubly censored data and built up from sets of the two limit tobit model is given by:

$$lnL = \sum_{yi=Io1} ln\emptyset\,(\frac{Ioi - Xi\beta}{\sigma}) + \sum_{yi=yi*} ln\frac{1}{\sigma}\emptyset\,(\frac{Iyi - Xi\beta}{\sigma}) + \sum_{yi=I1i} \ln\,[1 - \emptyset\,(\frac{I1i - Xi\beta}{\sigma})]$$

Where Ioi= 0 (lower limit) and I1i= 1 (upper limit) where $\emptyset$ and $\sigma$ are normal and standard density functions.

In efficiency analysis, it is not only the level of inefficiency that is important, but the identification of the socio economic and institutional factors that cause it. Even though the approaches for the identification of these factors may vary to some extent with the methodology employed, the most commonly followed procedure in both approaches is what is usually referred to as the two step procedure (Jema, 2008). First, the efficiency or an inefficiency index is estimated. Second, the inefficiency or efficiency index is taken as a dependent variable and is then regressed against a number of other explanatory variables that are hypothesized to affect efficiency levels.

In a tobit model, each marginal effect includes both the influence of explanatory variables on the probability of dependent variable to fall in the uncensored part of the distribution and on the expected value of the dependent variable conditional on it being larger than the lower bound. By following

McDonald and Moffitt (1980), Greene (2003) and Gould et al (1989) cited in Endrias et al (2013) from the likelihood function decomposition of marginal effects was proposed as follows two limit tobit model:

The unconditional expected value of the dependent variable:

$$\frac{\partial E(y)}{\partial Xj} = [\emptyset(Zu) - \emptyset(Zl). \frac{\partial E(y*)}{\partial Xj} + \frac{\partial[\emptyset(Zu) - \emptyset(Zl)]}{\partial Xj} + \frac{\partial[1 - \partial(Zu)]}{\partial Xj}$$

The expected value of the dependent variable conditional upon being the limits

$$\frac{\partial E(y*)}{\partial Xj} = \beta m. [1 + \frac{\{Zl\emptyset(Zl) - Zu\emptyset(Zu)\}}{\{\emptyset(Zu) - \emptyset(Zl)\}} - \left[\frac{\{\emptyset(Zl) - \emptyset(Zu)\}2}{\{\emptyset(Zu) - \emptyset(Zl)\}2}\right]$$

The probability of being between the limits

$$\frac{\partial[\emptyset(Zu) - \emptyset(Zl)]}{\partial Xj} = \frac{\beta m}{\sigma}[\emptyset Z(l) - \emptyset Z(u)]$$

Where $\emptyset(l)$= the cumulative normal distribution,
$\emptyset(u)$= the normal density function

$Zl = \frac{X'i\beta}{\sigma}$and$Zu = \frac{1-X'i\beta}{1}$ are standardized variables that come from the likelihood function given the limits of Y* and $\sigma = standard\ deviation\ of\ the\ model.$

To attain the major objective of this study, the data collected from the study area were analyzed and interpreted. In the process of data analysis and interpretation, major attention will be given to quantitative analysis although it is going to be supported by qualitative technique.

**Table 2: Variables and their expected signs**

| Variables | Unit of measurement | Expected sign |
|---|---|---|
| Seed | Kg | + |
| Labor | Person equivalent days | + |
| livestock | TLU | + |
| Dap | Kg | + |
| Urea | Kg | + |
| Farm size | Tsimadi | + |
| Access to irrigation | 1= yes o= no | + |
| Sex | Male=1 female= 0 | + |
| Age | Person equivalent | + |
| Education level of HHH | Years of education | + |
| Training | Yes=1 no=0 | + |
| Membership of cooperatives | Yes=1 no=0 | + |
| Credit | Yes=1 no=0 | + |
| Family size (adult equitant) | Persons | +/- |

## 4. Results, Discussion and Analysis

### Distribution of respondents by Woreda

We employed a stratified random sampling technique and the following sample size was considered in the five woredas.

**Table 4.1: List of woredas**

| Woreda | Frequency | Percent |
|---|---|---|
| Ganta Afeshum | 75 | 25.00 |
| Gulo Mikada | 74 | 24.67 |
| Kilte Awlaelo | 76 | 25.33 |
| Saesie Tsaeda Emba | 75 | 25.00 |
| Total | 300 | 100.00 |

Source: Survey data (2016)

**Table 4.2: List of Tabias**

| Tabia | Frequency | Percent |
|---|---|---|
| Dibla Siet | 75 | 25.00 |
| Aditesfa | 74 | 24.67 |
| A/tesfa | 76 | 25.33 |
| Sindeda | 75 | 25.00 |
| Total | 300 | 100.00 |

Source: Survey data (2016)

As Table 4.1 above displayed that about 25% of the total respondents were from Ganta Afeshum, 24.67% from Gulo Mekeda, 25.33% from Kilte Awlalo and the remaining 25% were from Saesie Tsaeda Emba. And the tabia representation of the households was also depicted in table 4.2.

**Household size of the respondents**

Respondents' Household size in the four sample woredas may affect the adoption of row planting. Because planting in rows requires high labor cost, households with large family size may have a greater chance of adopting this technology while households with small family size may find it challenging to apply row planting technology.

As displayed in table 4.3 belowabout43/299 (14.38%) of the total respondents had a small household size ranging between one to three family members, among these 27.95%, 18.6%, 16.3% and 37.2% of respondents were in Gulomekeda, K/Awlalo , Gant Afeshum and Saese Tsaeda Emba woredas respectively. Due to this the proportion of respondents that had small family size is relatively small that may not negatively affect the application of row planting technology.About62.21%ofthetotalrespondentshadmediumhousehold size composed of four up to seven members of family, of these27.4%, 23.1% 25.3% and 24.2% were from. Gulomekeda, K/Awlalo, Ganta Feshum and Saese Tsaeda Emba woredas respectively. Among the total respondents 23.41 % had large family size ranging between eight and ten members.

**Table 4.3: Family size of respondents by woreda**

| Woredas | Household size | | | | | | Total | |
|---|---|---|---|---|---|---|---|---|
| | 1-3 | | 4-7 | | 8-10 | | | |
| | No | % | No | % | No | % | No | % |
| Gulomekeda | 12 | 27.9% | 51 | 27.4 | 12 | 17.1 | 75 | 25.1 |
| K/awlalo | 8 | 18.6% | 43 | 23.1 | 24 | 34.3 | 75 | 25.1 |
| Gantafeshum | 7 | 16.3% | 47 | 25.3 | 20 | 28.6 | 74 | 24.7 |
| Saesetsaeda | 16 | 37.2% | 45 | 24.2 | 14 | 20 | 75 | 25.1 |
| Total | 43 | 100% | 186 | 100% | 70 | 100% | 299 | 100% |

Source: Survey data (2016)

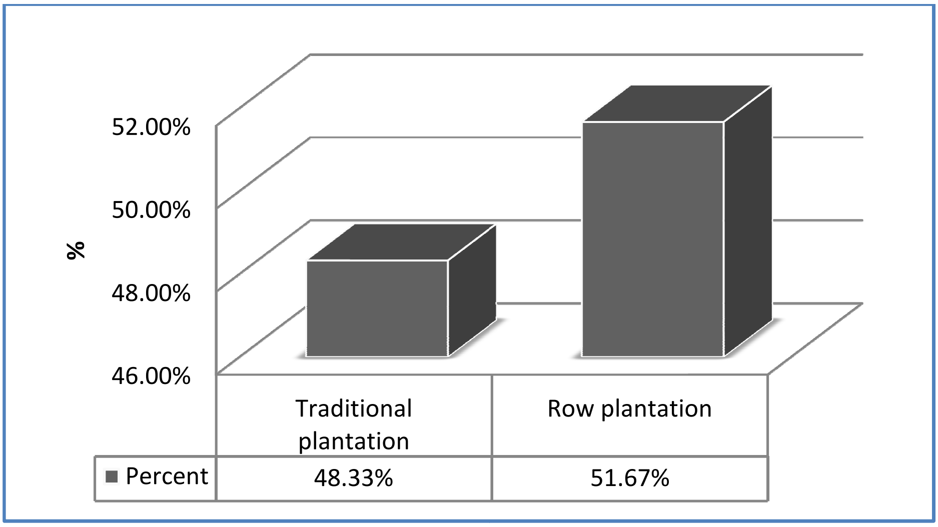
**Table 4.4: Description of demographic variables**

| Variable | Observation | Mean | Standard deviation | Minimum | maximum |
|---|---|---|---|---|---|
| HHH Age | 300 | 48.49333 | 11.50876 | 25 | 80 |
| HHH Gender | 300 | 40= Female | 260= Male | | |
| HHH experience in farming | 300 | 23.533 | 13.62 | 1 | 60 |
| Plot type | 300 | 0.572 | 0.321 | 1= irrigated, 0=otherwise | |
| Credit take | 300 | 0.653 | 0.478 | 1=loan take, 0=otherwise | |
| Extension service | 300 | 0.87 | 0.273 | 1=participate, 0=otherwise | |
| TLU | | | | | |

Source: Survey data (2016)

The average age of the household head is 48.493. from the total 300 respondents 260 were male headed households while 40 were female headed households. The experience in farming of the households ranges from 1 year to 60 years with an average of 23.5 years. As the table above depicts the average land holding of the farmers is 0.573 hectare.

**Figure 4.1: Technology types employed by hhhs**




Source: Survey data (2016)

From the total respondents 51.67 percent were row plantation users while the remaining 48.33 percent were traditional sowing cultivators.

The average inputs allocated by the farmers are 2.19 Tsimad of land (Check with reality), 15.055 man-days of family labor, 1.81 quintal of fertilizer, 11.9 oxen, and 13.37 compost. Using these inputs they got an average output of 266.5 KG with standard deviation of 142.45 kg of barley.

**Table 4.5: Summary statistics**

| Plantation technology | Land size tsimad | Fertilizer kg | Labor days | Oxen days | Compost quintal |
|---|---|---|---|---|---|
| Traditional technology | 2.206897 (1.189634) | 1.501241 (6.327388 ) | 12.689655 (1.01554 ) | 8.758621 (1.141896 ) | 11.86552 (23.30022 ) |
| Row technology | 2.187097 (1.194071) | 2.105645 (8.138873) | 18.29032 (1.190109) | 14.90323 (1.374006 ) | 14.77742 (16.2549) |
| Total | 2.196667 (1.189976) | 1.813517 (7.313725) | 15.055 (1.121905) | 11.93333 (1.301898) | 13.37 (19.99192) |

Source: Survey data (2016)

The livestock ownership in the study area was on average of 4.996 TLU for the farmers who use row plantation and 4.145 TLU for the farmers who use traditional plantation while the average TLU of the sample respondents was 4.757.

**Descriptive Analysis (Empirical Results)**

The statistical summary in table 4.6 depicts that a typical household head who cultivates his land using row plantation have, on average, 7.9% of inefficiency while of the sampled households who use traditional cultivation system have 5.5% have technical inefficiency; the two sample t-test result shows that the difference is statistically significant at 1% level. Thus, from this we can deduce that row plantation is positively contributing to agricultural production and productivity improvement.

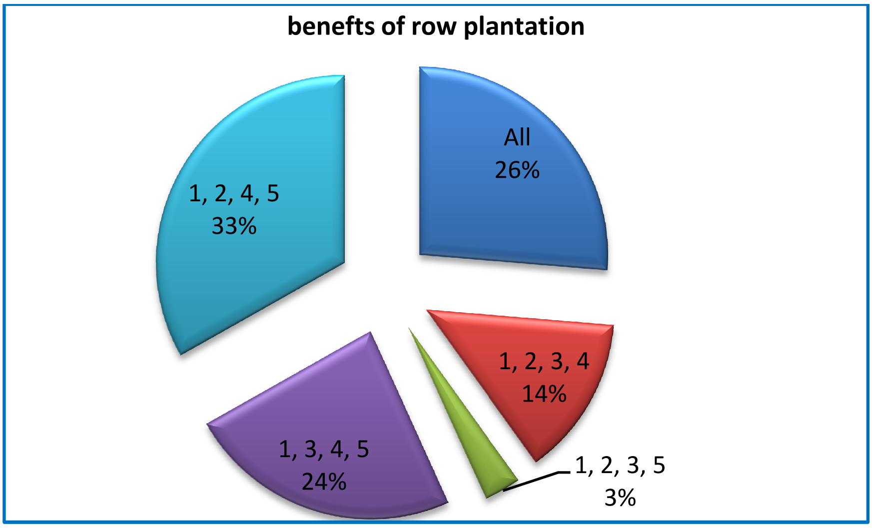
**Table 4.6: Two-sample t test with equal variances**

| Variable | Mean (Std. Err.) |
|---|---|
| Traditional Plantation | 0.55 (0.003259) |
| Row Plantation | 0.79 (0.0025703) |
| Combined | 0.682 (0.0021678) |
| Difference | -0.24 (.0041227) |
| t = -5.7467*** | Obs = 300 |
| degrees of freedom = 298 | |

Source: Survey data (2016)

The major benefits of planting crops using row plantation are listed by the households. As stated by the farmers, row plantation have five major benefits namely, easier weeding [1], easier harvesting [2], higher crop yield [3], use less seed [4] and easier pest control [5]. On top of that, the benefits of row plantation have multiple benefits. Thus, in the following table the multiple responses are listed with their frequencies.

**Figure 4.2: Benefits of row plantation**




Source: Survey data (2016)

The average family size of the households was 5.56 with standard deviation of 2.07 and minimum of 1 and maximum of 11 members. The average adult equivalent was 4.8 with standard variation of 1.78 members accompanied by minimum of 0.74 and maximum of 10.34 adult equivalent members. The findings of the study depicted that as the number of family members in the household increases, the technical efficiency also increases too. 6.3 percent of the households having family size of 1-2 had technical efficiency of 51.2 percent.

About 34.33 percent of the household with family size of 3-5 had technical efficiency of 68.1 percent. As the number of household members increased to 6-8, the level of technical efficiency also rose to 75.4 percent and decreased to 74.4 percent in 9-10 family size households and further decreased 69.9 percent when the family size is 11 and above. Thus, we might suggest that level of technical efficiency and family size have directly related to each other.

**Table 4.7: Family size of households and level of efficiency**

| Family size | Freq. | Percent | Cum. | Technical efficiency |
|---|---|---|---|---|
| [1-2] | 19 | 6.33 | 6.53 | 0.512 (0.016) |
| [3-5] | 103 | 34.33 | 40.67 | 0.681 (0.011) |
| [6-8] | 124 | 41.33 | 82 | 0.754 (0.013) |
| [9-10] | 24 | 8.00 | 90 | 0.744 (0.029) |
| 5>=11 | 30 | 10.00 | 100 | 0.699(0.098) |
| Total | 300 | 100.00 | | 0.682 (0.038) |

**Econometrics Analysis**

The study from its stochastic frontier model found that the magnitude of technical efficiency varied from one farmer to another and ranged from 42.4% to 75.4%, with a mean of 68.2%. The differences in the technical inefficiency among the farmers is probably caused by farm management practices, the socio economic characteristics of the households and other factors related to natural factors.

The results from the Tobit regression model of the technical efficiency indexes showed that scores of the technical efficiency varied from 42.4% to 75.4%, with a mean of 68.2%.

The result from the Tobit model revealed that age, family size, TLU, row plantation technology, membership of cooperative and access to irrigation are among the major determinants factors of technical efficiency of smallholder farmers producing barley. In this study, household age was found to be negatively related to technical efficiency. This might be because of as age increases households' participation in labor related activities is decreased. On the other hand, family size measured in adult equivalent is found positive and significant. This might be because of efficient utilization of the available labor force in the production efficiency of barley. Total livestock ownership was measured using the standard tropical livestock unit (TLU). In this study, TLU was found positive and significant at ten percent. One explanation for positive association between cash technical efficiency and TLU might be livestock are useful in cultivating land and useful in liquidity effect.

**Table 4.8: Determinants of technical efficiency of barley production (Tobit Regression)**

| Variable | Coefficient | Robust standard error | P-Value |
|---|---|---|---|
| HHH age | -.0639421 | .0205987 | 0.002** |
| HHH gender (male) | .0357281 | .1106029 | 0.747 |
| HHH years of education (primary) | -.0019312 | .0063909 | 0.763 |
| HHH years of education (secondary) | -.0014873 | .0057688 | 0.797 |
| HHH years of education (tertiary) | .0005978 | .0084691 | 0.944 |
| Adult equivalent | .1207017 | .0332742 | 0.000*** |
| Extension service (1=yes) | .0861191 | .539241 | 0.190 |
| Credit take (1=yes) | -.118265 | .06031515 | 0.643 |
| Training participation (1=yes) | .0094242 | .0467622 | 0.840 |
| TLU | .005914 | .032773 | 0.074* |
| Plantation technology (1=row) | .0204387 | .0038395 | 0.000*** |
| Membership of cooperative (1=yes) | .138255 | .24471135 | 0.023** |
| Access to irrigation (1=yes) | .0333089 | .0041482 | 0.000*** |
| Constant | -1.552087 | .4970916 | 0.002 |
| /sigma | .0319756 | .0013127 | |

Number of obs = 300

LR chi2(12) = 98.51

Prob> chi2 = 0.0000

Log likelihood = 600.05196 Pseudo R2 = -0.0894

Source: Survey data (2016)

*In addition, farmers who have cooperatives are found to be positively affecting* technical efficiency. This might be due to the demonstration effect that needs to improve efficiency in production, disseminating agricultural information to the farmers and helped them access to agricultural extension service easily. The result from the Tobit regression model revealed that the production frontier of the farmers who use row plantation as sowing technology is higher than that of the farmers who use traditional sowing technology. This might be due to row plantation technology has benefited like easier weeding, easier harvesting, higher crop yield, use less seed and easier pest control. Last but not the least, the study found that access to irrigation was found to be positive and significant at one percent. This might be because of irrigation might decrease the potential to crop failure and increases the opportunity to multiple cropping.

