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MARKET IMPERFECTIONS AND LAND PRODUCTIVITY IN THE ETHIOPIAN HIGHLANDS

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ABSTRACT

This study analyzes how market imperfections affect land productivity in a degraded low-potential cereal-livestock economy in the Ethiopian highlands. A wide array of variables is used to control for land quality in the analysis. Results of three different selection models were compared with least squares models using the HC3 heteroskedasticity-consistent covariance matrix estimator. Market imperfections in labor and land markets were found to affect land productivity. Land productivity was positively correlated with household male and female labor force per unit of land. Female-headed households achieved much lower land productivity than male-headed households. Old age of household heads was also correlated with lower land productivity. Imperfections in the rental market for oxen appeared to cause overstocking of oxen by some households. Conservation technologies had no significant positive short-run effect on land productivity. The main results were consistent across the different econometric models.

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KEYWORDS: Market imperfections, land productivity, Ethiopian highlands

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MARKET IMPERFECTIONS AND LAND PRODUCTIVITY IN THE ETHIOPIAN HIGHLANDS

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1. INTRODUCTION

Market imperfections[4] are common in rural markets in developing countries (Hoff et al. 1993; de Janvry et al. 1991) and the efficiency implications of market imperfections have been a controversial issue since Marshall claimed that share tenancy was an inefficient institutional arrangement (Cheung 1969; Stiglitz 1974). Singh et al. (1986) developed the separable farm household model as a benchmark approach to the analysis of rural economies. This model was based on the assumption of perfect markets, except for one market, that of land. de Janvry et al. (ibid.) developed a more general theoretical model, allowing for market imperfections in rural economies. The presence or absence of market imperfections may have significant efficiency and other policy implications. The resource distribution is likely to be important for the existence of and participation in rural factor markets.

There have been few studies of the efficiency of factor markets in Africa (Udry 1996). Barrett (1996), Gavian and Fafchamps (1996) and Collier (1983) found an inverse relationship between farm size and efficiency in Madagascar, Niger and Kenya. Gavian

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[4]Defined broadly as deviations from perfect market conditions.

and Fafchamps (1996) found that yields were strongly influenced by the manpower available to farm households in Niger, indicating that marginal returns to land and labor are not equalized across households. Udry (1996) found evidence of imperfections in labor and land markets in Kenya and of imperfections in capital and insurance markets in Burkina Faso. Gavian and Ehui (1999) found in a study in Ethiopia that total factor productivity was lower on rented land but that input intensity was not different on rented land. Other studies of efficiency in agriculture in Ethiopia (Suleiman 1995; Croppenstedt and Mamo 1996; Asfaw and Admassie 1996) have studied the efficiency of each farm, which is different from our focus on whether factors are allocated efficiently across farms. Of the above studies, only Udry (1996) controls for land quality when testing the efficiency of factor markets.

In this study, we test whether factor markets are able to eliminate the potential inefficiencies which may accrue due to unequal distribution of factors in a low potential crop-livestock economy in the Ethiopian highlands where land has been reallocated to ensure equity in land distribution but where other resources, especially livestock, have not been subject to redistribution policies. We use farm plot level data and control for a wide array of plot level land quality characteristics. We assess whether after controlling for prices and plot characteristics, there remains a significant correlation between land productivity and household (resource) characteristics, so that we can test the hypothesis of perfect factor markets. We test the robustness of the results by applying different econometric approaches.

We develop a conceptual framework for the analysis, including some tentative hypotheses, in part 2 of the paper. In part 3 we describe the case study area and data, while the estimation procedures are described in part 4. The results and discussion follow in part 5, leading to a conclusion in part 6.

2. THEORETICAL MODEL

Our basic hypothesis is that high transaction costs and imperfect information cause market imperfections and non-separability of production and consumption decisions in poor rural economies. With perfect markets and perfect information, land productivity would only be a function of exogenous output and input prices (p_j), where subscript j refers to outputs and inputs, and land characteristics (A_q): $\Pi = \Pi \ (P_j, A_q)$. Factor market imperfections may reduce land productivity at plot level. We may illustrate this in a simple theoretical model as follows. We assume that crop output (q) is a function of land (A), labor (L) and oxen (O) (traction power), $q = q(A, L, O)$. With one market imperfection, e.g. a missing market for land, the utility maximizing problem of the land user may be formulated as follows:

(1) $$U = V(p_c q(\bar{A}, L, O) - p_w L - p_r O)$$

with the following first order conditions:

(2) $$P_c \frac{\partial q}{\partial l} = P_w ; P_c \frac{\partial q}{\partial o} = P_r$$

where P_c is the price of the output, P_w is the wage rate, and P_r is the rental rate for oxen. In this case we get no inefficiencies and land productivity is only a function of exogenous prices and land characteristics: $\Pi = \Pi(P_j, A_q)$ However, if we have imperfections for two of the factors, e.g. missing markets for land and labor, we get inefficiencies if the input ratios vary across farms and the inputs are imperfect substitutes. For example, assume for simplicity that there is low substitutability between these inputs. In the (extreme) case of no substitutability (Leontief production function), one of the fixed inputs will be binding and the marginal return to the other will be zero[5]. There will be a non-utilized portion of the non-binding fixed input (cause of inefficiency). If land is the binding factor for one household, the marginal return to labor will be zero and there will be underemployment, and if family labor is the binding factor for another household, the marginal return to land will be zero and the household will not utilize all its land. In this case, it is easy to show that land productivity at the plot level in a cross-section of households[6] will be a function of the household specific fixed factors:

