Farming or burning: shadow prices and farmer's impatience on the allocation of multi-purpose resource in the mixed farming system of Ethiopia

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Abstract

In a crop-livestock mixed farming system where farm yard manure (FYM) is considered as an important multi-purpose resource such as source of soil organic matter, additional income and household energy, soil fertility depletion could takes place within the perspective of the household allocation pattern of FYM. This paper estimates a system of FYM allocation model in the presence of corner solution, to examine the role of various returns to FYM and farmer's impatience on the propensity to allocate FYM for different purposes. We illustrate the model using data on a random sample of 493 farm households in the central highlands of Ethiopia. Results indicate heightened incentive to divert FYM from farming to marketing for burning outside the household when returns to selling FYM are high. Heterogeneity in time preference is also found an alternative justification to elucidate the correlation between farmers' impatience and FYM allocation. The results are of paramount importance for the design of sustainable land management policy where soil fertility depletion is salient for low agricultural productivity.

Key words: *impatience, shadow price, allocation, farm yard manure, Ethiopia*

JEL Classification: Q01, Q12

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Introduction

The problem on sustainable development in developing countries has been closely associated with the extent of resource degradation (Pender 1996). In countries where agriculture is the main stay of the economy, soil fertility depletion is an important source of resource degradation causing low agricultural productivity and declining per capita income. Fundamentally in the ideal agrarian economy, productive and sustainable production system requires a combination of inorganic fertilizers and organic fertilizers such as farm yard manure (FYM) to replenish the soil and maintain the soil organic matter level (Place et al 2003; Heerink 2005). However, the limited use of inorganic and organic nutrient inputs among small holder farmers exacerbates soil nutrient deficiency (Place et al 2003).

A strand of literature indicated that the use of inorganic fertilizer is limited in developing countries due to low rural incomes, the high cost of fertilizer, inappropriate public policies and infrastructure constraints (Ehui et al 2003; Croppenstedt et al 2003). On the other hand, the fact that FYM has historically been considered as an important resource (Keplinger and Hauck 2006; Place et al 2003; Erkossa and Teklewold 2009), improving soil fertility is severely constrained due to the dwindling of FYM from the livestock system (Ehui et al 2003; Heerink 2005) with competing demand for its use. Under constrained availability of FYM, the household allocation pattern of FYM are interlinked with management of soil resources in such a way that the demand for FYM for energy within and outside farm households shifts the resources to the extent that the application of FYM to the farm is limited for improving soil fertility.

FYM as a source of energy for the farm households and used for farming as ameliorating soil fertility is well documented (Place et al 2003; Mekonnen and Köhlin 2008; Erkossa and Teklewold 2009). In Ethiopia, Mekonnen and Köhlin (2008) has examined the determinants of the rural households' decision to use dung as fuel and as soil fertilizer. However, previous studies were not considering the role of FYM as a source of additional income allocated for selling for use mostly by peri-urban and urban dwellers outside the farming community. This missing element could be associated with two important caveats: First, there is growing evidence (Mekonnen and Köhlin 2008) and observation in most rural and peri-urban areas that despite the knowledge of alternative energy resources such as kerosene, electricity and liquefied petroleum gas, high prices and lack of access hinder their wider application as a source of domestic energy. As a consequence, due to the substitutability of FYM to these alternative sources of energy (Heltberg et al 2000), the demand for FYM and its price in the market has risen. Under such condition, the allocation of FYM among the various alternatives (farming, energy or income source) depends on the selling price of FYM and the return from farming. The selling price and the return from farming of FYM is also the opportunity cost of allocating a unit of FYM for own energy source than selling in the market for burning outside the farm household or allocating for farm production.

Second, naturally, due to the long time for the mineralization process in which the nutrients in the organic compounds can become available to the crop (Place et al 2003) and the seasonality for the agricultural production, the benefit from farming with FYM is not forthcoming in short time compared to the benefit earned from selling FYM. The discounted utility model states that later returns should be discounted by a fixed proportion of their utility for every time interval that they are to be delayed. In perfect market setting, this devaluation should generally closely relate to the market interest rate. However, in the presence of credit market failure and constrained access to financial resources, which is typical for developing countries such as Ethiopia, farmers' subjective discount rate routinely deviates and usually higher than from the prevailing market interest rates (Pender 1996; Yesuf and Bluffstone 2009; Bezabih 2009). The underlying assumption of this relationship is that poor individual with limited financial resources and binding credit constraints discounts future consumption at a disproportionately high rate. Following the definition of Becker and Mulligan (1997), the marginal rate of substitution between current and future utilities interchangeably uses with rate of time preference, impatience or discount factor. Hence, an impatient farm household has a low discount factor (high discount rate) and high rate of time preference.

The implication here is that allocation of FYM depends on the extent to which farmers' degree of impatience to wait the returns from FYM among the various alternatives. If individuals are impatient, they may be disinclined to invest in long-term investment in future income and adjustment of FYM eventually occurs such as diverting the resources from the farm to the non-farm. Hence, impatience may explain why soil fertility depletion is often the consequence. That the multi-purpose use of FYM for farming or burning is generally considered as a link between farmers' behavior and resource degradation, the causes of soil fertility depletion extend beyond the farm and receiving effects from household socio-economic conditions.

Hence, building on the economic theory of the agricultural household model under credit and financial constraints, this paper aims at examining the effect of farmer's discount rate and various returns to FYM on the propensity to allocate FYM as input to agricultural production or burning those for fuel within and outside farm households. This study extends the existing economic literature of soil fertility depletion by providing a better understanding and explicitly incorporating FYM selling as additional alternative source of income that compete FYM for farming; and farmer's impatience as determinants of allocation of FYM for alternative purposes. To the best of our knowledge this is the first study in the economics of soil fertility management.

The empirical analysis is based on a system of equations for farmers' allocation of FYM for different purposes. The farm household survey data in the central highlands of Ethiopia operating the mixed crop-livestock farming system is used for investigation. Due to low agricultural productivity that constrained the availability of FYM, farmers face the problem of allocation of FYM among the different alternatives. The data supports the predictions and shows that farmer's time preference and the returns to FYM are important predictors of the allocation of this multi-purpose resource in the real world. Farmers with high degree of impatience, decrease the allocation of FYM to the farm; and the higher the selling price of the FYM is the higher the incentive for the farm households to divert the resources to selling for burning outside the farm households.

Conceptual framework

In order to explain the FYM allocation behavior of agricultural households, we construct a farm household model assuming farmers engaged simultaneously in production and consumption decision. This model is assumed non-separable due to the presence financial and credit market constraints and given that most of the farm households in the study areas are non- or semi-commercial producers who mainly produce for their own consumption. Non-separability is a common feature of studies with applications to agriculture in developing countries (Jacoby 1993; Skoufias 1994). It means that each farm household determines FYM production and consumption by maximizing its utility subject to a shadow price of FYM for different activities which is unobserved and unknown, except to the household itself, and which varies between households depending on household and village characteristics (Sadoulet and de Janvry 1995). We build on Mekonnen and Köhlin (2008) and developed an approach in the spirit of Fisher et al (2005) and Shively and Fisher (2004) who derived a system of a labor allocation model in which households divide their labor resources among farming, forest employment and non-forest employment; and provide an improved assessment on the effect of the household shadow price in a given activity for forest decline. However, we add two main features in the model: the various returns from FYM to allow for decisions driven by profit or consumption motives; and include an experimentally measured time-preference component to capture the farmers' impatience on the decision to divide their FYM among household consumption, selling and farming.

The model presented below captures the case of a farm household involved in mixed crop-livestock farming system, where FYM (Q_m) is one of the most important by-products of the system, assumed to be a function of the vector of farm inputs and structural characteristics of the farm household. Utility is derived from consumption of agricultural and purchased goods (C), energy (E) and leisure (L_l). The demand for FYM burning at farm household level is a derived demand from the demand for energy (E) where energy is sourced from FYM (M_e) and other sources such as kerosene and other biomass (O_e). Agricultural production (Q_a) takes place on individual plots using organic (FYM) and inorganic fertilizer. We assume inorganic fertilizer is the purchased variable input while FYM is obtained from livestock production within the farm households.