## 5. Conclusion and Recommendation

### Conclusion

This paper has attempted to increase the understanding of the technical efficiency and determinant factors of row plantation technology in comparison with traditional sowing technology. More specifically, the aim of this study was to capture the production efficiency (technical efficiency) of row plantation production system with the conventional one using stochastic frontier model and to analyze the socioeconomic variables that may explain the differences in the estimated levels of technical inefficiency.

The results from the two tail test indicate that row plantation technology have a better contribution to farmers production efficiency. Moreover, the result from the Tobit model confirms the significance of row plantation in technical efficiency.

The study found that the magnitude of technical efficiency varied from one farmer to another and ranged from 42.4% to 75.4%, with a mean of 68.2%. Consequently, due to technical inefficiency farmers have lost close to 32% of the potential output. Moreover, the result from the stochastic frontier function revealed that the production frontier of the farmers who use row plantation as sowing technology is higher than that of the farmers who use traditional sowing technology. In line with this, the data collected showed that, the inputs used by the row plantation technology users is much higher than that of traditional technology users.

In general, the result from the Tobit model revealed that age, family size, TLU, row plantation technology, membership of cooperative and access to irrigation are among the major determinants factors of technical efficiency of smallholder farmers producing barley. Thus, the researchers recommend, among others, the farmers who use traditional sowing technology has to upgrade to the row plantation technology to gain the production efficiency. In line with the integration access to irrigation, establishing cooperatives and providing trainings to younger farmers to increase production efficiency.

## Recommendation

Policy makers should pay due consideration to these factors that affect the production efficiency.

Row plantation was found positive and significant in affecting technical production. Thus, farmers should have to get trainings on how to plant seeds, on the use of better techniques and application of fertilizer and other capital equipment. In addition, the regional government should focus in integrating those who use traditional cultivation method to this new technology to achieve more viable production and productivity.

Encouraging the cooperativeness of youngsters with elders will improve the technical efficiency of old farmers. Thus, the development groups and/or one- five networks should have to consider different age groups to increase efficiency.

Having many livestock have found to be positively affecting technical efficiency. Therefore, policies that encourage asset accumulation processes through promoting investments in animal traction will create virtuous circle between technical efficiency and assets creation.

Membership to cooperatives should have to be strengthening to gain extension services and access market information.

The study found the impact of irrigation on production efficiency is direct and immediate, therefore, there is still potential of integrating farm households' for those who don't use row plantation technology in cropping to gain technical efficiency.

Lastly, the study leaves for other researchers to study starting from the finding that age of the household head, when gets older, affects production efficiency negatively. That is, is this a lifecycle effect (meaning that the current generation of young farmers may also leave from being efficiency when they get older), or a generational shift? Investigating such questions could assist policy makers in designing strategies to improve currently precarious farming livelihoods, while facilitating a smooth exit from farming for those who wish to take it.

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# Implication of Animal Feed and Water Scarcity on Labor Allocation, Food Production and Per Capita Food Consumption in Tigray Region, Ethiopia*

**Muuz Hadush**[1]

*Inadequate quantity and quality of animal water and feed resources are major factors limiting the productivity of livestock farming in Ethiopia. It is common that households spend a considerable share of their daily time to search for theses scarce resources by displacing available labor time away from more productive farming activities and leisure consumption. This paper examines the impact of time spent looking for animal water and grazing feeds on households' agricultural food production and per capita food consumption expenditure using NMBU-MU Tigray Rural Household Survey of 518 sample farmers. To address our objectives, we employ IV 2SLS for estimating per capita food consumption expenditure and double log for estimating food production drawing on non-separable farm household model. Our results do support the hypothesis of a negative relationship between total household labour input to crop farming and resource scarcity. Likewise, the findings confirm that reducing time spent looking for water leads to an increase in food production, per capita food consumption, and food security. In addition for the median household, the total impact revealed that decreasing searching time for water, grazing and collecting time for straw leads to an increment in food security. The results from the quantile regression further proved that the effect of these scarce resources is not uniform across the food production and consumption distribution. In line with our suspicion, the income variable was found to be endogenous and instrumental variables for it were statistically significant and bear the expected signs.*

**Keywords:** Animal Feed, Water Scarcity, Food Production, Food Consumption; Ethiopia

**JEL Classification: Q01, Q16, Q57, Q13**

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## 1. Introduction

Land degradation significantly contribute directly to poverty, by reducing the availability of important environmental goods and services to poor rural households, leading to increasing the demands on labor needed to seek for such goods in East Africa (Lal and Stewart, 2010; Kirui et al., 2014). Rural households in developing countries heavily rely on environmental products such as fuel wood, fodder, and water to meet their daily animal water and feed requirements. One possible negative consequence is the reallocation of labor time from farm, off farm and leisure activities to searching these scarce resources. The scarcity of these resources may impact agriculture and food security by influencing the allocation of factors of production, namely labor since scarce resources require more time to spend on their collection. Reduction in agricultural output stemming from less labor input is very likely to have detrimental welfare consequence (Cooke, 1998; Cooke et al., 2008; Mekonnen et al., 2015).

Rural households face considerable tradeoffs in the allocation of time between crop production and collecting these scarce resource for animal feed and energy sources (Cooke et al., 2008). Households that rely on agricultural outputs as a source of food and those that spend considerable time for animal feeding, watering may have then less time left to devote to food production. This has a negative implication for future agricultural production and food security in general (Mekonnen et al., 2014; Mekonnen et al., 2015; Yilma et al., 2011). The scarcity affects household food production and consumption either by affecting livestock production directly, affecting crop and off farm income through labor reallocation or through its direct impact on time for leisure consumption and food preparation. In poor households, searching and collecting scarce resources are a significant cost of production where poor farmers lack alternatives to these resources.

In Africa, livestock production depends mainly on natural resources such as grazing land and water (Bezabih and Berhane, 2014) but feed shortage, water scarcity and diseases are frequently ranked as the most binding constraints for animal rearing (Bishu, 2014). The livestock sector is a key player in increasing water use and water depletion (Steinfeld et al., 2006). A recent survey in rural

Ethiopia and South Africa found that feed and water shortage, labor scarcity and lack of capital were major constraints limiting livestock production (Descheemaeker, 2008; Tegegne, 2012). Ownership of livestock in Ethiopia has steadily declined mainly due to low availability of feed and water (Abegaz et al., 2007). Likewise, results from Hassen et al. (2010) revealed that shortage of water and feed are common in dry season as compared to wet season in Ethiopia. Thus, increasing scarcity of grazing land, water for animal and straw can be a significant burden to poor households, as grazing and water are a key factor of agricultural production in the country.

The research question that we want to answer is whether households reduce labor input in agriculture as a result of increasing time allocation to searching grazing, water for animal and collecting straw due to feed and water scarcity and test whether the time allocation to search and collect these scarce reduces crop production on the production side and household's utility on the consumption side by taking away time from leisure. In regard to this issue, we add to a relatively small list of studies examining this relationship. One early analysis is the article by Cooke (1998), which revealed that households that have higher costs of collecting environmental products devote less time to farming activities and thus reductions in agricultural output, thereby low welfare in Nepal. The studies from Damte et al. (2012) and Mekonnen et al. (2015) suggest that as a result of increasing water, grazing land and feed scarcity, many households increase the time they spend on collecting these resources. It is further suggested that increasing competition on household members' time allocation between searching and collecting scarce resource and cropping, reduces agricultural output that further diminishes households' food supply and incomes, and hence their capacity to achieve food security and human welfare (Damte et al., 2012; Mekonnen et al., 2015; Tangka et al., 2005).

The results of Mekonnen et al. (2015) in Ethiopia show that the shadow price of fuel wood has a negative and significant impact on time spent on agriculture; however, scarcity of water for humans has no effect on time spent on agriculture. The only directly and slightly related to our study are of Mekonnen et al. (2017), whose result indicated that farming productivity decreases as time spent collecting dung increases in rural Ethiopia and

Bandyopadhyay et al.(2011), whose result indicates that amount of biomass negatively affected rural per capita consumption expenditure in Malawi. To the best of our knowledge, empirical studies examining the effect of grazing, water and straw on food production and consumption are, unfortunately, missing (Cooke et al., 2008; Khan, 2008; Tangka et al., 2005).

For this purpose, we draw on the agricultural farm household model (Singh et al., 1986) as a framework for the analysis by incorporating the time spent for searching these resources in to the model. Following Yotopoulos et al. (1976), an econometric estimation was presented using the NMBU-MU Tigray Rural Household Surveys dataset collected in 2015. In aggregate, the findings confirm that reducing time spent looking for water by 1% leads to an increase in food production by 0.155%, PCFE by 0.133% and food security by 0.142% while a 1% decrease in time wastage for searching grazing land increase food production, PCFE and food security by 0.279%, 0.086% and 0.102% respectively. Besides, an increment of 0.328% in food production and 0.0731% of PCFE is achieved by 1% reduction in straw collecting time, leading to an aggregate effect of 0.092% increment in food security.

The noble contribution of this paper is that it considers time allocation on animal feeding and watering, and its effect on food production and food consumption. This is important because livestock production in Ethiopia is an important economic activity that promotes and sustains people's livelihoods. It is a major source of capital investment and employment: ensure food security by providing milk and meat; improve soil fertility through manure (Herrero et al., 2013). Few studies by Cooke (1998) and Kumar and Hotchkiss (1988) in Nepal, and Mekonnen et al. (2015) in Ethiopia focused on the effects of scarce environmental goods such as fuelwood, leaf fodder and grass on labor allocation farming and farm activity, there is scarce evidence on how grazing, water and straw scarcity affect household food production and food consumption expenditure. This paper, unlike the previous studies, use unique information on the entire set of food production and consumption, along with the distance to grazing, water and crop residue of each household. The use of IV estimation method also gives an extra information that treating income as exogenous and hence estimating the consumption model using OLS would give misleading result for both policy and inference. Finally, estimating the effect of scarce resources on total food security provides extra information in assessing farm management across ecological zone.

## 2. Review of Background and Empirical Studies

In Ethiopia, the agricultural sector is a cornerstone of the economic and social life of the people. Livestock sector contributes about 12–16% of the total GDP, and 40% of total agricultural GDP excluding the values of draught power, transport and manure, and contributes to the livelihoods of about 60–70% of the population (Asresie et al., 2015; Halderman, 2005). Ethiopia is a home of 35 million tropical livestock unit (TLU), and on average, one TLU requires about 25 liters of water per day and the total daily water requirement for livestock is estimated at 875 million liters amounting to about 320 billion liters per year. Despite its large population size, the contribution of livestock production to agriculture is deteriorating (Ilyin, 2011). The major feed resources are crop residues and natural pasture but their availability is gradually declining as a result of crop expansion, settlement and land degradation (Gebremedhin et al., 2009). Both human and livestock suffer from the shortage of water and feed. Most of the year, animals have to walk long distances in search of water and are usually watered once in two to three days(Abegaz, 2005).

In many parts of the highlands, feed and water deficits start in December–January, when the natural pastures are at their lowest quantity and the supply of stored crop residues is beginning to diminish. There is usually a gap of four to five months of the dry season before the start of the short rains. The gap which lasts for about 150 days between October and March is, therefore, the critical period in a feeding and watering system that is largely based on natural grazing pasture (Sileshi et al., 2003). According to CSA (2010c), the total agricultural land is reported to be about 16 million ha occupied by 12.9 million households accounting for an average of 1.23 ha per household, out of the total agricultural land, 75 % is used for temporary crops while grazing land accounts for 9%. Total grazing land in the study region is estimated to be 47,431 km2 while tropical livestock unit (TLU) per km2 of grazing land was increased from 44,000 TLU in 2001/02 to 55,000 TLU in 2007/08 (Tilahun and Schmidt, 2012).

Based on Tesfaye (2010), the estimated crop residues from cultivated land in the region is found to be about 1,229,651 tons dry matter/year. The region has an estimated 878,322 ha of arable land available for crop production and contributes about 45% of the animal feed demand. Belay et al. (2013) revealed that the most important problems of livestock production perceived were feed shortage (100%) and water shortage (27%) in Ethiopia. Livestock suffers from a seasonal shortage of feed (grazing land) and water (Descheemaeker, 2008). In the high altitude zone, livestock cover less than 1 km distance to reach water compared to the low altitude zones (Hassen et al., 2010). As a result, there is a shortage of labor for livestock management (Tegegne, 2012). Nahusenay et al. (2015) found that adult males are much more responsible for feeding animals (57%) and adult female accounts for 25% in feeding animals.

Cooke (1998) considered the effect of time spent on the collection of fuelwood, leaf fodder and cut grass on labor time to agriculture and his result revealed that a reallocation of time away from farm work and leisure may occurred as environmental goods became scarce and costly in Nepal. The work of Kumar and Hotchkiss (1988) linked time allocation behavior and deforestation in Nepal. They found that time spent in farming declines with a higher degree of deforestation (fuel scarcity). Mekonnen et al. (2015) examined the effect of the scarcity of fuelwood and water on time spent in agriculture using a panel data set collected from Ethiopia. The results of the empirical analysis show that fuelwood scarcity, as reflected by the shadow price of fuelwood, has a negative and significant impact on time spent on agriculture; however, scarcity of water has no effect on time spent on agriculture. Likewise, Cooke (2008) explained the effect of forest scarcity on the livelihood of rural people in Nepal and found a negative effects on health, labor burden and agriculture. Another related study by Damte et al. (2012) in Ethiopia indicated that rural households respond positively to fuelwood shortages by increasing their labor input for fuelwood collection even if they fail to investigate whether the increase in labor comes from agriculture or other activities.

According to Bandyopadhyay et al. (2011) study in Malawi, more time spends on scarce fuelwood collection was associated with negative welfare even if the effect on their overall welfare is small. Bhattacharya and Innes (2006) highlighted that forest degradation spurs rural poverty in Sub-Saharan Africa. In addition, Mekonnen et al. (2017) explored the effect of time spent on dung, fuelwood and crop residue on agricultural productivity and the result indicated that agricultural productivity decreases with increasing time spent on collecting animal dung but increases with time spent on collecting crop residue. None of the above studies examine the effect of grazing and water for animal on time allocation, food production and food consumption (Cooke et al., 2008; Khan, 2008).

## 3. Theoretical Model

In a mixed crop–livestock farming systems, Ethiopia owns a significantly large livestock population (Tegegne, 2012). In the country, livestock production mainly depends on natural resources such as grazing land, water and own crop residue (Bezabih and Berhane, 2014). The contribution of livestock to food and nutritional security is significant and serves as an important source of livelihood (Swanepoel et al., 2010). However, crop - livestock farming activity require huge inputs of labor either from own family or labor market. In rural farm households, total time endowment is divided into three main activities: farm activities, off-farm activities and leisure, where rural farms take a significant share of total time endowment and a substantial part of the production is retained at home for consumption. The scarcity of grazing and water resources for animal may even takes the largest proportion of family labor time in countries like Ethiopia, which is characterized by a critical shortage of animal feed and water, having a negative implications for agricultural production and food security (Tangka et al., 2005).

Considering the time spent on looking scarce resource, the total time endowment is further divided into four main activities: farm activities, off-farm activities, leisure and searching or collecting these resources activities. Labor allocation for these scarce resources displaces household's labor from productive activities such as agricultural production and off-farm employment, food preparation and leisure, resulting in low welfare (Cooke et al., 2008; Mekonnen et al., 2015). The scarcity of grazing and water resources adversely affects household food production and consumption either by affecting livestock production directly, affecting crop and off farm income through labor reallocation or through its direct impact on time for leisure consumption and food preparation.

The theoretical framework for modeling the effect of resource scarcity on food production and consumption is, in general, built within the framework of household utility model. Modeling households' decision of production and consumption as a recursive method enables us to understand the households' action as if it first maximizes profit (Straus, 1986). Following the work of Singh et al. (1986), it makes sense first to maximize profit and then decide consumption and leisure since income and utility are positively related. For simplicity, the well-behaved quasi-concave household utility function have the following form:

$$U = U(X, X_L; \phi), \qquad \textbf{(1)}$$

where vector of home produced goods such as meals and purchased goods consumed, and  is consumption of leisure. The meal production is a function of agricultural goods, off farm income , fuel sources such as straw or dung as well as labor days the household spend on searching grazing land, water and crop residue. The production of household goods is also influenced by the vector of household characteristics,

$$X = X_j\left(Q_j, E, S, T_A; \phi\right). \qquad \textbf{(2)}$$

An implicit production function which is assumed to be the quasi-convex relating outputs and inputs, increasing in outputs and decreasing in inputs (Strauss, 1986), and which allows for a separate production function for each output or joint production function is therefore formally denoted by:

$$F\left(Q_j, V, K, T_A\right) = 0, \qquad \textbf{(3)}$$

where  is implicit production function,  is vector of household productions such as crops, and are vectors of variable inputs including labor, and fixed inputs respectively.  is labor time spent by the household on searching grazing land, water and crop residue as a proxy of scarcity indicator. Expressing total income of a farm household as the sum of its time endowment, value of households' production and other incomes such as transfer, minus the value of variable inputs required for production, the budget constraint stating total consumption equals total income can be presented as:

$$\sum_{j=1}^{L} P_j X_j = P_L(T + T_A) + \sum_{j=1}^{n} P_j Q_j - \sum_{i}^{m} P_i V_i - P_L L + E, \quad \textbf{(4)}$$

where  is commodities consumed, is price of output, is time endowment, is wage, is household production, is price of variable inputs, is non-labor variable inputs, is labor demand and is exogenous income. While the left hand side of Equation (4) represents market value of commodity consumed with the last term () being the value of leisure, the right hand side gives full income of the household which consists of households time endowment, plus the value of households total production, minus the value of variable inputs including labor, and plus exogenous income which is generated outside the household such as transfer from relatives or friends.

