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Crop Mix and Rural Household Response to Shocks in Ethiopia: Household Modelling Approach: Evidence from Ada'a Woreda

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Abstract

This study assesses the response of rural households to output and input prices as well as technological changes in mixed crop production in Ethiopia, in the case of Ada'a woreda, by selecting a sample size of 100 households using a non-separable household modeling approach. The Cobb-Douglas function is used for the production and utility functions, and major constraints like land, labor, seed, and fertilizer are considered to find the optimum values that would enable the household to maximize their utility. The 7 most widely produced crops in the village were selected (teff, wheat, chickpea, lentil, bean, barley, and maize). The optimal value exposes that mono-cropping (teff production) is better than multiple cropping to maximize utility. Output price, factor price, and technology stocks were introduced to see how households respond and how and to what extent the production, consumption, and welfare of households are changed. The finding of the study reveals that households tend to leave the agricultural sector if all input prices are increased by 10%, which is the case when households face a minimum welfare level. When output prices increase by the same figure, farmers allocate all of their labor to the agricultural sector. A technological improvement of 20% on teff enables households to fully engage in agricultural activities and secure the highest utility compared to other shocks, while other crops are not responsive to technological change. This implies that stakeholders should focus on improving the method of production of teff in the village. In addition, the government should get involved in such a way that factor prices shouldn't be increased beyond a certain point.

Keywords: Crop mix, farm household, non-separable agricultural household, Nonlinear Program

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Introduction

Ethiopia is one of the poorest countries in the world. Famine attacks the country almost in every decade. The country is characterized by a large food self-sufficiency gap at the national level and food insecurity at the household level. People live in extreme poverty in the midst of plenty of fertile land and a relatively preserved environment. Due to the fact that a predominant portion of agricultural production takes place at the subsistence level, the government focuses mainly on agricultural investment on the smallholders. Together, these smallholders produce a yearly average of 12 million tons of cereals, which is 68 percent of total agricultural production. Averaged over the period 2004/05–2007/08 cereals were grown on 73.4 percent of the total area cultivated, by a total of 11.2 million farmers. Ethiopian smallholders are producing multiple of crops at the same time. In addition, the average land holding of Ethiopian farmers is 1.37 hectares. (Diao et al, 2005).

This calls for the implementation of land-saving techniques and technologies, i.e., increasing crop yields per unit of land. The main land-saving techniques appropriate to subsistence agriculture are: improved crop varieties and knowing the optimum mix of the crop to increase productivity which is the most effective and least costly mechanism. Problems normally faced by farmers include what to plant, how much to plant, and when to plant. Even though crop mix has enormous benefits, farmers in Ethiopia in general, and in Ada'a woreda, in particular, don't know the optimum level of crops to bring the best outcome and maximize their gain and utility. As a result, the optimal allocation of resources is not yet identified to boost up the farmers' income by maximizing their utility. Though they have experience in mixing crops, farmers do not know exactly the specification of the crop mix maximization problem given the constraints they have in a bid to maximize their utility. As a result, they are not familiar with the optimal bundle of crops that is supposed to be mixed in the production process. Households would be vulnerable to both output and input price shocks when they produce multiple crops at the same time. In addition, opting for the appropriate technology for each cereal makes it a daunting challenge for policy makers. Price of crops as well as basic inputs changes across time which requires the appropriate response of households by changing their crop mix.

Alison Kay Bittinger (2010) also examined crop diversification and technology adoption decisions made by households using a simultaneous equation model. His finding indicated that Ethiopian smallholders do react to changes in the level of market access by altering their product mix. Mixed crop production under a small-scale system is a risk management strategy and an important step for the transition from subsistence to commercial agriculture.

Reviewing the most notable empirics and findings, there are some strong research gaps that are supposed to be filled by this study. Among many, several studies have been carried out regarding crop mix efficiency; most of them are at the community or regional level, by analyzing consumption and production separately using secondary data; which is an inappropriate estimation in LDCs in general and in Ethiopia in particular. Besides, none of them apply the agricultural household model using GAMS software. Almost all consider farmers as if they make a separate economic decision as producers and as a consumer in a single model of addressing household problems. Besides, agricultural households allocate their labor to the range of activities. So how do they allocate their labor and other production factors in a way that enables them to maximize their utility? All these assessments require a rigorous modeling to fill this gap, a localized study at the household unit of analysis is crucial using the agricultural household model via GAMS. Moreover, consideration of the inseparable nature of decisions received heavy attention in this study in order to relate farm production and household consumption. Hence, this study will consider households that consume what they produce and decisions that are simultaneously or jointly determined, which is not the case in the standard microeconomic theory in which the production and consumption decisions are separable. This study will use the household model in Ada'a Woreda, specifically the selected study area by assessing how crop mixing and farm household utility will be maximized. And more of that how households respond to different external shocks like exogenous price, factor input price, and change in technology.

The principal objective in any crop mix problem is to search for an optimal combination of crops amongst those considered such that it maximizes the total overall contributions while satisfying a system of constraints such as land availability, capital, and others. In this regard, the main objective of the study is to examine and measure the rural farm household utility linked with crop mixing in Ethiopia, the case of Ada'a woreda. The specific objectives of the study are presented as follows: to measure the change in the price of agricultural outputs on the level of utility of the households; to measure the change in factor input price on the utility of the household, and to examine the effect of the change in technology on agricultural production setup of the household.

Literature Review

Theoretical literature review:

The household model is worth mentioning in the heart of micro aspects of development economics and considers the micro foundation of macro agricultural development by specifying the optimal decision of households given the constraints they have in order to maximize their objective function. Household-farm models are also a very useful tool to examine how household-specific economic behavior in general and transaction costs in particular respond to the change in exogenous policy and market changes in rural areas.

Households in several developing countries sustain their livelihood through producing goods and services, mainly agricultural products, by exploiting household labor as the main factor of production. By selling their output in the market, they maximize their profit and income given the constraint function. On the same pattern, they partly consume some portion of their own products. This peculiarly leads to households being a producer and consumers, unlike the traditional microeconomic theories. They make simultaneous decisions about production and consumption. Note that a production decision consists of the decision of output level, the demand for factors, and the choice of technology and consumption also incorporates the decision regarding labor supply and commodity demand. Such a mixture of the economics of households and firms at a time is typically a characteristic of most households in developing countries. The issue of separability and non-separability is a point of departure between microeconomics and household economics. Separability is the case where the consumption, production, and labor decisions are made separately, which is the standard microeconomic theory. The case of non-separability is where the household's production, consumption, and labor decisions are simultaneously or jointly determined (Jill et al., 2003).

