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Water, Smallholders and Food Security

- An econometric assessment of the effect of time spent on collecting water on households' economy and food security in rural Ethiopia

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Abstract

Due to a lack of basic infrastructure, it is common in least developed countries that households spend a considerable share of the hours that they have available per day for production activities on fetching water. This study analyzes the economic impact of time spent by Ethiopian rural farm households on fetching water. In this analysis, both their water-based agricultural production and household consumption decisions are taken into account. For this purpose the agricultural farm household model has been adopted and labor allocation for water collection is incorporated into the model. The agricultural farm household model provides a framework for analysis of farm household economics that integrate the production decision and simultaneous consumption decision since both are made by a single entity at the household level. Based on this analytical framework, an empirical application is presented based on econometric estimates using the Ethiopian Rural Household Surveys (2011) dataset. The analysis is conducted to test the hypothesis that reducing time spent on fetching water frees labor for productive activities such as farm production and contributes to food security positively. The findings confirm that in aggregate production and consumption, reducing time spent on fetching water by one percent leads to an increase in per capita food consumption by 0.165 percent. This total effect of labor allocation for water collection on food security shows that reducing time spent on fetching water can have a significant contribution to food security, and improve development and welfare of the society.

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1. Introduction

In the last few decades ensuring food security has been one of the main objectives of developing countries, where a significant proportion of the population lives in poverty. FAO, WFP and IFAD (2012) reports that 870 million people are chronically undernourished worldwide in 2010-12. The largest share lives in developing countries, where about 15% percent of the population is food insecure. Ensuring food security is challenged by drought and famine augmented by lack of proper water management.

Causes of food insecurity are many and varied. According to Shiferaw et al. (2003) until the 1980s food insecurity was thought to occur solely because of food supply shortage, which led to analysis of the case only from supply side. But the existence of food shortage amid the declining food price and surplus food after late 1970s made scholars reconsider the believed source of the problem. Recent studies show that the problem occurs not only due to supply shortage but also wide variety of factors such as lack of distribution system from food abundant areas to food scarce areas. The existence of food shortage at household level in the abundance of food at national level led to the belief that the problem occurs mainly due to lack of access to food by the poor. The work of Sen (1981) can be mentioned among the studies which brought the paradigm shift. The focus of the studies also shifted from global and national level to household level eventually leading to the development of agricultural household model. The agricultural household model provides a comprehensive framework integrating both demand and supply sides of the economies of rural households.

Food insecurity and related problems are also major concerns of Ethiopia. Ethiopia is largely composed of small scale rural farm households, whose consumption as well as aggregate calorie intake depends on their annual agricultural production. The practiced agriculture by the small scale rural farm households is mainly composed of subsistence agriculture which primarily depends on rain. Only a very small portion of rural households use other sources of water such as irrigation and water reservoirs for agriculture. As a result most households spend a significant amount of their time on collecting water for farm production, drinking and sanitation, usually from distant sources.

This study focuses on determinants of food security in rural Ethiopia with an aim of investigating the impact of households' labor allocation for water collection on food security using the agricultural household model as a foothold for building the model to be used for analysis. The rest of the study is organized as follows. Up on reviewing water, water management and food security conditions in section 2, the agricultural household model will be adapted and labor allocation for water collection will be incorporated in section 3. Section 4 presents background of the study areas, dataset and econometric specification of the estimated model. In section 5 the model will be estimated using the Ethiopian Rural Household Surveys Dataset 1989-2009 (2011) and the results will be presented and discussed. Finally section 6 concludes with brief summary and policy recommendations.

1.1. Purpose of the study

The purpose of this study is to investigate the impact of water availability for drinking, sanitation and agricultural production on food security in rural Ethiopia. Frequently water, weather fresh or saline, is considered to significantly influence food security through its impact on agricultural productions. Thus, most commonly throughout the literature, the role of water in achieving food security is assessed with respect to agricultural production. In this thesis, water is also introduced in the consumption side in order to account for the effect of time spent looking for clean water for drinking and sanitation. Labor allocation for water collection will be integrated with the agricultural household model and its overall effect on the rural households' economy will be analyzed for the case of rural households in Ethiopia.

1.2. Scope of the study

The scope of this study is limited to analyzing the economic effect of labor allocation for water collection on rural farm households of Ethiopia using the Ethiopian Rural Household Surveys Dataset 1989-2009 (2011). Investigating the effect of time spent on water collection enables to understand its impact on food security. This study does not address health, risk and government administration related determinants of food security. However it is understood that these variables play vital role in achieving food security. This study provides a ground for interested future scholars to integrate other aspects.

2. Literature Review: Water, Water Management and Food Security

2.1. Hydraulic Shocks and Economic Impact

Hydraulic shocks (extreme drought and flood) have been challenging fragile economies of developing nations. For instance, the World Bank (2007) study in Kenya shows that the 1997-8 flood and the 1999-2000 drought had impacted the Kenyan economy by up to 40 percent of the GDP spread over three years. The study of Davies (2010) on the impact of shocks on consumption in rural Malawi shows that drought and flood has prominent short-term negative impact on the level of consumption. But in the long run flooding has been found to have positive impact because households benefit from the increased rainfall.

The impact of hydraulic shocks extends beyond water related sectors such as to infrastructure and slowing industrial production. The condition is worsened by insufficient investment and institutional infrastructures to control the seasonal extremes in developing countries. For instance, according to World Bank (2007) the broadly publicized 1984-85 drought in Ethiopia left 8 million people vulnerable while killing more than one million. It also led to a 21% reduction in agricultural production and 9.7% decrease in GDP. The most recent drought, in 2002-3, necessitated emergency food assistance for 14 million people and electric power rationing due to drying hydroelectric dams. Flooding augmented by mountainous terrain and poor conservation practices in Ethiopia has led to massive soil loss and land degradation. According to Hurni (1993) the rate of soil erosion is 10 times that of soil formation in Eastern highlands of Ethiopia.

The impact of hydraulic shocks on Ethiopia, whose major share of economy is held by subsistence agriculture, has long been recognized but there is lack of empirical studies quantifying the impact and revealing the spread. One of few of such studies is Dercon (2004), which analyzes the impact of drought and famine on living standard growth using panel data from rural parts of Ethiopia for the years 1989 to 1997. Using a linearized growth model he shows that rain fall shocks have persistent effect on consumption growth and the impact of the shocks in 1980s lingers to 1990s. In addition Dercon et al. (2005) analyzes the impact of drought, flood and other shocks on socio-economic aspects of rural Ethiopia. It shows that Ethiopia is a shock-prone country, the most important shocks being drought and illness. In particular they find that the 2002 drought in Ethiopia has lowered per capita food consumption by 20%. It also confirms that the effect lingers for several years exacerbated by low risk mitigation nature of rural households. In addition the study of sources of growth and inefficiency in agricultural production in Ethiopia by Nisrane et al. (2011) shows that drought significantly decreases efficiency of agricultural production.

2.2. Water Resource, Rainfall Distribution and Topography in Ethiopia

When only mere volume is considered, Ethiopia is endowed with a great amount of water resources. The country is divided by four major drainage systems composed of 12 major river basins with an annual runoff of 122.52 km^3 per year. The 12 major river systems provide an economical irrigation potential of about 3.7 million hectares (World Bank, 2007). In addition, Ethiopia has 11 fresh and 9 saline lakes, 4 crater lakes and over 12 major swamps or wetlands. The total surface area of these natural and artificial lakes is about 7,500 km^2. It also possesses ground water potential of 2.6 Billion Metric Cube annually rechargeable resource (Awulachew et al., 2007).

The major four river basins (*Abay* (Blue Nile), *Tekeze*, *Baro Akobo*, and *Omo Gibe* basins) hold 90 percent of the country's water resource while supporting only 40 percent of the total population. The rest 60 percent of the population depends on less than 20 percent of the total water resource. In spite of the county's vast irrigation potential only 5% is irrigated as of 2001. The national average water supply is confined at estimated 30.9 percent, the rural water supply coverage being 23.1 percent and that of urban being 74.4 percent (UNESCO 2004). Moreover there is great seasonal variation in the water supply reaching up to 30 percent (World Bank, 2007).

Ethiopia's rain fall greatly varies across its geographic area and time (inter-seasonal and inter-annual). The southwestern highlands get the maximum annual rainfall of more than 2,700 millimeters per year, most of which during a single peak season called *Kiremt* (from June to September). The rainfall gradually gets scarce to the northeast reaching below 100 millimeters per annum. The rainfall pattern in the central, eastern, and northeastern areas of the country is characterized by a two peak (bi-modal) rainfall distribution. The two peak rainy seasons are called *Belg* (smaller rains from February to May) and *Kiremt* (big rains from

June to September). The south and southeastern areas experience two distinct rainy seasons (September to November and March to May) separated by two dry seasons (World Bank, 2007).

Ethiopia's highly varying topography put significant challenge for its water management. Elevations rise up to 4,620 meters at the top of Mount *Ras Dashen* in the north from 110 meters below sea level at *Afar* Depression in the northeast. About 88 percent of the country's population lives in an elevation of above 1,500 meters above sea level, that is 43 percent of the country's geographic area. The altitude variations generate vast variety of climatic conditions, as well as soil, flora and fauna. The temperature in the northeastern lowlands reaches an alarming 45 degree centigrade and it gradually decreases to below zero degrees centigrade in the northern highlands. (Gebeyehu, 2002).

2.3 Food Security and Water Management in Ethiopia

The world food summit (FAO, 1996) states that:

> *"Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life".*

Imbedded in this definition is that, in order to secure nutritional needs, food does not only need to be available but also diversified enough to meet the individuals' preference and dietary need. In addition mere availability of food without the individual's economic purchasing power is meaningless. Food availability and access has to be supported with proper use including clean water and sanitation for healthy life.

Even though Ethiopia has long struggled with insuring food security, it has been a policy issue only in the last couple of decades. According to Alemu et al. (2002) policy instruments addressing the issue of food security started being developed only after the famine of 1983. Two of the many challenges of food security Ethiopia has been facing are backward nature of the agriculture sector and inadequate water management. Agriculture in Ethiopia, which accounts for 42 percent of the GDP, supports 81 percent of the active labor and 85 percent of the export. It has been affected by the high seasonal variability of rainfall because it is mainly rain fed highland mixed farming system, where about 80 percent of rural households cultivate less than 1 hectare of land per household. The traditional nature of agriculture on which the country heavily depends has left up to 4 million people severely food insecure even in good years (Frenken, 2005).

Empirical studies investigating determinants of food security in Ethiopia also show that the determinants of agricultural production are also the main determinants of food security. According to the studies of Demeke et al. (2011), Shiferaw et al. (2003), Yared et al. (1999), and Webb et al. (1992) the main determinants of food security in Ethiopia are ownership of livestock, cultivated land size, adult family labor, employment opportunities, market access, levels of technology application, levels of education, health, weather conditions, crop diseases, rainfall, oxen, and family size. In addition the empirical analysis of Holden et al. (2005) using Bio-economic model and data from Eastern Amahara region of the Ethiopian highlands shows that access to credit for fertilizer together with land conservation can increase grain production and improve food security. It also shows that increasing farm households' awareness and involving the local community in policy decision making is important to optimize the benefits of policy instruments.

Despite its vast water resource endowment and adequate rainfall, Ethiopia has experienced severe drought and famine through years. The country's water endowment is unevenly distributed leaving much of the north and northeastern part of the country drought vulnerable. Ethiopia's highly varying topography poses significant challenge for its water management. Water management in Ethiopia is characterized as poor and the sector lacks sufficient investment. According to Frenken (2005) in 2001 only 2.5% of cultivated land is water managed in Ethiopia. In addition, the lack of proper infrastructure to tackle seasonal hydrological extremes has amplified pervasive and unpredictable flood and drought. Grey and Sadoff (2007) argue that achieving water security through investment in water infrastructure and institutions have an increasingly positive impact on growth. The World Bank (2007) conducted a study on the impacts of water management in Ethiopia by developing a dynamic Hydro-Economic Model which incorporates and assesses the effects of hydrological variability, poor infrastructure and challenging topography on growth and development. The result of the study shows that lack of proper management and mitigation of hydrological variability has led to loss of one third of Ethiopia's economic growth potential necessitating water security for a better achievement on growth and food security.