(3) $$\Pi = \Pi(\overline{A}, \overline{L})$$

The household specific fixed factor ratios determine which factor is binding in each household. Econometrically, this may be tested for by using the factor ratio as an independent variable, $\Pi = \Pi\ (A_q, \overline{A}, \frac{\overline{L}}{\overline{A}})$ Missing markets is an extreme case of market imperfection. The intermediate case with a price band, some selling, some self-sufficient, and some buying households for each factor may be a more realistic representation of

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[5] It is not necessary to assume nonsubstitutability. Imperfect substitutability implies that different factor ratios lead to different marginal products and this is sufficient to get inefficiency when markets for these factors are missing. The inverse farm size-yield relationship follows with missing factor markets for land and labor in constant returns to scale production.

[6] We assume this is a constant price sample and therefore ignore prices, except the endogenous shadow prices that result from the imperfect markets.

factor markets in Ethiopia where there are rental markets for land and oxen and also a labor market. Price bands reflecting transaction costs may accrue due to search costs and moral hazard (labor markets), immobility of land and transportation costs (land markets), moral hazard and seasonality/timing constraints (oxen rental markets) and so forth. We may illustrate this with an extension of our simple model:

(4) $$U = V(p_c q(A, L, O) - p_{\ominus}^{i} A - p_w^i L - p_r^i O)$$

where $i \in \{s, *, b\}$ s denotes households selling the factor, * denotes self-sufficient households, and b denotes households buying the factor. Actual factor use may be as follows:

(5) $$A = \overline{A} + A^i,\ L = \overline{L} + L^i,\ O = \overline{O} + O^i$$

where A is the operated farm size, $\overline{A}$ is the owned farm size, and A^i is the land rented in or out (negative if rented out), and similarly for the two other factors. The utility maximization problem then becomes:

(6) $$U = V(p_c q(\overline{A} + A^i, \overline{L} + L^i, \overline{O} + O^i) - p_{\ominus}^{i} A^i - p_w^i L^i - p_r^i O^i)$$

and yields the following first order condition for the land factor:

(7) *Seller of land:* $$P_c \frac{\partial q}{\partial A_s} = P_{\Theta}^{s}$$

Self-sufficient: $$P_c \frac{\partial q}{\partial A^*} = P_{\Theta}^{*}$$

Buyer of land: $$P_c \frac{\partial q}{\partial A_b} = P_{\Theta}^{b}$$

We have that $P^{s}_{\Theta} < P^{*}_{\Theta} < P^{b}_{\Theta}$. The implication of this is that marginal productivity of land for each household depends on whether the household is a seller, self-sufficient, or buyer of the various factor inputs. There is an inverse relationship between resource price and resource demand. If different households face different price ratios, this affects land productivity at the plot level. Empirically, we may test whether land productivity at the plot level is a function of owned farm size, household labor force per unit of land, and owned oxen per unit of land: $\Pi = \Pi\left(\bar{A}, \frac{\bar{L}}{\bar{A}}, \frac{\bar{O}}{\bar{A}}\right)$. If any of these variables are significant, this is a sign of factor market imperfections and significant transaction costs. On the other hand, if these factor endowments are insignificant, this may indicate that factor markets function reasonably well or that factors are in abundant supply for all.

We specify a reduced form productivity function, based on the theory outlined above:

$$(8) \qquad \Pi / mi = \Pi\left(P_q, \bar{A}, \frac{\bar{L}}{\bar{A}}, \frac{\bar{O}}{\bar{A}}, T_q, C_h\right)$$

Equation 8 says that if there are market imperfections, land productivity at the plot level is a function of a vector of farm plot characteristics (P_q), farm size $(\bar{A})$, family labor per unit of land $(\frac{\bar{L}}{\bar{A}})$, oxen per unit of land $(\frac{\bar{O}}{\bar{A}})$, a vector of technologies (T_q) applied at plot level, and a vector of household characteristics (C_h). Implicit in this formulation is the optimal choice of inputs and crops for each plot, given the same market constraints.

Variable input levels are assumed to be endogenous and a function of the same factors as profit in equation (8).

Bhalla (1988) and Benjamin (1995) argued that unobservable land quality may explain the frequently observed inverse farm size-productivity relationship. Larger farms tend to be less fertile and therefore also less productive. By including a large number of land quality variables we hope to control for this land quality bias. However, there may still be unobservable land quality factors and if these are correlated with observed explanatory variables, like plot size, we have a omitted variable bias. It may lead to type I error; we may reject the perfect markets hypothesis when it is correct. If this problem is worse on large plots (poorer quality) than on small plots, plot quality will be negatively correlated with plot size (Udry 1996). We have included plot size to attempt to control for this possible bias. Following Udry (1996) we have also subtracted the plot size from the farm size and included the area of other household plots rather than total farm size. This specification eliminates the potential technological explanation (decreasing returns to scale) on a given plot for the inverse relationship.

We may distinguish between profit-maximization in the short run and in the long run and there may sometimes be tradeoffs between the two as short-term profit maximization may undermine long-term profits. This was found to be the case in the study area (Shiferaw and Holden 1998). In this study we focus on short-term profit maximization decisions as we have data only for short-term land productivity measured in monetary terms. In this short-term perspective it may appear irrational that households decide to leave some plots fallow.