One of the earliest models of a farm household was that of Chayanov (1925) who provided a theory of peasant behavior at the level of the individual family farm. He believed that behaviors of farm households were best understood in a household-firm framework, where potentially important interactions existed between external labor markets (non-farm labor markets), the farm operation, and household consumption. Chayanov hypothesized that households act to maximize utility by striking a balance between the satisfaction of consumption and distaste for labor or leisure. A related class of models based on Chayanov's ideas has become known as the new household economics (NHE) models, first introduced by Becker (1965). The new household economics models assume that the household acts as a unified unit of production and consumption, which aims to maximize utility subject to its production function, income, and total time constraint. The other model is Becker's (1981) unitary household model that forms the foundation of the agricultural household model (Singh, Squire and Strauss 1986), through its assumptions on household decision-making through a single household head.

The NHE framework is, however, widely adopted in many studies and has provided a foundation for the study of household behavior (Hossain, 1989). Nakajima (1986) also extended the NHE theory to agricultural households and developed several kinds of models depicting various agricultural household situations. These agricultural household models, also known as integrated, production-consumption models, integrated farm-household models, or simply farm household models, are important as they provide a framework for predicting the responses of farm households to variations in such things as output prices, input prices, wage rates, technology, and family structure. These models also incorporate aspects of farm-household choices regarding home consumption of output versus sale of output to purchase non-farm consumption needs.

Historically, household-farm models were first introduced to explain the counterintuitive empirical finding that an increase in the price of a staple did not significantly raise the market surplus in the rural sector of Japan (Yoshimi et al., 1978). The search for an explanation led to a model in which production and consumption decisions are linked because the deciding entity is both a producer, choosing the allocation of labor and other inputs to crop production, and a consumer, choosing the allocation of income from farm profit and labor sales to the good produced and consumed by the same household, and consumption included both purchased and self-produced goods. As long as perfect markets for all goods, including labor, exist, the household is indifferent between consuming own produced and market-purchased goods. By consuming all or part of its own output, which could alternatively be sold at a given market price, the household implicitly purchases goods from itself. By demanding leisure or allocating its time to household production activities, it implicitly buys its own time, valued at the market wage (Edward et al., 2002).

The agricultural household models are widely used in micro research on rural economies in order to examine, analyze price policy, technology adoption and deforestation and the like even in the context of imperfect-market environments in rural economies. Considering joint engagement of in production and consumption, it is possible to use household model and agricultural household model interchangeably. However, strictly speaking, agriculture model heavily engaged in the agricultural activities.

As the agricultural household model (AHM) is one type of the household model, it recognizes that agricultural producers, both produce and consume the agricultural output produced by the household – i.e., the model assumes that farm output is consumed by producing households, with the surplus being marketed, a reality for most farm households in developing countries (Singh, et al. 1986). Further, the model incorporates a farm production function, reflecting the returns to farm self-employment. Moreover, the agricultural household model assumes a nonlinear farm production function, assuming that the marginal returns to labor decline with increases in production. The simple economic household model typically assumes that households maximize household utility subject to a set of linear constraints in the wage rate – inclusion of a function reflecting farm self-employment returns means that the returns to labor are assumed not constant.

As both production and consumption decisions are linked, setting the optimal level in the allocation of labor and other inputs to crop production is a key role in the production side, and choosing the optimal level in the decision of income allocation from farm profits and labor sales to the consumption of commodities and services is also a crucial move in the consumption side. The profit they have incorporated implicit profits from the produced and consumed goods by the same household. Note that their consumption includes self-produced and purchased goods. If considering the perfect competitive market, households reach the same level of decision between consuming market-purchased and own-produced goods. There is also a tradeoff between work time and leisure time in allocating their time to produce agricultural outputs. Such allocation of time and resources also put on its own implications to production and consumption decision.

The fundamental difference between an agricultural household model and a pure consumer model is that, in the latter, the household budget is generally assumed to be fixed, whereas in household-farm models it is endogenous and depends on production decisions that contribute to income through farm profits. Thus, to the standard Slutsky effects of the consumer model, agricultural household models add an additional, “farm profit” effect, which may be positive (e.g., if the price of the home-produced staple increases) or negative (as when the market wage increases, compressing profits). In a consumer model, when the price of a normal good (say, food) increases, its demand unambiguously decreases: a negative "real income" effect reinforces a negative "substitution" effect, as illustrated in the most basic indifference-curve analysis. However, the household farm is both a consumer and producer of food. As a consumer, it is adversely affected by a higher food price, but as a producer, its profit from food production increases. This adds a positive "farm profit" effect of the negative Slutsky effects on food demand, pushing the budget constraint outward. If this profit effect outweighs the Slutsky effect, the household's demand for food increases with the food price (Inderjit et al., 1986).

A key assumption of most agricultural household models is that the household can obtain perfect substitutes for family labor in local labor markets—and conversely, that it can sell its own labor at a given market wage. This permits the household to decouple production from leisure: in response to a policy or market change, it can increase production (and demand more labor) while at the same time, consuming more leisure, by hiring workers to fill the resulting excess demand for labor. In its twofold role as consumer and producer, the households jointly put on the decision regarding production, consumption, and labor allocation in an interdependent way. Their objective function is to maximize a discounted future stream of expected utility subject to a large set of constraints. However, in most cases, several agricultural household models are static and households are considered risk neutral. In the end, a household-farm model generates a set of complex equations for all outputs, inputs, consumptions, prices, and the like.

Empirical Literature review:

Different studies are made using a household model. Among those: An econometric application of the theory of the farm household studied by (Howard H. Barnum & Lyn Squire, 1978), used Cobb Douglas specification for production function and modified linear expenditure system to analyze the impact of migration, output price, and technological change on the agricultural sector in Malaysia. And the result was, the economic cost of rural-urban migration is small in relation to the marginal productivity of the migrant prior to his departure; that the output price intervention is not effective in increasing marketed surplus; and that the benefits of increases in agricultural output prices and of improvements in technology are distributed through the labor market to those who rely heavily on wage employment as a major source of income.

A study made by Mariapia Mendola (2007) reviewed theoretical and empirical research on farm household production choices in developing countries. The paper focused on recent insights into the way peasant households manage the trade-off between income risk and expected returns when making production decisions in the context of weak or missing institutions. Several contributions point out that farm household behavioral responses to market imperfections in low-income settings may generate situations of efficiency losses and "poverty traps." Yet, the extent to which such vicious circles are generated by the farm household decision-making process itself was assessed in the study. Intra-household modeling farm-household system, by Maria Fay Rola-Rubzen and J. Brian Hardaker (1999), studied an Intra-Household Model of a

Farm-Household System in the Philippines. This model took into consideration intra-household dynamics. A number of factors were also considered such as the characteristics of the system being modeled, the risk environment faced by decision-makers, and the risk behavior and goals of the decision-makers.

A study made by Alemayehu Seyoum Taffesse (1998), titled, "An Economic Model of Ethiopian Farm Household", used the agricultural household model to capture three aspects of the policy regime characterizing the Derg period. These are compulsory grain, rationing in manufactured consumer goods, and rationing in modern farm inputs. The model involves two main innovations within the agricultural farm household modeling framework. First, a new procedure for analyzing the impact of the policy of forced grain procurement is introduced. The producer enables to directly characterize the effects of that policy on farm households' welfare, as well as the production and consumption choices they make. Second, it provided a more direct way of determining the welfare effects of rationing, grain delivery, price, & income.