3. Production and Consumption Decision Framework of Farm Households

Total time endowment of a rural farm household is divided into three main activities: farm activities, off-farm activities and leisure. Leisure includes time spent on non-income generating activities such as cooking, cleaning and sleeping hours. In rural households of developing countries time allocated to agricultural production take significant share of total time. Moreover substantial part of production is retained at home for consumption. For these reasons production decision and consumption decisions of rural farm households are interlinked.

Figure 1 depicts the relationship between the household as a producer and consumer, and the product and labor markets. In this figure households supply labor to the labor market and earn wages. The supplied labor can be employed on off-farm activities or on own farm.

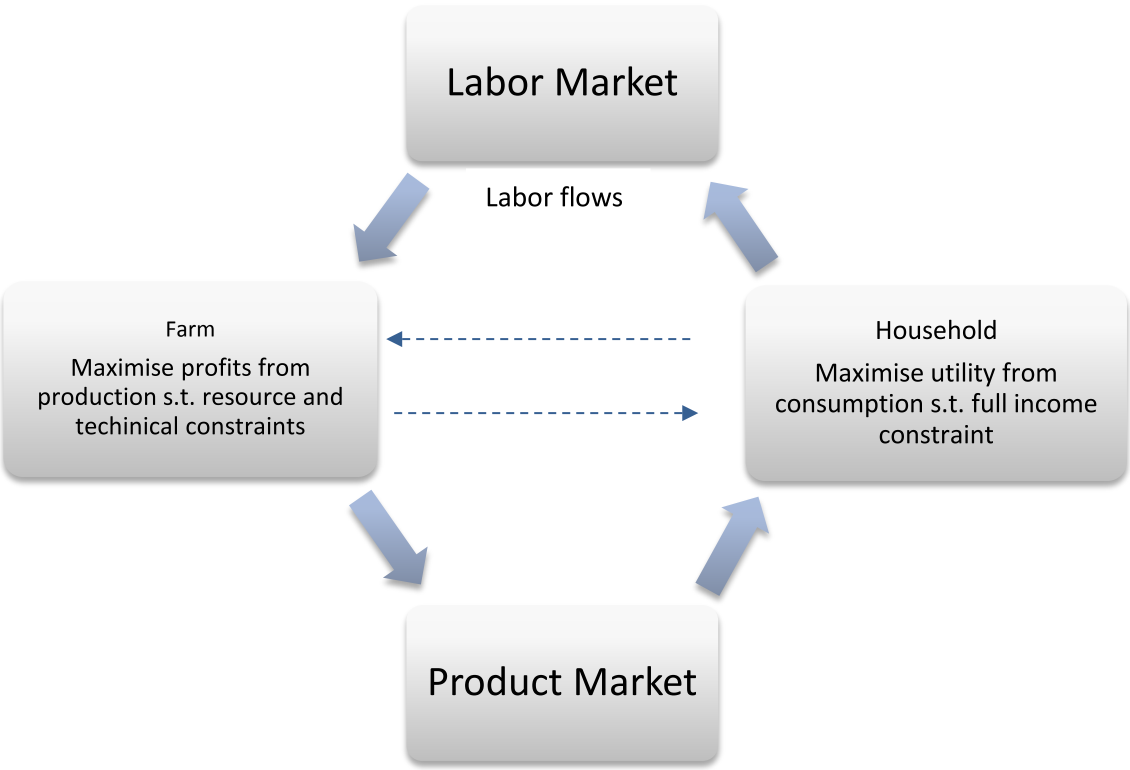

Figure 1: Structure of the farm-household. Source: Delforce (1994), pp 166

The same household which supplies labor to the labor market is the owner of the farm. The farm produces using own labor or hired labor. Farm products are supplied to the product market. The household earns income by selling its farm products in the product market. In addition the household also buys other products from the product market. Thus the household's total income is generated from wage from labor market and revenue from product market. The household as a production farm maximizes profit subject to resource and technical constraints. Further, the household as a consumer maximizes utility subject to full income constraint.

In rural households demand and supply are interlinked because the same household is consumer and producer. The impact of a price increase in any main agricultural product goes beyond the usual income and substitution effects of basic microeconomics. The effect of a price change on demand is extended through profit effect from production. For example consider an increase in the price of wheat. Microeconomic theory (Varian, 1992) tells us that for a normal good demand will decrease. The total change can be decomposed into income effect and substitution effect.

When the price of wheat increases, for a given budget, the amount of other goods that the consumer must sacrifice, in order to buy a unit of wheat, increases. In order to stay at the same satisfaction level the consumer substitutes the expensive good with relatively cheaper goods, which means that the relative consumption of wheat decreases. This effect is commonly referred as substitution effect. For a given budget, with the increased price the consumer has less purchasing power. The decrease in purchasing power due to higher prices indicates the income effect of a price increase. As a result of this income effect, consumption of wheat and other goods decreases further.

When the consumer is a semi-commercial rural household there is more to the story. Production response to the price increase is positive, i.e. production of wheat increases. An increase in production and higher prices will result in an increase in household income, which in turn induces more consumption of all goods. Therefore the total change of consumption of wheat depends on the magnitudes of the negative response from demand side and the positive effect of production. Singh et al. (1986) describes the effect from production part as profit effect. According to Singh and Janakiram (1986), and Strauss (1986), profit effect is significant and it can change the magnitude and sign of response of demand to a price increase.

Further a price increase of a product will also affect the households' labor supply by increasing the marginal product value of input. In order to increase production, labor demand will increase. The household may respond to these by supplying more labor. But the increase in household income may increase the consumption of leisure. So the total impact of an increase in price on labor supply depends on these two opposing changes.

The Agricultural household model provides a comprehensive framework of analysis of rural household economies integrating production and consumption interactions. In the following sub-section the agricultural household model will be reviewed. Subsequently, based on the agricultural household model, a model will be developed to incorporate labor allocation for water collection in the consumption and production decision of the farm household.

3.1. The Agricultural Household Model

The integrated production and consumption decision characteristic of the farm household is modeled using the agricultural household model. Most theoretical and empirical studies of the agricultural household model assume that the two decisions are made separately and recursively in two stages. First profit is maximized through production decision, and then utility is maximized through consumption decision. But it can be argued that this is not always the case. In the next section agricultural household model where production and consumption decision are assumed to be separated is reviewed. In the subsequent section an alternative model where the two decisions are not assumed to be separate is presented. Then proposed methods of test for the assumption of separated production and consumption decision will be reviewed. Consequently empirical studies which apply the agricultural household model on the real world data will be summarized.

3.1.1. Separated Production and Consumption Decision

Assuming a separated production and consumption decision means that the household maximizes utility, first by achieving maximum profit through making production and consumption decisions separately and consecutively. In other words, decision is made in two steps and the flow of the relationship is one way from profit maximization through production decision to utility maximization through consumption decision. The only link between profit maximization and utility maximization is income. To make this decision the farm household is assumed to have complete information about fixed and variable inputs, and market prices of inputs and outputs. Given that the household knows the production technology, as a rational consumer and producer it equates marginal revenue product of labor equal to wage in attempting to reach maximum profit (Singh et al., 1986).

In this model households are price takers of all commodities including labor. Consumption of a product is determined independent of production of the same product, hence the assumption of separated production and consumption decision. Family labor supply can also be determined independent of consumption because the difference between family labor supply and labor demand can be hired at market wage. Consumption is constrained by income which in turn is determined by profit. According to Singh et al. (1986) since income and utility are positively related it makes sense first to maximize profit and then decide consumption and leisure.

The household maximizes utility subject to production function, budget constraint and time.

Assume a well-behaved household utility function exists which is quasi-concave with positive partial derivatives:

$$U = U(\boldsymbol{X}, X_L) \quad \text{......} \quad (1)$$

Where - $\boldsymbol{X}$ is vector of commodities consumed, and

X_L is consumption of leisure.

Total income of a farm household is summation of its time endowment, value of household production and other incomes such as remittance, minus the value of variable inputs required for production. The budget constraint which states total consumption equals total income can be put as:

$$\sum_{j=1}^{L} P_j X_j = \mathrm{P_L T} + \sum_{\mathrm{j=1}}^{\mathrm{n}} \mathrm{P_j Q_j} - \sum_{\mathrm{i}}^{\mathrm{m}} \mathrm{P_i V_i} - \mathrm{P_L L} + \mathrm{E} \quad \text{......} \quad (2)$$

Where – X_j is commodities consumed,

T is time endowment,

P_L is wage,

Q_j is household production,

P_j is price of output,

P_i is price of variable inputs,

V_i is non-labor variable inputs,

L is labor demand, and

E is exogenous income.

The left hand side of equation (2) ($P_j X_j$) is market value of commodity consumed with the last term $P_L X_L$ being the value of leisure. The right hand side gives full income of the household which is composed 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 remittance. Labor demand consists of both family and hired labor, which are assumed to be perfect substitutes.

In addition the household production capability is constrained by its production technology, which is expressed by production function. Outputs and inputs are related by an implicit production function which is assumed to be quasi-convex, increasing in outputs and decreasing in inputs. In the usual explicit production function output is equal to a function of inputs. But in this specification of implicit production function both output and input are stated under one function which is equal to zero. According to Strauss (1986b) implicit production function specification allows for a separate production function for each output or joint production function. This means that for example if the household produces wheat and barley there can be separate production functions for both wheat and barley or joint production function of wheat and barley. Therefore the number of crops produced included in the model is not restricted.

$$F(\boldsymbol{Q}, \boldsymbol{V}, \boldsymbol{K}) = 0 \qquad (3)$$

Where – $F(\boldsymbol{Q}, \boldsymbol{V}, \boldsymbol{K})$ is implicit production function,

$\boldsymbol{Q}$ is vector of household productions such as crops,

$\boldsymbol{V}$ is vector of variable inputs including labor, and

$\boldsymbol{K}$ is vector of fixed inputs.

As described in Straus (1986b), according to Jorgenson and Lau (1969) and Nakajima (1969) the problem of household utility maximization subject to its budget and production function constraints, given output and labor prices, can be modeled as recursive even though the decisions are made simultaneously in time. When the households' decision of production and consumption is modeled as recursive, the household acts as if it first maximizes profit. Since the households' choice variables in order to maximize output are only variable inputs; maximizing profit is the same as maximizing full income given by the right hand side of equation (2) subject to the production function. Upon achieving maximum income through profit maximization, the household maximizes utility subject to its full income.