Given a total amount of FYM at her disposal, farmer's decision consists of allocating Q_m between farming (M_f), burning in the household (M_e) and selling in the market as additional source of income (M_s) for burning outside the household. The implication is that farm households in the area are semi-commercial where even if markets for FYM exist most kept some for home consumption and farm production. Observation of the data for this study has also revealed that all farm households obtained FYM for burning (M_e) and farming (M_f) from their own production system without making any purchase. The net marketed amount of FYM is therefore non-negative: $Q_m - M_e - M_f \geq 0$. Households also choose the amount of labor for on-farm (L_f) and off-farm (L_o) activities. The household budget constraint bounds the value of consumption of agricultural goods and purchased goods (C) by households total income (Y) originates from agricultural income, off-farm work (L_o) at wage rate (w), FYM selling (M_s) at price (p_s). Agricultural production is specified as function of M_f, L_f and other variable inputs (X) such as inorganic fertilizer, seeds, pesticide, etc. Agricultural income is the farm restricted profit where the value of the total amount of crop produced $(p_a Q_a)$ minus the cost of production.

In each year, the agricultural season is divided in to two: the wet or planting season and the dry or harvesting season. The nature of the agricultural production is such that for FYM applied to the field at the planting season agricultural output is expected at the harvesting period. Investing FYM on the farm means postponing the current consumption originated from burning FYM in the household or income earned from selling FYM in the market. This loss interpreted as the benefit obtained from selling or burning FYM now is assumed to be compared and offset by the discounted returns of FYM in farming at a later time. When imperfect credit markets prevent perfect consumption smoothing, depending on the individual implicit discount rate, farmers often opts to sell or burn FYM likewise limits their ability to FYM farming. Hence, with the subjective discount rate parameter (δ) the relationship between time preference and allocation behavior are more pronounced. A farmer's discount rate is expected to affect a household resource allocation following the standard intuition: a higher δ should result in higher resources towards for current consumption.

Formally, given these specifications, farmers are assumed to choose M_f, M_e, M_s, L_l, L_f, L_o and X so as to:

$$Max\ U = U\left(C,\ E, L_l; Z_c\right) \tag{1}$$

subject to her resource and productivity restrictions:

$$Y=\frac{1}{\delta}\pi+wL_o+p_sM_s \qquad \text{(Income constraint)} \qquad (2)$$

$$\pi=p_aQ_a\left(M_f, X, L_f; Z_q\right)-p_xX \qquad \text{(Farm restricted profit)} \qquad (3)$$

$$E=E\left(M_e, O_e\right) \qquad \text{(Energy constraint)} \qquad (4)$$

$$Q_m=M_e+M_s+M_f \qquad \text{(FYM constraints)} \qquad (5)$$

$$L=L_l+L_o+L_f \qquad \text{(Household time constraints)} \qquad (6)$$

$$M_i\geq 0 \qquad \text{for i = e, s, f} \qquad \text{(Non-negativity constraints)} \qquad (7)$$

where Z_c and Z_q are a vector of individual household and farm characteristics influencing preferences and farm production, respectively.

Substituting the constraints in to the utility function above and assuming the farm household's choice at the start of the dry season, we can specify the Lagrangean as:

$$\begin{aligned}\ell=&U\left(C, E(Q_m-M_s-M_f, O_e), L-L_o-L_f; Z_c\right)+\lambda\left[1/\delta\left(p_aQ_a(M_f, X, L_f; Z_q)-p_xX\right)\right.\\ &\left.+wL_o+p_sM_s\right]+\eta_fM_f+\eta_eM_e+\eta_sM_s \qquad (8)\end{aligned}$$

where λ is the Lagrangean multiplier associated with income constraints and η_f, η_e and η_s are Lagrangean multiplier associated with inequality constraints on FYM farming, burning and selling, respectively.

Maximization of this Lagrangean with respect to M_s , M_f and M_e provide the following first order conditions:

$$\frac{\partial U}{\partial E}\frac{\partial E}{\partial M_e}=\lambda p_s+\eta_s \qquad (9)$$

$$\frac{\partial U}{\partial E}\frac{\partial E}{\partial M_e}=\lambda\frac{1}{\delta}p_a\frac{\partial Q_a}{\partial M_f}+\eta_f \qquad (10)$$

The above first order conditions indicate that, at the optimum, farm households allocate FYM across alternative options so as to equate the marginal value of household energy from FYM with that of FYM spent on farming or selling; that is the discounted future marginal revenue product from agricultural production or net returns from marketing. In other words, the discounted gains from the extra increment of future agricultural production due to improved soil fertility and the net returns from FYM selling is equalized to the household specific opportunity cost of FYM for burning. The complementary slackness condition for constrained maximum in equation (9) and (10) may infer the shadow price of FYM for selling and farming, respectively. When households optimally allocate FYM in the market and in farming then her shadow price of FYM selling $\left(p_s^* = p_s + \frac{\eta_s}{\lambda} \right)$ and FYM farming $\left(p_f^* = \frac{1}{\delta} p_a \frac{\partial Q_a}{\partial M_f} + \frac{\eta_f}{\lambda} \right)$ equal to the respective observed FYM price $(p_s^* = p_s)$ or the discounted marginal value product of FYM $\left(p_f^* = \frac{1}{\delta} p_a \frac{\partial Q_a}{\partial M_f} \right)$. This is because, for an interior solutions, the complementary slackness condition requires $\eta_i = 0$ given ($M_i > 0$; for $i = f, s$). However, again following the complementary slackness condition that requires $\boldsymbol{\eta_i} > 0$ for a farmer who exhibit corner solutions ($M_i = 0$; for $i = f, s$), then the shadow prices, p_s^* and p_f^* will be in general greater than the observed selling price and the marginal value product, respectively.

The shadow prices of FYM measured in real terms denoting the unobservable internal prices in the case of non-separability. They may be defined as the market price or returns plus the value that a farmer assigns for herself for supplying or not supplying FYM to the market or to the farm. For instance, this difference in selling price or marginal value product of FYM seems to be caused by the farmers' subjective discount rate. For an impatient farmer, the discounted marginal revenue product of FYM on her farm is lower than the selling price of FYM. Thus the shadow prices of FYM are endogenously determined by parameters affecting the household's production and consumption decision variables. The first order conditions above can be combined to derive a set of an estimable reduced form Marshallian demand functions for FYM for farming, for household energy and the supply of FYM for selling in the market. These are expressed as functions of shadow prices, farmer's time preference and other individual and farm characteristics:

$$\left.\begin{array}{l} M_f \\ M_s \\ M_e \end{array}\right\} = m\left(p_s^*,\ p_f^*, \delta; Z_q, Z_c\right) \tag{11}$$

Empirical strategy

The empirical strategy in this article involves a sequence of estimation stages. First, we estimate a production function to obtain the marginal product of FYM for those participating in FYM farming. Second, we use the marginal revenue product estimates from the above step and the observed selling price and employ sample selection model to compute shadow returns for the subsample of households that do not supply FYM for farming or market. Third, we estimate a system of FYM allocation function.