Different studies have confirmed that intercropping provides a balanced diet, minimizes risks of crop failure due to adverse effects of pests, improves the use of limited resources, reduces soil erosion, increases yield stability, and produces higher returns (Anil et al., 1998). With the growing population pressure worldwide and particularly in African countries, the need to produce diverse products from ever-shrinking land holdings, farmers with subsistence living are becoming involved with intercropping of different crops. One way of increasing production by small farmers is to efficiently use all the resources available in the production process. Efficiency measurement is important because it leads to substantial resource savings (Bravo-ureta & Rieger, 1991). One of the strategies for increasing agricultural production is a combination of measures designed to increase the level of farm resources as well as make efficient use of the resources already committed to the farm sector. The analysis of efficiency is generally associated with the possibility of farms producing a certain optimal level of output from a given bundle of resources or a certain level of output at least cost.

Methodology of the Study

In contrast to the conventional models of the firm and of the household, the subjective farm-household model emphasizes the interdependence between consumption and production decisions which arise mainly as a consequence of the existence of endogenous prices of labor and non-traded goods.

Nevertheless, early applications of the agricultural household model typically assumed that consumption and production are separable or recursive. This is mainly due to econometric difficulties in estimating non-separable subjective equilibrium models. If recursively holds, production and consumption decisions are taken according to a two-stage process. In the first step, production decisions are taken to maximize profit with respect to the various outputs and input prices. In the second step, agricultural households choose their consumption and leisure levels conditional on the profit earned on the farm. Consumption decisions are influenced by production, but the reverse is not true. The decision process is said to be recursive, and corresponding models are said to be recursive or separable. At this stage, it is worth noting that the assumptions, allowing one to define a recursive model are rather restrictive: all markets are competitive and perfect, there are zero transaction and commuting costs, and family and hired labor are perfect substitutes in the production function, on- and off-farm family work are perfect substitutes in the utility function, (see, e.g., Strauss, 1986, De Janvry et al., 1991).

In this study, a household model, the particularly agricultural household model will be used to assess the profitability of the crop mix at a household unit level. The most widely used approach to modeling farm households is the econometric approach. Econometric methods are used to establish relationships between and among variables in the farm-household systems. Modeling farm households using econometric approaches involve the estimation of a set of functional relationships indicating the production behavior of a farm and the consumption behavior of the household with the use of production or profit functions and demand functions.

A conventional assumption in most complete econometric farm-household models is that production and consumption are separable. That is to say, production decisions are independent of consumption decisions. This assumption allows the model to be solved in a recursive manner whereby production decisions are first made, after which consumption decisions are made. The interaction between production and consumption can then be traced through the responses that have been estimated. And there are strict conditions needed to justify the separability assumption like the presence of perfect and complete markets and the assumption that production decisions can be made independently of consumption and labor supply decisions.

There have been some attempts to develop farm-household models that account for simultaneous decisions in production and consumption (Lopez 1984, Jacoby 1992). For example, Lopez (1984) modeled simultaneous decision-making in production and consumption in Canadian farm-households and concluded that non-separable models are theoretically and empirically sounder than separable models. However, as pointed out by Fleming and Hardaker (1991), there are some difficulties involved in dropping the assumption of separability in econometric models. One of the problems is the demanding data requirements which in many cases may not be met. A second problem is that the ensuing estimation procedures are complex if the separability assumption is dropped, and, at the same time, are also based on strong assumptions about farm-household behavior. Finally, model results are likely to be sensitive to changes in the specification (Fleming and Hardaker 1991). For these reasons, most econometric farm-household studies adopt the separability assumption.

However, for LDC country, where most of the population living with subsistence agrarian life, the separation property does not hold. Therefore, a model of household, which is jointly engaged in production and consumption commonly called the "Agricultural Household Model" (AHM) will be used in this research.

Population and Sample

In this study, both random and purposive sampling techniques are used. The 10 of the kebeles are selected using purposive sampling, which is kebeles located in rural areas of the selected Ada'a woreda in which the living households lead their lives based on agriculture. Therefore, from 23 kebeles 19 are selected, while the rest are located in cities. And out of the 19 kebeles, 10 were selected for sampling purposes. For the 100 households, random sampling is used in order to select the households that are going to be interviewed. So from each kebele, 10 households were selected with a total sample size of 100 households.

Source of Data

The study required both primary and secondary data. The primary data source is from the resident households who live in the specified area. A questionnaire in the form of an interview was used in order to get the data. Secondary data are collected from the central statistics agency (CSA), MOFED annual report, and Ethiopian Economic Association (EEA).

Model Specification and Estimation

The primary motivation for constructing agricultural household models is to understand the impacts of policies and other exogenous shocks on household-farm behavior. The household-farm model comprises a set of core equations of outputs, input demands, consumption demands, and prices (for household non-tradable) or marketed surplus (for household tradable). The solution to the household-farm model represents all dependent or endogenous variables as functions of exogenous variables (prices of tradable, farm assets, household time constraints, and other household characteristics), usually including some that are influenced by policy. The form of this solution, particularly the interactions between production and consumption determines resource allocation in the economy.

The difference between an agricultural household model and a pure consumer model is that the household budget is generally endogenously determined in the household model and hence depends on production decisions that contribute to income through farm profits. Rural households allocate their labor either to produce on the family farm or to sell on the labor market. This is typically the case in Ethiopian smallholder farmers. This ensures the prevalence of mixed effect on the household objective function given the fact that the effect of the increase in the price increase is to allocate more labor to on-farm production and less to wage work because the opportunity cost of labor on the farm has gone up. Alternatively (and, in the basic model, equivalently), it may continue to supply labor to the market while hiring workers needed to expand staple production and maximize profits.

The household model depicted below has the same functional specifications as Gabriel (2009). The utility function or the objective function of the household and the production function has a Cobb-Douglas functional form. Here, the household tends to maximize its utility from the consumption of goods services, and leisure. In the non-separable household model, the utility function contains goods produced and consumed by the farm household as well as purchased goods.

The amount of goods produced by the household is either greater than or equal to the amount consumed by the household itself and sold by the household to the market. The income of a household is from two main sources: exogenous income, from labor, and from the sales of goods and services. This total income will be expended to consume purchased goods or to purchase other intermediate inputs or labor. The amount of resources used such as labor and land are less than or equal to the amount of total resources supplied. This is what we call it resource constraint. The following model comprehensively depicted the above-mentioned specifications.

$$\max_{f_{ij},Ca_i,x_i,Cm_i,Cl_i,i_h} U \leq \alpha_u Cm_i^{\alpha_m} Cl_l^{\alpha_l} \prod_i Ca_i^{\alpha_i}$$

$$\beta_{i,\text{constant}} \prod_j f_{i,j}^{\alpha_i,j} \geq Ca_i + X_i$$

$$Y_x + \sum_i p_i x_i \geq \sum_i \left(p_m X_i + q_j f_{ij}\right) \pm wl_h$$

$$\sum_i f_{i,labour} + l_l < L$$

$$\sum_i f_{i,land} < A$$

$$f_{xj} \geq 0, Ca_i, X_i, Cm_i \geq 0, l_l \geq 0, l_h \geq 0$$

The aforementioned variables could be divided into two.