The Lagrangian function of the utility maximization subject to full income and production function can be stated as follows:

$$Ł = U(\boldsymbol{X}, X_L) + \lambda \left[P_L T + \sum_{j=1}^{n} P_j Q_j - \sum_{i}^{m} P_i V_i - P_L L + E - \sum_{j=1}^{L} P_j X_j \right] + \mu[F(\boldsymbol{Q}, \boldsymbol{V}, \boldsymbol{K})] \ldots . \ldots \ldots (4)$$

According to Straus (1986b) and Sicular (1986), assuming interior solutions exist, the first order conditions are:

$$\frac{dŁ}{dX_j} = \frac{dU}{dX_j} - \lambda P_j = 0; \;\; i = 1 \ldots L \quad \ldots \ldots (4.1)$$

$$\frac{dŁ}{d\lambda} = P_L T + \sum_{j=1}^{n} P_j Q_j - \sum_{i}^{m} P_i V_i - P_L L + E - \sum_{j=1}^{L} P_j X_j = 0 \ldots \ldots (4.2)$$

$$\frac{1}{\lambda}\frac{dŁ}{dQ_i} = P_j + \frac{\mu}{\lambda}\frac{d\mathrm{F}}{dQ_i} = 0 \quad \ldots \ldots (4.3)$$

$$\frac{1}{\lambda}\frac{dŁ}{d\mathrm{L}} = \mathrm{P_L} + \frac{\mu}{\lambda}\frac{d\mathrm{F}}{d\mathrm{L}} = 0 \ldots \ldots (4.4)$$

$$\frac{1}{\lambda}\frac{dŁ}{dV_i} = P_i + \frac{\mu}{\lambda}\frac{d\mathrm{F}}{dV_i} = 0 \ldots \ldots (4.5)$$

$$\frac{dŁ}{d\mu} = F(\boldsymbol{Q}, \boldsymbol{V}, \boldsymbol{K}) = 0 \ldots \ldots (4.6)$$

The solution to the first order conditions yields standard demand functions, which are functions of market price and income. Barnum and Squire (1979a), Straus (1986b) and Sicular (1986) show that the first order derivatives can be arranged into a system of linear equations in matrix form and the solution for commodity demands, marginal utility of full income, output supplies, variable input demands and associated multipliers can be solved.[1]

According to Straus (1986b) and Sicular (1986) utility and production function assumptions ensure that second order conditions for maximization are met and therefore, the two decision problems can indeed be solved recursively, despite their simultaneity in time. In addition Barnum and Squire (1979a) show that household characteristics can be introduced into the model as linear functions. According to Straus (1986b), as long as household characteristics are treated as fixed variables, introducing them as linear functions will not change the analysis.

Based on the arguments of Straus (1986b) the recursive model shows that farm technology, quantities of fixed inputs and prices of variable inputs and outputs do affect consumption decisions; however the reverse is not true as a result of recursivness of the model. Production decision is not affected by preferences, prices of consumption commodities and income.

Solving the above system of equations becomes more tedious as the number of commodities consumed and outputs produced by the household increase. An alternative approach to estimating separated production function for each output type is to aggregate production and sum inputs to derive aggregates such as total labor, total capital and total land. According to Strauss (1986a), following such a method will not only reduce the number of parameters to be estimated but also addresses the probable existence of jointness (such as intercropping). In addition, some households report zero capital or variable input for some products, yet report positive outputs. For example some households report zero capital for poultry, but positive poultry production. Others report positive capital for non-farm activities such as small scale side business but no output. In such cases further survey may indicate that the household might have adopted the non-farm capital for poultry production. When aggregation is used there is a greater chance that such errors will cancel each other out.

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[1] For further details see Barnum and Squire (1979) pp 88, Straus (1986b) pp 74 and Sicular (1986) pp 283.

3.1.2. Joint Production and Consumption Decision

The separable model is relatively easy to estimate using standard econometric procedures, and is more widely used by researchers. Singh et al. (1986) agrees that separability should be assumed unless there is strong evidence suggesting otherwise. If separability is mistakenly assumed, estimated parameters will be inconsistent and further estimated elasticities will be erroneous. Studies such as Benjamin (1992) and Lopez (1986) show that there are likely cases where separation will fail. Some of such cases are if utility function is misspecified, if there is disutility attached to working off-farm, or if family labor and hired labor are imperfect substitutes, then separation cannot hold. In addition if physical strength of household labor, which depends on the dietary variety and amount of consumption, affects production then marginal product of labor will be directly related to consumption and separation cannot be assumed.

Further, if production decisions affect household income as well as any market price, then the household is no longer price taker and its decision of production and consumption cannot be modeled as recursive. If household decision of labor supply affects wage, such as in a case of a missing market for labor, then households' supply of labor is determined by the shadow price (Delforce, 1994). Skoufias (1994) elaborates this using two equilibrium conditions depicted in Figure 2. The indifference curve U represents the trade-off between consumption C and leisure L. According to Skoufias (1994) the slope of the indifference curve is the shadow wage rate. The line DEBT shows the budget constraint of the household, which includes different sources of income. The first linear segment DE is the off-farm income portion while the last linear segment BT is the real non-work income of the budget constraint. The slope of the off-farm income part indicated by W is the constant marginal effective real wage earned in the market. The middle curved segment GEB indicates income from farm production and its slope is the marginal product of family labor. The marginal product of family labor is decreasing as more time is allocated to farming. The equilibrium is determined at the intersection of the budget constraint and the indifference curve. Assuming that all households have the same production technology, the equilibrium point is determined based on the household's preference.

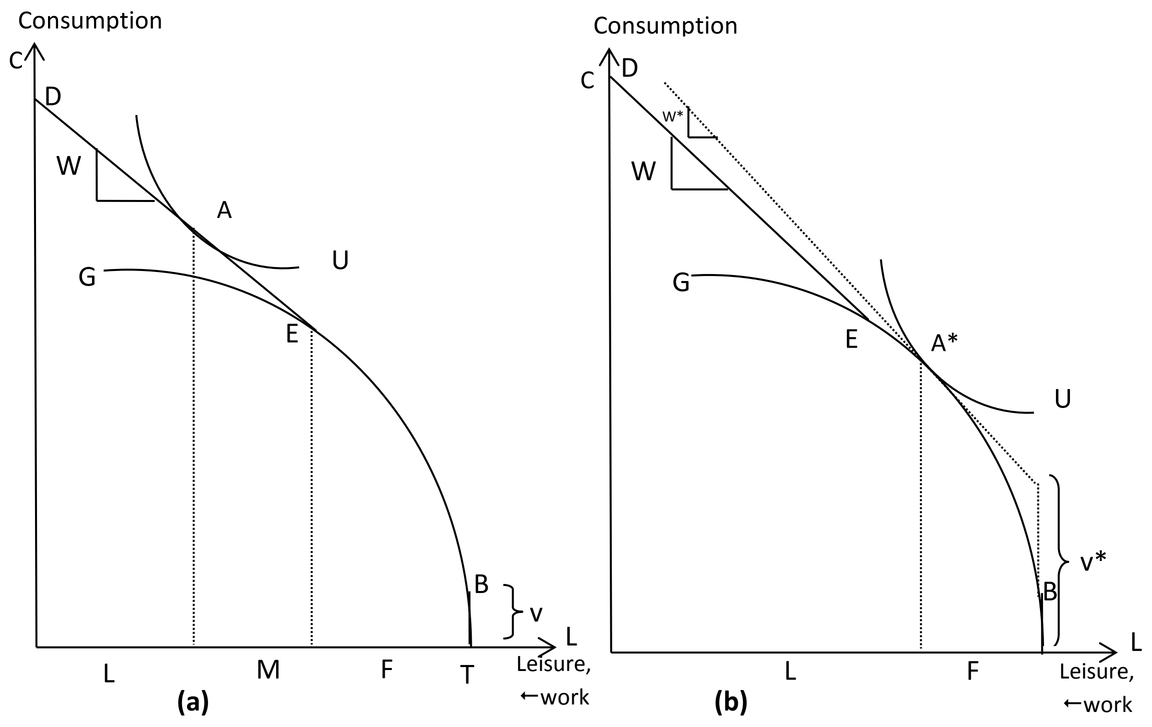

Figure 2: Two possible equilibrium positions of an agricultural household. Source: Skoufias (1994), pp 218

In Figure 2(a) the household preferences are such that the utility curve intersects the budget constraint at its linear section of the graph as shown by point A. In this equilibrium L amount of time is allocated to leisure, M amount of time to market work and F amount of time on-farm work. At point A the market wage and marginal return from work on the farm are equated and then the remaining time is divided between market work and leisure. According to Skoufias (1994) the marginal returns across all activities are exactly equal and the shadow wage rate is equal to the effective wage rate earned off-farm.

In Figure 2(b) the household preferences are such that the utility curve intersects the budget constraint at its curved section of the graph at point A*. In this equilibrium the household prefers not to supply any labor off-farm. Instead L and F amount of time are allocated to leisure and on-farm work respectively. According to Skoufias (1994) at the equilibrium point A*, the shadow wage rate W* and the slope of the farm production function are equal. As it can be inferred from the slopes, the shadow wage rate W* is greater than the market wage rate W. This suggests that for households depicted in this equilibrium condition, the market wage rate may underestimate the opportunity cost of time.

According to Singh et al. (1986) when the household's consumption and agricultural outputs are not homogenous, if the household chooses to consume all of its production, it will end up in a corner solution. In this case the households' labor supply decision is the same as the one shown in Figure 2(b). When the household's decision leads to a corner solution, separability does not hold and there exists a virtual price which is a function of both preferences and technology. Other reasons for rejection of the assumption of separability include imperfections in the product market, such as restriction on volume of trade (Sicular, 1986), and when risk and risk aversion are significant factors of decision (Delforce, 1994).

One way of dealing with non-separability of household production and consumption decision is to derive shadow price in order to incorporate the impacts of factors which are the reasons for non-separability. In order to drive shadow price and explore the consequences, Singh et al. (1986) defines the full income function at maximized profit as the maximization of the right hand side of the budget constraint (equation 2) with respect to outputs and variable inputs subject to the production function.

$$\max_{Q_j, V_i} \; P_L T + \sum_{j=1}^{n} P_j Q_j - \sum_{i}^{m} P_i V_i - P_L L + E$$

$$\text{sub. to. } F(\mathbf{Q}, \mathbf{V}, \mathbf{K}) = 0$$

And then full income at maximized profit can be written as

$$Y = \Lambda\big(P_L, P_j, P_i, \boldsymbol{K}, T, E\big) = P_L T + \pi\big(P_L, P_j, P_i, \boldsymbol{K}\big) + E \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (5)$$

The full-income function is the sum of the value of time endowment $\{P_L T\}$, a short-run profits function ($\pi\big(P_L, P_j, P_i, \boldsymbol{K}\big)$, which has the usual properties such as convex in all prices), and exogenous income $\{E\}$.

For the expenditure side of full income (the left hand side of equation 2), Singh et al. (1986) defines expenditure function as the minimum expenditure, required to meet a specified level of utility (say $\overline{U}$). That is the same as:

$$\min_{X_j} \sum_{j=1}^{L} P_j X_j$$

$$\text{sub. to. } U(\boldsymbol{X}, X_L) = \overline{U}$$

And the resulting expenditure function $\mathrm{e}(\mathrm{P_j}, \overline{\mathrm{U}})$ is concave in prices, and the partial derivatives with respect to price are the Hicksian (compensated) demand functions.[2]

The households' equilibrium is set at the equality of the expenditure and the full income at maximized profit.

$$\Lambda(\mathrm{P_L}, \mathrm{P_j}, \mathrm{P_i}, \boldsymbol{K}, T, E) = e(P_j, \overline{U}) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. (6)$$

According to Singh et al. (1986) this condition holds whether or not households face given market prices. Assume for a reason such as missing market, there are additional identities to the household equilibrium, which is the household has to equate consumption with production for some commodities. Equivalently, for each of the commodities that the market is missing, the household is required to equate the commodities demand and supply. Singh et al. (1986) states that this second set of equilibrium conditions implicitly defines a set of virtual prices or shadow prices which, if they existed, would make the household reach the second identity of the equilibrium.

As the virtual prices are driven from the two equilibrium identities, they will be a function of market prices, time endowment, fixed inputs, either exogenous income or utility, and fixed household characteristics, if it is included in the model. These virtual prices are determined by the household's preferences and its production technology. They are not taken parametrically by the household as market prices are. In the existence of virtual prices, change in market prices will not only affect household behaviors directly but also indirectly through changes in the virtual prices. In addition the relationship between consumption and production will not be only through income as in the separated model. According to Singh et al. (1986) household commodity demands will depend on production technology, both through the virtual price and through full income. These virtual prices will also link household preferences and output supplies and input demands. Therefore output supplies

[2] Shephard's lemma – states that the derivative of the expenditure function with respect to the price of the good, at a given level of price and utility, gives the demand (Hicksian demand) function. Varian (1992) pp 74.

and input demands will be functions of household characteristics, in addition to production sector variables.