Households may also allocate plots for grazing, grassland, or for tree planting. We were unable to measure the output on these plots. Yet the decision to crop or not to crop (to leave the land fallow, for grazing, grassland, or tree planting) may also be affected by other variables than those determining short-term profits. Tree planting may be very profitable in the long run but not in the short run. Leaving a plot fallow for another year may reduce short-term profits but increase long-term profits. Grass production or using land for grazing may be profitable in the short run also but we were unable to measure this profit. Some households who do not have oxen may fail to cultivate a plot because they lack oxen and fail to rent in oxen. Asymmetric information and transaction costs may also cause them to fail to rent out these plots. These factors may cause a selection bias that may cause a type II error; we fail to reject the perfect factor market hypothesis when it is false. We estimated selection models (censored regression models) to attempt to control for such a potential selection bias.

3. CASE STUDY AREA, DATA, AND VARIABLE SPECIFICATION

The data were collected from a sample of 102 households in seven villages in a highly degraded crop-livestock farming system in the Ethiopian highlands (Andit Tid, North Shewa, 50-60 km from Debre Berhan). The survey was carried out in 1998. Farm plot level data were collected for 606 farm plots, which included all the plots of the sampled households. Data from 598 plots were used in the analysis. Out of these, 461 plots were cultivated and planted with crops during 1997. The data included biophysical and technology characteristics at the plot level and farm household characteristics at the farm level. We have earlier analyzed data from a 1994 survey in the same area focusing on resource degradation and adoption of conservation technologies (Shiferaw and Holden 1998). This study goes further and considers the existence of market imperfections and how they affect the returns to cropping. An overview of the biophysical, technology and household characteristics variables included in the analysis are presented in Table 1.

Table 1--Overview of variables used in the analysis.

Variable name	Variable type	Variable definition	Mean	St.dev
Nprodvaha	Cont.	Net production value, Birr/ha, dependent variable	478.731	291.156
Village	Dummies	6 dummy variables for 7 villages		
Soil type	Dummies	8 dummy variables for 9 soil types		
Land type	Dummy	1=outside treated catchment area	0.746	
Plot size	Cont.	Area of plot in ha	0.559	0.395
Distance	Cont.	Distance from home to plot (km)	0.971	0.979
Slope	Cat.	1=flat, 2=foothill, 3=midhill, 4=steep hill	1.951	0.851
Soil depth	Cat.	1=shallow(<30cm), 2=medium, 3=deep(>60cm)	1.482	0.679
Land quality	Cat.	1=poor, 2=good, 3=very good	1.622	0.633
Susceptibility	Cat.	to erosion: 1=very high, 2=high, 3=low, 4=none	2.594	0.646
Degradation	Cat.	1= very high, 2=high, 3=low, 4=none	2.633	0.926
Zone	Cat.	1=dega zone, 2=wurch zone (high altitude)	1.354	0.479
Season	Dummy	0=meher, 1=belg (short rains)	0.248	
Tradit	Dummy	Traditional ditches in the plot, 0=no	0.749	
Cut-off drain	Dummy	1=cut-off drain in the plot, 0=no	0.635	
Waterway	Dummy	1=waterway in the plot, 0=no	0.005	
Boundary	Dummy	1=boundary planting around the plot, 0=no	0.662	
Bunds	Dummy	1=bunds in the plot, 0=no	0.276	
Fanya juu	Dummy	1=funya juu (conservation structures),0=no	0.125	
Crop: Barley	Dummy	1= Barley, 0=Wheat		
Crop: Other	Dummy	1=Other crops (non-cereals), 0=Wheat		
Sex of hh head	Dummy	0=female, 1=male	0.912	
Age of hh head	Cont.	Years	49.56	
Type of house	Dummy	1=corrugated iron roof, 0=thatched roof	0.235	
Educat	Cont.	Education of household head, years	1.039	1.978
Educavg	Cont.	Average education, persons > 16, years	0.977	1.091
lnvariable	Cont.	Log of variable		
lnvariable2	Cont.	Log of variable squared		
dvariable	Dummy	1 if *variable*=0, 0 if *variable*>0		
Oxenha	Cat.	Oxen owned by the household per ha	0.461	0.343
TLUsuboxha	Cont.	Tropical livestock units excluding oxen per ha	1.102	0.726
Malelabha	Cont.	Household male labour force per ha	0.563	0.424
Femlabha	Cont.	Household female labour force per ha	0.423	0.283
Subtrarea	Cont.	Farm size minus plot size	2.377	0.932
Consunitha	Cont.	Consumer units based on nutritional requirem.	1.834	1.171
Manurha	Cont.	Manure on plot in baskets/ha	1.681	6.794
DAPcha	Cont.	DAP fertilizer on plot, cost in Birr/ha	0.238	1.586
Ureacha	Cont.	Urea fertilizer on plot, cost in Birr/ha	0.098	1.08
Rentin	Dummy	1 = rented in plot, 0 = other plots	0.074	
Rentout	Dummy	1 = rented out plots, 0 = other plots	0.064	
Crop 96le	Dummy	1 = if plot was planted with legume in previous year	0.145	
Crop96fa	Dummy	1 = if plot was fallow in the previous year	0.249	
Offincha	Cont.	Off farm income, Birr/ha	37.406	138.059

"Profit" could not be measured directly as prices of non-traded inputs were endogenous and could not be revealed easily. Instead, for each plot the value of gross output minus the cost of purchased inputs was used as the dependent variable.