Endogenous variables

$U \equiv$ Utility of consumption of own agricultural produce, market purchased commodities and leisure.

$f_{ij} \equiv$ Factor input j for the production of crop i ;

$Ca_i \equiv$ Consumption of own agricultural produce i;

$Cm_i \equiv$ Consumption of market purchased goods i;

Cl_l ≡ Consumption of leisure;
X_i ≡ Marketed surplus of own agricultural output i;
l_h ≡ Quantity of sold (-) or purchased (+) labour

Exogenous variables

L ≡ Labour capacity of the farm household;
A ≡ Land endowment (fixed) of the farm household;
Y_x ≡ Exogenous income (non-farm earning and remittances);
P_i ≡ Vector of price of commodity *i*;
q_j ≡ Vector of price of factor input *j*;
w ≡ Wage rate

Parameters

$\alpha_i, \alpha_m, \alpha_l, \alpha_u$, . . . parameters of the utility function; and
β_i, β_{ij}, . . . parameters of the production function with output *i* and input *j*.

Model Result and Analysis

This section of the paper tries to show the whole result and analysis of the result of the research. The collected data was appropriately compiled and all the necessary parameters were computed and fed to GAMS as per the requirement of the software. Cobb Douglas function is applied for both production and utility functions and also NLP model is used. With this, results are displayed accordingly. The outcome will be presented sequentially starting from the initial data outputs up to simulating different scenarios for the purpose of policy prescription.

Initial Optimal Values

The initial optimal values are computed from the primary data collected from the village and all the necessary parameters of the model have been computed such that the initial optimal values have been generated by using the household model specified in the methodology part. The results of the optimization problem reveal that households should produce, consume, and sell more of teff to maximize their utility (Table 1). This is evidenced by the fact that in the actual production setup of the village, the villagers are producing 16.09 quintals of teff of which 5.57

quintals are for consumption and 10.74 would be availed to the market for sale. But, the model result shows that such figures go as high as 39.85 quintals for production, 4.70 for consumption, and nearly 35 quintals for sale.

Table 1

Production and Consumption

Activity	Initial actual Production Value	Optimal values	Initial actual Consumption	Optimal values	Initial actual Market Value	Optimal values
Teff	16.09	39.85	5.57	4.70	10.74	35.16
Wheat	8.85	1.40	3.65	1.40	5.28	0
Chickpea	10.01	0.88	1.59	0.88	8.8	0
Lentil	1.88	0.10	0.23	0.10	1.71	0
Bean	1.63	0.19	0.91	0.19	1.24	0
Barley	0.16	0.07	0.22	0.02	0.03	0
Maize	0.08	0.05	0.33	0.05	-0.03	0.05
Livestock		3.00		2.01		0.99

Source: - Author simulation based on Household model.

As more of the production is geared to teff, maize is also supplied to the market at a smaller amount (0.05 quintal) in the case of the optimal values to maximize utility. For the rest of the crops, the optimal values show that the amount of crop produced and consumed are below 2 quintals with no surplus to market, which is a much lesser amount compared to the initial value. Therefore, the initial optimal values of the model entail that the households should mostly be engaged in the production of teff in order to maximize utility and profit to less extent of maize while producing the rest of the crops for consumption purposes.

Factor Input Distribution of Each Crop

Farmers use different production factors to produce agricultural outputs. The levels of technology as well as the production behavior of farmers determine the way production factors are combined. The most prominent production factors in the rural Ethiopian production system are land, labor, seed, fertilizer, and so on.

Table 2 shows how factor inputs are distributed among each production of the crop. Out of the average available land of 3.75 hectares, the households actually use 1.96 hectares for teff production and 0.69 for wheat, 0.76 for chickpea, 0.15 for lentil, 0.14 for bean, and 0.02 for barley which is the same amount as maize. Though farmers in the village allocate more of their land to teff but the model result for the optimal values escalates the figure to be 3.46 hectares which account 92.26% of the total land if they optimally combine production factors to maximize their utility. This is because the model revealed that teff is the most consumed and traded commodity by households. The rest 7.3% of the land has been allocated for different crops as presented in Table 2.

Table 2

Factor Input Distribution of Each Crop

Activity	Initial Land Value	Optimum value	Initial Labor Value	Optimum value	Initial Seed Value	Optimum value	Initial Fertilizer Value	Optimum value	Initial Pesticide Value	Optimum value	Initial Feed Value	Optimum value
Teff	1.96	3.46	23	71.48	1.09	1.56	0.62	5.17	0.44	0.01	0	0.01
Wheat	0.69	0.12	22	2.69	1.34	0.10	0.36	0.28	0.26	0.01	0	0.01
Chickpea	0.76	0.10	18	1.46	1.28	0.10	0.03	0.01	0.29	0.17	0	0.01
Lentil	0.15	0.01	16	0.16	0.16	0.01	0	0.01	0.01	0.01	0	0.01
Bean	0.14	0.02	14	0.28	0.26	0.04	0	0.01	0	0.01	0	0.01
Barley	0.02	0.01	18	0.06	0.15	0.01	0	0.01	0	0.01	0	0.01
Maize	0.02	0.01	7	0.01	0.26	0.01	0	0.01	0	0.01	0	0.01
Livestock	0	0.01	17	0.01	0	0.01	0	0.01	0	0.01	0.83	1.24

Source: - Author simulation based on Household mode.

The same as the allocation of land, the majority of labor should be allocated to teff to maximize the utility of the households. But, farmers more or less allocate their labor equally to teff and wheat in reality. But the model result reveals that almost 71.5 men per day out of out 118.47 men per day should be allocated to teff. This is because teff is the most consumed and the most traded commodity by households.

The same pattern of distribution as labor and land is observed by other factors of production. On average households used fertilizer only for teff, wheat, and chickpea at an insignificant amount. But 5.17 quintal was supposed to be used for teff in order to maximize production while the figure goes as low as 0.28 quintal for wheat and almost 0 (zero) for the production of chickpeas.

Scenario Development and Shocks

The impact of the policy or economic shock is estimated by comparing the economic situations before and after the shock, as illustrated in the table below. There are three important exogenous shocks that affect the production, consumption, and welfare status of rural households. These are changed in price of agricultural outputs, changes in price of factors of production, and change in the level of technology, a policy change or economic shock is introduced, and the economy converges to a new equilibrium, governed by the economic relationships as specified in the system of equations.