3.1.3. Separability Test

In the literature related to agricultural household models there are only a few studies which test the assumption of separability. One of the seminal papers in this stream of literature is Lopez (1986). In Lopez's study the assumption of separated production and consumption decision is violated due to the presence of significant commuting time to off-farm work. The cost of commuting causes a wage difference between on-farm and off-farm labor. The study uses standard non-nested hypothesis techniques to test hypotheses of no independence using recursive and non-recursive models estimated on household data from Canada. According to Benjamin (1992) this testing procedure is sensitive to misspecification, whether statistical or of functional form, and it is difficult to interpret a rejection of separation.

Another study by Pitt and Rosenzweig (1986) focuses on evaluation of the impact of change in health on productivity, labor supply, and overall farmers' income. In their study they implement an indirect method of testing separation by investigating the relationship between farmers' illness and profit. They test the hypothesis that if labor supply is not dependent on household characteristics then farmers' illness should not affect profit. This also means that family labor and hired labor are perfect substitutes and any missing labor from the household can perfectly be substituted by hired labor. Their analysis provides a method to test non-separability arising from missing labor market.

Benjamin (1992) tests the hypothesis that household labor demand (farm employment) is independent of household composition. To test for the independence of labor demand from household characteristics, he investigates three conditions. The first condition is non-separation arising due to constraints on off-farm employment opportunities that affect on-farm employment decisions. The second case is when farmers' labor demand is constrained by labor shortages such as in peak agricultural seasons. The third and more general condition is when there is wage difference between family labor and hired labor. The third case provides a means of interpreting efficiency difference between family and hired labor.

Benjamin (1992) suspects that the most likely cause of correlation between demographic variables and hired labor demand is labor market imperfection. In an imperfect labor market household labor and hired labor wages differ, which suggests efficiency difference. In order to test efficiency difference, assume that hired labor wage is different from off-farm wage for family labor, which might be due to transport cost, transaction cost, or lack of market opportunities. According to Benjamin (1992) the wage difference implicitly represents the wage of using labor of differing efficiencies, even though it is determined by the market. The household maximizes profit by hiring labor until the marginal product and wage of hired labor are equal. At the optimum point labor supply of the household is a function of off-farm income, maximized profit, total income, household time endowment and household characteristics. Labor demand is a function of hired labor wage and fixed input.

In order to test efficiency difference between family labor L_f and hired labor L_h, let one hour of hired labor is perfectly substitutable but equal to α hours of family labor. Measured in family labor equivalent efficiency hours:

$$L^* = L_f + \alpha L_h \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (7.1)$$

The objective is to test whether $\alpha = 1$, *i.e.* one hour of hired labor is perfectly substitutable to one of hour of family labor. Total labor $L = L_f + L_h$ and so

$$\frac{L}{L^*} = 1 + (1-\alpha)\frac{L_h}{L_f + \alpha L_h} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ldots\ldots\ldots\ldots\ldots\ldots.\ldots. (7.2)$$

Benjamin (1992) implements modified Lagrange multiplier framework and testes whether $\alpha = 1$ using household data from Java. If $\alpha = 1$ then $L^* = L$, which means that there is no difference between family labor and hired labor efficiency and assumption of separation holds. The empirical result of Benjamin (1992) does not reject the null hypothesis that there is no efficiency difference between family labor and hired labor.

3.1.4. Review of Empirical Studies

The first systematic review of theoretical and empirical studies of agricultural household models is provided in Singh et al. (1986). According to Singh et al. (1986) the first empirical studies of agricultural household models using econometric approach are Yotopoulos et al.

(1976); Lau et al. (1978); Kuroda and Yotopoulos (1978), (1980); Adulavidhaya et al. (1979); Adulavidhaya et al. (1984); and Barnum and Squire (1978), (1979a, b). These studies assume that farm household production and consumption decision are separable. They aggregate agricultural productions and consumption into one commodity; purchased market goods into one nonagricultural commodity, and leisure. They apply a system of linear equations using real world data and their elasticity estimates show that the profit effect is an important part of households' production and consumption decision making. They also estimate own price elasticities and cross price elasticities of agricultural consumption, marketed goods and labor supply, and suggest that the level of farm incomes and the availability of nonfarm goods are important determinants of responsiveness.

In agricultural households production is usually diversified in order to satisfy the household's needs. Singh and Janakiram (1986) extend the agricultural household model to incorporate multi-crop production characteristics of farm households. They apply programming models using data from Nigeria and Korea. The sample area in Korea is highly commercial even though they retain parts of production for home consumption. The households in this sample area are highly involved in product and factor market and off-farm income contributes significant proportion of their total income. In contrast, the households surveyed in Nigeria are from a semi-arid area where most of agricultural output is produced for consumption. They are far from product and factor markets but they still earn a small proportion of their total income from off-farm activities. Singh and Janakiram (1986) analyze household behaviors of these two dissimilar areas and find that the Nigerian households' consumption is more income responsive and less price responsive than the Korean households. In addition they show that the impact of government policies, which are directed towards farm households, is determined by the integration of production and consumption in a single household and policy makers need to be aware of this relationship in order to determine the direction and magnitude of the impact of a policy.

The study of Strauss (1986a) analyzes food consumption and caloric availability in Sierra Leone. It explores the effects of price and income on nutrient availability using agricultural household model, which assumes that output supply and input demand are separable. Using a quadratic expenditure system approach, the result of the study shows that, in general, an increase in food price leads to an increase in caloric availability due to the profit effect for producers. But a rise only in the price of rice has negative impact on caloric availability for middle and high expenditure households which suggest that there might be a tradeoff between long run output growth and short run nutritional availability.

Bezuneh et al. (1988) analyzes the impact of food aid in the form of food for work project on Kenyan development. It implements a separable agricultural household model using linear programing. The result shows that food for work has significantly increased agricultural production, income, capital investment, employment and marketable agricultural production surplus. This indicates that food aid can have a positive impact on food security and development of Kenya. Likewise, Shiferaw et al. (2003) develops a separable household food security model following the agricultural household model outlined by Singh et al. (1986) in order to analyze determinants of food security in southern Ethiopia. It compares the significance of supply-side and demand-side variables and finds that supply-side variables (technology adoption, farming system, farm size, and land quality) are more significant.

Most studies including studies in this section that are reviewed so far assume that production decisions are made independently of consumption and labor supply decisions. This approach eases application of agricultural household model by enabling independent estimation of production and consumption sectors. Nevertheless, Lopez (1986) shows that there are likely cases where production decisions cannot be made independently of consumption and labor supply decisions. These include cases in which the utility function is misspecified, where there is disutility attached to working off-farm, or where family labor and hired labor are imperfect substitutes. Lopez (1986) develops a structural model where production and consumption decisions are interdependent and proposes a statistical test to identify the separability of the two decisions. Then the structural model is applied to a farm-household cross-sectional data from Canada. The result of the study shows that for this specific dataset the assumption of independent production and consumption decision does not hold. It also shows that joint estimation of production and consumption sectors of the farm household model results in an important gain in explanatory power of the structural model. Moreover it shows that estimated labor supply elasticities of on-farm and off-farm employments are different, thus suggesting that farm household models should allow for behavioral difference towards on-farm and off-farm work.

Benjamin (1992) proposes an empirical model for testing the separation assumption of agricultural household model which could be distorted by imperfections in labor market arising due to reasons such as hiring constraints or efficiency difference between family labor and hired labor. For this purpose he uses data from rural Java on actual labor used on the farm, both family and hired. The findings for the farm households of rural Java indicate that separation assumption cannot be proven wrong. In contrast Skoufias (1994) shows that the assumption of non-separability is more plausible. The study uses data from rural India to estimate shadow wages of family male and female labor. The estimated shadow wages and shadow incomes are used in order to estimate structural model of labor supply. Skoufias (1994) conducts the analysis in three steps. First production function of the farm household is estimated with family male and female and hired male and female labors specified as heterogeneous inputs. Second, shadow wages (marginal products) for all labors and shadow income of the farm households' is derived from the estimated production function. Then total hours of off-farm and on-farm employment by family labor are regressed on shadow wages and shadow incomes. The analysis shows that the relationship between household characteristics and labor demand indicates that there is significant relationship between production and consumption decision making that hinders functionality of the assumption of separability.

An independent study by Henning and Henningsen (2007) develop a rural household model which incorporates transaction costs and labor heterogeneity and estimated it using data from Midwest Poland. Their result shows that farm households' behavior is significantly influenced by transaction costs and labor heterogeneity which indicates that the assumption of separability does not hold for their dataset. However, their result also shows that price elasticities do not change significantly if transaction costs and labor heterogeneity are neglected. In addition the findings of Grimard (2000) based on a dataset from Côte d'Ivoire also shows that the assumption of separation is rejected for the dataset indicating that there exists an interdependency between amount of rainfall, labor input and households' composition.

Bowlus and Sicular (2003) follow Benjamin's (1992) model and test for separability using panel data on farm households in 16 villages in Zouping County, China for the period 1990 to 1993. They estimate labor demand in farm production as a function of household size and composition in order to test the null hypothesis that coefficients of household size and composition are not significantly different form zero. Non rejection of the null hypothesis implies separability. Their test of separability between household labor demand and supply rejects the assumption of separability due to underdeveloped factor market in rural China. On the other hand their result also shows that separability holds around towns where there exists wider factor market.

Vakis et al. (2004) uses mixture distribution techniques and develops a model which does not depend on labor market participation to identify separability of farm households' production and consumption decision. Fitting the model with a data from Peru shows that there are two different types of households. The first type of households has separable production and consumption decisions and the second type has non-separable. Further, in an attempt to avoid issues that previous studies of separation test encountered, such as simultaneity bias and estimation of the production function, Le (2010) develops two types of tests which the author claims them to be simpler and less data intensive. Then the testes are applied to a data from farm households in Vietnam. The result of the empirical analysis shows that separation assumption does not hold for the Vietnamese dataset.

Despite the contributions of the existing studies, the assessment of the progress made in rural household modeling by De Janvry and Sadoulet (2006) concludes that there has not been significant progress in addressing the issues of market failure and separability of production and consumption decision of rural households since thorough introduction of the topic by Singh et al. (1986). This leaves wide opportunity for development of structural models and empirical assessment.

3.2. Model: Incorporating labor allocation for water collection

Labor allocation for water collection displaces household's labor from productive activities such as agricultural production and off-farm employment (Harvey and Taylor, 2000). A farm household that is located in an area with a well-built infrastructure may not need to worry about the time spent looking for clean water and its impact on total productive activities. But in developing countries like Ethiopia, only less than 30% percent of the rural farm households have access to clean water. The Ethiopia Rural Household Survey (ERHS) dataset 1989-2009 shows that on average households with no access to clean water allocate up to three hours of their productive time per day for water collection. This problem has been long recognized and there are governmental and non-governmental organizations working to alleviate the problem; however there is a lack of studies which assess the economic impact of the problem. In this part of this study an empirical model will be developed which incorporates the labor allocation for water collection into the agricultural household model. The model will enable assessing if the total time spent looking for clean water has significant impact on the households' economy as well as food security.

The household as a consumer faces standard utility maximization problem under the assumption of separated production and consumption decisions. Assume a well behaved utility function as in equation 1:

$$U = U(\boldsymbol{X}, X_L) \text{ ……………………………… } (8)$$

Where - $\boldsymbol{X}$ is vector of consumption of commodities, and

X_L is consumption of leisure.