The fact that cross-section data from a fairly small area were used for the analysis should control for most of the output price variation. Distance from the home to the plots and village dummies were used to control for the remaining local price variation. The village dummies should also control for most of the local climatic variation. The year for which the data were collected had good rainfall and prices were therefore also normal and stable and should not deviate significantly from the expected prices of rational farmers. To eliminate the potential bias introduced by crop choice and price and input use differences among crops, we also carried out an additional analysis for the dominant crop in the area, barley. We did this analysis for the 270 plots planted with barley. Crop diversity, even if land productivity in monetary terms is significantly different for different crops, may be a sign of market imperfections, causing a subsistence orientation in production. However, this could also be due to agro-climatic differences (which we try to control for) and a deviation between short term and long-term objectives (e.g. crop rotation may reduce short term productivity but enhance long term productivity). Uninsured production and price risks (limited insurance markets) may also be another important explanation (Barrett 1996).

Conservation technologies have been introduced in the area through projects. In addition, there exist several traditional conservation techniques. On any plot one could find a mix of externally introduced and traditional technologies. Dummy variables were specified for the existence of each of these at the plot level to control for their influence.

Very few of the plots received fertilizer and credit was not available during the 1997 cropping year in the study site. Fertilizer use is considered very risky at this high elevation and households are therefore reluctant to buy it. Only twenty out of the 598 plots received fertilizer, of which 16 received only DAP and the remaining ones received both DAP and urea. The low number of plots and the fact that there may be a selection bias related to plots selected for fertilizer use makes it impossible to get reliable estimates of the effects of fertilizer on land productivity.

Manure was applied to some of the plots (101 out of 598 plots). We had no good instruments to predict manure use as most variables that could determine its use are already in the model. We ran the regression with and without it. The variable was not significant (Table 4).

Most land rental arrangements in the area involve share tenancy. Marshallian inefficiency may cause lower input use and lower profit on plots that are sharecropped (Cheung 1969; Stiglitz 1974). To test for this, dummy variables were included for plots rented in and rented out. Selection bias may, however, invalidate this test. It is therefore necessary to interpret the signs on these dummy variables with care. There were 30 out-rented plots and 43 in-rented plots in the sample.

Off-farm income may affect land use decisions and short-term profitability in several ways. Access to off-farm income may provide resources for farming as the liquidity constraint may be relieved. On the other hand, involvement in off-farm activities may take labor away from farming activities if hired labor is an imperfect substitute for family labor and there are significant search and monitoring costs related to hiring of labor. Access to off-farm income may also reduce interest in farming. The effect of access to off-farm income on the profitability of land use is therefore ambiguous. The problem of estimating the effect of off-farm income on land use profitability is that off-farm income may be endogenous and we have no good instruments to estimate it. We expect that many of the variables included in the analysis of land use profitability will also influence the off-farm income of households. Omitting off-farm income from the analysis may also leave us with an omitted variable bias, however. We therefore ran the model with and without the off-farm income variable.

There is a fairly strict gender division of labor in the study area and some farm activities are carried out by men only. We therefore divided the labor force by gender. Such cultural restrictions reduce the substitutability of male and female labor and the scarcity of one type of labor may cause inefficiency unless the labor market works well. We also included a dummy variable for sex of household head. Female-headed households face special problems because they usually have insufficient male labor and oxen. Nine out of the 102 households were female headed. They had on average only half the amount of male labor per ha and less than one third the amount of oxen per ha of that of male headed households. Since we are already controlling for these differences, however, then any significant difference due to the sex of household head variable would have to be explained differently, such as by differences in managerial skills.

To control for selection bias we needed to identify some unique variables for the selection equation. Identification requires[7] that at least one continuous variable is unique in the switching equation (Deaton 1997). We decided to use the following variables as instruments in the selection equation:

1. Fallow 96: land fallowed in the preceding year is likely to be fallowed also the year under study.
2. Legume 96: land planted with legume in the previous year is likely to be cropped this year as the legume is planted to improve the soil for the following crop.
3. TLUsuboxen/ha: tropical livestock units, excluding oxen, (livestock population pressure) may affect the area planted with crops or used for grazing.
4. Oxen/ha: Oxen are important for land cultivation and may contribute to an increase in the probability of cropping when factor markets are imperfect. On the other hand, oxen also require fodder and that increases the probability that plots are left for grazing or grass production.

We cannot rule out that these variables also influence farm productivity directly, but this effect is uncertain.

4. ESTIMATION PROCEDURE

To test for selection bias in relation to choosing plots for cropping we estimated the following censored sample selection model:

(9) $$\Pi = d[x'\boldsymbol{b} + \boldsymbol{n}]$$

where the dependent variable is determined by the regressors x, an unobservable error term v, and the indicator variable d, which determines whether the dependent variable is

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[7] This is not strictly required but it helps increase statistical power.

censored (plot is not used for cropping) or not. This indicator variable is assumed to be determined by a vector of conditioning variables, *z*, through a binary choice model:

(10) $$d = 1[z^{'} g + \in > 0]$$

where $1[C]$ denotes an indicator function for the event *C (cropping)*, g is a vector of unknown coefficients, and $\in$ is an unobserved error term. This model may be estimated in several ways. The classical parametric approach has been based on normality assumptions for the error terms:

$$n \sim N(0, s),\ \in \sim N(0,1),\ corr(n, \in) = r$$

Estimating the first equation by ordinary least squares would yield biased estimates when $r \neq 0$. The Heckman selection model (Heckman 1976) has been the standard model for correcting selection bias. It provides consistent and asymptotically efficient estimates for all parameters in such models.