So, in this study, there are four major simulation scenarios (shocks) applied in order to clearly see how the economic behavior of farmers in the Ada woreda changes and how they respond to such shocks in a way that enable them to maximize utility. The shocks considered in this research are: (1) Output price increased by 10%; (2) Factors prices increased by 10%; (3) both output price and factor price increase at the same time by 10%; and (4) technology increase by 20% on each of the crops separately.

Output price increase by 10%

The impact of the increase in the price of agricultural output may instigate rural households to increase their production. This is classical thinking. But the household model that we have imputed so far revealed that households produce and consume agricultural commodities simultaneously. In addition, the household model incorporates a tradeoff between what it consumes and sells from its production. The share of consumption of teff by households is relatively higher. As households are consuming other cereals, they have to produce a certain proportion. Such an increase of price doesn't affect the production volume of teff but households tend to consume more of than the initial optimal value. This is because teff was the only traded commodity by households in the initial optimal values.

Table 3 shows the change in price of output on the production, consumption, and marketed surplus of the economy. In this regard, production for wheat, chickpea, lentil, and bean rose in some amount while for barley and maize, it is constant. However, for teff it shows a decrement by 0.62 quintals. This is due to the fact that households in the area tend to produce other crops other than teff, they prefer to produce other crops when the whole output price increases. Seeing the consumption response, all of the crops whose production increased also increase consumption.

Table 3

Output Price Increase by 10%

Activity	Initial optimal production values	After shock	Initial optimal consumption	After shock	Initial optimal values	After shock
Teff	39.85	39.23	4.70	6.06	35.16	33.17
Wheat	1.40	1.82	1.40	1.82	0	0
Chickpea	0.88	1.14	0.88	1.14	0	0
Lentil	0.10	0.13	0.10	0.13	0	0
Bean	0.19	0.25	0.19	0.25	0	0
Barley	0.07	0.07	0.02	0.03	0	0.04
Maize	0.05	0.05	0.05	0.05	0.05	0
Livestock	3.00	3.00	2.01	2.59	0.99	0.14

Source: - Author simulation based on Household model

Impact of output price increase on factor distribution of the household

In the above table, due to an increase in output price, the households tend to shift from producing teff to producing other crops and because of that the land has been reallocated in favor of other cereals. Hence, the land allocated for teff has been decreased by 0.07 hectare and labor allocation decreased by 5-man days. But the allocation of these factors of production has increased for other products by a very infinitesimal value (Table 4) consequently.

Table 4

Effect of an Increase in Output Price on Factor Distribution

Activity	Initial Land Value	Optimum value	Initial Labor Value	Optimum value	Initial Seed Value	Optimum value	Initial Fertilizer Value	Optimum value	Initial Pesticide Value	Optimum value	Initial Feed Value	Optimum value
Teff	3.46	3.39	71.48	66.48	1.56	1.69	5.17	5.59	0.01	0.01	0.01	0
Wheat	0.12	0.16	2.69	3.27	0.10	0.14	0.28	0.40	0.01	0.01	0.01	0
Chickpea	0.10	0.13	1.46	1.79	0.10	0.14	0.01	0.02	0.17	0.25	0.01	0
Lentil	0.01	0.02	0.16	0.20	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0
Bean	0.02	0.03	0.28	0.35	0.04	0.05	0.01	0.01	0.01	0.01	0.01	0
Barley	0.01	0.01	0.06	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0
Maize	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0
Livestock	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	1.24	1.24

Source: - Author simulation based on Household model

Factor price increase by 10 %

The second simulation is an increase in the price of all factors by 10%. Table 5 clearly shows that following the increase in factor price, there is a decrement in production, consumption, and marketed surplus of all cereals and crops. The decrement is relatively higher. The price of land is extremely high and the share of land in the Cobb Douglas production function is relatively higher such that when the price of land increases farmers tends to produce less and their response is high as farmers relatively rent half of their land holding for production. So, when the prices of factors of a production increase by 10% it severely affects production, consumption, and marketed output (Table 5).

Table 5

Effect of An Increase in Factor Price on the Village Economy

Activity	Initial optimal production values	After shock	Initial optimal consumption	After shock	Initial optimal values	After shock
Teff	39.85	8.38	4.70	3.44	35.16	4.95
Wheat	1.40	1.00	1.40	1.00	0	0
Chickpea	0.88	0.63	0.88	0.63	0	0
Lentil	0.10	0.08	0.10	0.08	0	0
Bean	0.19	0.14	0.19	0.14	0	0
Barley	0.07	0.07	0.02	0.02	0	0.05
Maize	0.05	0.05	0.05	0.04	0.05	0
Livestock	3.00	3.00	2.01	1.47	0.99	1.53

Source: Author simulation based on Household model

Table 6 shows that 10% increase in factor price has a negative impact on the utilization of all the factors, which means as the input price increases households tend to produce less of agricultural production and engage themselves on other woks other than agricultural production.

Table 6

Effect of an Increase in Factor Price on The Distribution of Factors

Activity	Initial Land Value	Optimum value	Initial Labor Value	Optimum value	Initial Seed Value	Optimum value	Initial Fertilizer Value	Optimum value	Initial Pesticide Value	Optimum value	Initial Feed Value	Optimum value
Teff	3.46	0.72	71.48	15.34	1.56	0.30	5.17	0.99	0.01	0.01	0.01	0
Wheat	0.12	0.09	2.69	2.01	0.10	0.06	0.28	0.19	0.01	0.01	0.01	0
Chickpea	0.10	0.07	1.46	1.09	0.10	0.07	0.01	0.01	0.17	0.12	0.01	0
Lentil	0.01	0.01	0.16	0.12	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0
Bean	0.02	0.02	0.28	0.21	0.04	0.03	0.01	0.01	0.01	0.01	0.01	0
Barley	0.01	0.01	0.06	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0
Maize	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0
Livestock	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	1.24	1.24

Source: Author simulation based on Household model

Both output price and factor price increase by 10%

An increase in the price of production factors and the prices of output enable farmers to opt between non-farm and farm activities. As the price of factors of production increases, it is very profitable for farmers to engage in other non-farm activities. This scenario reveals that when output and factors of a production increase by the same 10%, the economic decision of peasants remain the same as in the initial case.

Table 7

The Net Effect of An Increase in Factor and Output Price

Activity	Initial optimal production values	After shock	Initial optimal consumption	After shock	Initial optimal values	After shock
Teff	39.85	39.86	4.70	4.89	35.16	35.16
Wheat	1.40	1.40	1.40	1.40	0	0
Chickpea	0.88	0.88	0.88	0.88	0	0
Lentil	0.10	0.10	0.10	0.10	0	0
Bean	0.19	0.19	0.19	0.19	0	0
Barley	0.07	0.07	0.02	0.02	0	0
Maize	0.05	0.05	0.05	0.05	0.05	0.05
Livestock	3.00	3.00	2.01	2.01	0.99	0.99

Source: Author simulation based on Household model

As the above shock dint affect the economic decision of households in the village, Table 8 shows that there is almost no change in the factor distribution setup, which implies the output price increment almost offsets the factor price increment. Therefore, the net effect is almost zero.