Estimation of shadow prices

Following Jacoby (1993) and Skoufias (1994), the first step in the empirical analysis is to obtain the value of marginal productivity of FYM (p_f^*) estimated at the slope of the production surface around the input use vector for each farm household. The farm-level production function in logarithmic form is specified as:

$$ln\,Q = \beta_f\, ln\, M_f + \sum_k \beta_k\, ln\; x_k\; + \varepsilon \qquad (12)$$

where Q refers the total value of agricultural outputs (**OUTVALU**) produced, M_f is quantity of FYM used as organic fertilizer (**FYMFARM**) and β_f is the estimated parameter for it; x_k are the quantity of other inputs used, $\beta_k' s$ are parameters estimated for other inputs, and ε is the error term. The specified production function includes the following inputs: quantity of inorganic fertilizer (**FERTILIZER**), seed used (**SEED**), hours of labor (**FARMLABR**), cropped area (**CROPAREA**), draft animal services (**BULOCK**), share of area covered with modern crop varieties (**MODERNVAR**) and fraction of area with good soil quality[2] (**GOODSOIL**). Locational dummies (**ZONE1** and **ZONE2**) are also included to control village specific factors. In the empirical model fertilizer and improved seed use are usually considered as potentially endogenous (Kassie et al 2009). In line with Jacoby (1993) who worked on cross-sectional data and had rely on production and consumption side instruments that are valid under non-separability, the endogeneity (reverse causation) of farm inputs such as fertilizer and improved seed is controlled with instruments using two stages least square method (**IV-2SLS**). We instrumentalise these endogenous variables with village specific and household characteristics and verify the statistical validity of the instruments by performing an over identification test.

Following the estimation of the production function, the estimated parameters for FYM is used to derive the value of marginal product (p_f^*) as follows:

$$p_f^* = \frac{\hat{Q}_a}{M_f}\beta_f \qquad (13)$$

where $\hat{q}$ is the predicted value of output from the estimated coefficients.

[2] Using indigenous soil quality classification, soil quality in the study areas are grouped into three: ***lem, tef*** and ***lem-tef*** , which referred good, medium and poor soil quality, respectively.

If all farm households engaged in FYM farming or selling, then the standard resource allocation model emerges. However, as pointed out above the samples in this study are likely to be non-random due to the presence of non-participant farm households (about 20% in each activity) where the marginal product or selling price is not observed for these. Hence direct estimation for participants only might lead to the potential sample selection bias. A farmer's decision regarding her participation in FYM farming or selling may, however, be endogenously determined with the respective return from FYM. Therefore, following the approach of Shively and Fisher (2004) and Fisher et al (2005), a Heckman specification with sample selection is used to estimate participation in FYM farming and the value of marginal product jointly applying the maximum likelihood approach (Heckman 1974). The linkage between the discrete and continuous choice of the model imply that first the participation equation which essentially serves as an endogenous dummy variable to account any gap between the observed price and the household shadow price in the given activity provide a correction for the estimation of shadow value (Shively and Fisher 2004).

According to this procedure, one first estimates marginal product for the subsample of farm household participating in FYM farming, with appropriate correction of sample selection bias due to endogeneity of farmer's FYM farming participation an estimated shadow value can be computed for those without a FYM farming practice, given their control variables. The empirical identification of the model requires that, in addition to the exogenous variables both in the participation and outcome equations, one or more identifying variables are included only in the participation equation and at least one variable in the shadow value equation that does not enter to the FYM equations (Fischer et al 2005). In the case of FYM farming to enable the identification of the shadow value we use eight potential variables[3]. These

[3] Instruments include**:** average distance from home to farm (**DSTFARM**); household's access to own means of transportation (**DONKEY**); off-farm income (**OFFINCOM**); herd size (**TLU**); distance to the most visited

variables hypothesized to affect the likelihood of participation in FYM farming by changing the household's shadow value. For instance, average plot distance affects FYM productivity and hence decision to participate in FYM farming. Identification of FYM allocation equations on the other hand is obtained with the use of location variables, an approach employed by Fischer et al (2008); and extension variables. We expect that the effect of these identifying variables works through their effect on participation and shadow value rather than directly.

Since the selling price of FYM in the market varies depending on the location and time of sale, it is potentially endogenous. Hence, a similar estimation method as above is motivated by an extension of Heckman's suggestion for imputing farmer's asking price for FYM or the shadow price in FYM marketing (the value that the farmer places on FYM for selling). Again, the estimation relies on two behavioral schedules: the function determining participation of a farm household in the market and the function determining the selling price equation. As with FYM farming, in the case of FYM selling, the empirical model for predicting the selling price of FYM rests on the estimation of the usual univariate discrete choice probability for the full sample of households regarding on the participation of FYM marketing, including appropriate exclusion restrictions and then estimation of selling price equation.

Econometric specification: Farm yard manure allocation

The specification of the econometric model for the analysis of FYM allocation is based on the three-way choice structure established in the previous section. Conceptually, farmer's FYM allocations are related one another among the available alternatives. Because these allocation outcomes are correlated, it is expected those disturbance terms across models of each outcome might also be correlated. This does not provide enough support to build separate models of allocation for each option, rather as a set to increase efficiency. Such interconnectedness thus

market center (**DSTMKT**); size of cultivated land (**CRPAREA**); whether household adopt stove (**STOVADOP**) and expenditure on alternative energy sources (**KEROSEN**).

implies that OLS models, which assume the absence of correlation among the disturbance terms, yield inefficient estimates of coefficients. A more efficient estimation technique in such case is the seemingly unrelated regression, or SURE (Zellner 1962). SURE relaxes the assumption of uncorrelated residuals and simultaneously estimates the three equations as set. The basic idea is to adjust the standard errors of the coefficients and obtain more efficient estimates of the effects of explanatory variables on the outcomes. As a consequence, SURE can account for the interrelated nature of FYM uses in an allocation model and provide better estimates of the effects of time preference and shadow prices and other household characteristics.

The systems of equations for FYM farming, burning and selling respectively can be expressed more parsimoniously as:

$$M_f = \alpha_{ff} p_f^* + \alpha_{fs} p_s^* + \alpha_{f\delta}\delta + \alpha_{fz_q} z_q + \alpha_{fz_c} z_c + \upsilon_f \qquad 14$$

$$M_e = \alpha_{ef} p_f^* + \alpha_{es} p_s^* + \alpha_{e\delta}\delta + \alpha_{ez_q} z_q + \alpha_{ez_c} z_c + \upsilon_e \qquad 15$$

$$M_s = \alpha_{sf} p_f^* + \alpha_{ss} p_s^* + \alpha_{s\delta}\delta + \alpha_{sz_q} z_q + \alpha_{sz_c} z_c + \upsilon_s \qquad 16$$

Each equation is expected to satisfy the assumptions of the classical regression model. However, if the regression disturbances in the different equations are mutually correlated then: $E\lfloor \upsilon_i, \upsilon_j \rfloor = \sigma_{ij}$ for $i, j = f, e, s$. That is, σ_{ij} is the covariance of the disturbances of the i^{th} and j^{th} equations, which is assumed to be constant over all observations, and is the link between the i^{th} and j^{th} equations.

As discussed in the literature of a system of equations (Green 2008), in examining allocations of FYM by a farm household, each make decisions based on variables that reflect their expected objectives, the disturbances in the allocation equations certainly include factors that are common to all of the farmers as well as factors that are specific to a particular farmer.

Hence in each equation the parameters could be estimated consistently, if not efficiently, where the SUR framework is its treatment of the correlation across observations. The system of equations provides a SUR model that can be used to estimate the parameters of the model. The estimation procedure of SUR model was based on the Feasible Generalized Least Squares (FGLS[4]) approach. The Lagrange Multiplier test developed by Breush and Pagan (1980) will test the specification for SUR model with the null hypothesis of $\sigma_{fs} = \sigma_{fe} = \sigma_{se} = 0$. The test statistic is given by: $\lambda = N\sum_{i=2}^{3}\sum_{j=1}^{i-1} r_{ij}^2$; *where* $r_{ij}^2 = \frac{\sigma_{ij}^2}{\sigma_{ii}\sigma_{jj}}$, is the squared correlation. λ has χ^2 distribution with 3 degrees of freedom. If the test fails to reject the null hypothesis, estimation with SUR will be efficient.