The difference between equation (1) and (8) is imbedded implicitly in the definition of consumption of leisure. In the former equation total time is allocated between off-farm and on-farm activities, and leisure. So, leisure is implicitly defined as total time minus household's total time of off-farm and on-farm activities. While in equation (8) total time is divided between off-farm and on-farm activities, water collection and leisure. Leisure is implicitly defined as total time minus time spent on off-farm and on-farm activities and water collection. The relationship between time allocated for water collection and utility is negative because time spared for water collection reduces the consumption of leisure, i.e.

$$\frac{dU}{dT_w} = \frac{dU}{dX_L}\frac{dX_L}{dT_w} < 0 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (8.1)$$

Where $-$ T_w is time allocated for water collection.

The budget constraint of the utility maximization is defined in the same way as equation (2) except the total time endowment of the household is divided between time allocated for water collection (T_w) and the rest of household activities (T).

$$\sum_{j=1}^{L} P_j X_j = \mathrm{P_L}(\mathrm{T}+T_w)+\sum_{\mathrm{j=1}}^{\mathrm{n}} \mathrm{P_j Q_j} - \sum_{\mathrm{i}}^{\mathrm{m}} \mathrm{P_i V_i} - \mathrm{P_L L} + \mathrm{E} \quad \ldots\ldots (9)$$

The modified Lagrangian function of utility maximization subject to budget constraint and production function is:

$$Ł = U(\boldsymbol{X}, X_L) + \lambda \left[P_L(\mathrm{T}+T_w) + \sum_{j=1}^{n} P_j Q_j - \sum_{i}^{m} P_i V_i - P_L L + E - \sum_{j=1}^{L} P_j X_j \right] + \mu[F(\boldsymbol{Q}, \boldsymbol{V}, \boldsymbol{K})] \ldots \ldots (10)$$

The first order conditions given by equations 4.1 – 4.6 still holds with slight modification on equation 4.2 provided by equation 10.1 and an additional first order condition because now the household have additional choice variable, which is time allocated for water collection.

$$\frac{dŁ}{d\lambda} = P_L(\mathrm{T}+T_w) + \sum_{j=1}^{n} P_j Q_j - \sum_{i}^{m} P_i V_i - P_L L + E - \sum_{j=1}^{L} P_j X_j = 0 \ldots \ldots \ldots (10.1)$$

$$\frac{dŁ}{dT_w} = \frac{dU}{dT_w} + \lambda P_L = 0 \ldots \ldots \ldots (10.2)$$

With the changes made so far the method of analysis reviewed under the separated production and consumption decision of the agricultural household model (section 3.1.1.) holds. In line with Barnum and Squire (1979), Straus (1986b) and Sicular (1986) solving the first order derivatives arranged into a system of linear equations in matrix form provides solutions for commodity demands, marginal utility of full income, output supplies, variable input demands, labor supply for water collection and associated multipliers.

4. Empirical Application

4.1. Background of the Study Areas

The Ethiopian government (official name Federal Democratic Republic of Ethiopia) is organized as Federal state → Regional state → Zone → Woreda → Kebele (or Peasant Association). Kebele is the smallest unit of government. It is composed of smaller villages and individual households. Woreda contains several adjacent kebeles. Likewise zone contains adjacent woredas and regional states comprise adjacent zones. Each regional state is a semi-autonomous body with its own governor or president. There are nine regional states - Tigray, Afar, Amhara, Oromiya, Somali, Benishangul/Gumuz, Southern Nations Nationalities and Peoples, Gambella, and Harar. The regional states have the power to make fiscal decisions and they are directly accountable to the Federal Government. In addition Addis Ababa City administration and Dire Dawa city council are independent administrative states. They are directly accountable to the Federal Government of Ethiopia as well. Further all the regions are divided into 800 woredas and around 15,000 kebeles (5,000 Urban & 10,000 Rural). Except at two of the regional states, it is woredas that have the significant local power. Their decisions directly affect the welfare of the citizens. In the two regions it is zones that have the local power. In these regions, woredas are directly accountable to zones and fiscal decisions like budget is made at zone level (Hailu, 2000; FDRE, 2008).

The cross section data used for this study comes from the Ethiopia Rural Household Survey (ERHS) dataset 1989-2009. The survey was conducted in six different years (1994, 1995, 1997, 1999, 2004 and 2009) by selecting 15 villages stratified by main agro-ecological zones and sub-zones giving a sample of 1477 households. To select a sample of random households from the villages, first the list of the households were organized in association with the Kebele officials. Then the households are stratified by household head, weather a household is headed by woman or man. Random households are selected from both groups and surveyed (Dercon & Hoddinott, 2011). Table 1 provides background of the survey sites.

Table 1: Characteristics of the sample sites. Source: Dercon and Hoddinott (2011)

Survey site	Location	Background	Main crops	Perennial crops?	Mean Rainfall in mm
Haresaw	Tigray	Poor and vulnerable area.	Cereals	no	558
Geblen	Tigray	Poor and vulnerable area; used to be quite wealthy.	Cereals	no	504
Dinki	North Shoa	Badly affected in famine in 84/85; not easily accessible even though near Debre Berhan.	Millet, teff	no	1664
Debre Berhan	North Shoa	Highland site. Near town.	Teff, barley, beans	no	919
Yetmen	Gojjam	Near Bichena. Ox-plough cereal farming system of highlands.	Teff, wheat and beans	no	1241
Shumsha	South Wollo	Poor area in neighborhood of airport near Lalibela.	Cereals	no	654
Sirbana Godeti	Shoa	Near Debre Zeit. Rich area. Much targeted by agricultural policy. Cereal, ox-plough system.	Teff	no	672
Adele Keke	Hararghe	Highland site. Drought in 85/86	Millet, maize, coffee, chat	yes, no food	748
Korodegaga	Arssi	Poor cropping area in neighborhood of rich valley.	Cereals	no	874
Turfe Kechemane	South Shoa	Near Shashemene. Ox-plough, rich cereal area. Highlands.	Wheat, barley, teff, potatoes	yes, some	812
Imdibir	Shoa (Gurage)	Densely populated enset area.	Enset, chat, coffee, maize	yes, including food	2205
Aze Deboa	Shoa (Kembata)	Densely populated. Long tradition of substantial seasonal and temporary migration.	Enset, coffee, maize, teff, sorghum	yes, including food	1509
Addado	Sidamo (Dilla)	Rich coffee producing area; densely populated.	Coffee, enset	yes, including food	1417
Gara Godo	Sidamo (Wolayta)	Densely packed enset-farming area. Famine in 83/84. Malaria in mid-88.	Barley, enset	yes, including food	1245
Doma	Gama Gofa	Resettlement Area (1985); Semi-arid; droughts in 85, 88, 89, 90; remote.	Enset, maize	yes, some	1150

According to the summary provided by Dercon and Hoddinott (2011), out of the total households included in the sample 32.4% are from grain ploughing central highlands of Ethiopia which comprises 27.7% of the country's total population. 25.6% of the sample comes for Arsi/Bale which is also a grain ploughing area in central Ethiopia and it holds 9.3% of the country's total population. 12.4% of the sample is from Sorghum plough/hoe Hararghe area in the east of Ethiopia holding 9.9% of the total population. 29.6% of the sample comes from Enset producing areas of southern Ethiopia which holds 31.9% of the total population. Five of the fifteen villages surveyed are enset producing. Enset (scientific name Enset Ventricosum) is a perennial herb with edible corm, supporting about 13 million people in Ethiopia (Amede and Delve, 2006).

4.2. Dataset

The publicly available Ethiopian Rural Household Surveys dataset (2011) from 1989 to 2009 provides comprehensive household level data on household characteristics, agriculture and livestock information, food consumption, health, women's activities, as well as community level data on electricity and water, sewage and toilet facilities, health services, education, NGO activity, migration, wages, and production and marketing (Dercon & Hoddinott, 2011). The availability of this dataset has considerably reduced the financial cost and time required to collect such data for this study. The publishers require that any study which chooses to use the dataset must contain the following acknowledgement:

> *"These data have been made available by the Economics Department, Addis Ababa University, the Centre for the Study of African Economies, University of Oxford and the International Food Policy Research Institute. Funding for data collection was provided by the Economic and Social Research Council (ESRC), the Swedish International Development Agency (SIDA) and the United States Agency for International Development (USAID); the preparation of the public release version of these data was supported, in part, by the World Bank. AAU, CSAE, IFPRI, ESRC, SIDA, USAID and the World Bank are not responsible for any errors in these data or for their use or interpretation."*

For this thesis, cross sectional data for the year 2009 is extracted and organized from the survey for production and consumption related variables. The variables are summarized on table 2.

Table 2: Data summary. Data source: Ethiopian Rural Household Surveys Dataset (2011)

Variables		**Mean**	**std. Dev.**
Agriculture Productions	Barely (in Kg)	633.6245	906.1408
	Wheat (in Kg)	977.1268	1951.084
	White Teff (in Kg)	582.1974	1341.079
	Black Teff (in Kg)	288.2727	258.106
	Sorghum (in Kg)	381.1397	371.2853
	Maize (in Kg)	634.4357	1045.236
Per capita food expenditure in Birr		165.9143	131.2337
Area of harvested land in hectares		1.161882	1.20682
Number of oxen		1.253404	1.379012
Fertilizer use in kg		86.22656	133.8057
Number of Adult labor in the household		1.845972	5.0528
Number of Hired labor		1.675005	7.366236
Time required to reach to a water source in minutes per day		16.11044	17.03943
Production capital in Birr		385.2985	1141.376
Number of visits by extension service agent		5.835855	12.17913
Annual total income in Birr		3579.457	6847.143
Current total Livestock endowment in Birr		7946.609	11310.81
Household size		5.687546	2.567312
household head's schooling years		1.694915	2.758962
Age of household head		51.34342	17.13327
Number of household heads at least with one years of education		669 (49%)	
Water harvesting number of households		160 (12%)	
Number of households whose one or more crop is severely affected during the last harvesting season		568 (42%)	
Irrigating number of households		332 (25%)	
Number of male headed households		828 (61%)	
Number of enset producing households		349 (26%)	
Total observations 1350			

The main agricultural products produced in the surveyed villages are barely, wheat, white teff, black teff, sorghum and maize. In addition 26% of the households produce enset. Only 25% of the households practice irrigation on a smaller share of their harvested land and only 12% are involved in water harvesting. Approximately 42% of the households report that one or more crops have been severely affected by unfavorable weather conditions in the last harvesting season. 61% of the households have male heads with an average age of 51 and family size of 5. The average schooling years of the household heads in the sample is 1.7 years and 49% of the household heads have at least a one year of education.

Subsistence agriculture is commonly practiced with an average land holding of 1.2 hectares, one ox on average, and an average use of 86 kilograms of fertilizer per harvesting season. The average allocation of domestic adult labor on different plots owned by the households is about 1.8 and hired labor is about 1.7. An average household owns a production capital worth about 385 birr and has been visited by an extension agent about 6 times in the past five years. In addition, the average livestock endowment of the sample households is worth 7946 birr and average total income including sales from agricultural outputs is 3579 birr and the average per capita food expenditure is 166 birr.

On average the households spend 16 minutes to reach a water source, maximum time reaching up to 3 hours in the data. The total time depends on the proximity of households to a water source that they depend on for daily supply. Households that are situated far from a water source require longer time.