Table 8

The Net Effect of an Increase in Factor and Output Price on the Distribution of Factor Inputs

Activity	Initial Land Value	Optimum value	Initial Labor Value	Optimum value	Initial Seed Value	Optimum value	Initial Fertilizer Value	Optimum value	Initial Pesticide Value	Optimum value	Initial Feed Value	Optimum value
Teff	3.46	3.46	71.48	71.50	1.56	1.56	5.17	5.17	0.01	0.01	0.01	0.01
Wheat	0.12	0.12	2.69	2.68	0.10	0.10	0.28	0.28	0.01	0.01	0.01	0.01
Chickpea	0.10	0.10	1.46	1.46	0.10	0.10	0.01	0.01	0.17	0.17	0.01	0.01
Lentil	0.01	0.01	0.16	0.16	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Bean	0.02	0.02	0.28	0.28	0.04	0.04	0.01	0.01	0.01	0.01	0.01	0.01
Barley	0.01	0.01	0.06	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Maize	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Livestock	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	1.24	1.24

Source: Author simulation based on Household model.

Technology level increases by 20%

One of the most difficult challenges in the economic decision is to opt for crop or agricultural outputs that respond to technological advancement. So, to scrutinize the crop or the agricultural output that responds to technology, we opted for the three most heavily produced crops in the village and the likely impact of technological advancement has been visualized. The result reveals that teff is more responsive to change in technology more than wheat and other crops. Here an experiment is conducted on each of the crops in order to assess the effect of the change in the technology of a single crop on the whole production and allocation of factor inputs. The response of teff for the technological change is powerful that it increases the whole production of the crops as it can be seen in table 9. The highest production increment is recorded for wheat, which is 57.14% followed by chickpea and teff. This implies that an increment in teff technology allows the households to shift to producing wheat and other crops while also increasing the teff production. But the effect is higher for the crops other than teff.

Table 9

Impact of A 20% Increase in the Technology of Teff

Activity	Initial optimal production values	After shock	Initial optimal consumption	After shock	Initial optimal values	After shock
Teff	39.85	46.57	4.70	8.70	35.16	37.87
Wheat	1.40	2.20	1.40	2.20	0	0
Chickpea	0.88	1.37	0.88	1.37	0	0
Lentil	0.10	0.15	0.10	0.15	0	0
Bean	0.19	0.31	0.19	0.31	0	0
Barley	0.07	0.07	0.02	0.04	0	0.03
Maize	0.05	0.06	0.05	0.06	0.05	0
Livestock	3.00	3.00	2.55	3.00	0.99	0.45

Source: Author simulation based on Household model

The technological change of crops changes not only the production pattern but also the factor distribution setup of the households. For teff made less usage of land and labor of the crop to decrease by 0.13 hectare and 8.63 men per day to be distribute it among the rest.
For the other factors it goes on the same way (Table 10).

Table 10

Impact of a 20% Increase in Technology of Teff on the Distribution of Factors

Activity	Initial Land Value	Opti	Initial Labor Value	Opti	Initial Seed Value	Opti	Initial Fertilizer Value	Opti	Initial Pesticide Value	Opti	Initial Feed Value	Opti
Teff	3.46	3.33	71.48	62.8	1.56	1.83	5.17	6.04	0.01	0.01	0.01	0.01
Wheat	0.12	0.19	2.69	3.74	0.10	0.18	0.28	0.53	0.01	0.01	0.01	0.01
Chickpea	0.10	0.15	1.46	2.04	0.10	0.18	0.01	0.03	0.17	0.32	0.01	0.01
Lentil	0.01	0.02	0.16	0.23	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Bean	0.02	0.04	0.28	0.40	0.04	0.07	0.01	0.01	0.01	0.01	0.01	0.01
Barley	0.01	0.01	0.06	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Maize	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Livestock	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	1.24	1.24

Source: - Author simulation based on Household model
N.B: Opti stands for optimum value.

Technological change for wheat is not as responsive as teff. The same 20% increment in the crop has a same 20% rise for its production. While for the other crops there is no variation

Table 11

Impact of A 20% Increase in Technology

Activity	Initial optimal production values	After shock	Initial optimal consumption	After shock	Initial optimal values	After shock
Teff	39.85	39.35	4.70	4.70	35.16	35.16
Wheat	1.40	1.68	1.40	1.68	0	0
Chickpea	0.88	0.88	0.88	0.88	0	0
Lentil	0.10	0.10	0.10	0.10	0	0
Bean	0.19	0.19	0.19	0.19	0	0
Barley	0.07	0.07	0.02	0.02	0	0.05
Maize	0.05	0.05	0.05	0.05	0.05	0
Livestock	3.00	3.00	2.01	2.01	0.99	0.99

Source: Author simulation based on Household model

The factor distribution setup remains the same with the change in technology for wheat. This shows that the effect of the production increment has no factor distribution impact.

Table 12

Impact of A 20% Increase in Technology of Wheat on Distribution of the Factors

Activity	Initial Land Value	Optimum value	Initial Labor Value	Optimum value	Initial Seed Value	Optimum value	Initial Fertilizer Value	Optimum value	Initial Pesticide Value	Optimum value	Initial Feed Value	Optimum value
Teff	3.46	3.46	71.48	71.48	1.56	1.56	5.17	5.17	0.01	0.01	0.01	0.01
Wheat	0.12	0.12	2.69	2.69	0.10	0.10	0.28	0.28	0.01	0.01	0.01	0.01
Chickpea	0.10	0.10	1.46	1.46	0.10	0.10	0.01	0.01	0.17	0.17	0.01	0.01
Lentil	0.01	0.01	0.16	0.16	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Bean	0.02	0.02	0.28	0.28	0.04	0.04	0.01	0.01	0.01	0.01	0.01	0.01
Barley	0.01	0.01	0.06	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Maize	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Livestock	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	1.24	1.24

Source: Author simulation based on Household model

Table 13 below shows, a 20% increase in technology for chickpea increases a 12.85% of production and consumption of chickpea while the other crops remain persistent.

Table 13

Impact of A 20% Increase in Technology of Chickpea

Activity	Initial optimal production values	After shock	Initial optimal consumption	After shock	Initial optimal values	After shock
Teff	39.85	39.35	4.70	4.70	35.16	35.16
Wheat	1.40	1.40	1.40	1.40	0	0
Chickpea	0.88	1.06	0.88	1.06	0	0
Lentil	0.10	0.10	0.10	0.10	0	0
Bean	0.19	0.19	0.19	0.19	0	0
Barley	0.07	0.07	0.02	0.02	0.05	0.05
Maize	0.05	0.05	0.05	0.05	0	0
Livestock	3.00	3.00	2.01	2.01	0.99	0.99

Source: Author simulation based on Household model

Table 14 shows without any change in any of the factors of distribution, the production and consumption of chickpea has increased by 12.85%. For the rest of the crops, the factor setup remains unchanged.