Generally, the household maximizes utility subject to production function, budget constraint, and time constraint. Maximizing output by the households depends only on the choice of variable inputs, and maximizing profit is the same as maximizing full income given by the right-hand side of equation (4) subject to the production function. Then, the household maximizes utility subject to its full income upon achieving maximum income through profit maximization. The Lagrangian function of the utility maximization subject to full income and production function can be expressed as follows:

$$L = U\big(X_j\big(Q_j, E, S, T_A; \phi\big), X_L\big) + \lambda[(T + T_A) + \sum_{j=1}^{n} P_j Q_j - \sum_{i}^{m} P_i V_i - P_L L$$
$$+E - \sum_{j=1}^{L} P_j X_j] + \gamma[F(Q, V, K, T_A)]. \quad \textbf{(5)}$$

Assuming that interior solution exists, the first order conditions based on Straus (1986) are:

$$\frac{d\mathcal{L}}{dX_j} = \frac{dU}{dX_j} - \lambda P_j = 0, \quad \textbf{(5.1)}$$

$$\frac{d\mathcal{L}}{dL} = \gamma \frac{dF}{dL} - \lambda P_L = 0, \quad \textbf{(5.2)}$$

$$\frac{d\mathcal{L}}{dV_i} = \gamma \frac{dF}{dV_i} - \lambda P_i = 0, \quad \textbf{(5.3)}$$

$$\frac{d\mathcal{L}}{dT_A} = \frac{dU}{dX_j}\frac{dX_j}{dT_A} + \lambda P_L + \gamma \frac{dF}{dT_A} = 0, \quad \textbf{(5.4)}$$

$$\frac{d\mathcal{L}}{dQ_j} = \frac{dX_j}{dQ_j} + \lambda P_j + \gamma \frac{dF}{dQ_j} = 0, \quad \textbf{(5.5)}$$

$$\frac{d\mathcal{L}}{d\gamma} = \mathrm{F}(Q, V, K, T_A) = 0, \quad \textbf{(5.6)}$$

$$\frac{d\mathcal{L}}{d\lambda} = P_L(T + T_A) + \sum_{j=1}^{n} P_j Q_j - \sum_{i}^{m} P_i V_i - P_L L + E - \sum_{j=1}^{L} P_j X_j = 0. \quad \textbf{(5.7)}$$

Following Straus (1986), the solution to the first order conditions of the above expressions yields standard demand function for inputs and outputs in terms of all prices, the wage rate, time for searching and collecting scarce resource, fixed land, and capital. Substituting optimal labor, and optimum output into RHS of Equation (4) produces optimum income or full income under the assumption of maximized profit. Likewise, the first order conditions of the LHS of Equation (4) gives consumption demand function in terms of prices, the wage rate, and income and household's preferences represented by household demographic characteristics. The effect of scarce resource on agricultural production $\left(\frac{dF}{dT_A}\right)$ is investigated through the production sector and its direct impact on household's utility $\left(\frac{dX_j}{dQ_j}\right)$ is explored through consumption sector. Thus, the total effect which is sum of the two effects can be explained using the budget constraint total income as

$$\frac{dM}{dT_A} = \frac{dX_j}{dy}\frac{dy}{dT_A} + \frac{dX_j}{dT_A}, \quad \textbf{(6)}$$

where$y = \sum_{j=1}^{n} P_j Q_j - \sum_{i}^{m} P_i V_i - P_L L$ represents the net agricultural output or profit from agricultural production and total income of the household is equal to households time endowment, plus the value of households total agricultural production, minus the value of variable inputs including labor, and plus exogenous income in the RHS of Equation 4. The main question that interests us is whether scarcity of these resources adversely affects crop production and per capita food consumption expenditure. The hypothesis to be tested here is that farmers that spend more time on searching these scarce resources are likely to have less time for crop production and leisure consumption that is we test weather, $\frac{\partial L}{\partial T_A} < 0$, or $\frac{dF}{dT_A} < 0$ and $\frac{\partial X_j}{\partial T_A} < 0$ using walking distance[2] to these resources sites as indicator of scarcity in the study area.

In this case, utility and production decision problems can indeed be solved recursively, despite their simultaneity in time (Straus, 1986). Barnum and Squire (1979) show that household characteristics can be introduced into the model as linear functions and prove that introducing them as linear functions will not change the analysis as long as household characteristics are treated as fixed variables. Since solving the above system of equations becomes more tiresome as the number of commodities consumed and outputs produced increase, an alternative approach to estimating separated production function for each output type is aggregate production. Aggregation gives a greater chance to cancel out errors when some households report zero variable input for some products but positive outputs and will not only reduce the number of parameters to be estimated but also addresses the probable existence of jointness (Strauss, 1986).

## 4. Description of Study Area and Dataset

Ethiopia is a federal country divided into 9 regions and 2 administrative cities. Each region is subdivided into zones and zones into woredas. Woredas, in turn, are divided into Peasant Associations (PA) or Tabias, an administrative unit consisting of a number of smallest villages and individual households. The study is conducted in Tigray region, the northern part of Ethiopia by randomly selecting 632 sample households from 21 PAs. This study used a cross-sectional data from NMBU-MU[3], Tigray Rural Household Survey (TRHS)[4] dataset collected in 2015. TRHS includes a panel of five rounds conducted in 1997/98, 2002/03, 2006/07, 2009/10 and 2014/2015 where the

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[2] See for a similar approach in the work of (Cooke, 1998; Cooke et al., 2008 and Baland et al., 2010)

[3] NMBU-MU refers to Norwegian University of Life Science-Mekelle University.

[4] This dataset has been used by Gehbru Hosaena (2010); Holden et al. (2009, 2011). Hagos and Holden (2011) and others.

author is involved only in collecting the data for the last round. The data has been originally designed by a doctoral student from Ethiopia in Norway and PhD students who joined the same university continued to use the same design. The available panel dataset provides comprehensive household and plot level data on household characteristics, agriculture and livestock information, food consumption, rental market participation, land certificate perception as well as community level data on GPS information including rainfall, total cultivated, irrigated and grazing area, wages, and conservation activities under safety net activities.

The primary data used in this paper is adapted from the last, 2014/2015, household survey since some variables used in this estimation were only added in the last round of the wave. Table 1 presents the basic socio-economic characteristics of 518 farm households drawn from a total of 632 sample farmers. For this study, the need for information regarding livestock activity restricted us to use only 518 farmers, those who only owned cattle during the study year (82 percent of the original data, 632). The dependent variable in the production side is aggregate household agricultural production or monetary value of all crops produced during the survey production season. In the consumption side, the dependent variable is per capita food consumption expenditure.

Crop production in Ethiopia is dominated by small-scale subsistence farm households that on average cultivate less than a hectare of land. The main agricultural products produced in the surveyed villages are Tef, barely, wheat, maize, millet, sorghum, field pea, lentil, linseed etc. An average household owns a production capital worth about 639 birr and has produced an average agricultural output of worth 41,645 birr in the year. In addition, the average livestock endowment of the sample households is 4 TLU which expected to increase food security (Kassa et al., 2002), and average total income including sales from agricultural outputs is worth 49,426 birr while the average per capita food expenditure is 2,490 birr.

## Table 1: Descriptive and Summary Statistics

**N=518**

| Variables | **Description** | **Mean** | **SD** | **Min** | **max** |
|---|---|---|---|---|---|
| | **Dependent Variables** | | | | |
| PCFE(ETB)[e] | Monetary value of per capita food expenditure | 2,490 | 3,722 | 22.22 | 34,962 |
| Output (ETB) | Monetary value of crop production | 41,645 | 87,517 | 152.40 | 892,500 |
| Income(ETN) | Monetary value of total income[b] | 49,521 | 92,642 | 300 | 892,730 |
| | **Independent Variables** | | | | |
| Market distance | Distance to nearest market in minute | 82.30 | 54.79 | 10 | 240 |
| Water distance | Distance to animal water source in minute | 74.85 | 65.54 | 10 | 360 |
| Feed distance | Time to transport crop reside and grass | 576.55 | 557.87 | 18 | 6,000 |
| Family size | Household family size in number | 5.87 | 2.41 | 1 | 12 |
| Age | Household head age in years | 56.83 | 15.20 | 18 | 99 |
| Religion | 1 if household head is orthodox and 0 Muslim | 0.82 | 0.38 | 0 | 1 |
| Gender | 1 if household head is male | 0.74 | 0.44 | 0 | 1 |
| Education | 1 if household head is literate | 0.33 | 0.47 | 0 | 1 |
| TLU | Herd size in TLU | 3.92 | 3.20 | 0.01 | 22 |
| Grazing distance | Time spent looking for grazing land in minute | 91.12 | 83.44 | 10 | 1,200 |
| Shocks (2012-2014) | Number of shocks due to theft, flood, death | 0.58 | 0.83 | 0 | 5 |
| Irrigation | 1 if household head has access to irrigation | 0.26 | 0.44 | 0 | 1 |
| ashock13 | 1 if household face animal shock in 2013 | 0.04 | 0.20 | 0 | 1 |
| Shock exposure | 1 if household face any shock in 2012-2014 | 0.09 | 0.29 | 0 | 1 |
| Information | 1 if hh had access to TV, radio and mobile | 0.42 | 0.49 | 0 | 1 |
| Network | 1 if hh get support from relatives and friends | 0.61 | 0.49 | 0 | 1 |
| Water harvest | 1 if hh access water harvesting well, ponds | 0.02 | 0.14 | 0 | 1 |
| Location | 1 if hh lives in highland(>2500masl) | 0.06 | 0.24 | 0 | 1 |
| Oxen | Number of oxen the household head own | 1.93 | 1.05 | 1 | 9 |
| Area | Total cultivated land in tsmdi[c] | 4.45 | 3.14 | 0.25 | 22 |
| Family labor | Total adult family labor in man day | 85.52 | 69.33 | 1 | 778 |
| Fertilizer | Total fertilizer used in KG | 68.55 | 49.24 | 0.5 | 425 |
| Manure | Total manure used in KG | 775.60 | 1,585 | 1 | 20,000 |
| Farm tool (ETB) | Total monetary value farm tool[d] | 639.10 | 1,451 | 10 | 14,650 |

*Notes*: a: It includes crop, fruit and vegetable production

b: It includes income from Agriculture, off-farm, transfer and safety net

c: One Tsmdi is approximated to one-fourth hectare

d: Total monetary value of all farm implements such as plough parts, hoe, cart, sickle, spade

e: ETB refers to Ethiopian currency in which 1USD 23 ETB

Referring to figures of zonal distribution of production and per capita consumption in the appendix, the average per capita food expenditure was 3200 Birr for Southern and around 2000 for the rest zones, showing that average per capita food expenditure in Southern is much higher than the overall average result; perhaps this is due to the densely populated livestock of the zone compared to other zones. The same result in the appendix display that average values of output and income of that household living in the southern zone are 3.7 and 3.3 times larger than their respective values by an average household in the other zone.

On average the households spend 75 minutes to reach a water source for animal and 91 minutes to search for communal grazing land daily, maximum time reaching up to 6 hours for water site and 8 hours for grazing land in the data. Besides, the average time spent on transporting crop residue by the households is 576.6 minutes, ranging from a minimum value 18 to maximum value of 6000 minutes in the study area. Households that are situated far from a water and grazing land source require longer time. The graphical display in the appendix showed that farmers living in Raya Azebo district travel 110 minutes to reach grazing land followed by Easterners while those from central zone spend minimal time. With regard to distance to animal water source, North Westerners commute about 90 minutes followed by South Easterners. Households from North West spend around 800 minutes to transport crop residue while Easterners travel half of the distance of North West (400 minutes).

Farmers having a larger size of livestock holding (TLU) seem to be more worried to supply enough feed to their animals and spend more time to search for feed and water. In relation to this, Bishu (2014), whose study in Ethiopia indicated that there was a shortage of water during the dry season for livestock drinking in the study site (Abegaz, 2005; Tesfaye, 2010). It is therefore hypothesized that any labor spent on searching scarce resources is inversely related to the production and per capita consumption (Mekonnen et al., 2015). The distance to the nearest market, on average, was 82 minutes. Thus, its expected effect on consumption is negative, indicating that longer distance leads to less frequency of visit and hence less likely to get market information about selling and buying prices (Feleke et al., 2005; Shiferaw et al., 2003). As of the survey, average land holding is 1 ha, which is less than the family member size in the study area and holding large size is expected to play a significant role in influencing households' food production and food security positively (Najafi, 2003).

Fertilizer and manure are used in most studies as a proxy for technology that augments agricultural productivity and is expected to boost the overall production, contributing towards attaining household food security. Each household uses an average of 68.5 KG fertilizer and 775.6 KG manure during the harvesting period, while the number of oxen by an average household is 2. All inputs are expected to increase production and thus food consumption (Brown, 2004; Di Falco et al., 2011). In many developing countries, oxen serve as a source of traction, thereby significantly affecting households' crop production and consumption by enabling households to cultivate greater areas of land (Govereh and Jayne, 1999). Hence, a positive relationship between ox ownership and food expenditure and crop production is expected in this study. On average, each household had 85.5 man day labor used for farm production.

The magnitude of this variable is smaller than the result from the previous empirical finding of Sakketa and Gerber (2017) and Mekonnen et al. (2015), who found the average household labor time is about 114 and 117 man day in Ethiopia. I have also tried to look at the correlation between the time spent on searching water, grazing land and crop residue and time spent on crop farming. The result indicated that farm time and resource scarcity are negatively associated in the study area. This is consistent with result of Mekonnen et al. (2015), who investigated the impact of scarcity of fuelwood and water for human on labor allocated to agriculture. Given adequate land, adequate labor supply input is expected to foster production and is expected to have a positive effect (Di Falco et al., 2011; Sarris et al., 2006).

Out of the total sample, 6.4% lives in highland parts of the region. Only 27% of the households have access to irrigation and only 2% are involved in water harvesting practices such as ponds and well. Nearly 39% of the households report that they have been severely affected by eleven different level of shocks including, drought, pests, flood, theft, illness and death, loss of job and home damage in the last harvesting season, and 4.25 % of households report having been affected by animal shocks one year before the harvesting season. Both shocks are expected to affect production and consumption negatively (Abdulai and Huffman, 2014; Dercon et al., 2005). Evidence showed that male headed households have a better opportunity in terms of access to a resource such as labor, land, modern input, education, credit and extension services compared to female headed households (FAO, 2001). 74% of the households are male heads with an average age of 57 years and family size of 5.87. Since resources are very scarce, high family size may put much more pressure on consumption than it contributes to production. The expected sign of consumption is then negative because food requirements increase with the number of persons in a household.

Nearly 32% of the household heads have at least a one or more years of education. Thus, it is hypothesized that education is negatively related to consumption value. Around 82% of the households are Orthodox followers while 18% of the households are Muslim households in the study area. Out of the 518 households in the sample, 61% got assistance either from their relatives or friends and is expected to increase production and consumption (Di Falco et al., 2011). More than 40 percent of household heads site attend media via TV, radio and mobile phone about any development intervention. Hence, it is expected that households with information are more likely to produce more and be food secure. The expected effect on production and consumption is positive (Di Falco et al., 2011).

## 4. Econometric Model Specification

This paper draws on the AHM which provides a holistic framework to analyze the economic relations of production and consumption decision in the farm household. We choose the recursive AHM since it has an advantage of econometric estimation simplicity and fits best to the available data. Although the separation property of the recursive model enables us to separate the estimation of consumption and production sectors, it will result in inconsistent estimators whenever one of the assumptions does not hold true. This problem is even more significant for studies that deal on production side than consumption (Delforce, 1994). But, as the focus of this study mainly inclines to consumption side. The problem is less worrisome.

With regard to estimation, first, the production function was identified. Multiple crop outputs are aggregated into a single output measure using the medians of their reported village's prices within each village following Jacoby (1993) and Gutu (2016). Then, food demand equation (per capita food expenditure) was specified using the utility maximization results of the AHM. The parameters from production side were estimated using the Cobb-Douglas production function since the output is a simple function of labor and capital. However, it does not allow other variables than just the two which can significantly affect production such as fertilizer and land. For this reason, the General Cobb-Douglas (GCD) production function, developed by Diewert (1973) was adopted in order to incorporate these variables into the production function and denoted as:

$$y = m \prod_{i=1}^{n} \prod_{n=j}^{n} \left(\frac{1}{2}x_i + \frac{1}{2}x_j\right)^{\alpha_{ij}}, \qquad \textbf{(7)}$$

where  is output,  are quantities of the  inputs, ,  and  (This is the assumption of constant return to scale). Assuming that  for all , and taking natural log of equation (7) produces a standard Cobb-Douglas equation with many inputs, which is to be estimated in its natural log form:

$$ln\, y = \alpha_0 + \sum_{i=1}^{n} \alpha_i\, ln\, x_i + e, \qquad \textbf{(8)}$$

where,  is the constant term in equation (8), and  is the error term.

The GCD production function is often criticized for being restrictive due to its assumptions of constant returns to scale (CRTS) and perfect competition in both input market and output market even if it handles a large number of inputs. Its assumptions make it difficult to measure technical efficiency levels and growth effectively. But, the assumption about market does not significantly affects the estimation power of Cobb-Douglas production function as long as factors are paid according to their relative shares (Murthy, 2004). In addition, Miller (2008) argued that GCD can be estimated by relaxing the CRTS assumption and then test whether the summation of the coefficients is significantly different from one using the standard econometric procedure.