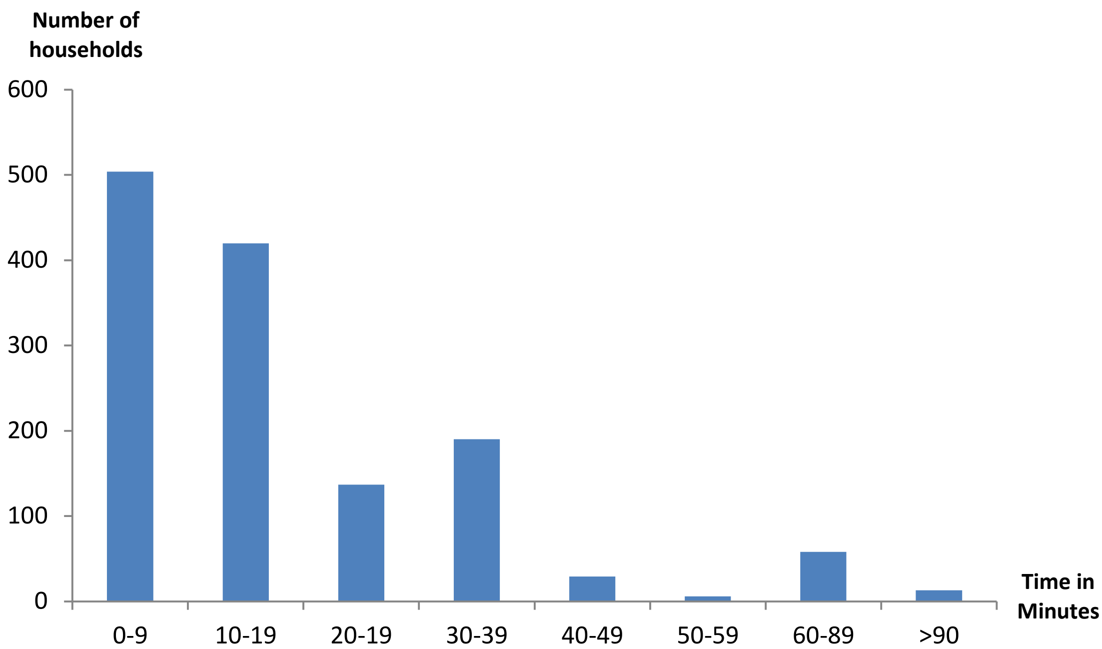

Figure 3: Length of time households need to reach a water source.

Furthermore, the relationship between the time required by the households to reach a water source and their wealth illustrated on Figure 3 shows that wealthier households spend less time collecting water daily. However, a detailed investigation of the survey data shows that water sources such as borehole, well and piped water are geographically almost equally distributed for both high income and low income households. Wealthier households spend less time collecting water because they have better means of transportation such as donkeys for carrying water and small motor vehicles.

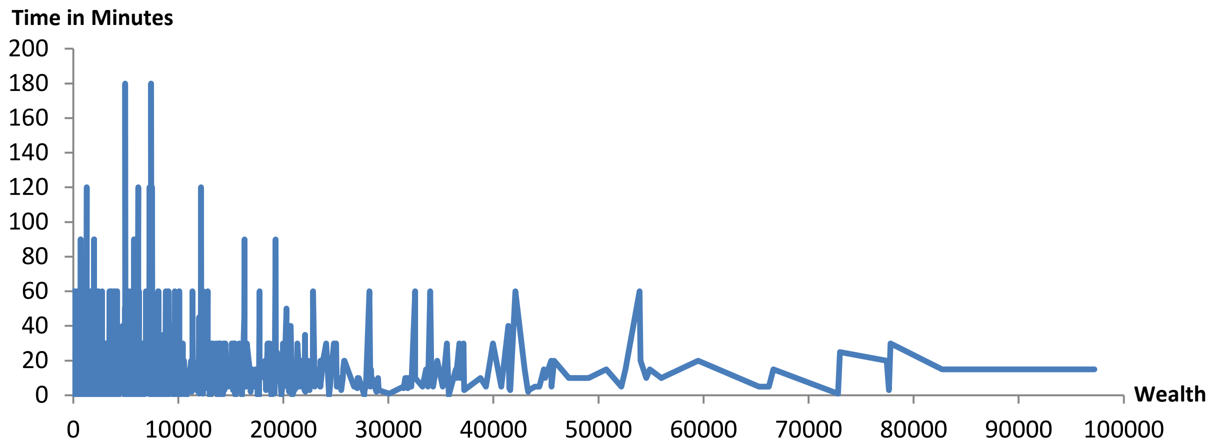

Figure 4: Plot between wealth measured in livestock endowment and required time to reach a water source.

4.3. Econometric Model Specification

The agricultural household model provides a holistic framework to analyze the economic relations of production and consumption decision in the farm household. The recursive agricultural household model has an advantage of econometric estimation simplicity and it is best suitable for the available data. The separation property of the recursive model enables separate estimation of consumption and production sectors. However, when one of the assumptions does not hold it will result in inconsistent estimators. According to Delforce (1994) the problem is significant for studies that focus on production side than consumption. As the focus of this study is investigating determinants of food security, the study inclines to consumption side.

Assuming that the assumptions of the recursive model holds, first the production function will be defined. Then food demand equation will be specified using the utility maximization results of the agricultural household model.

The production side parameters are estimated using the Cobb-Douglas production function which is one of the most widely used functional forms. In the simple Cobb-Douglas production function output is a function of labor and capital. However, there are more variables than just the two which can significantly affect production such as fertilizer and land. In order to incorporate these variables in the production function we adopt General Cobb-Douglas production function developed by Diewert (1973). Diewert (1973) shows that the General Cobb-Douglas production function satisfies properties of standard production function which are non-negative, non-decreasing, continuous and quasi-concave.

The Generalized Cobb-Douglas production function is given by:

$$y = k \prod_{i=1}^{n} \prod_{j=1}^{n} \left(\frac{1}{2} x_i + \frac{1}{2} x_j \right)^{\alpha_{ij}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(8)}$$

Where y is output, $x_1, \ldots, x_n$ are quantities of the n inputs, k>0, $\alpha_{ij} = \alpha_{ji}$ and $\sum_{i=1}^{n} \sum_{j=1}^{n} \alpha_{ij} = 1$ (which is the assumption of constant returns to scale).

Assuming that $\alpha_{ij} = 0$ for all $i \neq j$, and taking natural log of equation (8) gives a standard Cobb-Douglas equation with many inputs, which is to be estimated. In its natural log form:

$$lny = \alpha_0 + \sum_{i=1}^{n} \alpha_i lnx_i + e \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(9)}$$

Where $\alpha_0 = lnk$ (k is the constant term in equation 8), and e is the error term

Even though the generalized Cobb-Douglas production function can handle a large number of inputs and satisfies properties of a standard production function it 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. These assumptions make it difficult for the Cobb-Douglas model to measure technical efficiency levels and growth effectively. Murthy (2004) argues that as long as factors are paid according to their relative shares the assumption about market does not significantly affect the estimation power of Cobb-Douglas production function. Moreover it 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. Moreover, according to Miller (2008), given that the assumptions hold, the Cobb-Douglas production function fits very well to the real world data.

The aim of this study would have been addressed better if consumption side is estimated with calorie intake as an independent variable. But due to limited data I am forced to approximate calorie intake by per capita food expenditure. In order to estimate consumption side, it is assumed that the demand equation from the utility maximization of the recursive household model has a functional form of log-linear. The log-linear demand equation is widely used because the estimated coefficients are the respective elasticities of demand and it is capable of modeling nonlinear effects. According to Oum (1989) the log linear demand function resembles the demand function obtainable form a Cobb-Douglas utility function. Oum (1989) states that the main drawback of the log linear demand model is that estimated elasticities are invariant across all data points, and not dependent on the location of the demand curve. But this is a problem only for studies that are interested in investigating variations in elasticities across different cross section and over time. Rather than estimating single demand equations for each product consumed or for each individual member of the household, aggregate demand equation per household is estimated for per capita food consumption expenditure.

$$lnK = \beta_0 + \sum_{i=1}^{n} lnx_i + u \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

Where - K is household’s per capita food consumption expenditure;

x_i for $i = 1 \ldots n$, includes consumption side variables and household characteristics;

u is an error term which is assumed to be uncorrelated with the production function error term e.

5. Estimation, Results and Discussion

Often survey data suffer from measurement error and missing data owing to reasons such as unwillingness of respondents to give valuable information. In such cases some observations will not be consistent with the rest of the data set and distort estimation because they constitute either outliers or missing values. Before immersing into estimation it is important to check the consistency of the observations included in the data set. According to Gujarati (2003) observations that distort estimation are outliers, leverages or combinations of the two, which are sometimes called influential points. Outliers are observations with significantly higher residuals than the rest of the observations. Leverages are observations with significantly high value of an explanatory variable. Few of the reasons for the occurrence of such observations are missing data, measurement error or data entry error. For instance, in one of the detected outliers in the data set organized for this study, the household has reported high income, land endowment and household size, but no output or consumption expenditure. Such observation result from important missing data and they have the ability to distort estimation. Their influence can be seen by estimating with and without such observations. Outliers and leverages need to be carefully examined in order to determine if they are results of data collection error or combination of unusual conditions which might reveal important information. Upon determining causes of data distorting observation, if necessary they have to be removed from the data set for the sake of reliable estimation. Such observations have been identified using Cook's D and DFITS statistic, which provide the aggregate impact of outliers and leverages. After a thorough examination, from all the distorting observations 50 were dropped from the dataset, which is about 3% of the total sample observations.

5.1. Production Sector of the Farm Household

Production sector of the farm households is estimated using ordinary least square (OLS) on log transformed form of the Generalized Cob-Douglas production function specified in section 4.3. The dependent variable is aggregate household agricultural production, which is the monetary sum of all crops produced during the surveyed production season. The explanatory variables included are:

Harvested land – which is the summation of all plots of lands used by the household for crop production, in hectares. Harvested land size is expected to have a positive impact on production because assuming that the additional unit of land is arable, increasing land size increases agricultural production.

Oxen – is the number of oxen that the household owns and uses for agricultural production purposes such as ploughing and threshing. The number of oxen is also expected to have positive relationship with production.

Adult labor – is the number of adult members of the household who are involved in farm activities. Adult labor being one of the vital inputs of agricultural output of rural farm households it is expected to have direct relation with production.

Hired labor – is the number of labor hired from outside during the surveyed harvesting season. Hired labor is also expected to exhibit positive sign.

Fertilizer – is total kilograms of fertilizer used. Keeping other inputs constant a unit increase in use of fertilizer is expected to result in an increase in agricultural production.

Time spent looking for water – is the total time in minutes that the household requires to reach the water source. Allocating labor time for water fetching diverts productive labor from farm activities. So its estimated coefficient is expected to have negative sign.

Extension service – is the numbers of times that a household has been visited by a government extension service agent in the last five years. The data on extension service is available as the number of visits in last five years and the duration is acceptable because the main purpose of extension service agents is to teach modern agricultural methods. Leaving centuries old agricultural practices and migrating to modern ways requires years to be completely adopted. Once adopted, modern agricultural practices provide better technology leading to an increase in production. So extension service is expected to have a positive relationship with agricultural production.

Production capital – is the monetary value of production equipment owned by the household such as hoe, ploughs, and sickle. An additional unit of capital is expected to have a positive impact on production.

Dummy for water harvesting – is a dummy variable which is equal to one if the household has been involved in water harvesting. Water harvesting enables households to save water during rainy seasons to be used during dry seasons. So it is expected to show positive relation with agricultural output.

Dummy for season – is a dummy variable which is equal to one if one or more crops were severely affected by weather condition in the previous harvesting season. It is expected to have negative sign because weather conditions that have the ability to severely affect one or more crops also have the potential to degrade agricultural land.

Dummy for irrigation – is a dummy variable which is equal to one if the household irrigates any portion of the land harvested. Irrigation provides sustainable water for agriculture; hence its estimated coefficient is expected to have positive sign.