The result of the crops other than the above mention 3 crops, it is found in the appendix part of the paper.

Table 14

Impact of A 20% Increase in The Technology of Chickpea on The Distribution of The Factors

Activity	Initial Land Value	Optimum value	Initial Labor Value	Optimum value	Initial Seed Value	Optimum value	Initial Fertilizer Value	Optimum value	Initial Pesticide Value	Optimum value	Initial Feed Value	Optimum value
Teff	3.46	3.46	71.48	71.48	1.56	1.56	5.17	5.17	0.01	0.01	0.01	0.01
Wheat	0.12	0.12	2.69	2.69	0.10	0.10	0.28	0.28	0.01	0.01	0.01	0.01
Chickpea	0.10	0.10	1.46	1.46	0.10	0.10	0.01	0.01	0.17	0.17	0.01	0.01
Lentil	0.01	0.01	0.16	0.16	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Bean	0.02	0.02	0.28	0.28	0.04	0.04	0.01	0.01	0.01	0.01	0.01	0.01
Barley	0.01	0.01	0.06	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Maize	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Livestock	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	1.24	1.24

Source: Author simulation based on Household model

Welfare Maximization of the Household

The table below clearly shows the summary for the welfare effect of households considering the above shocks. Major changes are shown on the welfare of the households in Ada'a for the three shocks, output price, factor price change, and technology increment only for teff. The change in the technology of teff is high as it can be seen the highest utility, leisure, and purchasing power is recorded on this shock. This shows that households are more responsive to technological change and they maximize their welfare with such change.

Output price has also a significant effect on the welfare of the households. On the other side, the factor price increment has also a negative effect on the production and productivity of the agricultural sector because the households shift to other non-agricultural sectors in order to sustain their utility. So, the labor trade in this case increased to 64.66. This justifies the fact that households leave the agricultural sector when the prices of production factors increase. This implies that the marginal productivity of labor in the rural area is small.

Table 24

Welfare Maximization of The Household

	Initial optimal value	Output 10%	Factor inputs 10%	Both by 10%	Technology by 20% for teff	Technology by 20% for wheat	Technology by 20% for chickpea
Utility	6.55	8.18	4.92	6.58	10.18	6.69	6.56
Leisure	42.20	46.20	34.95	42.19	49.04	42.20	42.20
Market purchased	1095.69	1555.25	802.38	1204.46	2029.38	1095.69	1095.69
Labor trade	0.10	0.10	64.66	0.10	0.10	0.10	0.10

Source: Author simulation based on Household model

Conclusion and Recommendation

In most developing countries of the world, agriculture is the backbone of the economy contributing the largest share of the GDP. The economy of Ethiopia has also such characteristics. From the total share, 39.9% of the GDP goes to agricultural production of the country. More than 80% of the population depends on this sector as their source of livelihood. The Ethiopian agricultural sector is dominated by smallholders. This is evidenced by the fact that 80% of the total farmland is on the hand of small householders owning a one hectare or less, leading a subsistence farming life.

Expansion of the sector has been done only through area extension rather than an increase in land productivity. Many constraints are responsible for the low development, both exogenous and endogenous. Exogenous constraints include drought, unreliable rainfall, land degradation, rapid population growth, scarcity of land, and so on, While the endogenous constraints include low availability of improved or hybrid seed, lack of seed multiplication capacity, low profitability and efficiency of fertilizer use due to the lack of complimentary improved practices and seed, and lack of irrigation and water constraints and above all lack of technique to increase productivity with the existing limited resource.

One of the peculiar features of the Ethiopian economy is its high intensity of crop mix. Farmers produce different cereals on a given land. This widens the likelihood exposed to output price and input price shocks. In addition to this, the existence of a such high level of crop mix makes it difficult to opt the appropriate technology for each crop. In this study, crop mix, which is one of the mechanisms implemented these days in order to increase the productivity of the sector within a small plot of land is considered for a village found in Debrezeit called Ada'a woreda and a case study has been conducted in order to find the optimum value of crop combination and how the households should react to different shocks using agricultural household model applied to GAMS software.

The optimal values have indicated that households in the village should produce more teff to maximize their utility. Hence, more of land should be allocated to this cereal. Four shocks have been considered to characterize the response of farmers in the community. The result reveals that farmers are very much responsive to changes in factor prices. The technological progress of teff is the best strategy to increase the welfare of households in the village. Increasing output price increases welfare but not to the extent that technological improvement ensures. On the other hand, the effect of the increase in factor price is significant, that it affects welfare negatively.

Therefore, the result of this study reveals that mono cropping is much better than mixed cropping for households living in Ada'a woreda. Based on those findings, the following recommendations are forwarded: When output price increases, the production of all of the crops also increased and the households shift their factor inputs to produce other crops other than teff. The utility level, leisure, and market purchased show a positive response, while the trade-out labor remains the same. So, in order to sustain and keep the household's welfare, the government should give more attention on the output price increment and protect it not to decrease.

The study reveals that households are more vulnerable to the second shock, which is the increase in factor price. When this is the case, the government should get involved in such a way that factor prices shouldn't be increased beyond a certain point. When factor prices increase, farmers leave the agricultural sector. This signifies the fact that the marginal productivity of labor is low in the agricultural sector. Therefore, in this regard, the government should design mechanisms in order to increase the productivity of the sector, so that the productivity of labor increases. In other words, the productivity of labor in the agricultural sector has to be attractive. This view has been corroborated by the last shock that enables farmers to invest much of their time on agricultural activities. Regarding the technological change of the sector, teff is more responsive to the 20% increase in technology and changed the whole production setup than the rest of the crops. Therefore, the government should give focus on enhancing the technology on teff rather than the other crops. For the rest of the crop, the change in technology is not that much able to bring the required change on the welfare of households. This shows more emphasis should be given to improving the technology of teff.

References

Adulavidhaya, Kamphol, Yoshimi Kuroda, Lawrence Lau and Pan Yotopoulos. (1984). The Comparative Studies of the Behavior of Agricultural Households in Thailand. Singapore Economic Review 29:67-96.

Alemayehu S, Taffels (1998). An economic model of the Ethiopian farm household WPs/ 99.26

Alison, Kay Bittinger (2010). Crop diversification and technology adoption: the role of market Isolation in Ethiopia

Andrews D.J. and Kassam A.H. (1976). The of multiple cropping in increase world food supplies in: papendick R.I., sanchez P.A. and Triplett G.B. (eds) Multiple cropping. Special Publication number 27. Pp. 1-10. Madison: American society of Agronomy.

Anil L, Park J, Phipps RH, Miller FA (1998) Temperate intercropping of cereals for forage: A review of the potential for growth and utilization with particular reference to the UK. Grass Forage Sci 53:301-317.