In order to estimate consumption side, we are forced to approximate calorie intake by per capita food expenditure due to limited data assuming that the demand equation from the utility maximization of the recursive household model has a functional form of log-linear. Thirumarpan (2013) and Asfaw et al. (2012) used consumption expenditure to reflect the socio-economic welfare of household and is a reliable indicator of food accessibility and degree of vulnerability to food insecurity. Its capability of estimating respective elasticities as its coefficient and modeling nonlinear effects makes it applicable and preferable (Oum, 1989). Oum added that the log-linear demand function resembles the demand function obtainable from a Cobb-Douglas utility function with the drawback of invariant estimated elasticities across all data points. Like in the production side, aggregate demand equation per household is estimated for per capita food consumption expenditure rather than estimating single demand equations for each product consumed or for each individual member of the household.

$$lnM = \beta_0 + \delta Y + \sum_{i=1}^{n} \beta_n \ln x_i + \nu, \qquad \textbf{(9)}$$

where $M$ is households per capita food consumption expenditure; $x_i$ for $i = 1, \cdots, n$, includes consumption side variables and household characteristics; $\nu$ is an error term which is assumed to be uncorrelated with the production function error term . $\delta$ and β are parameter coefficients of income and the vectors of an exogenous variables, $x_i$. The effect on agricultural production is investigated through the production sector and its direct impact on household's utility is explored through consumption sector.

Since farm and off-farm income is not randomly distributed among rural households, this variable is likely to be endogenous, which could be caused by omitted variables, measurement error, simultaneity or household unobservable (Hidalgo et al., 2010), First, a reverse causality problem might exist, because per capita food expenditure at the household level might also influence labor productivity and thus farm productivity. Second, farm and off-farm income might be influenced by household unobservable, which can lead to correlation with the error term. In the presence of endogeneity, the use of the OLS estimator biases the effect of income. In order to avoid an endogeneity bias, we adopted Two-Stage Least Squares (2SLS) approach, using household shock experience and a number of plots as instruments (Angrist and Evans, 1998) which are the most common instrumental variable estimator (Wooldridge, 2009). This is similar to approaches that have been used by Sarris et al. (2006) and Abdulai and Huffman (2014) in different contexts. With this procedure, the structural equation is specified as

$$lnM = \delta + \delta^{iv}\hat{Y} + \sum_{i=1}^{n} \beta_n \, ln \, x_i + \varepsilon, \quad \textbf{(10)}$$

where $ln\,M$ is percapita food expenditure, $\hat{Y}$ is predicted values of the endogenous income variables and is an error term, that is uncorrelated with , $Y, \delta$ and $\beta$ are parameter coefficient of income and the vectors of an exogenous variables, $x_i$. To obtain income $(Y)$, first stage regression equations is estimated by OLS based on the following specifications;

$$ln\,Y = \alpha + Z'\gamma + \sum_{i=1}^{n} \beta_n \, ln \, x_i + \varepsilon, \quad \textbf{(11)}$$

where is $ln\,Y$ total farm and off farm income of the household, $\gamma$ is parameter coefficients of the vector of the instrumental variables, $Z$ which are assumed to correlate with income $Y$ but not with the error term, $\varepsilon$ in the structural equation (10). The estimated per capita food consumption expenditure of the household, in (10) is now assumed to be unbiased.

## 6. Economic Results

### 6.1 Estimation of Household Labour Allocation to Crop Farming

What is the consequences of increasing grazing, water and straw for agricultural labour input? We answer this question by examining the link between resource scarcity and labour input to crop farming in rural areas of Ethiopia using similar estimation methods of Cooke (1998) using cross section data in Nepal. In this paper, the variables of greatest interest are animal water and feed scarcity measured by the time taken to collect them. A priori, animal water and feed scarcity should reduce labour time on the crop farm because they take away time from crop farms and leisure as people search for these resources. The estimate of the effect of resource scarcity on time spent in crop farming is presented in Table 6.

Our results do support the hypothesis of a negative relationship between total household labour allocation to crop farming and resource scarcity at the household level. With respect to the variables of interest, higher searching times of water, grazing and collecting straw were shown to significantly reduce labor time to crop farming. We found that that a 1% increase in searching times of water, grazing and collecting straw results in a 0.0598%, 0.0929% and 0.0992% respectively decrease in time spent on crop farm. This result finds favor among a number of researchers (Cooke, 1998; Cooke, 2008; Bandyopadhyay et al., 2011; Mekonnen et al., 2015). We found significant effects of other covariates as well. Land area in crops has a significant positive effect on total household labour input to farming. Real off farm wage has a significant positive effect on household farm labor input.

As expected, we also found that large family households spend more time on crop farming. The households living in lowland areas spend more farm labour input to farming than their counter part. Wealthier households who have more livestock spend more time for farming. Higher on-farm income is associated with household's more time input to crop farming. Hiring labor from the local market decrease labor family input to farming and higher altitude motivate farmers to allocate more labor input to crop farming. These findings correspond to the results of previous studies by Cooke (1998), Okwi and Muhumuza (2010), Bandyopadhyay et al. 2011) and Mekonnen et al.(2015).

### 6.2. Estimation of Monetary Value of Aggregate Production

In order to estimate production sector of the farm households, we used ordinary least square (OLS) on the log-transformed form of the GCD production function specified in section 5. The dependent variable is aggregate household agricultural production, which is the monetary sum of all crops produced during the survey harvesting season. The estimates of the production function and the effect of water, grazing the land and feed scarcity on agricultural production are presented in Table 2 under 3 columns respectively. In general, the estimation shows that all explanatory variables exhibit significant and theoretically expected signs. Variables of interest in this paper are time spent on looking water and feed resources included so as to capture the effect of feed and water scarcity on agricultural production. The first column presents the estimation of the food production function with water scarcity taken into account as do the second and the third columns, putting grazing land and feed transport into consideration. The result is in favor of our hypothesis.

As expected Column (1) of Table 2 indicated that time spent on animal water source is found to be negative significant, suggesting that a one percent increase in time spent looking for water decreases agricultural production by 0.155 percent, and time spent on searching grazing land have stronger effect than this variable as shown in Column (2) i.e., a one percent increase in time spent searching for grazing decreases agricultural output by 0.279 percent. Another feed scarcity related variable is time spent for transporting crop-residue from threshing center to homestead. Increasing distance significantly resulted in a negative sign as expected, implying that farmers that spend one minute more for collecting crop residue produce about 0.328 percent less output (Column 3). The output effect obtained here support the claim that time spent for searching scarce resources displace labor time from production activity and hence reduce crop production in line with the findings of (Damte et al., 2012; Mekonnen et al., 2015; Tangka and Jabbar, 2005), who generally concluded that collection of scarce resources such as water, firewood, and grass negatively affect production activity by reducing labor time allocated to crop farming.

The estimated coefficient for land (0.278, 0.304 and 0.201) shows that increasing land size by one percent increases agricultural production, on average, by almost 0.3 percent, implying that land is a vital input of agriculture. The result is similar to what it was found by Nisrane et al. (2011), whose study revealed that cultivated land had a positive effect on agricultural production in Ethiopia. Moreover, Foster and Rosenzweig (2010) showed that land size had a positive impact on net revenue in India while the empirical results from Sarris et al. (2006) in Tanzania also appear to support the above result.

**Table 2: OLS Estimation of log Monetary Value of Aggregate Agricultural Production**

| Variables | (OLS) Ln(output) | (OLS) Ln(output) | (OLS) Ln(output) |
|---|---|---|---|
| Ln(area) | 0.278*** | 0.304*** | 0.201*** |
| | (0.0595) | (0.0579) | (0.0523) |
| Ln(manure) | 0.0854** | 0.0857** | 0.0501 |
| | (0.0369) | (0.0363) | (0.0324) |
| Ln(oxen) | 0.228** | 0.248*** | 0.186** |
| | (0.0973) | (0.0951) | (0.0851) |
| Ln(fertilizer) | 0.145** | 0.174*** | 0.150*** |
| | (0.0665) | (0.0652) | (0.0581) |
| Ln(family labor) | 0.353*** | 0.306*** | 0.197*** |
| | (0.0650) | (0.0641) | (0.0581) |
| Hired labor(1/0) | 0.472*** | 0.481*** | 0.307*** |
| | (0.0928) | (0.0907) | (0.0822) |
| Location(1/0) | -0.493*** | -0.453*** | -0.544*** |
| | (0.174) | (0.169) | (0.150) |
| Ln(farm tool) | 0.0566** | 0.0561** | 0.0162 |
| | (0.0254) | (0.0249) | (0.0224) |
| Ln(mktdistance) | 0.0745 | 0.0808 | -0.000798 |
| | (0.0551) | (0.0538) | (0.0485) |
| Info(1/0) | 0.0959 | 0.0549 | 0.0264 |
| | (0.0851) | (0.0836) | (0.0746) |
| Well(1/0) | -0.260 | -0.218 | -0.0514 |
| | (0.299) | (0.292) | (0.261) |
| Ln(shocks) | -2.160*** | -2.091*** | -1.932*** |
| | (0.321) | (0.311) | (0.278) |
| Irrigation(1/0) | 0.0627 | 0.0931 | -0.0440 |
| | (0.0980) | (0.0955) | (0.0860) |
| Education(1/0) | 0.284*** | 0.246*** | 0.243*** |
| | (0.0904) | (0.0887) | (0.0790) |
| Ln(water distance) | -0.155*** | | |
| | (0.0475) | | |
| Ln(grazing distance) | | -0.279*** | |
| | | (0.0471) | |
| Ln(feed distance) | | | -0.328*** |
| | | | (0.0254) |
| Constant | 6.873*** | 7.383*** | 9.496*** |
| | (0.500) | (0.492) | (0.476) |
| Observations | 509 | 508 | 509 |
| R-squared | 0.394 | 0.423 | 0.538 |

*Note*: P-values are for slopes; ***P<0.01; **P<0.05 and *P<0.10 = Significant at 1%, 5% and 10% probability level respectively.

As expected fertilizer and manure use are found to be significant and positive variables incongruent to the studies conducted by (Demeke et al., 2011; Kidane et al., 2005; Nisrane et al., 2011; Di Falco et al., 2011) in Ethiopia. In Ethiopia ox is the main capital input used for ploughing and threshing and can be considered as an equivalent substitute of the uses of the tractor. In this paper number of oxen is found to be significant, leading to a 0.23 percent increase in the agricultural output. A similar result is found in the study of Mekonnen et al. (2015) who found a positive effect of ox input food crop productivity in Ethiopia.

In line with the predictions of economic theory, inputs such as farm capital and labors are significantly associated with an increase in the quantity of production value. A one percent increase in man day labor causes to increase production by about 0.353 percent, a finding that is consistent with this notion is of Di Falco et al. (2011) and Abdulai and Huffman (2014). But the coefficient on seed input contrasts with the findings by Di Falco et al. (2011) in Ethiopia and Bulte et al. (2014) in Tanzania, who both found a positive significant on harvest. Farmers hiring one percent extra labor seems to increase their production value by 0.481 percent, confronting with the result of Sarris et al. (2006) whose result revealed a negative relation. Another capital input included in the analysis is production capital which is the monetary value of farm tools. It is found to be statistically significant. A one percent increase in production capital has the ability to increase agricultural output by 0.056 percent. This finding is consistent with the earlier study by Sarris et al. (2006).

Not surprisingly, we found that shock experience appears to be negatively related to the household's production. An increase in shock has a quite large detrimental effect of food production (-2.16%) which is consistent with a previous study (Abdulai and Huffman, 2014) who confirmed a negative effect of drought or illness shock on production. The variable representing education of the farmer is positive and significantly different from zero, suggesting that more educated farmers are more likely to produce more in favor of Abdulai and Huffman's (2014) result.

## 6.3. Per Capita Food Expenditure Estimation

The objective of utility maximization by the household is analyzed using the demand functions derived from maximized utility subject to budget constraint and technology constraint of farm production and its estimated result is presented in Table 3 using naïve OLS and IV method, where total income is instrumented by shock occurrence and a number of plots of the household head. Shock caused by crop theft and death of a household member is expected to affect income and output negatively, thereby reducing food expenditure (Abdulai and Huffman, 2014; Dercon et al., 2005). The exposure of previous year's shock (2012-2014) have a direct effect on the household income and indirect effect on the consumption side through its effect on income. The source of rural farm income is mainly from crop or animal farming which is operated by family labor. Thus, farm income is expected to decrease with increasing any shock on crop or animal farming caused by a theft or illness of the household. Then, its effect on consumption reaches through its effect on farm income.

## Table 3: IV Estimation of log Per Capita Food Expenditure

| Variables | (OLS) lnPCFE | (IV) lnPCFE | (OLS) lnPCFE | (IV) lnPCFE | (OLS) lnPCFE | (IV) lnPCFE |
|---|---|---|---|---|---|---|
| Ln(output) | 0.0940*** | 0.0562*** | 0.0909*** | 0.0563*** | 0.0986*** | 0.0623*** |
| | (0.0121) | (0.0171) | (0.0125) | (0.0169) | (0.0122) | (0.0170) |
| Ln(livestock) | 0.0336*** | 0.0277** | 0.0334** | 0.0289** | 0.0352*** | 0.0295** |
| | (0.0129) | (0.0137) | (0.0131) | (0.0137) | (0.0130) | (0.0137) |
| Ln(Family size) | -0.385*** | -0.357*** | -0.397*** | -0.369*** | -0.388*** | -0.362*** |
| | (0.0529) | (0.0562) | (0.0535) | (0.0566) | (0.0534) | (0.0564) |
| Gender(1/0) | -0.119** | -0.140** | -0.0993* | -0.117* | -0.115* | -0.136** |
| | (0.0588) | (0.0621) | (0.0590) | (0.0620) | (0.0593) | (0.0624) |
| Info(1/0) | 0.0591 | 0.0370 | 0.0454 | 0.0247 | 0.0487 | 0.0260 |
| | (0.0539) | (0.0570) | (0.0545) | (0.0573) | (0.0544) | (0.0573) |
| Location(1/0) | -0.0411 | -0.0543 | -0.114 | -0.133 | -0.149 | -0.173 |
| | (0.140) | (0.147) | (0.140) | (0.146) | (0.141) | (0.147) |
| Ln(mktdistance) | 0.00283 | 0.0196 | 0.00252 | 0.0200 | 0.00144 | 0.0174 |
| | (0.0337) | (0.0358) | (0.0340) | (0.0360) | (0.0340) | (0.0359) |
| ashock13(1/0) | -0.489** | -0.379* | -0.550*** | -0.442** | -0.540*** | -0.440** |
| | (0.191) | (0.203) | (0.192) | (0.204) | (0.193) | (0.204) |
| Ln(shocks) | 0.212 | 0.374* | 0.307 | 0.465** | 0.267 | 0.428** |
| | (0.198) | (0.214) | (0.199) | (0.214) | (0.200) | (0.215) |
| Religion(1/0) | 0.121* | 0.152** | 0.101 | 0.130* | 0.115 | 0.145* |
| | (0.0700) | (0.0741) | (0.0705) | (0.0743) | (0.0706) | (0.0744) |
| Network(1/0) | -0.0833 | -0.191*** | -0.0761 | -0.178*** | -0.0729 | -0.177*** |
| | (0.0554) | (0.0666) | (0.0559) | (0.0665) | (0.0558) | (0.0667) |
| Age(years( | -0.000477 | -0.000808 | -0.000535 | -0.000848 | -0.000554 | -0.000886 |
| | (0.00174) | (0.00183) | (0.00175) | (0.00184) | (0.00175) | (0.00184) |
| Ln(income) | 0.0440*** | 0.0593*** | 0.0433*** | 0.0581*** | 0.0439*** | 0.0587*** |
| | (0.00187) | (0.00498) | (0.00189) | (0.00499) | (0.00189) | (0.00499) |
| Ln(wat distance) | -0.122*** | -0.133*** | | | | |
| | (0.0309) | (0.0327) | | | | |
| Ln(graz distance) | | | -0.100*** | -0.0860** | | |
| | | | (0.0336) | (0.0354) | | |
| Ln(feed distance) | | | | | -0.0642*** | -0.0731*** |
| | | | | | (0.0240) | (0.0253) |
| Constant | 6.018*** | 5.959*** | 6.046*** | 5.862*** | 5.917*** | 5.872*** |
| | (0.291) | (0.306) | (0.318) | (0.337) | (0.305) | (0.319) |
| R-squared | 0.710 | 0.670 | 0.705 | 0.668 | 0.705 | 0.667 |
| First stage Shock | | -20.124*** | | -20.076*** | | -20.123*** |
| | | ( 2.184) | | (2.185) | | (2.183) |
| Landsize | | -0.476 | | -0.4976 | | -0.487 |
| | | (0.308) | | (0.306) | | ( 0.306) |
| Observation | 496 | 496 | 496 | 496 | 496 | 496 |

*Note*: P-values are for slopes; ***P<0.01; **P<0.05 and *P<0.10 = Significant at 1%, 5% and 10% probability level respectively.

Similarly, the land holding size of the household head can be considered as a substitute for sources of wealth in rural areas and is expected to influence total income positively (Sarris et al. (2006)). In the same fashion, cultivation of more plots in rural areas of the country is a good indicator of wealth and directly affects the farm income he/she harvests. Increasing number of plots is expected to increase farm income directly but consumption indirectly thought its effect on income. Table 3 compares results from naive OLS and 2SLS estimates for all variables of interest, namely water, grazing land and crop residue distance. The potential candidate instruments used in the estimation were tested to check if they could pass the necessary requirements for an instrument to be as an instrument.

Table 4 reports test results for all scenarios presented in Table 3. The Wu-Hausman F-test with a p-value less than 0.05 rejected the null hypothesis that OLS estimation is consistent or income is exogenous and motivates the use of instruments. Besides, the Sargan chi2 –test fails to reject the null hypothesis that all instruments are uncorrelated with the error term in the structural model or all instruments are valid. This enables us to conclude that the instruments pass the over-identification requirement for all estimates. Finally, instruments were also tested if they could pass the second most important criteria that the instrument should be correlated or relevant to the endogenous variable income. To ensure the relevance of instruments, the Stock and Yogo (2005) F-test was employed and F-values for three models are about 42 which is extremely higher than the rule of thumb of at least greater than 10 (Table 4).