For positive values of $\prod$ the regression function is:

(11) $$\mathrm{E}(\prod |\ x, z, \prod > 70) = x' b + l(z' g)$$

where the last term is defined as:

(12) $$\lambda(z'g) = E(v \mid \varepsilon \geq -z'g) = r s_0 (\varphi(z'g/s_2))/(\Phi(z'g/s_2))$$

where $\varphi(\cdot)$ and $\Phi(\cdot)$ are the density and distribution functions of the standard normal distribution, s_0 and s_2 are the two standard deviations, and r is the correlation coefficient.

Given normality, the l function can be represented by the inverse Mills' ratio (IMR) and the remaining parameters estimated using least squares (Heckman 1976).

Following the recommendation of Davidson and MacKinnon (1993, p.545) we used ML for the estimation. The Heckman selection model relies on strict normality assumptions, however, and is sensitive to heteroskedasticity.

We tested for heteroskedasticity, using the Cook and Weisberg (1983) tests, which showed the presence of heteroskedasticity. We tried linear, log-linear and (reduced[8]) translog functional forms in an attempt to eliminate the heteroskedasticity problem. We were unable to eliminate these problems. However, the translog functional form gave the lowest X^2 values for heteroskedasticity and was therefore preferred. To handle zero levels of inputs we created dummy variables (=1 for nonusers) and used zeros in the log-transformed data for these rather than setting arbitrary small values that may bias the results.

We tested for normality of error terms using skewness and kurtosis tests as well as the Shapiro-Wilk and Shapiro-Francia tests for normality (Gould and Rogers 1991; Gould 1991)[9]. The tests showed significant departure from normality. Given the problems of heteroskedasticity and non-normality, we used two alternative models for robust estimation of the selection models to assess the sensitivity of the results to different econometric approaches. To relax the normality assumptions of the Heckman selection model, Deaton (1997) suggested using a polynomial form of the predicted probabilities of the binary choice model, rather than the inverse Mill's ratio from the binary choice model. The polynomial may then be regarded as an approximation to

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[8]The interaction terms of the translog form were not included as they resulted in severe multicollinearity.
[9] This was based on the recommendation of an anonymous reviewer. Normality tests for the censored data may be flawed, however, and cause false rejection of normality. Still the tests may give an indication of non-normality.

whatever the true $\boldsymbol{l}$ function should be. The prevalence of heteroskedasticity and violation of the normality assumption in this model was controlled for in the least squares models by using the conservative heteroskedasticity-consistent covariance matrix estimation (HCCME) named HC3 (Davidson and MacKinnon 1993) for standard error corrections. This implies that the diagonal elements of the covariance matrix were defined as:

(13) $$\frac{\hat{v}_t^2}{(1-\hat{h}_t)^2}$$

where

(14) $$\hat{h}_t = \hat{X}_t(\hat{X}'\hat{X})^{-1} X'_t$$

is the t^th diagonal element of the "hat" matrix that projects orthogonally onto the space spanned by the columns of $\widehat{X}$. This method has generally performed well in Monte Carlo experiments and is considered better than the White/sandwich method (Davidson and MacKinnon 1993, p.554).

We also tried a third method for robust estimation of the censored model. This method is called Powell's censored least absolute deviations (CLAD) estimator (Powell 1984) and provides consistent parameter estimates. It is considered a desirable alternative due to its robustness to conditional heteroskedasticity and distributional misspecification of the error term (Chen and Khan 2000). We may write the model as follows:

(15) $$\Pi = 1(x'\boldsymbol{b}+\boldsymbol{n}) = \max(0, x'\boldsymbol{b}+\boldsymbol{n})$$

and take the median conditional on x to get:

(16) $$q_{50}(\Pi | x) = \max(0, x'\boldsymbol{b})$$

where $q_{50}(\Pi | x)$ denotes the median of the distribution conditional on x and the median of v is assumed to be 0. $\boldsymbol{b}$ may be consistently estimated by the parameter vector that minimizes:

(17) $$\Sigma \,|\, \Pi - \max(0, x'\boldsymbol{b}) \,|$$

Knowledge of the distribution is not required for consistency, and homoskedasticity is not assumed. Median regressions are used repeatedly, first on the total sample and later on a truncated sample. In each iteration observations with negative predicted values are eliminated, until the procedure converges. Standard errors are finally estimated through bootstrapping (resampling households in our case). This approach tends to create larger variances (less efficient) than least squares methods and a fairly large sample size may be required for it to be useful (Deaton 1997). In our case we have a sample size of 102 households and this may be fairly small, but at least it allows us a comparison with the results of the other estimators.

5. RESULTS AND DISCUSSION

Our basic hypothesis was that imperfect information and high transaction costs cause factor market imperfections in the type of resource-poor rural economy we have studied. Factor markets are not able to eliminate the inefficiencies due to unequal distribution of factors if this is the case. We tested this by seeing whether land productivity at plot level depended on farm size, household male and female labor force, and owned oxen per unit of land, while controlling for selection bias and land quality.

The results of the probit model, whether to crop or not to crop, are presented in Table 2.