Table 3: OLS result of estimated production function. Dependent variable: aggregate household agricultural production. (*** p<0.01, ** p<0.05, * p<0.1)

Explanatory variables	Coefficients (standard errors)
Log harvested land	1.849*** (0.128)
Log oxen	0.181* (0.0999)
Log fertilizer	0.211*** (0.0232)
Log adult labor	0.0725 (0.0643)
Log hired labor	0.000355 (0.0454)
Log time spent looking for water	-0.205*** (0.0477)
Log production capital	0.135*** (0.0431)
Log extension service	0.0186 (0.0358)
Dummy for water harvesting	0.0264 (0.138)
Dummy for season	-0.113 (0.0809)
Dummy for irrigation	0.0409 (0.0978)
Constant	5.626*** (0.239)
	Observations 1,224 R-squared 0.503

The distribution of land by household head's age indicates that households with head aged between 30 and 60 own more land than the rest. The interaction effect of household head's age and land endowment on production is investigated by creating an interaction variable. Including this variable resulted in a positive but insignificant coefficient. In addition introducing the interaction variable resulted in high variance inflation factor (VIF)[3] indicating existence of multicollinearity. As a result it has not been included in the main analysis.

The result of estimation of production function presented on Table 3 shows that statistically significant variables are harvested land, fertilizer, time spent looking for water, production capital, and number of oxen. The estimation also shows that all explanatory variables exhibit theoretically expected signs.

Land being a vital input of agriculture it has the highest coefficient (1.849), which is significant at 1% and positive. The estimated coefficient shows that when land possession of the farm households increase by one percent agricultural production increases by 1.85 percent. This finding is in line with the findings of Nisrane et al. (2011). In their study of sources of growth and inefficiency in agricultural production in Ethiopia, they estimate determinants of production and find out that the size of cultivated land is the largest coefficient and it is positive and significant determinant of agricultural production growth.

The main contents of fertilizer such as nitrogen, phosphorus and potash are important nutrients for crop production and productivity making it one of the important determinants of agricultural productions. As shown on Table 3, in this study fertilizer is found to be significant variable at 1%, with the second largest coefficient of 0.211. This indicates that a one percent increase in fertilizer use leads to a 0.211 percent increase in agricultural outputs. As studies conducted elsewhere, studies conducted in Ethiopia too (such as Demeke et al., 2011; Kidane, 2005; and Nisrane et al., 2011) show that fertilizer is one of the vital inputs to agricultural production. Based on the significance of fertilizer for crop production it might be expected to have a higher coefficient, but Nisrane et al. (2011) also finds a smaller coefficient and argues that it is because fertilizer needs to be combined with other inputs such as water and improved seeds in order to increase production.

[3] "VIF shows how the variance of an estimator is *inflated* by the presence of multicollinearity" (Gujarati, 2003).

The main capital input used by rural farm households of Ethiopia for ploughing and threshing is oxen. The agricultural use of oxen for the rural households can be considered as an equivalent substitute of the uses of tractor and combine for large scale commercial farms. In this analysis number of oxen is found to be significant at 10% with a coefficient of 0.181. A one percent increase in the number of oxen owned by a household leads to a 0.181 percent increase in the households agricultural output. Another capital input included in the analysis is production capital which is the monetary value of production equipment owned by the household such as hoe, ploughs, and sickle. It is found to be statistically significant at 1%. A one percent increase in production equipment has the ability to increase agricultural output by 0.135 percent.

Time spent looking for water is an explanatory variable included to capture the impact of labor allocation for water collection on agricultural production. This variable is found to be significant at 1%. A one percent increase in time spent looking for water decreases agricultural production by 0.205 percent implying a negative relationship as expected. Another water related variable included in the production function estimation is dummy variable for water harvesting. This variable is not found to be significant even though it has a positive coefficient. The dummy variable incorporated to capture the impact of irrigating any portion of the total land harvested on the rural households' agricultural production is also not statistically significant but estimation has resulted in a positive sign as expected.

Moreover, the rest of explanatory variables, which are adult labor, hired labor, number of times a household is visited by extension service agent, and the dummy variable for the impact of previous season, are not found to be statistically significant but their coefficients exhibit expected signs.

5.2. Consumption Sector of the Farm Household

The utility maximization objective of the farm household is analyzed using the demand functions resulting from maximized utility subject to budget constraint and technology constraint of farm production. As stated in section 4.3, per capita food expenditure equation is formulated based on the resulting demand equations of the maximization problem and estimated using the following explanatory variables:

Total income – is the households' total income composed of off-farm employment, transfers, sales of agricultural outputs and income generated from business activities. Keeping other variables constant, an increase in the household's total income is expected to increase food consumption expenditure. So, total income is expected to have positive coefficient.

Output – is the monetary summation of all of the household's agricultural outputs. It is also expected to have a positive relationship with food consumption expenditure.

Livestock – is the monetary value of the household's livestock endowment. In rural farm households livestock serves as both food source and security against difficult times when crop production fails. It is expected to have positive effect.

Time spent looking for water – is the total time in minutes that the household requires to reach a water source. Allocating labor time for water fetching diverts productive labor from household activities so its estimated coefficient is expected to have negative sign.

Household size – is the number of members of the household. Keeping other factors constant, increasing the number of household members decreases consumption per capita. So its estimated coefficient is expected to have negative sign.

Dummy for gender of household head – is a dummy variable which is equal to one if the household head is male, zero otherwise. It is expected to have positive sign because male heads are given higher status in the social and economic activities of the rural society.

Dummy for season - is a dummy variable which is equal to one if one or more crops were severely affected by weather condition in the previous harvesting season. It is expected to have negative sign because bad weather conditions will reduce production and food stored for the next season.

Dummy for Enset – is a dummy variable which is equal to one if the household produces enset. It is expected to have positive sign because enset is an additional source of food and security against drought due to drought resistance nature of the plant.

In addition the impact of interaction effect between schooling years and income was investigated by creating an interaction variable and it did not result in any significant outcome. Per capita food consumption expenditure function is estimated using instrumental variable regression. Total Income is instrumented by schooling years and age of household head. Schooling years measures the number of years the households head spent in school. The household head's general knowledge is expected to increase with increasing years of schooling because education is expected to enhance the household head's critical thinking ability leading to better household management and income generating skills. In addition age of household head can be taken as equivalent to work experience. Knowledge and experience are expected to influence total income positively.

Table 4: Instrumental variable, 2SLS estimation result of estimated per capita food expenditure function. Dependent variable: per capita food consumption expenditure. (*** p<0.01, ** p<0.05, * p<0.1)

Explanatory variables	Coefficients (standard errors)
Log total income	0.547** (0.251)
Log output	0.0125 (0.0563)
Log livestock	0.0257 (0.0306)
Log time spent looking for water	-0.0529** (0.0258)
Log household size	-0.805*** (0.178)
Dummy for gender of household head	0.122* (0.0651)
Dummy for season	0.118*** (0.0450)
Dummy enset	-0.0259 (0.0590)
Constant	1.770* (1.028)
First stage regression result	
Schooling years	0.146*** (0.0534)
Age of household head	0.079 (0.1103)
	Observations 1,357

The first stage regression results of two stage least square (2sls) shows that both instruments have positive relationship with income but only schooling years is found to be statistically significant. The validity of the instruments is confirmed using Sargan test of joint null hypothesis that the instruments are valid instruments. P-values of Sargan test shows that the null hypothesis cannot be rejected at 1%, 5% or 10%, implying that the instruments are valid. In addition endogeneity of total income is verified using Wu-Hausman test of the null hypothesis that the regressor is exogenous. The null hypothesis is rejected at 5% indicating that setting total income as endogenous and using instrumental variables is statistically acceptable.

The final estimation results show that the variables total income and time spent looking for water are statistically significant at the 5% level, household size and the dummy for season at the 1% level, while the dummy for the gender of household head is significant at the 10% level. All the explanatory variables have the expected signs except dummy for season and enset.

Total income of the household which consists of income generated from off-farm employment, business activities, transfers and agricultural production sales have the highest coefficient. It shows that a one percent increase in total income leads to 0.5 percent increase in per capita food expenditure. The studies of Njimanted (2006) in rural Cameroon and Demeke (2011) in rural Ethiopia also show that household income is one of the major determinants of food expenditure and food security in rural societies.

Another significant determinant of per capita food expenditure is household size. It has a negative coefficient as expected. A one percent increase in the number of member of a household leads to 0.805 percent decrease in per capita food expenditure. This result is in line with the findings of Ramakrishna and Demeke (2002) in Ethiopia and Nyariki et al. (2002) in Kenya. But the studies of Alene and Manyong (2006) in Nigeria, and Toulmin (1986) in Mali find positive relationship between household size and per capita food expenditure. They argue that households with more members have better opportunity to earn income from diversified sources which increases income earring leading to higher food expenditure and food security.

The dummy variable included to capture the impact of previous season is found to be significant but with a different sign than expected. The estimated coefficient shows that a weather condition that has severely affected one or more crops during the last season increases per capita food expenditure by 0.12 percent. A negative sign was expected based on a premise that bad weather reduces production and food stored for the next season. A possible explanation for the unexpected sign might come from the composition of the rural households' food consumption. In the rural parts of Ethiopia it has been customary to receive food aid from the government when crop production fails due to unfavorable weather condition. It is probable that food aid increases when the weather condition gets worse leading to a positive relationship with food consumption. The scope and analysis of this study does not enable to verify this condition therefore it is left for future studies. In addition the dummy variable for enset production has also resulted unexpected negative sign. Enset is known to be drought resistant source of food and income in southern Ethiopia. But it is not found to be significant in this study.

Time spent looking for water has resulted in a negative sign as expected and it is found to be significant determinant of per capita food expenditure. A one percent increase in minutes traveled to fetch water leads to a 0.05 percent decrease in per capita food expenditure. The dummy variable for the gender of household head is also found to be significant and it has expected positive sign. The estimated coefficient shows that household with male head has an advantage of 0.122 percent increment in per capita food expenditure. The sign is in line with the findings of Dercon et al. (2005), whose study shows negative but insignificant relationship between female headed households and per capita consumption.

In most studies of rural households agricultural output and livestock are significant determinants of food expenditure and food security (see for example Singh et al. 1986; Webb et al. 1992; Yared et al. 1999; Shiferaw et al. 2003; Dercon et al. 2005). In this study, even though they have positive signs as expected, they are not found to be statistically significant.

5.3. Food Security and Labor Allocation for Water Collection

In rural Ethiopia households spend a significant share of their daily productive time looking for clean water for drinking and other household activities such as cooking. The median household in the sample data of this study spends up to one hour to travel to a water source. The labor hour allocated for water collection reduces the total time available for productive activities in addition to the reduction on the households' leisure consumption. Its impact on agricultural production is investigated through the production sector of the farm household and its direct impact on household's utility is explored through consumption sector. Aggregate of the two will show the total effect.

In the econometric specification of section 4.3 per capita food expenditure is defined as a function of total income, time spent looking for water and the rest of the variables. Further in the budget constraint total income is defined as

$$I = \mathrm{P_L T} + \sum_{j=1}^{n} \mathrm{P_j Q_j} - \sum_{i}^{m} \mathrm{P_i V_i} - \mathrm{P_L L} + \mathrm{E} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

$$I = \mathrm{P_L T} + y + \mathrm{E} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (12)$$

Where $y = \sum_{j=1}^{n} \mathrm{P_j Q_j} - \sum_{i}^{m} \mathrm{P_i V_i} - \mathrm{P_L L}$, which is equal to net agricultural output or equivalently profit from agricultural production.

Where total income of the household (I) 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 which is generated outside the household such as remittance.

Moreover agricultural output is defined as a function of the time spent looking for water and the rest of the explanatory variables. The total impact of time spent looking for water on per capita food expenditure is:

$$\frac{dk}{dT_w} = \frac{dk}{dI}\frac{d\mathrm{I}}{dT_w} + \frac{dk}{dT_w}$$

$$\frac{d\mathrm{I}}{dT_w} = \frac{d(\mathrm{P_L T + y + E})}{dT_w} = \frac{dy}{dT_w} = -0.205$$

$$\frac{dk}{dT_w} = (0.547)(-0.205) + (-0.0529) = -0.165$$

The total impact of time spent looking for water on per capita food consumption expenditure is -0.165. This implies that for a one percent increase in minutes traveled to a water source, per capita food consumption will decrease by 0.165 percent. The median household of the sample data spends about 60 minutes to reach water source and have per capita food consumption expenditure of 200 birr. For the median household if minutes traveled to a water source decrease by 0.6 minutes it will increase per capita food consumption expenditure by 0.33 birr. This result is small but if it is aggregated per household per month it is about 60 birr which is equivalent to 5% of the household's total income per month. This implies that time spent looking for water has significant impact on the rural households' economy.