**Table 4: Instrumental Variables Tests**

| Estimates | Endogeneity | validity | Relevance |
|---|---|---|---|
| | | Criteria | |
| | Wu-Hausman (P-value) | Sargan (P-value) | Stock and Yogo, F-value |
| Water Scarcity Model | (0.0008) | (0.5562) | 42.28 |
| Feed Scarcity Model | (0.0011) | (0.5236) | 42.27 |
| Feed Collecting Model | (0.0013) | (0.5417) | 42.56 |

The first stage regression results of two-stage least square (2SLS) which are not reported here for the purpose of saving space show that both instruments have a negative relationship with income but only shock variable is found to be statistically significant in all scenarios (Table 3). Total income of the household which have positive coefficient significantly affected per capita food expenditure. Column (1, 3, and 5) of Table 3 shows the ordinary estimates of the income effect by estimating the consumption model using OLS estimator. The coefficient of income suggests that a 1% increase in income increases per capita food expenditure by around 0.044 %, whereas the 2SLS result display that a one percent increase in total income leads to 0.59 percent increase in per capita food expenditure in all estimates. It turns out that this naive ordinary estimate grossly underestimates the income effect than effects from the IV-2SLS estimate. This implies that estimating the model using OLS is not the correct approach and ignoring these differences would bias the income effect. The findings of Njimanted et al. (2006) in rural Cameroon, and Demeke et al. (2011) in rural Ethiopia also confirm that household income is one of the key determinants of food expenditure and food security in rural areas.

As hypothesized, time spent for searching animal feed and animal water directly affected per capita food expenditure. Time spent looking for water and grazing land has resulted in a negative sign as expected and they are found to be an important factors of per capita food expenditure. A one percent increase in minutes traveled to reach water source and grazing land leads to a 0.133 and 0.086 percent decrease in per capita food expenditure respectively (Table 3) referring to the IV estimates. In addition, a one percent increase in minutes traveled to collect crop residue from threshing fields to homestead leads to 0.073 percent decrease in per capita food expenditure. This supports the argument by Tangka and Jabbar (2005), whose study conclude that feed scarcity reduces livestock, crop, and non-farm productivity as well as access to food, resulting in less food security and low welfare by traveling long distance with an animal in search of feed and water in less developing countries.

We also report that agricultural output significantly affects households' food consumption. It is also the case that the OLS estimates significantly overestimate the size of the coefficient of the output variable. The elasticity of food consumption per capita with respect to the gross crop value is equal to 0.094 % for OLS and 0.056% for IV in the water scarcity estimates. Similar effects are found in the feed and transport estimates presented in Table 3 of Column 3 to 6.The larger elasticity originates from the fact that a larger share of income is derived from agriculture in rural areas. This is in line with Sarris et al. (2006) who found that that agricultural output significantly affects per capita consumption expenditure in Ethiopia.

The variable livestock ownership is positively correlated with welfare, suggesting that farmers with high herd size have a higher food consumption expenditure. Studies by Sarris et al. (2006) in Tanzania and Dercon et al. (2005) had similar findings in Ethiopia. Another significant variable is household size, leading to 0.357 percent decrease in per capita food expenditure for one percent increase in the number of family size, in line with the findings of Dercon et al. (2005) in Ethiopia and Sarris et al. (2006) in Tanzania but contradicts with the studies of Alene and Manyong (2006) in Nigeria. The dummy variable for the gender of household head is also found to be significant and has a negative sign against the findings of Dercon et al. (2005) in Ethiopia.

Experiencing an animal shock at least once in the previous year lowers per capita consumption by 0.379%, 0.442% and 0.440% for the three cases taking the estimated value of IV in Table 3. Dercon (2004) found that a livestock shock negatively affects per capita consumption expenditure in rural Ethiopia. The coefficient of household's religion is 0.152 % and is statistically significant, implying that orthodox households have 0.152 percent per capita consumption higher than Muslim group which is opposite to the result of Oldiges (2012) and Sinha (2005), who together found a positive relation between Muslim follower and per capita cereal consumption in India. Although the location is insignificant, per capita food consumption for farmers living in the highland is lower than for those living in the lowland area. This is in favor of results from Asmamaw et al. (2015) whose study in Ethiopia indicated that people from highlands are more chronically food insecure, and consume less than 50% of total calorie requirements than in the lowlands.

The negative and significant sign of network shows that individuals who got social supports have 0.191 % less per capita food expenditure, implying that supports from relatives or friends are not adequate enough to cover food expenditure for the recipient households (Sarris et al., 2006). Other insignificant variables are proximity to market (positive), the age of the household head (negative) in line with the study of Matchaya and Chilonda (2012).

### 6.4. Total Effect of Feed and Water Scarcity on Food Security

This analysis finalizes its discussion by exploring the total effect of animal water and feed scarcity on food security. In rural Ethiopia, households spend a large portion of their daily productive time searching for water and grazing land for the animal. Based on the descriptive statistics in Table 1, the median household in this sample spends up to one 75 minutes to travel to a water source, 91 minutes to search for grazing land and 577 minutes to transport crop residue yearly. The labor hours allocated for these resources then reduces the total time available for crop farming activities in addition to the reduction in the households' leisure consumption. Its effect on agricultural production is investigated via the production sector and its direct impact on household's utility is analyzed through consumption sector. The aggregate of the two shows the total welfare effect on the household's livelihood.

Then, the total effect is simply calculated by taking the slope coefficient of income in the consumption regression multiplied by the coefficient of time allocation in the production estimation, plus the coefficient of time allocation in the consumption regression. Based on Table 5, the total impact of time spent searching for water, feed and transporting feed on per capita food consumption expenditure is -0.142, -0.102 and -0.092 respectively. This implies that for a one percent increase in minutes traveled to a water and feed source, per capita food consumption decrease by 0.142%, 0.102%, and 0.092% respectively. If the median household in this data spends about 60 minutes to look for water and feed source and have per capita food consumption expenditure of 2490 birr. For the median household, decreasing traveling minutes to a water and feed source by 0.6 minutes will increase per capita food consumption expenditure by 354 birr, 254 birr and 229 birr. The results of this analysis based on per capita food expenditure can be good indicators of a necessary condition for food security (FAO, 1996).

**Table 5: Aggregate Effect of Resource Scarcity on Output, Food Expenditure, and Food Security**

| Estimates | Effect On Output (Y) | Effect On PCFE | Total Effect |
|---|---|---|---|
| Effect Of Water Scarcity( | -0.155 | -0.133 | -0.142 |
| Effect Of Feed Scarcity () | -0.279 | -0.086 | -0.102 |
| Effect Of Feed Collection () | -0. 328 | -.0731 | -0.092 |

**Table 6: Estimation of Household Labour Allocation to Crop Farming**

| Variables | (OLS) |
|---|---|
| | Ln (Family Labor) |
| Real wage(Wage/milk price) in ETB | 0.0112*** |
| | (0.0035) |
| Ln(Wat distance) | -0.0598* |
| | (0.0360) |
| Ln(Graz distance) | -0.0929** |
| | (0.0402) |
| Ln(Feed distances) | -0.0992*** |
| | (0.0287) |
| Ln (Family size) | 0.3570*** |
| | (0.0659) |
| Ln (Mark distance) | 0.0267 |
| | (0.0422) |
| Ln(land area) | 0.3420*** |
| | (0.0462) |
| Ln(oxen number) | 0.1420* |
| | (0.0732) |
| Ln(livestock in TLU) | 0.0312** |
| | (0.0142) |
| Gender of household head(Male=1) | 0.0677 |
| | (0.0722) |
| Age of Household head (Years) | 0.0012 |
| | (0.0022) |
| Household head literacy(Literate=1) | 0.0512 |
| | (0.0692) |
| Hired Labore(1/0) | -0.1510** |
| | (0.0698) |
| Household home altitude (GPS ) | 0.0005*** |
| | (0.0001) |
| Ln(farm output value) | 0.0601*** |
| | (0.0149) |
| Location(1/0) | -0.4570*** |
| | (0.1640) |
| Constant | 2.2990*** |
| | (0.5080) |
| Observations | 502 |
| R-squared | 0.3400 |

*Note*: P-values are for slopes; ***P<0.01; **P<0.05and *P<0.10 = Significant at 1%, 5% and 10% probability level respectively

## 7. Conclusion and Suggestion

In the least developed countries, it is common that households spend a large share of their daily hours available for production activities per day on searching the animal water and feed as well as collecting crop residue. This directly impacts farm production and utility consumption by displacing labor from production and leisure activity. This study analyzes the economic implication of animal water and feed scarcity on agricultural production and consumption activities of rural farm households in North Ethiopia. For the analysis, the agricultural farm household model has been adopted and time spent for searching the animal water and feed resources, capturing water and feed scarcity has been integrated into the model. The econometric model derived from the recursive AHM and an empirical application has been applied using a sample size of 518 extracted from Tigrai Rural Household Surveys dataset in 2015 harvesting season.

The results in this paper provide an interesting picture of smallholders in Ethiopia and hint at several areas that could be important for improving food security. Our results do support the hypothesis of a negative relationship between total household labour allocation to crop farming and resource scarcity at the household level. As expected, it appears that time spent looking for water and feed has a significant and negative effect on both production and consumption sectors. In aggregate, reducing time spent looking for water by one percent leads to an increase in food production by 0.155 percent, per capita food consumption by 0.133 percent and food security by 0.142 percent. Similarly, a one percent decrease in time wastage for searching grazing land increase food production, per capita food consumption and aggregate food security by 0.279 percent, 0.086 percent, and 0.102 percent respectively, and an increment of 0.328 percent in food production and 0.0731 percent in per capita food consumption is achieved by one percent reduction in feed transporting time, leading to an aggregate effect of 0.092 increment in food security. Thus, the total effect of water and scarcity on per capita food consumption expenditure shows that reducing time spent on this resource can bring a significant contribution to food security, and as a result improves the welfare of the society.

Another major conclusion is that the use of inputs such as land, family and hired labor, fertilizer, manure, oxen and farm physical tool appears to be positively related to the household's agricultural production, and are significant determinants of farm productivity as predicted by the economic theory. However, aggregate production seems to be impeded by the occurrence of shock and agroecology, indicating that farmers experiencing shock and living in the highland seem to suffer from less production. On the consumption side variables such as agricultural output, income, livestock ownership and religion affiliation are found to be major positive contributing factors but shock occurrence, family size, male headship and social network are found to reduce per capita food consumption. Results confirm the theoretical prediction that having a higher number of family member and shock exposure affect per capita food consumption expenditure adversely.

The empirical results presented in this paper lead to the following policy conclusions. Two areas of policy intervention can be emerged as relevant. The first involves policies and institutions that facilitate easier access to animal water tap by advocating on emergency relief grounds. The second area of policy intervention involves the introduction of more efficient animal feed management strategy that can be implemented by helping households adopt new technologies that improve cattle production and reduce land degradation. Third, given the evidence in this paper, it appears that policies that seek to promote information and reducing shock exposure would be useful in enhancing household level food security.

In general, this study can be helpful for policy makers working to alleviate animal water and feed problems in Ethiopia to justify their actions with an empirical result. Besides, this study's result can give a good lesson for policy analysts that labor allocation for reaching water and feed source imposes a negative impact on crop farm output and food consumption and hence on food security. Helping farmers to have a nearby water and feed source do not only alleviate labor constraints but also saves time that could be used for other productive farming activities. Such strategy enables farmers to keep their animals at the homestead in the form of stall feeding and tethering around the backyard.