Table 2--Maximum likelihood Probit Model: To crop or not to crop

Independent Variables	Parameter Estimate	p>|z|	dy/dx
Village2	0.4395	0.065	0.063
Village3	-0.2886	0.295	-0.056
Village4	-0.3249	0.379	-0.066
Village5	-0.8505	0.002	-0.195
Village6	0.1810	0.609	0.028
Village7	0.0058	0.977	0.001
soiltype_2	-0.2424	0.275	-0.043
soiltype_3	-0.2692	0.412	-0.052
soiltype_4	0.2980	0.233	0.045
soiltype_6	-1.4373	0.005	-0.451
soiltype_7	0.7979	0.010	0.080
soiltype_9	1.5937	0.112	-0.516
slope	-0.4218	0.000	-0.071
landtype	0.6090	0.013	0.103
zone	-0.4485	0.022	-0.075
lnplotsize	0.1854	0.153	0.031
distance	0.0083	0.916	0.001
soildept	0.2958	0.036	0.050
landqual	0.8873	0.000	0.150
suscept	0.1219	0.350	0.021
degradat	-0.2547	0.016	-0.043
cutoff	0.7160	0.000	0.139
waterway	0.7217	0.187	0.075
boundary	0.4964	0.007	0.093
bunds	0.1599	0.351	0.027
fanyaju	0.2425	0.430	0.036
sex	-0.4476	0.128	-0.058
age	0.0065	0.211	0.001
house	-0.5514	0.000	-0.112
lneducat	-1.0230	0.049	-0.173
lneducavg	-0.1309	0.184	-0.022
lnmalelabha	0.0243	0.935	0.004
lnfemlabha	0.8249	0.113	0.140
lnconsunitha	0.5612	0.010	0.095
lnoxenha	-1.0627	0.013	-0.180
lnsubtrarea	0.3386	0.167	0.057
lntlusuboxha	-0.0842	0.705	-0.014
lntlusubox2	-0.0745	0.394	-0.013
lnoxenha2	-0.6000	0.028	-0.102
lnconsu2	-0.2353	0.121	-0.040
lnmalelabha2	-0.1573	0.210	-0.027
lnfemlabha2	0.2693	0.235	0.046

lneducavg2	-0.1345	0.120	-0.023
lneducat2	0.3577	0.139	0.061
deducavg	0.0541	0.812	0.009
deducat	0.2229	0.288	0.038
dmalelabha	0.4787	0.454	0.059
dfemlabha	-0.1102	0.822	-0.020
doxenha	-0.5102	0.171	-0.107
doffincha	0.4103	0.046	0.064
lnoffincha	0.1268	0.023	0.021
rentin	1.194	0.030	0.103
rentout	1.097	0.009	0.098
crop96le	1.609	0.000	0.137
crop96fa	-0.6665	0.001	-0.139
Constant	-0.2673	0.793	

Dependent variable: 1=plot used for cropping, 0=plot is not cropped. Number of obs.=593, Wald chi2(55)=381.65, Prob.>chi2=0.0000,Log likelihood = -202.23, Pseudo R2 = 0.3691, standard errors adjusted for clustering on hhno, dy/dx is for discrete change of dummy variable from 0 to 1. The model predicted 91% of the cropped plots and 67% of the uncropped plots correctly.

We found that households with better houses (corrugated iron roof), and better educated heads were less likely to use their plots for cropping. Households without off-farm income were more likely to use their plots for cropping while higher off-farm income increased the probability of cropping for households with off-farm income. Human population pressure (consumer units/ha) increased the probability of cropping. For households with oxen, more oxen per unit of land reduced significantly the probability of cropping. Households without oxen were less likely to use their plots for cropping but this effect was insignificant. This may indicate an abundance of oxen for households with oxen as oxen do not contribute to increasing the cultivated area but rather demand that more land is used for fodder production. Plots planted with legumes in the previous year were more likely to be cropped and plots fallowed in the previous year were less likely to be cropped. Rented plots were more likely to be cropped. A number of the biophysical and technology characteristics also influenced whether a plot was cropped or not. The persistent significance of many of the household characteristics when controlling for land quality with this wide array of land quality variables, provides evidence of significant market imperfections. The following models provide further evidence.

We present the results of Heckman's selection model (H), Deaton's alternative model (D), and Powell's CLAD estimator (P) in Table 3 and the results of the least squares models in Table 4.

Table 3--Determinants of land productivity: Heckman model with maximum likelihood estimation and Deaton's censored regression model