Baker E.F.I. and Norman D.W. (1975) "cropping systems in northern Nigeria. In: proceedings of the cropping systems workshop, Los Banos, Philippines: *International Rice Research Institute.* Pp 334-361.

Becker, G. S. (1965). A Theory of Allocation of Time Economic Journal 75:493–517.

Becker, G.S. (1981) A Treatise on the Family. Cambridge, MA: Harvard University Press

Bravo-Ureta BE, Rieger L (1991). Dairy Farm Efficiency measurement using stochastic Frontier and Neoclassical Duality. American Jornal of Agrucultural Economics, 73: 421-428.

Central Statistics Authority, Statistical Bulletin, No 44, 59, 84.

CSA (2013 &2014). *Statistical abstracts for Ethiopian economy*,Ethiopia, Addis Ababa

Chayanov, A.V. (1925). Peasant farm organisation', translated in *A.V. Chayanov: The Theory of Peasant Economy*, eds D. Thorner, B. Kerblay and R.E.F. Smith (1966), Irwin, Homewood,Illinois.

Chayanov, A. V. (1966). The Theory of Peasant Economy." In D. Thorner, B. Kerblay, and R.E. F. Smith, eds., for the American Economic Association Translation Series. Illinois: Richard D. Irwin.

Chowings J.W. and Ingram J. (1991) Herbage Legume Intercropping for Organic Vegetable Growing. Cambridge: National Institute of Agricultural Botany.

Dapaah, H. K., Asafu-Agyei, J.N., Ennin, S.A. and Yamoah, C.Y. (2003). Yield Stability of cassava, maize, soyabean and cowpea intercrops. Jornal of agricultural science Cambrige 140:73-82.

De Janvry, Alani, Marcel Fafchamps, and Elizabeth Sadoulet. (1991). "Peasant Household Behavior with Missing Markets: Some Paradoxes Explained." *The Economic Journal* 101, 1400-1417.

Diao, X., P. Hazell, &J. Thurlow. (2010). The Role of Agriculture in African Development." World Development. 38 (10): 1375–1383.

D. J. Andrews and A. H. Kassam. (1976). A. Sanchez, and G. B. Triplett, Eds., vol. 27, pp. 1–10, ASA (American Society of Agronomy), Madison, Wis, USA.

FAO (1998). Rural Non-Farm Income in Developing Countries. Special Chapter in FAO. The State of Food and Agriculture. Rome.

FAO (1999). The State of Food and Agriculture. 'Part 3: Non-farm income in developing countries. www.fao.org/docrep/w9500e/w9500e12.htm

Fleming, E.M. and Hardaker, J.B. (1991, Micro-level approaches to analyzing rural development Problems, Paper presented at the Development Studies Conference on Mechanisms of Socio- Economic Change in Rural Areas, Australian National University, Canberra.

Findeis, Jill and Hema Swaminathan & Anuja Jayaraman, (2003). Workshop on Agricultural Policy Reform and Adjustment. *Imperial College*, Wye, Penn State University.

Gibreel T. (2009). Impact of Agricultural Policy on Resource Allocation in the Gum Belt of Sudan: A farm Household Modeling Approach. Farming & Rural Systems Economics Vol. 105. (ISBN): 978-3-8236-1567-5; (ISSN) 1616-9808.

Hossain, S.I. (1989) Effect of public programs on family size, child education and health', Journal of Development Economics 30, 145-58.

Hossain, M. M.; Huq, M. A. ; Saadullah, M. ; Akhter, S., (1989). Effect of supplementation of rice straw diets with sesame oil cake, fish meal and mineral mixture on dry matter digestibility in goats. Indian J. Anim. Nutr., 6 (1): 44-47

Howard H. Barnum & Lyn Squire, (1978) An Econometric Application of the Theory of the Farm-Household" Center for Research on Economic Development, University of Michigan, Ann Arbor and World Bank, Washington, DC.

Singh, Inderjit; Squire, Lyn; Strauss, John (1986). Agricultural household models: extensions, applications, and policy. The World Bank. The Johns Hopkins University Press

Jacoby, H.G. (1992). Shadow wages and peasant family labor supply: an econometric Application to the Peruvian Sierra', *Review of Economic Studies* 60, 903-22.

J.edward Taylor and Irma Adelma.(2002) Agricultural Household Models: Genesis, Evolutionand Extension". Department of Agricultural Resource and Economics,

Kate, S. & Leigh, A. (2010). Yield Gap and Productivity Potential in Ethiopian Agriculture: Staple Grains & Pulses, University of Washington.

Lopez, R.E. (1984). 'Estimating labor supply and production decisions of self-employed farm Producers', *European Economic Review* 24, 61-82.

Maria Fay Rola-Rubzen & J Brian Hardaker (1999). Intra-Household Modeling and Farm Household System,Curtin University of Technology and University of New England.

Mendola, M. (2007). Farm household Production Theories: Institutional and Behavioral Responses" Asian Development Review, vol.24, no.1, pp. 49-53.

MOFED (1998). Dynamics of Growth and Poverty in Ethiopia (1995/96–2004/05), Addis Ababa, Ethiopia: Ministry of Finance and Economic Development, Federal Democratic Republic of Ethiopia.

MoFED. (2002). Ethiopia: Sustainable Development and Poverty Reduction Program. Addis Ababa, Ethiopia, government printer.

NBE (1992, 2007, 2010,2011 $2013). Annual Reports of National Bank of Ethiopia, Addis Ababa.

NBE. (2013/14). Annual Report / VII, Investment, Addis Ababa, Ethiopia

Nakajima, C., (1969) Subjective Equilibrium Theory of the Farm Household Amsterdam: Elsevier.

Nakajima H, Tanaka A (1986). Continuous production of Oxytetracycline by immobilized growing Streptomyces rimosus cells. Appl. Microbiol.

Rola-Rubzen, M.F. and Hardarker, J.B. (1999). Impact of labour market policies on farm Households in philippiense, paper presented at the joint 43th Annual AARES/ 6th Annual NZARES conference, 20-23 January 1999.

Strauss, J(1986a). "The Theory and Comparative Statics of Agricultural Household Models: A General Approach." In *Agricultural Household Models*: *Extensions, Applications, and Policy*, I. Singh, L. Squire, and J. Strauss, eds., Baltimore, MD: The Johns Hopkins University Press, pp. 71-91.

Strauss, J(1986b). "Estimating the Determinants of Food Consumption and Caloric Availability in Rural Sierra Leone." In *Agricultural Household Models*: *Extensions, Applications, and Policy*,I. Singh, L. Squire, and J. Strauss, eds., Baltimore, MD: The Johns Hopkins University Press, pp. 116-152.

Singh, I., L. Squire, and J. Strauss, (1986). Agricultural Household Models. Baltimore: John Hopkins University Press.

Taffesse, Alemayehu S. (1998). An Economic Model of the Ethiopian Farm Household", Wps/99.26, Department of Economics Addis Ababa University.