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# Appendix

**Figure A1**: Zonal Distance to Grazing Land

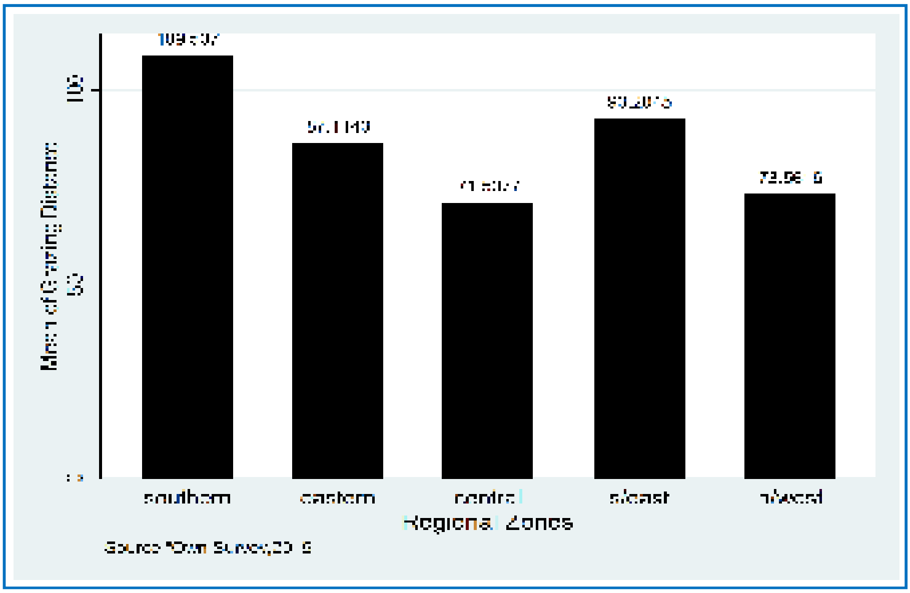



**Figure A2:** Zonal Distance to Water Source

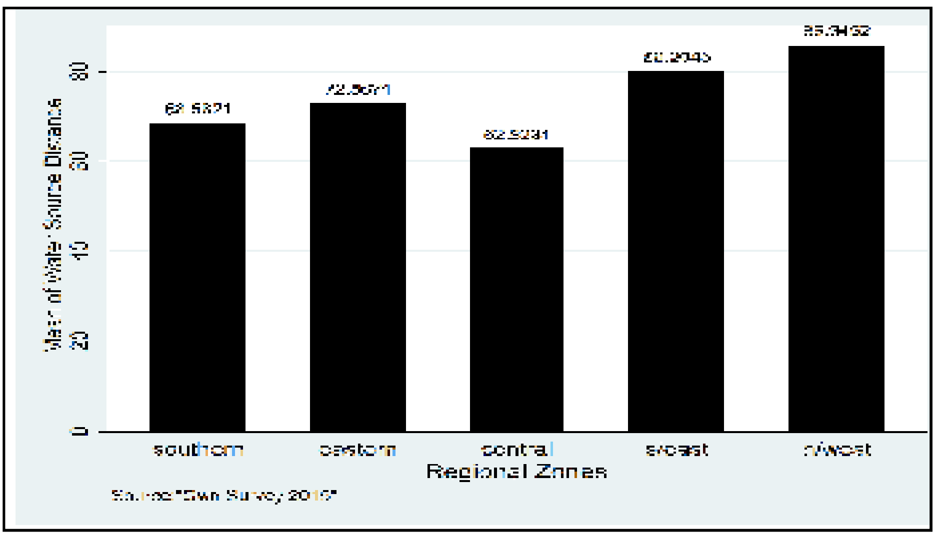


**Figure A3: Zonal Distance to Crop Residue Site**

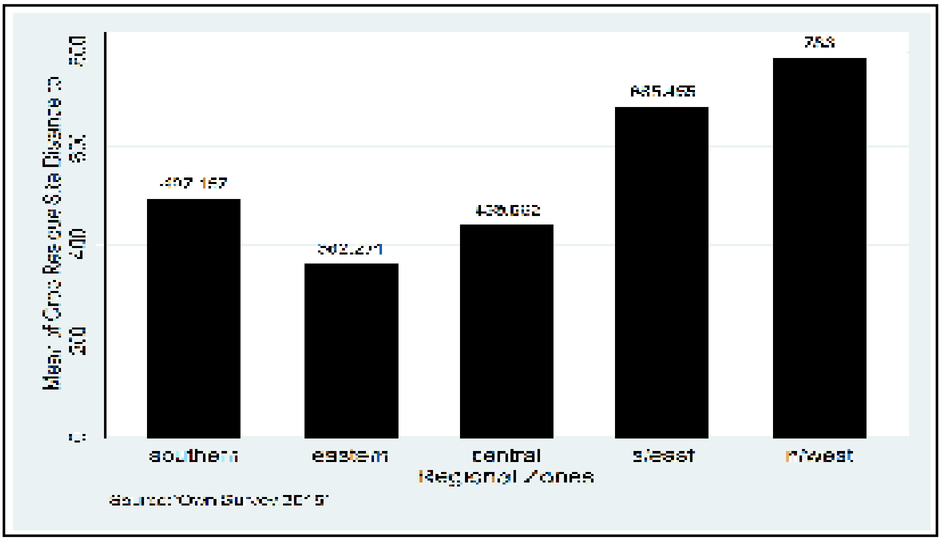



**Figure A4: Zonal Per Capita Food Consumption Expenditure**

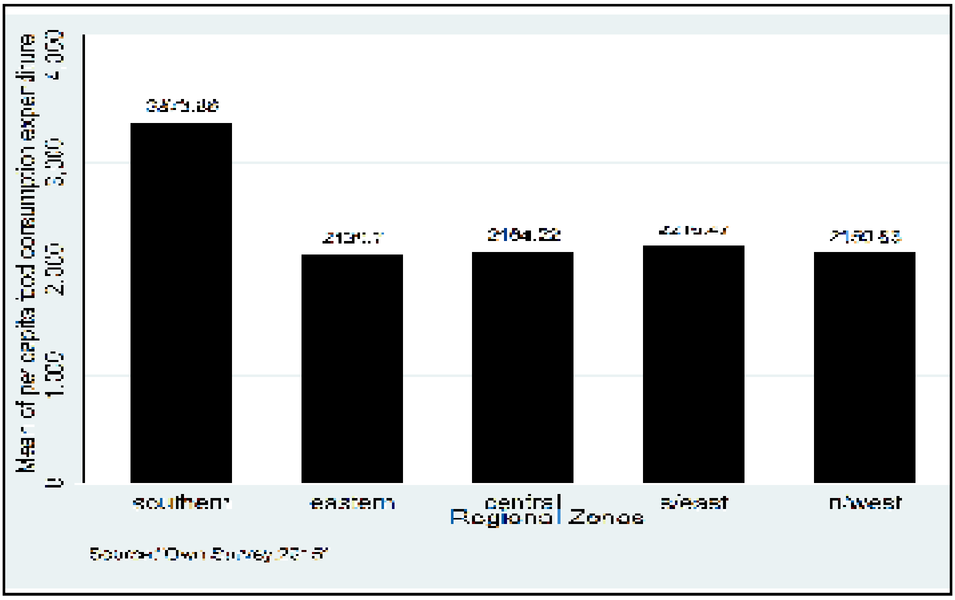


**Figure A5: Zonal Monetary Value of Farming Output**

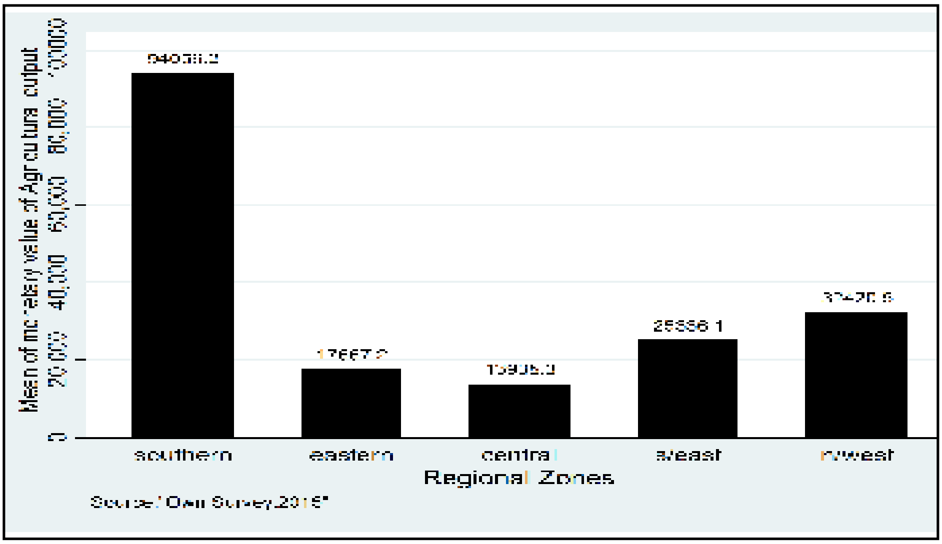



**Figure A6: Zonal Total Income**

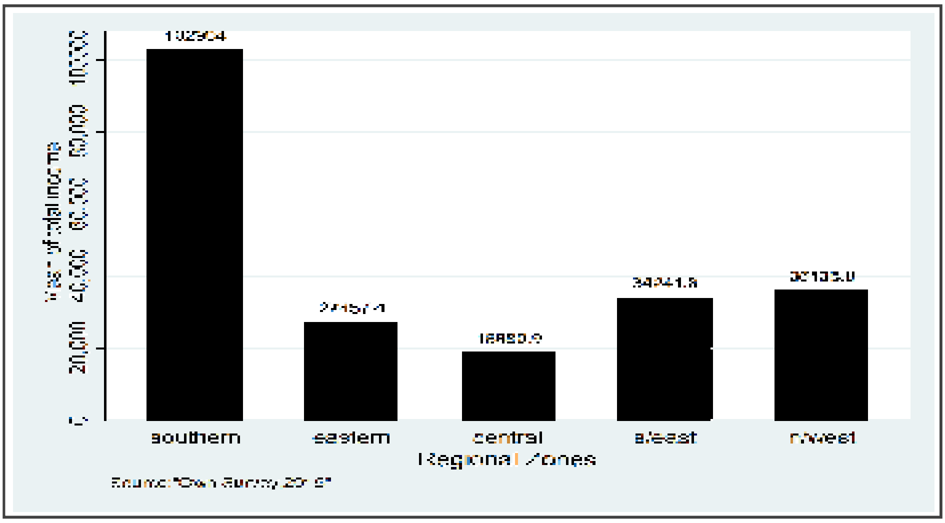


**Figure A7: PCFE Vs Market Distance**

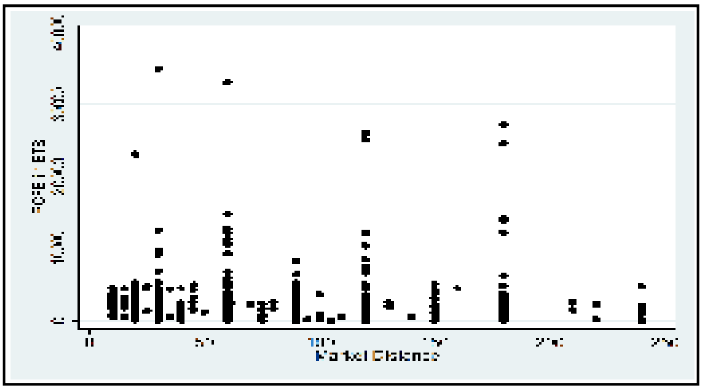



**Figure A8: Output Vs Market Distance**

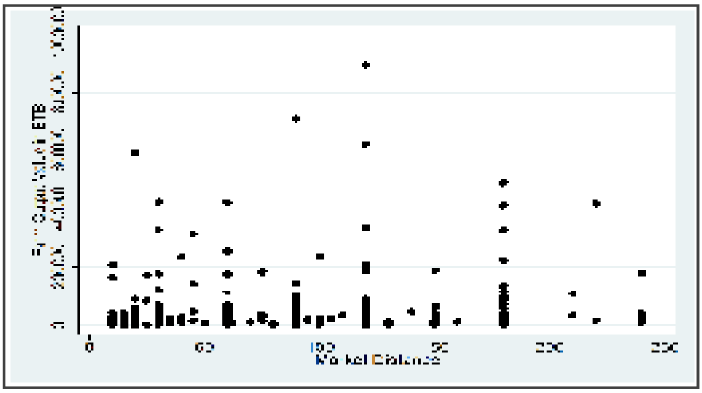



**Figure A9: Total Income Vs Market Distance**

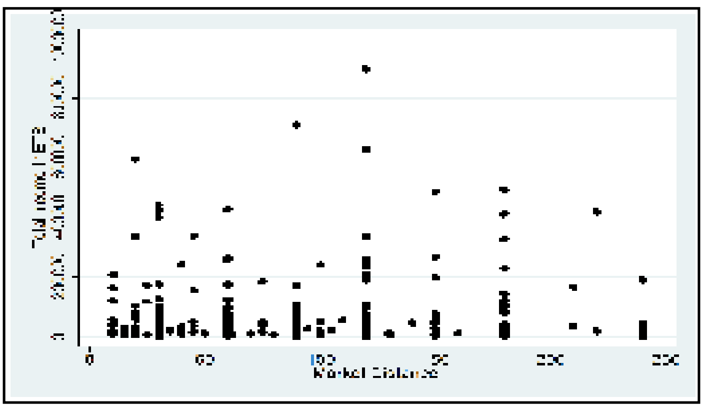


**Figure A10: PCFE Vs Water Distance**

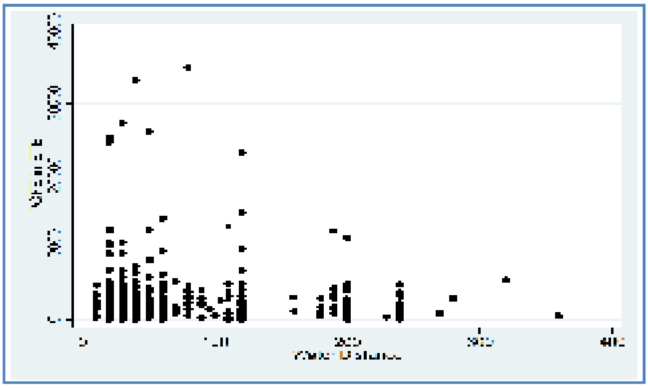


**Figure A11: Output Vs Water Distance**

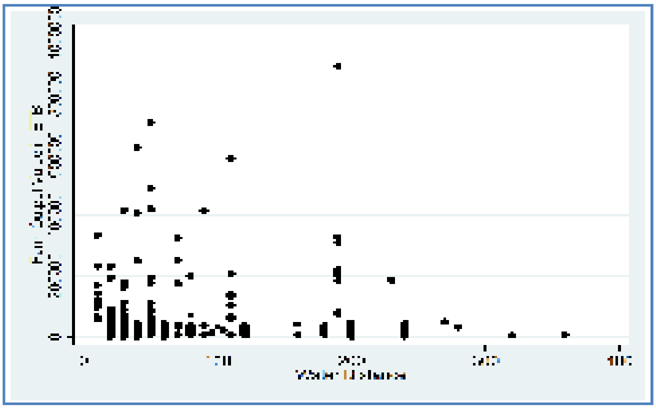


**Figure A12:** Income Vs Water Distance

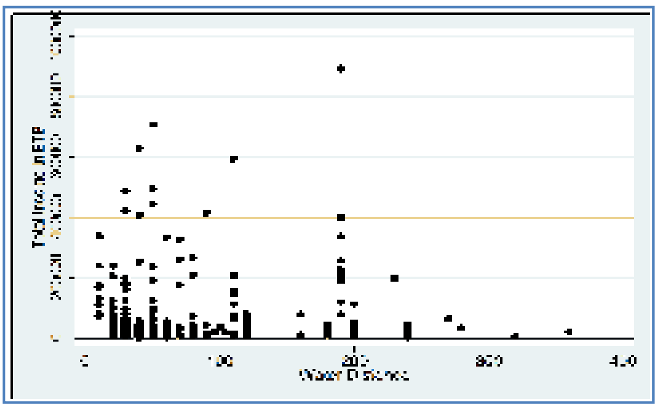


**Figure A13:** PCFE Vs Feed Distance

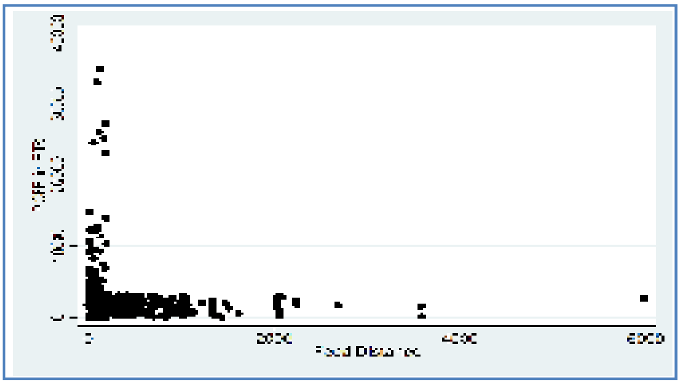



**Fig A14**. Output Vs Feed Distance

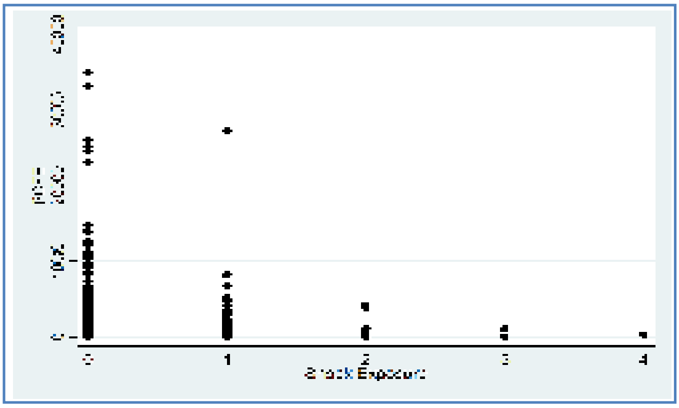



**Figure A15:** Income Vs Feed Distance

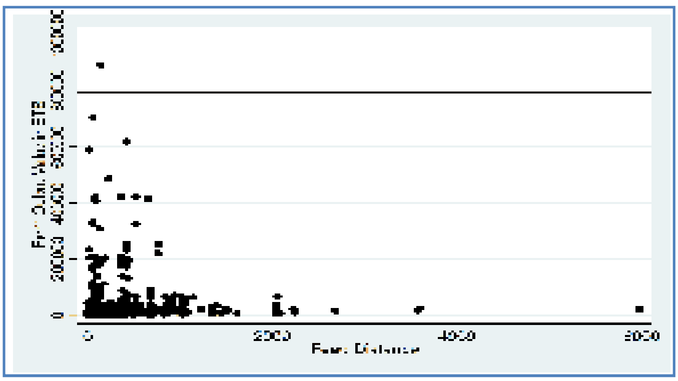


**Figure A16:** PCFE Vs Shock Exposure

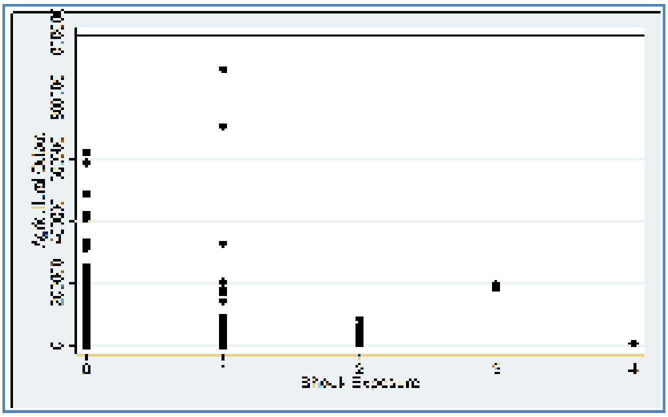
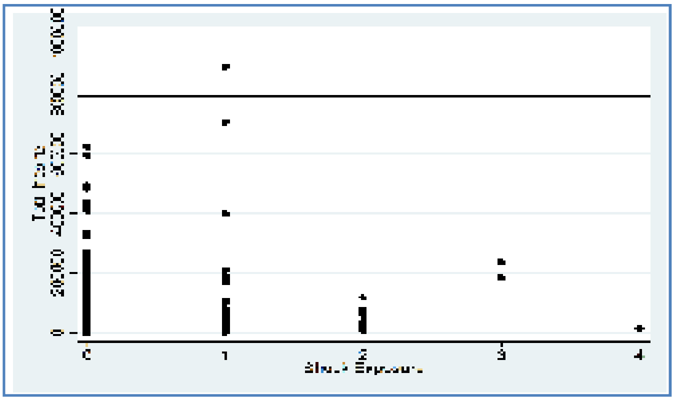



**Fig A17** Output Vs Shock Exposure



# Explaining Inter-regional Differentials in Child Mortality in Rural Ethiopia: A Count Data Decomposition Analysis

**Yibrah Hagos Gebresilassiea[1]* and Phocenah Nyatanga[2]**

***Abstract***

*Using data from the Ethiopian Demographic and Health Survey, 2016for a total of 1,295 number of under-five child deaths, this study examined the major determinants of inter-regional differentials in under-five child mortality in rural settings of Ethiopia. An extended detailed Oaxaca-Blinder decomposition technique to negative binomial regression model was applied to examine the relative individual contribution of different covariates to inter-regional differentials in under-five child mortality. Findings of decomposition analysis indicated that large portion of the regional differentials remained unexplained, being the lowest between Tigrai and Benishangul-Gumuz (12 percent) and the highest in Tigrai-Gambella regions (37 percent). The explained regional gap was due to differences in the distributions of measured factors across regions mainly attributable to differences in short birth-spacing, higher birth-order, antenatal healthcare services visits, women without education, home delivery, large household size, and poorest households' economic status. Hence, understanding inter-regional differentials in under-five child mortality and developing appropriate policies and strategies could further reduce the rate of under-five child mortality. Thus, on top of strengthening the health extension programme in rural Ethiopia, this study suggests that substantial efforts must also be made to improve the overall households' economic status and women's education levels.*

**Keywords:** Child, decomposition, determinant, mortality, region
**JEL Classification**: D24, I14, J13, R23, R58

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## 1. Introduction

Child mortality is one among the key indicators of the well-being of population and society, as measured by life expectancy and is considered as one of the Human Development Index's (HDI) dimensions used by the "United Nations Development Programme" (UNDP) (Aigbe & Zannu, 2012; NIMS et al., 2012; Patel & Sharma, 2013; UN, 2010). Reducing child mortality can significantly increase the life expectancy and hence, human capital, which is highly required for the overall development of one's nation (MOFED, 2004). The globe has made substantial improvement in overall under-five child mortality reduction. Overall, under-five child mortality rate (U5MR) has fallen dramatically from 12.7 million per year in 1990 to 5.9 million per year in 2015 (UNIGME, 2011, 2012, 2013, 2014, 2015). Despite the progress that the globe has made in reducing the overall child mortality, the rates of progress differ substantially across countries and regions (Shyama et al., 2014). For example, East Asia and the Pacific have exceeded the "Millennium Development Goal" (MDG-IV) target of a two-thirds reduction in U5MR between 1990 and 2015, whereas sub-Saharan Africa has had only a 24 percent decline over the same period (UNIGME, 2015). Despite the progress the Sub-Saharan Africa made, the region remains with the highest in U5MR in the world (Demombynes & Trommlerová, 2012; UNIGME, 2011, 2012, 2013, 2014, 2015). Most of the global under-five child deaths still occur in this region, where one child in every twelve dies before reaching five years of age (UNIGME, 2015). Also, evidence indicates that there is a substantial difference in the rate of progress within sub-Saharan Africa (UNIGME, 2015), where one child in every nine dies before celebrating his or her fifth birthday when compared to the death of one under-five child in every 152 in developed countries (UNIGME, 2012).