	Heckman Model		Deaton's Model		Powell's Model	
Variables	**Coef.**	**P> z**	**Coef.**	**P> t ***	**Coef.**	**P> t ****
slope	0.681	0.195	-0.0078	0.916	0.0121	0.882
season	-0.2207	0.074	-0.3600	0.015	-0.2239	0.296
landtype	-0.0564	0.663	-0.0047	0.973	0.1464	0.386
zone	0.1739	0.210	0.0353	0.772	0.0008	0.997
Inplotsize	-0.3519	0.000	-0.2858	0.000	-0.3507	0.000
distance	0.0444	0.242	0.0179	0.650	-0.0113	0.837
soildept	0.0174	0.768	0.0114	0.865	0.0252	0.759
landqual	-0.1451	0.051	0.0744	0.446	0.0715	0.455
suscept	0.0501	0.454	0.0529	0.531	0.1007	0.327
degradat	0.1515	0.005	0.0658	0.217	0.0605	0.368
tradit	0.1008	0.236	0.0846	0.414	0.1161	0.346
cutoff	-0.3370	0.000	-0.1408	0.151	-0.1249	0.225
waterway	0.137	0.779	0.3916	0.060	0.2915	0.798
boundary	-0.2208	0.010	-0.0713	0.424	-0.1453	0.254
bunds	-0.0636	0.459	-0.0273	0.767	0.0687	0.549
fanyaju	-0.1082	0.461	-0.3403	0.051	-0.0670	0.753
Crop: Barley	-0.0884	0.458	-0.1163	0.338	-0.2457	0.128
Crop: Other	-0.2960	0.009	-0.3995	0.002	-0.3575	0.032
sex	0.4889	0.006	0.5589	0.002	0.6749	0.004
age	-0.006	0.035	-0.0076	0.063	-0.0101	0.058
house	0.064	0.511	-0.0961	0.376	-0.1914	0.188
Ineducat	0.1552	0.596	-0.3044	0.343	-0.1902	0.649
Ineducavg	0.0881	0.153	0.1058	0.105	0.0516	0.536
Inmalelabha	0.3902	0.011	0.2723	0.076	0.3110	0.151
Infemlabha	0.4000	0.130	0.5046	0.094	0.5040	0.180
Inconsunitha	-0.245	0.104	0.1831	0.387	0.1724	0.424
Insubtrarea	0.2266	0.059	-0.1994	0.108	-0.1286	0.462
Inconsu2	-0.1600	0.136	-0.3203	0.040	-0.1894	0.214
Inmalelabha2	0.1348	0.063	0.1270	0.107	0.1851	0.093
Infemlabha2	0.2624	0.020	0.2823	0.027	0.2814	0.092
Ineducavg2	-0.0011	0.982	0.0015	0.976	0.0270	0.678
Ineducat2	-0.0336	0.810	0.1632	0.286	0.1131	0.553
deducavg	-0.1951	0.195	-0.2414	0.129	-0.2410	0.226
deducat	-0.1327	0.194	-0.0915	0.445	-0.0010	0.942
dmalelabha	0.0112	0.967	0.4319	0.118	0.2000	0.631
dfemlabha	0.6035	0.098	0.5481	0.278	0.8937	0.154
doffincha	0.0404	0.749	0.1972	0.114	0.0056	0.972
Inoffincha	0.0016	0.976	0.0423	0.207	0.0050	0.919
rentin	-0.0264	0.841	-0.0877	0.627	0.0728	0.697
rentout	-0.1239	0.403	-0.1025	0.541	0.0564	0.848
constant	5.955	0.000	8.5740	0.242	5.6284	.000
athrho	-1.245	0.004	p1 -8.6808	0.766		
lambda	-0.5948		p2 9.2926	0.807		

Number of obs = 598	481	472
Censored obs = 137	*Based on robust HC3	**Based on boot-
Uncensored obs = 461	standard errors	strapped st.errors
Wald chi2(46) = 140.47	R-squared = 0.70	Bootstrap reps.: 1000
Log likelihood = -650.4791	F(58, 422) = 69.67	Pseudo R-sq. = 0.19
Prob > chi2 = 0.0000	Prob>F = 0.0000	
LR test of indep. eqns.(rho = 0):	Cook-Weisberg test:	
chi2(1) = 3.18 Pr>chi2 = 0.0747	Chi2(1)=2.86, P=0.0909	

Not reported but included: 6 village dummy variables (all models) and 8 soil type dummy variables (D and P models only as Stata failed to solve the Heckman model with all the soil type dummies). The variable athrho is atanh $\rho=0.5\ln((1+\rho)/(1-\rho))$, and ρ is the correlation between the error terms in equations (9) and (10). Lambda refers to λ in equations (11) and (12) and is sometimes called the Inverse Mills Ratio (IMR). The variables p1, p2 and p3 refer to the first, second and third order polynomials from the selection model. A Hausman test for the polynomials failed to reject H0 (equations are independent).