Data and study areas

This study is based on data from the household survey conducted in the cereal-legume based mixed crop-livestock farming system of three zones in the central highlands of Ethiopia – east, west and north Shewa zones – fielded by the Ethiopian Institute of Agricultural Research (EIAR) in 2006. The mixed crop-livestock farming is the dominant farming system in the areas where FYM is considered as an important and integral part of the farming system. The three study areas are found within the radius of 100 km from the capital city of the country, Addis Ababa. This and the peri-urban areas around the study areas are important market opportunities for farmers for their agricultural products and by-products. In particular the three zones are characterized by differences in the availability and use of the FYM resources

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[4] The FGLS estimator of α is: $\alpha_{FGLS} = \left(y\hat{\Sigma}^{-1}y'\right)^{-1} y\hat{\Sigma}^{-1}M_j$; where y is vector of explanatory variable and $\hat{\Sigma} = \hat{\sigma}_{ij}$. The FGLS is a two-step estimator where OLS is used in the first step to obtain residuals and an estimator $\sum$. The second step compute α_{FGLS} based on the estimator $\sum$ in the first step.

and their access to FYM markets. The shorter the distance to the FYM market implies the lower the transaction cost and hence the higher the selling price of FYM.

Table 1 contains the empirical descriptions and descriptive statistics of the variables used in the estimation. The data set contains five hundred randomly selected farm households. However, after removing inconsistent and non-systematically missing information, data from 493 farmers remains for use in our empirical estimation. Two stage cluster random sampling technique was employed for selecting districts and respondents from each area. The sample households were randomly selected from the villages' rosters that exhaustively record all members of the villages. The data set features detailed information regarding household and farm characteristics, such as total agricultural outputs and inputs, annual quantity of FYM produced and used for farming, burning in the household and selling in the market; and annual earnings from selling livestock and livestock products including selling FYM. Selling price of FYM is defined as the quotient of annual earnings from FYM and total quantity of sales. The FYM price is determined in local markets and due to the high transaction costs associated with the bulkiness of the product we exhibit inter village prices' variation.

Table 2 presents the farm household's total annual production of FYM and its use for different activities. Farmers on average allocate 34% of their produce of FYM for farming as organic fertilizer, 38% for selling as additional source of income and the remaining 28% for burning as a household source of energy. FYM marketing in the study sites is an important source of household income covering 28 – 47% of the total livestock income. The empirical findings concerning the demand for FYM for farming may be more clearly understood if they are prefaced by the respondent's perception on her soil quality which is more of the indicator of soil fertility depletion due to lack of organic fertilizer. The survey participants were asked to evaluate the soil quality of their farms according to the locally widely known assessment criteria. Accordingly, on average 35, 31 and 34 percent of the respondent's farm were respectively classified as good, medium and poor soil quality. Despite the positive correlation between good soil quality and FYM used for farm (Fig. 1), having farming plot with medium and poor soil quality might be an indication that these farming plots may need more FYM to ameliorate the soil.

Farmers also responded to hypothetical question elicited information regarding their time preferences using the experiment mentioned below. In this study, for eliciting discount rates, choice task which is the most common method for eliciting time preference (Pender 1996; Holden et al 1998; Frederick et al 2002; Yesuf and Bluffstone 2009; Bezabih 2009) is used. Accordingly, all sampled respondents in the household survey were confronted with the hypothetical experiment designed to elicit their willingness to delay current consumption. Here, subjects were asked to choose between a smaller, more immediate reward and a larger, more delayed reward. This is the choice between the hypothetical future value payable after one year (almost one cropping season) equivalent to a fixed present value. As discussed by Frederick et al (2002) that to precisely estimate the discount rate and to avoid a single choice between two inter temporal options that only reveals an upper or lower bounds of the discount rate, this experiment presented a progression of choices that vary with the amount of the delay rewards. Hence, a series of six binary choices between the specified amounts of wheat grain (50 kg) to be received now or the alternative amount of wheat grain (such as 65, 80, 105, 130, 160 and 195 kg) to be given a year later were presented in the order mentioned to show which option the farmer preferred within each choice pair (see Table 3 for detailed description of the experiment).

The choice of the alternative amounts for future rewards is based on taking the midpoint of the alternatives from the credit terms of the local merchant who sometimes provide credit for cash constrained farmers for the purchase of farm inputs such as seed and fertilizer before planting; in agreement with repayment in kind with grain after harvest at about 100% rate of interest. Becker and Mulligan (1997) and the reference therein mentioned that in imagining future wants have the rate of discount factor gets larger as the future gets more remote. However, one can also note that the formulation of one-year time frame in this experiment might agree with the actual yearly agricultural production cycle. Formal credit usually linked with farm inputs (modern seeds, fertilizer and pesticide) provided by farmers' cooperatives with some down payments, usually 50%. Friends, relatives and neighbors are the other informal sources of finances often at zero interest rate and if any with low interest rate than the local merchants.

Few caveats for the hypothetical approach are in order. One limitation of the hypothetical choice experiment is the uncertainty about whether people are motivated to as they would do if outcomes are real (Frederick et al 2002). However, involving large stake rewards in one year time frame as in this hypothetical choice might relatively mimic the agricultural production environment and in terms of cost wise also difficult to conduct with real rewards. Like all experimental elicitation procedures, the results from such type of choice tasks can also be affected by procedural nuances such as the anchoring effect that when respondents are asked to make multiple choices between immediate and delayed rewards, the first choice they face often influences subsequent choices (Frederick et al 2002).

Empirical results

Estimation of shadow values

The first step in the empirical analysis is estimation of the agricultural technology to obtain the marginal revenue product of FYM. Table 4 reports the instrumental variable (2SLS) estimates of the agricultural production function. This estimation is based on farm inputs[5] and

[5] Similar to Skoufias (1994) and Jacoby (1993), the presence of zero values for some inputs is common in smallholder farming. Hence, to keep the empirical estimation manageable in such case, the logarithmic transformation was carried out by adding one to the relevant inputs.

total value of outputs recorded during the main growing season of the 2006 cropping period. Multiple crop outputs are aggregated in to a single output measure, value of output. The major crops grown in the study areas include wheat, tef, chickpea, lentil, fababean and grasspea. All the selected farm households are produced outputs at least from one crop.

The result found shows that agricultural output is significantly increasing with the application of FYM. Output is also overwhelmingly correlated with labor input, seed and cultivated land area with positive effect. A concern in estimation of agricultural production function is that agricultural outputs are in part determined the agricultural activities chosen by the farm households, a worry for the possibility of simultaneity bias. Because of the expectation of reverse causality that inorganic fertilizer and modern seed varieties are determinant of agricultural output, and are hence assumed as potentially endogenous, the model is estimated using instrumental variable. The choice of instruments for the endogenous regressors in this case is hypothesized to satisfy the relevance and validity conditions to which they are engaged in. The application of inorganic fertilizer and modern seed varieties are partly related to nearness of the farmer to information, household and farm characteristics.

The correlation of the included endogenous regressors with the instruments can be assessed by an examination of the explanatory power of the excluded instruments in the first stage regressions. The F-statistics in the first stage regressions for both endogenous variables are jointly significant at 1% level, which satisfy one condition that insures instruments validity. However, for models with more than one endogenous variable, as specified here, these indicators may not be sufficiently informative. The Hanson J statistics for over-identification test of all instruments does not reject the validity of the instruments, which may cast some light that the instruments satisfy the orthogonality condition required for their employment. In order to account for any heteroscedasticity induced by the two stage procedure in estimating the production function, the standard errors are based on White's (1980) heteroscedasticity consistent covariance matrix estimator.

The marginal product of FYM estimated from the production function is observed only for FYM farming participant farmers. Non-observing of marginal productivity is likely to be an indicative of non-participation in FYM farming. Hence, marginal products are imputed for each observation by estimating participation and marginal products equation jointly matching with the household, farm and village characteristics. This is used to estimate the parameters and hence predict the shadow value of FYM in farming for each observation. Table 5 presents maximum likelihood result of the determinants of participation in FYM farming and the return from it. Endogeneity stems from the fact that the participation and the marginal product of FYM are not independent. Sample selection bias here may be due to self-selection by the farm households who found FYM farming is more advantageous due to preexisting conditions or attributes than non-FYM farming. The marginal productivity of FYM function assumed for selected samples (FYM-users) does not, in general, estimate population shadow value of FYM in farming. Similarly, the shadow return of FYM selling is predicted for each observation by estimating market participation and selling price jointly (Table 5).