Ethiopia is a sub-Saharan African country experienced sizeable progress in under-five child mortality reduction at the national level, dropping from 211deaths in the 1990s to 88 deaths per thousand births in 2016 (CSA & ICFInternational, 2012), however, the country remains among the highest number of under-five child deaths in the world (UNICEF, 2015b). Although Ethiopia has already achieved its U5MR by two-thirds (68 deaths per thousand births) in 2012 (UNIGME, 2013, 2014) and dropped by 71 percent with average annual rate of reduction of 5 percent between 1990 and 2015 (UNICEF, 2015a), previous studies indicated the existence of substantial variations in the rate of progress across regions of the country (the regions are Afar, Amhara, Benishangul-Gumuz, Gambella, Harari, Oromia, Somali, Southern Nations Nationalities and People (SNNP) (Abebaw, 2013; CSA & ICFInternational, 2012; CSA & ORCMacro., 2006; UNDP, 2012). Oftentimes, the observed differences in the rate of progress across regions have been masked by the overall rate of reduction in under-five child mortality at the national average. Moreover, in Ethiopia, the inter-regional distribution of under-five child mortality indicate the marked regional disparities (Abebaw, 2013; CSA & ICFInternational, 2012; UNDP, 2012). In 2000, for example, the U5MR varied from as low as 169 deaths in Tigrai to as high as 233 death per thousand births in Gambella (CSA & ORCMacro., 2000). Similarly, in 2016, the U5MR also varied as low as 85 deaths in Tigrai to as high as 169 deaths per thousand births in Benishangul-Gumuz. The rates of decline in under-five mortality for all regions except Tigrai (85 deaths per thousand births) were significantly lower than the national average rate (88 deaths per thousand births) in 2016, indicating there was a disproportionate inter-regional gain in under-five child mortality rates across times (CSA & ICFInternational, 2012).

Furthermore, despite the overall rate of reduction in under-five child mortality, the magnitude of mortality rate inequalities has significantly varied between regions and over time. For example, the under-five mortality rate of the Ethiopian Somali and Benishangul-Gumuz regions have increased from 93 deaths in 2005 to 122 deaths per thousand births in 2016, and from 157 deaths in 2005 to 169 deaths per thousand births in 2016, respectively. Similarly, the U5MR for the Benishangul-Gumuz region has increased from 157 deaths in 2005 to 169 deaths per thousand births in 2016, a statistic (CSA & ICFInternational, 2012) even higher than for Angola with an under-five child mortality of 167 deaths per thousand, the highest in the world (UNICEF, 2014). This evidence shows that although most regions have reduced the under-five child mortality with different levels of reduction, some of them (Afar, Somali, and BG regions) have found to increase the U5MR instead from 2005 to 2016 (CSA & ICFInternational, 2012; CSA & ORCMacro., 2006). Moreover, compared to many other developing countries the improvement that Ethiopia has made in overall child mortality reduction remains very low. The country has been ranked 37th and is one among the ten top countries with highest absolute umber under-five children deaths (184 deaths per thousand). Hence, Ethiopia accounts for three percent of the share of global under-five child deaths in 2015 (UNICEF, 2015a; UNIGME, 2015). More importantly, about 59 of every one thousand children in Ethiopia are still dying before celebrating the age of five years (UNICEF, 2015a; UNIGME, 2015). Like in many developing countries, in Ethiopia mortality of under-five children in rural areas are considerably higher than in urban areas (CSA & ICFInternational, 2012; CSA & ORCMacro., 2006; Regassa, 2012). A child born in rural areas has 38 percent higher probability of dying than a child of urban counterparts (FMOH, 2014b). Previous studies have also noted that one child in every 11 Ethiopian children under-five dying before reaching the fifth births anniversary (CSA & ICFInternational, 2012; CSA & ORCMacro., 2006). Furthermore, most of the Ethiopian population is still primarily rural. Out of the total population (94 million), more than 15 percent (14.245 million) of them are under-five children (UNICEF, 2014). Since the share of rural population in Ethiopia is huge, combating under-five rural child mortality could further speed up the overall U5MR reduction both at the national and regional levels. The overall rate of progress that Ethiopia has made in U5MR (59) is considerably lower than infant mortality (41 deaths per thousand births) (UNIGME, 2015).

Furthermore, in Ethiopia, the regional disparities in under-five child mortality rates were twice higher than in infant mortality rates (UNDP, 2012). This suggests that the importance of addressing disparities in mortality of under-five children to further reduce the overall child mortality of the country. More importantly, much less is known about which factors explaining the regional variations in under-five mortality rates, while majority of previous studies have instead focused on factors influencing infant and under-five child mortality rates in Ethiopia (Amouzou et al., 2014; Dejene & Girma, 2013; Regassa, 2012; Tesfa & Jibat, 2014). These are the rationale as to why this study is carried out and focused on U5MR in rural areas of Ethiopia. This study, therefore, aims at identifying the major factors responsible for inter-regional differentials in under-five child mortality levels in rural settings of Ethiopia.

The remaining of the paper is systematised as follows: review of previous studies is presented in section two. In section three, data source and methodologies are described followed by analysis of results in section four. Section five discusses the findings. The chapter concludes the study in section six.

## 2. Review of previous literature

A substantial number of previous studies have evaluated the factors affecting infant and under-five child mortality rates (Caldwell, 1979; Dejene & Girma, 2013; Kabir et al., 2001; Khadka et al., 2015; Shyama Kuruvilla et al., 2014; Srinivasan, 2000). However, despite the overall improvement in under-five child mortality rates across countries, the rate of progress was varied not only across countries or between developing and developed countries, but within a country. In Sub-Saharan Africa where Ethiopian is located, the marked disparities in the rate of under-five child mortality remain very high across the countries (UNIGME, 2012, 2013, 2014, 2015). Hence, within demographic and development economics literature, currently, substantial interest has been observed in identifying and quantifying the separate relative contribution of specific determinants on how each explains the observed regional under-five child mortality differentials across states or regions within a country and across countries. In developing countries, there have been substantial regional, provincial or cross- state differences in infant and under-five child mortality. Hence, reducing the variations in child mortality within and between countries could considerably contribute to the overall health of the population(Houweling & Kunst, 2010). A study by Adedini et al. (2015) examined the sources of regional differentials in infant and under-five child mortality in Nigeria using 2008 demographic and health survey data. The study has applied Cox-proportional hazard regression model to identify the determinants of the regional differentials in child mortality (infant and under-five child mortality) in Nigeria. The findings simply indicated that differences in community infrastructure, households' wealth index, households' poverty status, place of delivery and residence distributions across the regions were the major factors of regional differentials in under-five child mortality while difference in birth-order, birth-spacing, mother's level of education, and mother's age at marriage distributions across regions were the most key factors explaining the regional disparities in infant mortality rate in Nigeria. The study concluded that to substantially reduce the overall child mortality of the country, much efforts should be exerted in addressing the sources of regional variations in these important health indicators by focusing on the disadvantageous regions of the country, however, the authors could not explain the percentage relative contribution of each covariate to the explained regional gap. A study by Jhamba (1999) indicated that despite the dramatic decline in child mortality among district of Zimbabwe, there have considerable disparities across districts. Hence, mother's education, the percentage of households with access to improved water and toilet facility was among the major determinants of regional variation in child mortality in Zimbabwe. Other factors such as malaria epidemic, religious and cultural determinants were also explained the district differentials in child mortality rates in Zimbabwe. Similar regional differences in under-five child mortality have been reported in many other developing countries (references). For example, In Libya, a study by Ghaffar and Bhuyan (2000) examined the factors explaining the regional differentials in child mortality in North-eastern Libya. The study was based on the seven localities and then these localities have developed into three regions namely, Benghazi, Darna, and Tobruk, where five out of the seven localities are found in Benghazi.

In Nepal, the disparities in child mortality by ecological region was examined by Goli et al. (2015). To examine the determinants of regional variation in child mortality, they used an Oaxaca-blinder decomposition technique based on Cox-Proportional hazard regression model using demographic and health survey data. The results of Cox proportion regression indicated that children of Mountainous areas had the highest probability of dying than children of the same cohort living in the other two areas (Hill and Terai). The results of the decomposition analysis revealed that differences due to the proportional differences in children of four birth-order or higher, mother's working status, place of residence, households' economic status, and father's level of education were reported to significantly explained the regional under-five child mortality disparities. The decomposed covariates altogether explained 40 percent of the regional variations in under-five child mortality between the mountain and the combined Hill and Terai regions while the larger 60 percent of the components of the gap remained an unexplained part. Findings of the decomposition analysis revealed that the differences in the proportional distribution of parental educational levels (mother's and father's education) contributed 34 percent of the regional variations in under-five child mortality. However, 30 percent of the explained gap by parental education was attributed to father's level of education, the largest contributor to the ecological differentials in under-five child mortality. The results further indicated that households' wealth status, households' place of residence, higher birth-order along with short spacing (less than 24 moths), and mother's employment status have contributed significantly to 25, 16, 11, and 5 percent of the explained ecological regional differences in under-five child mortality, respectively. In addition, mother's religion and mother's liberty on healthcare decision have contributed 3 percent each to the explained regional gap in under-five child mortality. Although its relative percentage contribution of the explained gap is very small, mother's exposure to mass media has also contributed to under-five child mortality differences between the two ecological regions. Furthermore, the study indicated that female under-five children are in a les advantageous situation in terms of the survival rate in the country compared to male cohort counterparts. The study has concluded that though Nepal has made a remarkable progress and achieved the "Millennium Development Goal" four (MDG-IV) in under-five child mortality reduction by two-third, there has been variations in rate of progress in child mortality across its ecological regions. Hence, the disparities in rate of progress of under-five child mortality should be addressed from an ecological region outlook (Goli et al., 2015).

In Mozambique, the geographic disparities in child mortality have been examined using the Mozambican demographic and health survey data of 2003 (Macassa et al., 2012). The ten provinces have been geographically classified into three regions; North, Central and South regions. The study has applied Cox regression analysis to identify the factors explaining the regional differences in under-five child mortality. An under-five child whose mother was living in the North and the central regions had higher mortality risks than a child of a mother who was living in the South regions. The study has also indicated that there have been significant differences in levels of under-five child mortality within the regions (among provinces of the same region). However, although the authors have attempted to indicate why the regional variations occurred in child mortality in Mozambique through discussing the reviewed literature, empirically; the authors have nor explored which factors and how much each did contribute to explain the geographic-specific variations in under-five child mortality. Employing the Iranian demographic and health survey data of 2000, a study by Hosseinpoor et al. (2006) examined the contribution of determinants differentials in infant mortality. The analysis was made using the concentration index based on logistic regression to compute the contribution of specific socioeconomic determinants inequalities in infant mortality. The magnitude of differences in households' economics status (36 percent), and mother's education level (21 percent) were the largest contributors to the regional infant mortality differences in Iran. The paper further indicates that risky or short birth-spacing (13 percent), place of residence (14 percent) and access to improved toilet facilities (12 percent) contributed significantly to the regional disparities in infant mortality rates in Iran. The findings have finally noted that provinces had different levels of inequalities in infant mortality rates (Hosseinpoor et al., 2006).

Similarly, the study of Assi (2014) has attempted to assess the factors explaining regional variations in under-five child mortality in Cote d'Ivoire based on 2016-2012 Cote d'Ivoire demographic and health survey data using logistic regression model. Findings indicated there were considerable variations in child mortality across the region of Cote d'Ivoire. Mother's education at least who completed secondary education was associated with under-five child mortality risk and was found to be statistically significant. However, the study failed to identify the sources of the observed regional variations in under-five child mortality in Cote d'Ivoire rather it has identified the factors affecting under-five child mortality not the regional variations in U5MR. More importantly, the study suggested further research be carried out explaining the sources of regional differences in child mortality. Similarly, a study by Akuma (2013) has evaluated regional differentials in infant mortality using the 2009 Kenyan DHS. For analyses purpose, the author has examined the regional differences in infant mortality by classifying provinces of the country into two regions (groups) as low and high infant mortality regions based upon the magnitudes or levels of infant mortality that the provinces had and applied logistic regression model to analysis the data. Hence, the results of the regression analysis revealed that there were regional disparities in infant mortality across regions. The mother's low level of educational attainment, poor socioeconomic status, and short birth spacing were the major determinants of infant mortality for the region of high mortality category that causes the regional variations in infant mortality between the mortality regions (high and low mortality regions). Finally, the author has concluded that the sources of infant mortality differentials across provinces of Kenya are due to differences in households' economic status and social development. However, the study did not consider other important demographic and other socioeconomic factors while examining the regional differentials in infant mortality that. More importantly, findings of the study might not really indicate the sources the regional differentials in infant mortality in Kenya Akuma (2013).

In Asia, a study by Khosravi et al. (2007) evaluated the mortality differentials among the Iranian provinces. Child mortality rates varied among the provinces from 25 to 47 per thousand births. The findings indicated that important sources of variations in child mortality among the Iranian provinces. These are the GDP per capita, life expectancy, and health care accessibility. Provinces having a high GDP per capita and high life expectancy had the lowest rate of child mortality. The Iranian study concluded that variations in child mortality were worse in the rural areas than the urban areas of the country. However, in Iran, the extent of variations in child mortality is lower than the child mortality differentials for other developing countries. Another study evaluating "inter-district variations in infant mortality in Sri Lanka" indicated that access to health care services, (33 percent); safe drinking water, (16 percent); low childbirth weight, (13 percent); and health care utilization (8 percent) explained infant mortality differences across districts of the country. Findings of the study noted that a unit increment in health care service accessibility and utilization reduces infant mortality rate by 4.3 and 7.1 percent, respectively (Chaudhury et al., 2006).

The reviewed literature revealed that there have been several factors affecting regional differentials in infant and under-five child mortality; however, prior studies available on this domain in Ethiopia have not given due emphasis on examining determinants of regional disparities in infant and under-five child mortality. Therefore, given the lack of empirical evidence on the relative individual contribution of determinants to regional differentials in under-five child mortality, there is a need to systematically examine the major drivers of inter-regional differences in under-five child mortality in Ethiopia. The present study, therefore, aims at quantifying and identifying the major factors responsible for inter-regional differentials in under-five child mortality levels in rural settings of Ethiopia.

## 3. Data and Methods

### 3.1 Data source

The study uses data from the Ethiopian "Demographic and Health Survey" 2016. The data are a cross-sectional and large-scale health survey carried out in nationally representative sample households across all regions of the country. The survey employed a multistage cluster sampling procedure to select sample households that are nationally representative. Altogether, a total 8,881 households were selected. However, the present study was delimited to a total of 5,481 households from nine administrative regions of rural Ethiopia. There were a total of 5,437 under-five children ever born at the national level. In this study, about 1,295 number of rural under-five deaths were considered for further analysis after excluding those missing values for the variables included in the regression analysis. Details of sampling procedure, data collection tools, and sample design are available in the report of the CSA and ICFInternational (2016).

### 3.2 Outcome variable

Analysis of this study was limited to rural children whose age is between 0-59 months as a primary health outcome variable (dependent variable), defined as the probability of a child dying by age under-five years per thousand births (CSA & ICFInternational, 2016). While examining the association between under-five child mortality and explanatory variables, the unit of analysis was number of under-five child deaths.

### 3.3 Explanatory variables (covariates)

Several previous studies have indicated that the importance of various determinants that affects infant and under-five child mortality across various countries (Akuma, 2013; Caldwell, 1979; CSA & ICFInternational, 2012; CSA & Macro, 2006; Dev et al., 2016; Gupta, 1997; Hong et al., 2009; Khadka et al., 2015; Mosley & Chen, 1984; Negera et al., 2013; Regassa, 2012). Hence, the inclusion of a set of explanatory variables in the analyses was mainly guided by these previous studies and availability of data on these potential explanatory variables. In the analytical framework employed in the study analysis, these covariates are grouped into three distinct classifications: I) proximate determinants such as the age of the child, gender of the child, multiplicity of birth, birth-order, birth size, birth spacing, and mother's age at birth. II) socioeconomic determinants such as mother's use of modern contraceptives, antenatal visits, mother's working status, mother's and father's education level, sex and age of household head, household size, and household's wealth index as a proxy measure for household's economic status. III) Environmental determinants such as place of delivery, access to toilet facilities, electricity facility, safe drinking water and household's region of residence.

### 3.4 An Oaxaca-Blinder decomposition model

Since the response variable is a count data variable, application of linear regression models based O-B decomposition could not be an appropriate technique of decomposition (Bauer et al., 2006). Thus, this warrant to use an extended nonlinear decomposition technique to count data modeling approach (Bauer & Sinning, 2008; Park & Lohr, 2010; Yun, 2004). The differences in the average rate of under-five child mortality for any two groups (regions is in the present context) can be explained by a set of independent variables (O'Donnell et al., 2008) and then are decomposed into two components. Namely, i) the "explained component" is the part of the outcome measure disparity due to differences in the magnitude of observable determinants across the two regions (characteristics or covariates effect), labeled as EC). ii) the "unexplained component" is the part of the outcome measure due to differences in estimated effects of theses determinants across the two regions (coefficients effect), labelled as UC) (Blinder, 1973; Fairlie, 2005; Oaxaca, 1973; Powers et al., 2011; Sen, 2014; Wagstaff et al., 2007).

Assume there are N number of under-five child deaths (U5MR$^{r}_{ih}$) (indexed, $i$ = 1., ,., $N_r$) belonging to $\dot{h}$household (h=1,. ,. ,. H)in R mutually exclusive and collectively exhaustive regions, $\dot{r}$ = 1,.,.,R, each region containing $N_{\dot{r}}$, $X_{jr}$ is a vector of j observable explanatory variables (as explained above), $\alpha_{jr}$ represents a vector of regression parameters to be estimated, and $\varepsilon_{jr}$ denotes the error term. Thus, following Bauer et al. (2006); Bauer and Sinning (2008); Park and Lohr (2010); Yun (2004) and Sinning et al. (2008), the O-B decomposition of two regions, continuing with Tigrai (TG) as a reference category and Harari (HR) as a comparison regions for example is computed by:

$$\hat{\Delta}^{TG,HR}_{NBR} = ln(U5MR^{r=TG}_{ih}) - ln(U5MR^{r=HR}_{ih}) = \Big[E_{\hat{\alpha}^{NBR}_{jTG}}(U5MR^{r=TG}_{ih}|X_{jTG} -$$
$$E\alpha jTGNBR(U5MRihR=HR|XjHR + E\alpha TGNBR(U5MRIHr=HR|XjHR -$$
$$E\alpha jHRNBR(U5MRihr=HR|XjHR \qquad [01]$$

The first bracketed segment on the right-hand side of equations [01] represents the “explained component”, the differences in U5MR due to differences in the magnitude of observable characteristics across the two regions (“characteristics effect or covariates effect”). The second bracketed segment represents the “unexplained component”, the regional differences in under-five child mortality rates due to effects of the estimated coefficient of the observable attributes across the two regions (“coefficients effect”).