The results should be interpreted for food security with caution because food security is multi-dimensional, and includes more variables than food expenditure. According to FAO (1996) the dimensions of food security includes availability, access, utilization, and stability of nutritious food for active and healthy life. Households' food consumption expenditure indicates food availability and accessibility. However it does not show utilization or nutritious quality to meet the minimum requirement for a healthy life. Therefore the results of the analysis based on per capita food expenditure can be good indicators of necessary condition for food security but not sufficient. Thus this study shows that reducing time spent looking for water increases per capita food consumption expenditure and as a result enhances food security.

5.4. Sensitivity Analysis

Sensitivity of the production sector estimation is conducted in relation to household members who are responsible for water collection every day. In rural households all members participate in household activities with a varying degrees based on their age and physical status. It can be argued that children might contribute significantly in daily water collection if the distance traveled is not long. Households with higher number of children might cover a significant share of their daily water requirement with the help from young family members who can collect water using small equipment such as clay pots. If a household's water need is supplied by young members, adult members will be totally free for productive activities. Hence time spent on collecting water will not have significant effect on productive activities, which is mainly done by adult labor. To investigate this effect the production function was estimated adding a variable that is the number of children in the household. The result shows that coefficient of time spent looking for water is still negative and significant. The magnitude of its coefficient changes from -0.205 to -0.210, with a difference of 0.005. This implies that despite the number of children in a household, time spent looking for water has negative and significant effect on household's production.

In addition, both the production and consumption sectors estimation results' sensitivity to a variation in an observation was tested by varying each variable by ±25% and sample average from highest and lowest quartiles. For both sectors the estimated coefficient of time spent on collecting water remained negative and significant with a minor variation in magnitude.

Furthermore, heteroscedasticity test of the production function and consumption function implies existence of potential heteroscedasticity. According to Gujarati (2003) OLS and 2SLS estimates are unbiased in the presence of heteroscedasticity. However the existence of heteroscedasticity affects the magnitudes of standard errors of estimated coefficients and calculated t-statistic. In order to address this issue Robust Standard Error estimation technique was used, which is the most common remedy for the effect of Heteroscedasticity. It resulted in slight change of the variances as well as the standard errors but the significance of the coefficients remains the same.

6. Conclusion

Due to a lack of basic infrastructure, it is common in least developed countries that households spend a considerable share of the hours that they have available per day for production activities on fetching water. This study analyzes the economic impact of time spent looking for water on rural farm households of Ethiopia. The total effect of labor allocation for water collection on the household's economy is investigated by taking into account its impact on both agricultural production and consumption activities. This approach allows deviating from the common way of studying the impact of water availability on-farm households' economy that is investigating its impact through agricultural production.

For the analysis, the agricultural farm household model has been adopted and a variable capturing labor allocation for water collection has been integrated in the model. The estimated econometric model has been developed based on the results of the recursive agricultural household model. Based on this analytical framework, an empirical application has been presented based on econometric estimates using the Ethiopian Rural Household Surveys (2011) dataset.

The findings of the analysis show that time spent looking for water has a significant and negative effect on both production and consumption sectors. In aggregate production and consumption, reducing time spent on fetching water by one percent leads to an increase in per capita food consumption by 0.165 percent. Thus the total effect of labor allocation for water collection on food security approximated by per capita food consumption expenditure shows that reducing time spent on collecting water can have significant contribution to food security, and as a result improves development and welfare of the society.

Hopefully this study will help stakeholders who are working to alleviate water problems in Ethiopia as well as other developing countries to justify their actions with an economic study. Furthermore policy analysts can learn from this study's result that labor allocation for water collection has significant impact on-farm households' agricultural output and food consumption. It imposes a negative impact on food security by displacing productive labor away from productive activities. Measures aimed at reducing time spent looking for water can improve household's food security plus welfare of the society.

Regarding the approximation of food security by per capita food consumption expenditure, future studies can address the broader concept of food security by collecting survey data on daily calorie intake, sustainable food supply, and diversity of food intake in order to meet dietary need for healthy life. In this way the direct effect of time spent on collecting water on food security can be addressed. Moreover this thesis can be used as a ground to incorporate health, risk, management, political and social variables with water availability and asses the overall impact on food security.

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Appendix

A.1. Location of survey sites

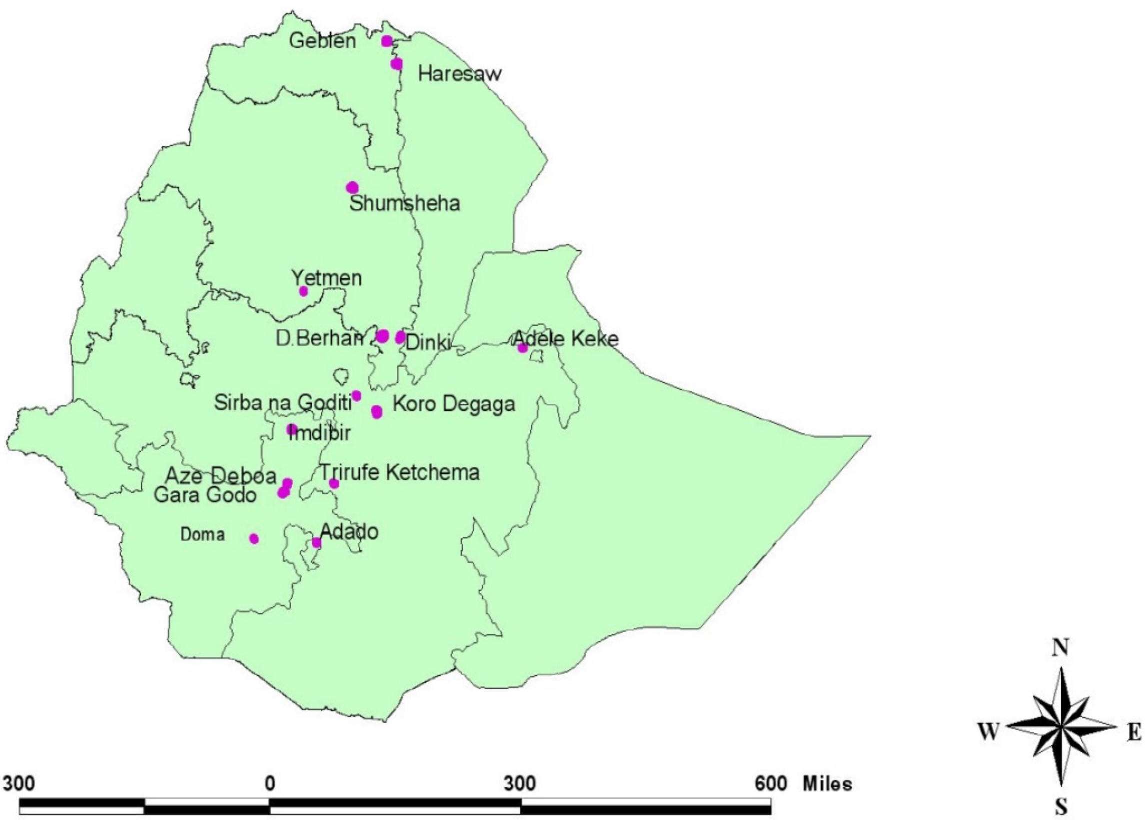

Figure 5: Ethiopian Rural Household Survey Villages. Source: Dercon and Hoddinott (2011)

A.2. Rainfall Distribution in Ethiopia

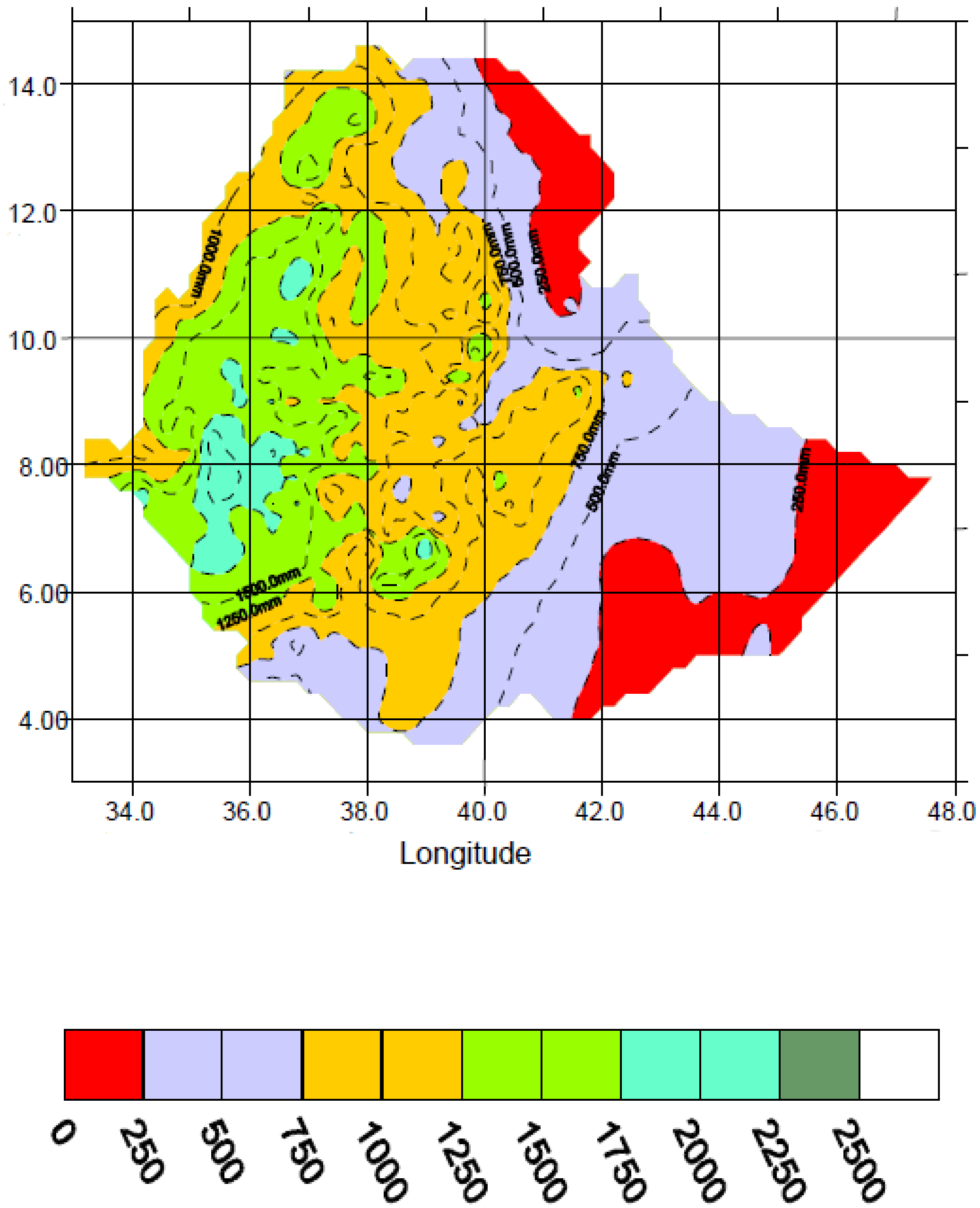

Figure 6: Cumulative Mean Annual Rainfall (mm). Source: National Meteorological Services Agency.