There are different factors determining the selection process. In such conditions, to enable identification, the additional eight more variables that are included in the participation equation (for both FYM farming and selling) than the outcome equations, as expected, are jointly significantly different from zero [$\chi^2(8) = 33.37$ with p-value of 0.001 for FYM selling; and $\chi^2(8) = 20.87$ with p-value of 0.008 for FYM farming]. The result is promising that the identifying variables are quite successful for their employment at enabling identification. Hence, these variables are more important to explain participation of FYM farming and selling equations. Specifically, of the included identification variables the significance of ***distfarm*** (average distance from home to farming plot) and ***donkey*** (number of donkeys owned) variables has important relation with the bulkiness of FYM for transportation in terms of the per ton value compared with commercial fertilizer and its important consideration for constraining the likelihood of participation in FYM farming for a distant farming plot. Since the demand for FYM to supply crop nutrient requirements is spatially constrained (Keplinger and Hauck 2006) household with more donkeys has an incentive towards to FYM farming participation. Donkey in rural areas has an important role used year round to ease the burden of domestic transportation of farm inputs and outputs to and from farm, home and markets.

Size of cultivated land, tree growing and off-farm income are included to control household's capacity in FYM farming, but the result found non-significant. As household's kerosene expenditure increases, the incentive for farmers to participate on FYM farming and selling increases as well. However, adoption of energy saving cooking devices and herd size reduce the likelihood of farmer's decision to participate on FYM farming and selling. The fitted shadow value of FYM in farming and selling from the above procedure is derived and kept for use in the FYM allocation model. Wald test for the joint significance of the instruments[6] used in each shadow value equations are presented in Table 5. At 0.01 probability, the instruments are jointly significant. This result confirms our instruments are informative for the identification of FYM allocation equations.

Testing equality of prices

In theory, individual allocates scarce resources among various alternatives until the point where the marginal returns across alternatives are equal. By doing so, farmers could choose the most profitable alternative options. For instance, if the productivity of FYM in farming is higher than the return of FYM from selling, it pays for farmers to shift FYM resources in to farming and away from selling it in the market. It has been observed that the average selling

[6] Instruments include: location variables (ZONE-1 and ZONE-2) and extension variables such as frequency of extension contact (EXTNFREQ) and whether farmers ever visited demonstration fields (DEMONVISIT).

price of FYM (ETB[7] 667/ton) is significantly lower (t-value = 13.21) than the average marginal revenue product of FYM (ETB 1018/ton), but it is significantly higher (t-value = 7.36) than the discounted marginal revenue product (ETB 544.74). These results cannot tell us whether or not the difference of the returns of selling FYM from the returns of FYM farming is commonplace.

In order to test whether the FYM allocations are efficient or not, the relationship between the estimated marginal returns of FYM and the observed FYM price from markets is examined. This test could shed some light on the presence of farm household preferences that are very salient determining the allocations. Following the approach of Jacoby (1993) and Skoufias (1994), who relate market wage with marginal productivity of labor in their agricultural labor supply analysis, we regress the discounted marginal product of FYM on the selling price as follows:

$$ln\, p_f^* = \gamma + \varphi\, ln\, p_s^* + v \qquad (17)$$

where p_f^* is the discounted marginal revenue product of FYM in farming; p_s^* is the FYM price by selling in the market and v is the random disturbance.

The regression result from (17) is shown below[8]:

$$ln\, p_f^* = \underset{(1.338)}{13.094} - \underset{(0.206)}{1.077}\, ln\, p_s^* \;;$$

The null hypothesis of efficient FYM allocations are contained in the conditions that $(\gamma, \phi) = (0,1)$. The value of F-statistics for $H_0 : \gamma = 0$ and $\phi = 1$ is 139.26; and the 5% critical value of F(2, 491) is 3.01. The value of the joint F-statistics obtained rejects the hypothesis irrespective of the significance level chosen. As explained by Skoufias (1994) that these test

[7] 1 USD = 8.76 ETB at the time of survey.
[8] Figures in parenthesis are robust standard errors

results provide evidence contrary to the efficient operation of the market, and thus, indirectly supports the concern about non-separability between the production and consumption decisions of farm households. It is possible that there must be various explanations for the rejection of the equality of the two values (p_f^* and p_s^*). Often the treatment of households' resource allocation behavior that wedge between the marginal revenue product and observed market price should be related to the household characteristics and constraints on factor availability and market imperfections (Barrett et al 2008; Jacoby 1993). Another explanation by Jacoby (1993) for this rejection from the ground that the estimated marginal products may in fact is systematically biased so that the instrumental variable method doesn't lead to consistent estimates. The next section explores the relationship between shadow prices, farmers' impatience and FYM allocations.

Shadow prices on farm yard manure allocation

The estimated shadow values predicted in the first stage of the analysis together with farmer's degree of impatience and other socio-economic information were matched with the individual farm household FYM allocation data. The parameters of the various allocation equations for FYM are estimated by a system of equations as a set of seemingly unrelated regressions. The result is presented in Table 6. The statistical performance of the estimated models is quite appealing. The calculated χ^2-statistic of 4702.75 is statistically significant at 1% significance level, providing evidence for the hypothesis of joint significance of the explanatory variables across all equations. As expected, the Breush and Pagan (1980) test of independence confirmed the rejection of the null hypothesis that state the covariance of the error terms across equations are not correlated. The test supports the estimation with SUR [$\chi^2(3)$ = 113.313 with the associated p-value of 0.000]. The estimates of FYM allocation functions with a full set of regressors provide empirical evidence on the effects of shadow value of

FYM affecting allocations across different purposes. The coefficients for shadow prices $\ell n\, p_s^*$ *and* $\ell n\, p_f^*$ provide estimates of the uncompensated own-price elasticity for FYM farming and selling, respectively. This comprises the usual opposing substitution and income effects. The result also provides the uncompensated cross-price elasticity for FYM farming, burning and selling. The estimated results are in agreement with the expectations.

The point estimate of the return of FYM from selling $\left(\ell n\, p_s^*\right)$ and farming $\left(\ell n\, p_f^*\right)$ in the FYM farming equation is negative but individually statistically different from zero at 1% significance level for selling price only. The negative sign of FYM selling price in the farming equation indicates the expected cross-price effect that as the selling price of FYM increases, farmer responds by allocating less to farming. The estimate for uncompensated elasticity is that a one percent increment of selling price of FYM leads to approximately one percent decline of FYM for farming. This puts a pressure that jeopardizes smallholder's soil fertility maintenance with adverse implications on sustainable management of one of the most important natural resources. This uncompensated price effect provides additional insights in to the Slutsky decomposition $\left(\partial M_f / \partial p_s^*\right)$ of income $\left(\partial M_f / \partial Y\right)$ and substitution $\left(\partial M_f / \partial p_s^*\big|_{u=\bar{u}}\right)$ effect.

Accordingly, the negative overall effect is either the negative compensated cross shadow price effect outweighs the positive income effect or the substitution and income effects are reinforced one another, if negative income effect is obtained. The available empirical evidence for expansion effect is the positive and statistically significant point estimates of off-farm income in FYM farming equation. Hence, the result confirms the negative uncompensated cross shadow selling price effect as a result of the negative compensated cross price effect that dominated the positive expansion effect. It is also worth noting the lack of statistical support for the effect of marginal productivity of FYM on the amount of FYM selling but the associated negative and significant effect on FYM burning. In the former case, there is no statistical evidence even that supports the income effects on FYM selling. The negative cross-price effect on the latter (-0.46 percent) is due to the negative cross-price substitution effect that dominates the positive and significant expansion effect. Hence, with the change in returns of FYM in farming, farmers might consider the allocation of FYM for burning in the household, considering the allocation of FYM for selling unchanged.