A separate decomposition analysis was performed for the nine regions continuing with Tigrai region as a reference category to examine how much of the overall regional disparity or the relative regional differentials specific to one of the covariates ($X_{jr}$) is attributable to differences in covariates (covariates effect) and differences in returns of these covariates (coefficients effect). the present discussion focused only on explained part of the components gap (covariates effect) because influencing the behavioural responses to the characteristics (captured by the coefficient effects) is more complicated (Jann, 2008; O'Donnell et al., 2009; Oaxaca & Ransom, 1999).

The statistical analyses are computed using Stata version 14 by adopting the "user-written mvdcmp Stata command" on nonlinear regression-based detailed decomposition technique of average outcome differentials proposed by Powers et al. (2011) and O'Donnell et al. (2008).

## 4. Empirical results

The results of decomposition analysis show that of the regions being compared with a benchmark of Tigrai region, Somali region seems exceptional in that its aggregate, characteristics, and coefficients effects were significantly smaller than in the case of the other regions. The results of detailed decomposition analysis indicated that the relative contribution of determinants to the regional differentials in under-five child mortality rates differ significantly across groups of regional comparisons of Ethiopia (Table 1). The relative contribution of a determinant (factor) reflects the differences between the groups of regional comparisons distributions of that covariate (variable) and the differences in the magnitude of the association of the variable with under-five child mortality (Van de Poel et al., 2009). Therefore, among the socioeconomic determinants, the most important relative contributions come from antenatal health care visits, maternal education, households' economic status, household size, and use of modern contraceptive. The differences in the proportion of children born to mothers have received antenatal healthcare services contributed a substantial 12, 9, 26, 55, 13, 37, and 32 percent to the explained Tigrai-BG, Tigrai-Harari, Tigrai-Amhara, Tigrai-Oromia, Tigrai-Somali, Tigrai-Afar, and Tigrai-SNNP regional gaps in under-five child mortality, respectively. On the contrary, the antenatal visit has been found to reduce 8 percent of Tigrai-Gambella regional under-five child mortality difference. Similarly, results of decomposition analysis revealed that the differences in under-five child mortality for Tigrai-BG, Tigrai-Somali, Tigrai-Afar, and Tigrai- Gambella regions were explained by the proportional differences in children to mothers with no education, which accounts for 3, 23, 6, and 21 percent of the total explained regional differences. However, this covariate contributed significantly to a 79, and 3 percent reduction of the Tigrai-Oromia and Tigrai- SNNP regional differentials in under-five child mortality, respectively. In the present study, households' economic status measured in households' wealth index was the most important socioeconomic determinants of the regional gap. The differences in the proportion of children to households in the poorest third index category contributed significantly to a 4, 12, 3, and 10 percent of the explained Tigrai-Harari, Tigrai-Amhara, Tigrai-Oromia and Tigrai-SNNP regional gaps in under-five child mortality, respectively. However, this factor has also been found to significantly reduce 8 percent of the explained Tigrai-Gambella regional gap.

Furthermore, results indicated that the proportion of children to larger household size explained significantly the Tigrai-BG, Tigrai-SNNP, and Tigrai-Amhara regional gaps in under-five child mortality by about 9, 4 and 9 percent, respectively. On the contrary, differences in the proportion of children to households with relative larger household size were found to significantly narrow down by about 10, 8 and one percent, respectively of the covariates effect of Tigrai-Harari, Tigrai-Afar, and Tigrai-Gambella regional differences. The regional gaps were also partly explained by differences in proximate factors. The differences in the proportion of children of four or higher between regions contributed a substantial 9, 4, 29 and 12 percent, respectively to the explained Tigrai-Harari, Tigrai-Oromia, Tigrai-SNNP and Tigrai-Gambella regional gap in under-five child mortality. However, its relative effect was the reverse for the other groups of regional comparisons and was found to significantly reduce 13, 10, 8 and one percent of the explained Tigrai-Amhara, Tigrai-Somali, Tigrai-Afar and Tigrai-BG regional differences U5MR, respectively. Similarly, the differences in the proportion of children whose birth size are less than average constituted significantly 36 percent of the Tigrai-Gambella regional gap while it has significantly reduced by less than one percent of the explained Tigrai-Amhara and Tigrai-Somali regional gaps in under-five child mortality rates. Interestingly, differences in children who had an average birth size contributed significantly 15 percent of the explained Tigrai-Gambella regional gaps in U5MR while it has also been found to significantly reduce the Tigrai-BG regional gap by less than one percent. As to the relative contribution of short birth spacing (birth spacing less than 24 moths), differences in proportional distributions of children of short birth spacing contributed 17, 5, 53, 2, 39, and 3 percent, respectively of the covariates effect in under-five child mortality for Tigrai-BG, Tigrai-Amhara, Tigrai-Oromia, Tigrai-Somali, Tigrai-Afar and Tigrai-SNNP regions, and the differences were statistically significant. However, unlike to the other groups of regional comparisons, short birth spacing significantly narrow down by 34 percent of the Tigrai-Harari regional child mortality differences.

Most importantly, children born to mothers with less than 20 years age at first birth contributed significantly 6 and .78 percent, respectively to the Tigrai-Amhara and Tigrai-Somali regional gaps while it has also been found to reduce 8 percent of the Tigrai-Gambella regional differences in under-five child mortality. Also, the differences in the proportion of children who have been delivered at home (out of health facilities) contributed significantly 3, 9, 10 and 3 percent of the Tigrai-Harari, Tigrai-Amhara, Tigrai-Somali, and Tigrai-Gambella regional differences in under-five child mortality, respectively.

More importantly, results of decomposition analysis revealed that the negative relative contribution of the male under-five child shows that female of the same cohort was in a less advantageous situation in terms of survival rate in the other comparison regions except for Harari and Somali regions. Likewise, the negative contribution of age of the child at the time of death in explaining regional gaps in under-five child mortality indicated that children of the comparison regions were relatively younger than children of the same cohort of the references category (Tigrai) except for Harari and Amhara comparison regions. However, results of decomposition analysis further indicated that no statistically significant regional differences were observed due to differences in the proportional distribution of access to improved toilet facility; electricity facility and safe drinking water across the regional comparisons (see Table 1).

**Table 1: Detailed decomposition of inter-regional differentials in under-five child mortality (between Tigrai RC and other regions)**

| Covariates | Tigrai-BG region | Tigrai-Afar region | Tigrai-Amhara region | Tigrai-Oromia region | Tigrai-Somali region | Tigrai-SNNP region | Tigrai-Gambella region | Tigrai-Harari region |
|---|---|---|---|---|---|---|---|---|
| | Contribution (in percentage) | | | | | | | |
| Child's age | -1.15 | -1.89 | 2.72 | -11.31 | 3.03 | -3.50 | -2.93 | 2.64 |
| Child =Female | -.05 | -0.06 | -.01 | -.12 | .03*** | -.39 | -.01*** | .51 |
| Birth order>4 | -.68 | -7.60*** | -13.02*** | 4.47*** | -9.96*** | 29.14** | 12.45** | 8.63*** |
| Birth size < average | -.08 | 3.90 | -.53** | -.76 | -.28** | -.60 | 36.17*** | 14.73 |
| Birth size = average | -.62** | -4.44 | .57 | .61 | .36 | -.89 | 14.71** | -4.31 |
| Multiple birth | .11 | -0.31 | -1.07 | -1.52 | -.33** | -.47 | .13 | 2.85 |
| Short birth interval | 16.68*** | 38.88*** | 5.06*** | 53.15** | 2.40** | 31.27** | -1.63** | -33.76** |
| Maternal age at birth <20 | -.05 | 12.63 | 5.78** | -5.11 | .79** | -11.74 | 11.49 | 3.52 |
| Maternal age at birth >35 | .09 | -6.04 | -17.09** | -9.34 | -2.26 | -1.60 | -8.31*** | 25.92 |
| Contraceptive use | -.46 | 14.66 | -8.57* | -.24 | -10.14* | -5.19 | .68 | 9.22 |
| Antenatal visits | 11.72* | 36.83* | 26.62** | 55.48* | 12.89* | 32.21* | -8.12* | 8.53* |
| Mother's education | 2.85** | 6.15** | -.90 | -79.54** | 22.97** | -3.52** | 21.42*** | 3.08 |
| Mother's work status | -5.63 | .78 | -.40 | -16.31 | -.17 | -9.98 | -12.15 | 9.53 |
| Female HH head | .04 | -0.66 | -.21 | -.55 | .69 | .01 | -6.31 | -2.96 |
| Age of HH head | -20.96 | -6.85 | 1.46 | -1.74 | -.96 | -40.00*** | -6.27 | -14.74 |
| Father's education | -.54 | -17.57 | -.28 | -1.54 | 6.31 | .67 | -.54** | -8.57 |
| Poorest third | 4.15 | 7.37 | 12.51* | 2.92* | -7.60*** | 9.98* | 3.90 | 4.44** |
| Middle third | .09 | -21.49 | .07 | 17.29 | -1.04 | .52 | -18.21** | -6.28* |
| Household size | 8.84*** | -8.45*** | 9.26*** | 6.69 | 5.20 | 4.33*** | -.81*** | -9.99*** |
| Toilet facility | -.33 | -32.14 | -.61 | -3.05 | -.50 | -2.37 | -.16 | -3.14 |
| Electricity facility | -1.34 | -0.37 | -2.21 | 1.32 | -1.69 | .04 | 3.08 | -3.20 |
| Home delivery | -1.12 | 24.86 | 9.17*** | 24.10 | 9.6*** | -5.79 | 3.41* | 2.70*** |
| Safe drinking water | 1.74 | -4.58 | -1.12 | -4.00 | 2.86 | 14.32 | -2.09 | 3.84 |

Source: Own computation, 2016 EDHS; Notes: The contribution of each covariate (characteristics) has been expressed in percentage. RC indicates the reference category. The relative contributions of individual covariates can be positive (>0 percent) or negative (<0 percent) and can exceed 100 percent. A positive value (sign) shows the component contributes to the greater differentials of U5MR between Tigrai and the other regional comparisons whereas a negative contribution designates the opposite. Asterisks denote the level of significance: *** p<0.01, ** p<0.05, and * p<0.1. HH represents household

## 5. Discussions

While Ethiopia has made a remarkable improvement in reducing the overall child mortality at the national level, evidence indicated that there were variations in rates of progress across its administrative regions (Abebaw, 2013; CSA & ICFInternational, 2012; CSA & ORCMacro., 2006; UNDP, 2012). To author' best knowledge, this study is the first to decompose the major determinants of inter-regional differentials in under-five child mortality into components gap (explained and unexplained parts). The results of the negative binomial regression analysis indicated that most determinants have the expected associations with the under-five child mortality rates and supported by previous studies (Dejene & Girma, 2013; Khadka et al., 2015; Regassa, 2012). The results of regression analysis show that there have been substantial differences in estimated coefficients of all regressed determinants on under-five child mortality, indicating substantial variations in degree of effects on under-five child mortality across regions.

Identifying the factors that explain most inter-regional differentials in under-five child mortality rates could help in minimizing the regional gaps and to speed up the rate of reduction in under-five child mortality both at regional and national levels of Ethiopia. The results of O-B decomposition analysis indicated that there have been substantial regional variations in under-five child mortality across regional comparisons. Only small part of regional gaps in under-five child mortality was explained (28 percent), being the lowest in Tigrai and Benishangul-Gumuz regions (12 percent) and the highest in Tigrai-Gambella regional comparisons (37 percent).

However, the substantial part of the regional differentials in under-five child mortality remained unexplained (72 percent), range from 62 percent (for Tigrai- Gambella regions) to 88 percent (for Tigrai-BG regions) which entails due attention. The results of decomposition analysis also indicated the substantial differences in socioeconomic, proximate and environmental determinants in explaining the regional gaps with socioeconomic factors being the major determinants of regional differentials in under-five child mortality followed by proximate. factors. More specifically, results of the detailed decomposition analysis reported the specific relative contribution of determinants to the regional gaps in under-five child mortality. The differences in the proportion of children born to mothers who have received antenatal healthcare services contributed a substantial to the explained regional gaps in under-five child mortality with different magnitude of effect and significance levels across regions. Evidence indicated that though the trends in antenatal health care coverage shows increasing rate, there has been wide disparities observed across regions of Ethiopia, ranging from the lowest 41 percent in Somali to the highest 100 percent in SNNP, Harari, Oromia and Tigrai regions (FMoH, 2014a). In low and middle-income countries, the socioeconomic disparities in child mortality are the key public health problem (Houweling & Kunst, 2010). Women education was considered as a major determinant factor of reducing under-five child mortality (Caldwell, 1979). Likewise, the contribution of the proportion of children to women with no education constituted to regional gaps in under-five child mortality for most regional comparisons. Comparable regional disparities in child mortality were reported in other developing countries. For example, in Iran, mother's level of education contributed 21 percent of the regional differences in infant mortality rates (Hosseinpoor et al., 2006), in Nepal, 4 percent of the explained regional differentials in under-five child mortality was attributed to mother's level of education (Goli et al., 2015). Also, in Nigeria, there have been regional child mortality differentials due to differences in women's education level (Adedini et al., 2015). Moreover, Jhamba (1999) and Akuma (2013)indicated that maternal education was the major determinants of regional variation in child mortality in Zimbabwe and Kenya, respectively.

The most striking regional differentials almost across the groups of regional comparisons occurred due to differences in the proportion of children from the poorest third index households. In line with present study, significant difference in child mortality was observed due the major difference in households' wealth index in Nigeria (Adedini et al., 2015), Nepal (Goli et al., 2015), Kenya (Akuma, 2013), and in Iran (Hosseinpoor et al., 2006). A mother who gave a birth at less than 20 years old could face delivery and pregnancy related problems due to the mother's biological immaturity. Also, the mother could not have basic knowledge on how to care babies (Pandey et al., 1998) and as a result, a child born to this mother could have more likely to significantly die than a child of a mother whose age is above 20 years (Babson

& Clarke, 1983). In the present study, the differences in distribution of maternal age at first birth less than 20 years was among the major determinants of regional differentials in under-five child mortality with different magnitude of effects and level of significant. In line with the present findings, it was also evident that the proportional differences in children of mothers whose age at first birth less than 20 years across regions explained the regional variations in child mortality significantly in Nepal (Goli et al., 2015), and in Nigeria (Adedini et al., 2015). How a child birth order determines child mortality and explains regional gaps in child mortality? A child of the first order is most probably to born from a young woman who is not biologically ready to accept and care for a baby. On top of this, the young woman has very limited basic knowledge on how to care for a baby (NIMS et al., 2012; Pandey et al., 1998). A child of higher birth-order, in contrast, is most probably to born to an older woman and is likely to be influenced by competition from older siblings in terms of resources (NIMS et al., 2012). Hence, in the present study, higher birth-order was among the major proximate determinants of under-five child mortality. The differences in the proportional distribution of children of birth-order of four or higher across the regions explained the regional gaps in under-five child mortality with different magnitude of effects and levels of significant. The present finding was consistent with some previous studies from Nepal (Goli et al., 2015), and in Nigeria (Adedini et al., 2015). Prior studies have indicated that birth spacing and child mortality has a direct relationship (Srinivasan, 2000; Sweemer, 1984). A woman who experienced short birth spacing may not recover instantly her health and then can deter baby's growth. Therefore, a child born to less than 24 moths birth spacing (short birth spacing) have more likely to die than a child born to a birth spacing of more 24 months (Hobcraft et al., 1983; NIMS et al., 2012). Likewise, a child born to less than 24 months birth spacing had more likely to die. The differences in the proportional distribution of children of short birth spacing across regions explained the regional differences in U5MR for most regional comparisons with different degree of effects and levels of significant. Findings on short birth spacing were in line with some of the existing literature in Iran (Hosseinpoor et al., 2006), Nigeria (Adedini et al., 2015)and in Nepal (Goli et al., 2015).Findings of this study further indicated that birth size less than average (2500g) affects under-five child mortality across regions. The differences in the distribution of birth size less than average explained significantly to 39 percent of the regional variations in under-five child mortality for Tigrai-Gambella regions. In Sri Lanka, low birth-weight explained the inter-district disparity in infant mortality rate (Chaudhury et al., 2006). However, the present findings revealed that for most regions child size at birth less than average contributed to reducing the regional differentials in under-five child mortality with small size effect. Furthermore, the unequal distributions of children who have been delivered at home (out of health facilities) attributed significantly to the explained regional gap in under-five child mortality; however, the relative percentage contribution of this variable was small. This result was in line with previous empirical studies from Nigeria (Adedini et al., 2015).

## 6. Conclusions

The present study has identified the inter-regional differentials in under-five child mortality in rural Ethiopia was due to different levels of determinants that are often associated with under-five child mortality. The results of decomposition analysis indicated that households' economic status, mothers' levels of education, birth-order, birth-spacing, antenatal visits, household size, and place of delivery attributed were the key determinants of regional disparities in under-five child mortality. The under-five child mortality disparities were largely due to the reflection of the wide regional differentials of these determinants. The findings of this study can help to draw a critical attention in developing specific national and regional policy based on the relative contribution of individual covariates to explained regional gaps that help in reducing child mortality disparities among regions of the country. Hence, on top of strengthening the Ethiopian health extension programme across regions, this study suggests that addressing those identified potential determinants focusing on improving households' economic status and women's education could help to minimize regional disparities in under-five child mortality and ensure universal health care coverage of the country. Also, further sustained effort is needed to speed up the rate of reduction in under-five child mortality both at the national and regional levels against a certain target set, for example, 75 percent disparity reduction goal in under-five child mortality among regions in 2025.

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