The point estimates for FYM selling price in FYM selling equation is positive and statistically different from zero at the 5% significance level. As expected, the finding reveals that farmers rationally respond to the change in price of FYM in the allocation of FYM for selling. The positive uncompensated own price effect works primarily through the positive substitution effect which outweighs the income effect. There is no statistical evidence that supports the significance of the income effect. As for allocating FYM for selling, it basically depends on the extent of the change in FYM for farming and the change in household's consumption of energy from FYM burning. The increase in selling price of FYM increases the price in terms of burning at home, thereby making burning FYM more expensive. This substitution effect, therefore, tends to cut the amount of FYM allocated for household energy. The uncompensated cross-price elasticity is positive but non-significant, while the expansion effect as proxy by off-farm income is positive and significant.

Farmer's impatience on allocation of farm yard manure

According to the theory impatient people have a positive time preference refers the observation that individuals show a systematic preference for receiving a commodity immediately, rather than at some later moment in time. When the respondent preference shifts from the early amounts to the amount for a later reward, the implicit one year rate of time preference was calculated as follows: $\delta = \ell n\left(f/p\right)$, where the respondent is indifferent between an amount of ‘p’ at the current time and a reward of ‘f ‘ received one year in the future. The mean discount rate in this experiment is about 94%. Pender (1996), however, has reported a discount rate of 30 - 60% for Indian villages, whereas Holden et al (1998) found a mean discount rate of 93% for Indonesia, 104% for Zambia, and 53% for one village in Ethiopia. Similar to Holden et al (1998) and Pender (1996) who found an upward bias from their experiment that asked farmers to adjust a present value equivalent to a fixed future value, about 64 per cent of farmers in this study were found to have a high discount rate (95 – 135%), in an experiment that asks the future value equivalent to a fixed present value, however (Fig. 1).

The data enabled us to link survey responses on FYM allocations from farm households to responses about discount rate by the same farm households. The key factor for the allocation of FYM among the available options is the trade-off between farm profitability due to soil fertility improvement but with delay; and immediate earning or energy consumption from direct selling or own burning. Hence, the farmer’s decision on FYM farming, selling or burning basically depends also on the fact that weather the outcomes from each allocations are temporally remote or not. This lets the decision makers to make comparisons between alternative options that have immediate or delayed outcomes. From the foregoing discussions, the marginal returns of FYM in farming is higher than the price of FYM from selling in the market, but that the former is with delayed outcomes and the latter with immediate benefits. As an inter-temporal choices in terms of motives associated with time, the trade-offs is a decision about allocating the resources between the competing interests, such as farming or burning, hence including the farmers’ degree of impatience measured with subjective discount rate is of important.

The parameter estimates for the farmer’s discount rate are in agreement with the expectation in the FYM allocation equations. The point estimate of farmer’s degree of impatience in the

FYM selling equation is statistically different from zero at the 90% confidence level. The positive sign indicates farmers that have high degree of impatience increase allocation of FYM for selling. Noting the theory that people have a positive time preference shows preference for receiving a commodity immediately are perfectly observed in the FYM selling equation. Here, farmers usually receive the return immediately so that, it is a chosen option among the available ones as far as impatient farm households are concerned. On the contrary, farmer's degree of impatience negatively affects the allocation of FYM in farming and burning, but the effect is statistically significant in the former case only. The outcome of allocating FYM in farming is quite remote due to the seasonality in agriculture, forcing the impatient farmers to switch away from FYM farming. Smallholders under imperfect credit market settings cannot afford to invest FYM the time today in increasing the future agricultural productivity of their own farm because farmers might look the alternative of selling FYM to meet immediate subsistence needs. The absence of credit for investing in on-farm improvements or consumption credit to meet immediate needs induces underinvestment and sacrifice the quality of the soil that results in lower future productivity and persistent poverty (Marenya and Barrett 2007).

This result is in perfect agreement with other few studies that combine the time preference experiments with field observations for better understanding of field behavior. The empirical study in Ethiopia (Shiferaw and Holden 1998) found a negative correlation between individual's rate of time preference and adoption of soil conservation technologies. In Brazil, fishermen who are impatient in a time preference experiment exploit the fishing grounds more (Fehr and Leibbrandt 2008); and in Sri Lanka people with higher rate of time preference extract more non-timber forest products causing depletion of forest resources (Gunatilake et al 2007). Therefore, a high rate of time preference is an important constraint for investments on soil conservation and could be viewed as a cause for the continuous depletion of the soil resources. In this context, allocation of FYM in farming plots is considered as investing now to improve the soil fertility and thereby improve agricultural productivity for increasing future agricultural returns. The policy implication of this is that high time preference rate due to poverty and financial market imperfections making farmers less patient to sacrifice current consumption due to income from immediate selling of FYM for future consumption due to income from investment of FYM as soil fertility.

Table 6 also provides several factors that are plainly to play as determinants of the allocation of FYM for different activities. We find statistical evidence for the change in allocations of FYM for household energy over the life cycle. Our findings show a U-shaped relationship between age and consumption of FYM for household energy. Households spend less FYM for energy until certain years old and they increase its consumption when they get too old (approximately over 70 years). The negative and significant signs of the variable sex of the household indicate female headed household spent more FYM for farming and household energy than male headed household. Apriori, one might expect the availability of labour as a major determinant of allocation of FYM for farming due to the bulkiness of the product. Our result reveals positive and significant correlation between number of women in the family and the amount of FYM spent for farming. The positive and statistically significant coefficient of the hire in labor variable in FYM-farming equation also supports the importance of labor in FYM farming. The positive correlation between the amounts of FYM spent for farming and education level of the household signals the importance of education in increasing the productivity of FYM farming.

Herd size (TLU) is a resource variable which provides a good indication for household's capacity to produce more FYM. The result shows that as the capacity to produce FYM increases, the amount of FYM spent for farming and burning in the household increases as well. TLU could also approximate the household's wealth status. We expect a negative and significant correlation of TLU variable in FYM selling equation. The correlation is statistically weak, however. We find a positive and statistically significant coefficient of "KEROSEN" variable in FYM-burning equation. A possible explanation is the complementarity between consumption of kerosene and FYM used for household source of energy, though the size of the effect is very small (the elasticity is about 0.07). In rural Ethiopia it is not uncommon to use kerosene as source of lighting. The coefficient of use of improved stoves in FYM-burning equation is negative and statistically significant, however. This coefficient is a measure of technical substitution (Amacher et al 1993) of stoves for FYM, suggesting improved stoves reduce household FYM consumption by about 15%. This result is consistent with Mekonnen and Kohlin (2008). The same study also indicated encouraging households to use more efficient cooking stoves as a possible solution to the problem of the limited use of dung as manure.

Conclusions

The causes of soil fertility depletion extend beyond the farm, receiving effects from household economic conditions. Here, a fundamental question in sustainable resource management is the extent to which resource allocation is linked to market fundamentals and basic features of farmers' preferences. The main contributions of this study are the analysis of the effect of various returns of FYM and farmer's impatience on the tradeoffs of using FYM as inputs to agriculture or burning them within or outside households. A better understanding of the determinants of farmer's FYM allocations is essential for informing policies and programs aimed at improving and maintaining the soil management system.

We find that the farmers' degree of impatience and the shadow prices of FYM are important determinants of FYM allocation behavior. The positive relationship between selling price of FYM and allocation of FYM for market and simultaneously its negative correlation with the amount of FYM for farming suggest important message for dealing the soil fertility issue, one of the most important smallholder farmers' problem in developing countries. In a traditional smallholder agriculture where agricultural productivity remains low, the returns from selling FYM will increase as the demand for biomass fuel rises and supply declines. In Ethiopia, driven by the continuous lifting of subsidies and rising tariffs of kerosene, and poor electricity infrastructure and rapid population growth in the urban and peri-urban areas, there is a growing interest in using FYM for energy production. For farmers, a sale of FYM to the consumers in these areas seems promising. A farmer's decision to divert FYM from farming to marketing due to heterogeneity in time preference is an alternative account to correlate input allocations with farmers' impatience. The high discount rates in this study indicate the substantial role time preference plays in investment and disregarding the long term effects of the sustainable management of resources.

Strands of literature that focus on the effect of other socio-economic variables on individual time preference provide an important policy direction for this study. Poor people are less patient is well documented (Holden et al 1998; Pender 1996; Tanaka et al 2010) suggesting economic development could influence preferences. Poverty is playing an important role in that poor farmers are degrading the natural resource base (Shively and Pagiola 2004) and poor are less likely to invest in environmental conservation (Holden et al 1998). The influence of poverty is irrational because the pressure of present needs blinds a person to the needs of the future (Becker and Mulligan 1997). This implies appropriate policies targeted on poverty reduction can potentially reduce farmers' impatience.

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Table 1. Definitions, means and standard deviations of variables used in the regressions

Variables	Description	Mean	Std. Dev.
OUTVALU	Total output value, ETB	16658.81	17206.74
p_f^*	Predicted shadow price of FYM for farming, ETB/ton	1018.30	568.82
p_s^*	Predicted shadow price of FYM for selling, ETB/ton	667.26	92.49
DISCOUNT	Farmer's discount rate	0.94	0.33
ZONE-1	Dummy: if location is north Shewa	0.42	
ZONE-2	Dummy: if location is west Shewa	0.15	
SEX	Dummy: 1 if male headed household	0.88	
MARITAL	Dummy: 1 if married	0.86	
EDUCATON	Years of education	4.08	4.11
AGE	Age of the household head, yrs	46.14	12.90
FAMLYSIZ	Total family size (in adult equivalent[9])	4.69	1.80
MALFAMLSIZ	Male family size (in adult equivalent)	2.62	1.34
FEMFAMLSIZ	Female family size (in adult equivalent)	2.07	0.98
FERTILIZER	Inorganic fertilizer applied, kg	38.72	37.31
FERTEXPEN	Total expenditure on commercial fertilizer, ETB	241.53	233.21
BULOCK	Bullock services, hrs	281.08	210.48
SEED	Seed used, kg	105.96	80.85
FARMLABR	Labor for farming, hrs	664.45	223.54
CROPAREA	Cultivated area, ha	2.33	1.71
MODERNVAR	Fraction of area with modern crop varieties	0.89	0.57
PRIVATGRAZ	Private grazing area, ha	0.07	0.01
HIREINLABR	Dummy: 1 if hire in labour	0.22	
COMPOUND	Size of the compound/garden (sq. meter)	405.99	143.65
EXTNFREQ	Frequency of extension contact per month	0.49	0.44
DEMONVISIT	Dummy 1: if ever visited demonstration field	0.41	
DISTFARM	Average distance from home to farming plot, hrs	0.27	0.17
DISTMKT	Distance to market	0.16	0.16
ROTATION	Fraction of area rotated with legume crops	0.21	0.18
GOODSOIL	Fraction of area with good quality soil	0.35	0.05
EQUB	Dummy: 1 if participated on rotating saving and credit club	0.44	
DONKEY	Number of donkey owned	1.66	1.65
OFFINCOM	Offarm income, ETB	111.59	231.11
TLU	Herd size (in TLU[10])	6.73	4.09
KEROSEN	Annual kerosene consumption, lit	86.51	78.59
TREE	Number of trees owned	98.40	124.11
STOVUSE	Dummy: 1 if use energy saving stove	0.49	

[9] Adapted the Amsterdam scale (see Deaton and Muellbauer 1980)
[10] Herd size measured in terms of Tropical Livestock Unit where 1 TLU (which equals 250 kg body mass) = 1 cattle = 6.67 sheep/goat = 1 horse = 1.15 mule = 1.54 donkey = 0.87 mule = 200 poultry

Table 2. Average shares of FYM by purposes, contribution of FYM to annual livestock income, Nitrogen (N) and Phosphorous fertilizers

Purpose	North Shewa	West Shewa	East Shewa	Total
FYM produced (ton/annum)	9.33 (8.18)	12.67 (16.69)	6.98 (10.11)	9.17 (10.57)
Farming (M_f)	0.27 (0.26)	0.32 (0.20)	0.46 (0.23)	0.34 (0.25)
Selling (M_s)	0.42 (0.27)	0.36 (0.25)	0.31 (0.23)	0.38 (0.26)
Household Energy (M_e)	0.31 (0.25)	0.31 (0.24)	0.23 (0.22)	0.28 (0.24)
Annual livestock income (Birr)	4476.88 (5180.29)	4313. 42 (8835.40)	2966.05 (4505.32)	4022.97 (5747.32)
Share of FYM income	0.30 (0.28)	0.47 (0.39)	0.28 (0.33)	0.32 (0.32)
Number of observations	278	75	140	493

* Numbers in parenthesis are standard deviation.

Table 3. Structure of the time preference experiment and farmer's discount rate

Choice	Nominal Size in kg of wheat		Rate of time preference*	Discount Rate Class
	Now (*p*)	12 months (*f*)	(**δ**), %	
1	50	65	26	Almost neutral
2	50	80	47	Slight
3	50	105	74	Moderate
4	50	130	96	Intermediate
5	50	160	116	Severe
6	50	195	136	Extreme

*The implicit one-year discount rate: $\delta = \ell n(f/p)$

Instruction: We would like to know your preference about taking wheat grain now compared with a wheat grain after a year. Please indicate for each of the following certain number of choices, whether you would prefer the smaller amount of wheat to receive now or the bigger amount of wheat to take later one year from now. For instance, which one would you choose: 50 kg wheat now or 65 kg wheat exactly after one year?

Table 4. Instrumental variable (2SLS) estimation of Agricultural production function (Dependent variable: *ln* (OUTVALU))

Variables	Coefficients	Robust Std. Err.
ZONE-1	-0.809***	0.131
ZONE-2	-0.344**	0.154
ln(FYMFARM)	0.214**	0.089
ln(MODERNVAR)	0.523	0.467
ln(FERTILIZER)	-0.151	0.282
ln(BULOCK)	-0.015	0.036
ln(FARMLABR)	0.329***	0.087
ln(CROPAREA)	0.375***	0.131
ln(SEED)	0.365***	0.113
GOODSOIL	0.979	0.939
CONSTANT	5.922***	1.357
Joint significance: F(10, 482)	71.10***	
Instrumented variables:	FERTILIZER, MODERNVAR	
Excluded instruments	DISTDA, DISTFARM, EQUB, AGE, FAMLYSIZE	
F test of excluded instruments:		
FERTILIZER: F(5, 479)	3.04***	
MODERNVAR: F(5, 479)	3.60***	
Overidentification test of all instruments:		
Hansen J Statistic:	5.185	
$\chi^2(3)$ p-value:	0.159	

** and *** refers significance level at 5 and 1 percent.

Table 5. Maximum likelihood estimate for participation and shadow values of FYM

	Farming		Selling	
Variables	Participation	Shadow Price	Participation	Shadow Price
CONSTANT	-0.13 (0.87)	998.29 (375.41)***	2.33 (0.94)**	463.13 (107.58)***
DISTMKT		1824.14 (388.81)***		219.58 (76.41)***
ROTATION		419.00 (193.36)**		-104.24 (53.98)**
EXTNFREQ		80.86 (14.51)***		-25.07 (4.40)***
DEMONVIST		-6.08 (64.44)		16.27 (19.03)
ZONE-1	-0.52 (0.18) ***	-334.33 (89.40)***	0.17 (0.18)	-189.37 (27.98)***
ZONE-2	-0.37 (0.23)	-390.63 (80.55)***	0.33 (0.22)	-44.96 (32.39)
AGE	0.07 (0.04) **	-19.72 (15.02)	-0.08 (0.04)**	13.12 (4.61)***
AGESQR (10^{-3})	-0.57 (0.35) *	117.35 (146.25)	0.69 (0.38)*	-101.38 (47.45)**
SEX	0.49 (0.27) *	-98.99 (135.38)	-0.01 (0.29)	60.79 (47.51)
MALFAMLSIZ	-0.03 (0.06)	57.12 (26.09)**	-0.01 (0.06)	-10.74 (6.91)
FEMFAMLSIZ	-0.04 (0.07)	35.79 (45.77)	0.01 (0.07)	3.40 (10.93)
EDUCATION	-0.04 (0.02) *	5.69 (9.78)	0.02 (0.02)	-5.19 (2.78)*
MARITAL	-0.31 (0.24)	19.36 (110.72)	0.09 (0.25)	-21.99 (38.35)
DISTFARM	-0.96 (0.42) **		-1.52 (0.39)***	
DONKEY	0.18 (0.08) **		-0.03 (0.07)	
OFFINCOM (10^{-3})	0.15 (0.32)		0.51 (0.44)	
CROPAREA	0.01 (0.05)		0.17 (0.06)***	
TREE (10^{-3})	0.12 (0.63)		-0.28 (0.56)	
KEROSEN (10^{-3})	3.15 (1.37)**		2.40 (1.12)**	
STOVADOP	-0.39 (0.18)**		-0.30 (0.17)*	
TLU	-0.08 (0.03)***		0.05 (0.04)	
Number of observation	493	400	493	405
Wald statistic	157.61[a]		104.82[a]	
Joint significance of instruments	20.87[b]	96.47[c]	33.37[b]	61.64[c]
Wald test of independent equations:				
$\chi^2(1)$	1.94		7.32	
Prob. > $\chi^2(1)$	0.164		0.007	

*, ** and *** refers significance level at 10, 5 and 1 percent respectively; parenthetical terms are robust standard errors.

[a] Wald test for joint significance of the explanatory variables distributed as a chi-square with critical values of 27.69 for 13 degrees of freedom at 0.01 probability.

[b] Joint significance of the instruments distributed as a chi-square with critical values of 20.09 for 8 degrees of freedom at 0.01 probability.

[c] Joint significance of the instruments distributed as a chi-square with critical values of 13.28 for 4 degrees of freedom at 0.01 probability.

Table 6. Maximum likelihood estimates for FYM allocation

	Farming		Selling		Energy	
Variables	Coefficients	Std. Err.	Coefficients	Std. Err.	Coefficient	Std. Err.
CONSTANT	4.469***	1.972	-7.641	4.643	0.732	3.912
$\ell n\, p_f^*$	-0.025	0.035	-0.101	0.081	-0.436***	0.069
$\ell n\, p_s^*$	-0.872***	0.309	1.458**	0.727	0.460	0.613
DISCOUNT	-3.135*	1.851	9.854**	4.359	-5.798	3.672
OFFINCOM (10^{-3})	0.120	0.059**	-0.083	0.139	0.229**	0.117
AGE	-0.006	0.007	-0.009	0.017	-0.038***	0.015
AGESQR (10^{-3})	0.079	0.069	0.059	0.165	0.272**	0.139
SEX	-0.121**	0.056	-0.002	0.131	-0.197*	0.110
MARITAL	0.049	0.048	-0.083	0.113	0.235***	0.095
MALFAMLSIZ	0.014	0.011	0.033	0.025	0.035	0.021
FEMFAMLSIZ	0.024*	0.014	-0.003	0.033	0.008	0.028
HIREINLABR	0.076**	0.033	0.046	0.077	0.025	0.065
EDUCATION	0.007*	0.004	0.001	0.009	0.017**	0.007
FERTVALU (10^{-3})	0.082	0.065	1.216***	0.153	1.326***	0.129
ROTATION	0.065	0.081	0.282	0.192	0.642***	0.161
DISTMKT	-0.016	0.522	1.272	1.229	-1.342	1.035
DISTFARM	0.065	0.079	0.022	0.187	0.009	0.157
DONKEY	-0.039***	0.012	-0.043	0.028	-0.031	0.024
CROPAREA	-0.017	0.048	-0.090	0.113	0.259***	0.095
PRIVATGRAZ	2.568*	1.352	-2.795	3.183	0.636	2.682
COMPOUND	0.012***	0.004	-0.023**	0.010	0.013	0.008
KEROSEN (10^{-3})	0.158	0.227	-0.695	0.534	0.882**	0.450
TREE (10^{-3})	0.134	0.114	-0.089	0.267	0.101	0.225
TLU	0.023***	0.005	0.018	0.012	0.029***	0.010
STOVUSE	0.014	0.035	0.213***	0.083	-0.162***	0.070
$\chi^2(24)$	3500.10		148.31		393.76	
p-value	0.000		0.000		0.000	
Observation	493		493		493	
Correlation matrix of residuals						
Farming	1		0.133		0.068	
Selling	-		1		-0.455	
Test of independence: $\chi^2(3) = 113.313$; p-value = 0.000						

*, ** and *** refers significance level at 10, 5 and 1 percent respectively.

Figure 1. Correlation between soil quality and FYM used for farming

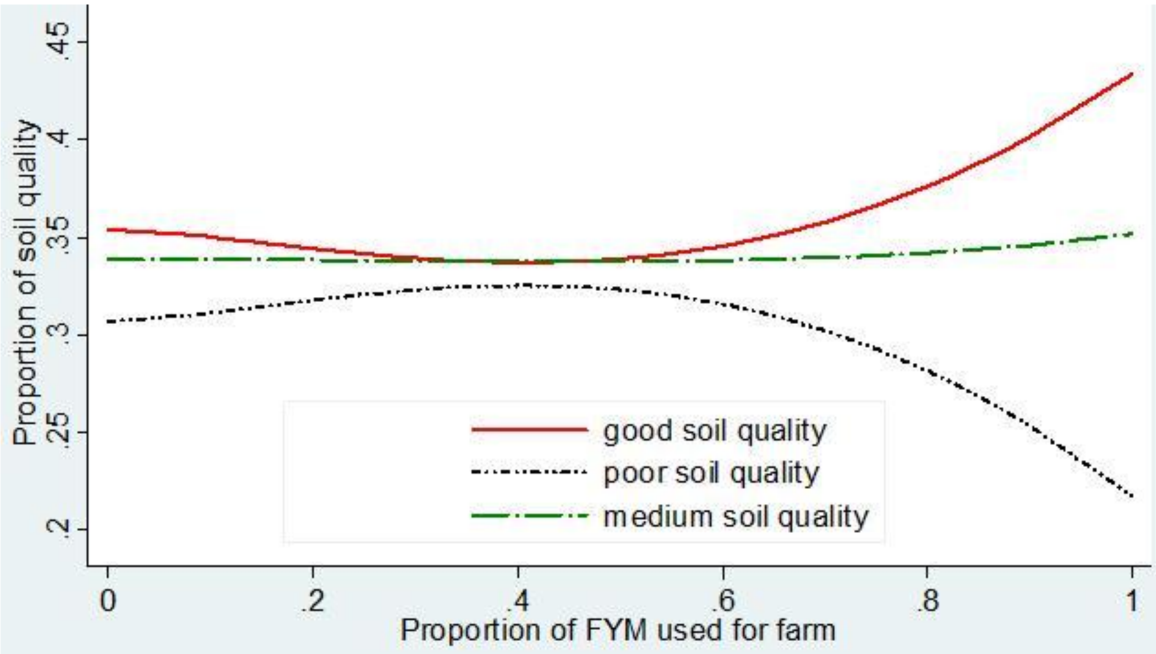

Figure 2. Farmers' discount rate responses for future value equivalents