Table 4--Determinants of land productivity: Cropped plots and Barley plots

	All Cropped Plots		Barley Plots	
Variables	**Coef.**	**P> z**	**Coef.**	**P> t ***
slope	-0.0027	0.970	0.0333	0.632
season	-0.2641	0.074	-0.3491	0.074
landtype	0.0692	0.616	-0.0190	0.902
zone	0.0023	0.987	0.2408	0.254
Inplotsize	-0.3580	0.000	-0.3787	0.000
distance	0.0402	0.350	-0.0534	0.237
soildept	0.0280	0.657	0.1239	0.078
landqual	0.0454	0.507	-0.0301	0.689
suscept	0.1121	0.184	0.1463	0.096
degradat	0.0708	0.182	0.0392	0.509
tradit	0.0892	0.387	-0.0420	0.720
cutoff	-0.2289	0.009	-0.1920	0.047
waterway	0.5154	0.043	0.3765	0.245
boundary	-0.1181	0.225	-0.1205	0.343
bunds	-0.0039	0.967	0.0101	0.917
fanyaju	-0.0505	0.784	0.0268	0.883
Crop: Barley	-0.1018	0.412		
Crop: Other	-0.3015	0.017		
sex	0.5054	0.007	0.6047	0.005
age	-0.0072	0.108	-0.0101	0.042
house	-0.0620	0.552	-0.1031	0.390
Ineducat	-0.1724	0.628	-0.0737	0.869
Ineducavg	0.0839	0.239	0.1213	0.098
Inmalelabha	0.3962	0.027	0.3914	0.043
Infemlabha	0.5265	0.085	0.6166	0.050
Inconsunitha	-0.0491	0.763	-0.0833	0.659
Insubtrarea	-0.1113	0.422	-0.2001	0.210
Inconsu2	-0.2225	0.060	-0.3107	0.022
Inmalelabha2	0.1410	0.089	0.1947	0.047
Infemlabha2	0.2951	0.021	0.2140	0.127
Ineducavg2	0.0205	0.707	-0.0034	0.953
Ineducat2	0.1067	0.522	0.0684	0.741
Inoffincha	0.0311	0.393	-0.0141	0.733
rentin	0.1495	0.365	0.4135	0.023
rentout	0.0169	0.924	0.2046	0.300
lntlusuboxha	0.1235	0.450	0.0831	0.697
lntlusubox~2	-0.0237	0.738	-0.0279	0.746
lnoxenha	-0.1587	0.579	-0.0529	0.856
lnoxenha2	-0.1481	0.454	-0.0278	0.901
lnmanurha	-0.0181	0.804	0.0208	0.796
lndapcha	-0.2716	0.371	0.0311	0.921
lnureacha	0.2019	0.521	0.2226	0.472
Constant	6.1277	0.000	5.7778	0.000

Number of obs	461		270
F(67,393)	2.41	F(63,206)	2.53
Prob > F	0.0000		0.0000
R-squared	0.2727		0.4195
Cook-Weisberg test:			
Chi2(1)	8.84		0.08
Prob > Chi2	0.0029		0.7737

* Results of village and soil type dummies and zero input value dummies are not included in the table.
** Based on HCCME robust(HC3) standard errors.

The H model indicated that there was significant correlation between the error terms in the two equations (under the assumption of normality). With the D model we did a Hausman test of the model with the three polynomial terms against the model without them. The was no significant effect. We therefore have conflicting evidence of selectivity bias since the H model confirms it and the D model rejects it. There is a risk of type I error, however, that we reject the selection bias hypothesis when it is actually true. We therefore did the analysis for both the cases to test the robustness of the results. By presenting the results of the three selection model approaches jointly, and by comparing them with the models assuming no selection bias, and judging the consistency of the results, we arrive at conclusions with higher confidence than we can by relying on only one of the approaches.

The sex of household head variable was highly significant (1% level) in all the selection models as well as the least squares models with HCCME (HC3) corrected standard errors. The land productivity was 49-67 % higher on plots operated by male-headed households than on land operated by female-headed households. The age of household head variable had a negative sign in all models and was significant in four out of the five models (at 5% level in two and 10% level in two). Land productivity is therefore lower on land operated by older household heads. The linear and squared log male household labor variables had positive parameter signs in all models. The linear term was significant in four of the models (5% level in three, 10% level in one). The squared term was significant in four models as well (5% level in one, 10% level in three). All models had at least one of the terms significant. Also the linear and squared log terms for female labor had positive parameter estimates in all models. The linear terms were significant in three of the models (5% level in one, 10% level in two) while the squared terms were significant in four models (5% level in two, 10% level in two). All models had at least one of the terms significant. This is strong evidence that land productivity is increasing with household male and female labor force, implying that labor and land markets do not operate efficiently. This is similar to what Gavian and Fafchamps (1996) found in Niger.

The farm size variable (lnsubtrarea= farm size - plotsize) had a negative sign but was significant only in one model. There is therefore only very weak evidence of an inverse farm size-productivity relationship. One reason may be the relatively egalitarian land distribution due to the Ethiopian land reform that causes fairly small variation in farm size within communities in Ethiopia. The plot size variable was highly significant and with a negative sign in all models. This may be due to unobservable land quality correlated with plot size as suggested by Udry (1996). It could also be due to a bias in plot size estimation. We used plot size data based on official local estimates used during land distribution. We have more recent data that indicate that the plot sizes in the area are biased downwards and more so on larger plots in difficult terrain.

Oxen per unit of land were included only in the selection equation in the selection models. In the least squares models the linear as well as the squared log terms had a negative sign but were insignificant. This may indicate that oxen were in abundant supply or that oxen sharing arrangements work well, so that oxen ownership does not affect productivity. Holden and Shiferaw (2000) estimated that on average the oxen in the study area worked at 60% of their capacity in the busiest season.

Farm level population pressure (linear and squared terms of log consumer units/ha) appeared to have a negative effect on land productivity. The parameter estimates of the linear and squared terms were negative in three of the models, while there was one positive and one negative parameter in the other models. Three of the squared terms were significant (negative), two at 5% level and one at 10% level. None of the linear terms were significant. Considering that population pressure increased the probability of cropping, this may imply that population pressure reduces fallowing and this may affect land productivity negatively when we have controlled for the higher labor inputs that also result from higher population pressure. Again, the significance of variation in farm-level population pressure is a sign of market imperfections.

We found no evidence of lower land productivity on rented plots. Land productivity was significantly higher (5% level) on rented in (mainly sharecropped) barley plots. Rented plots were more likely to be cropped and there is a danger of selectivity bias. Nevertheless, the analysis provides no evidence of share-tenancy leading to lower land productivity and sub-optimal input use. The small number of plots being rented in or rented out may indicate significant transaction costs in the rental market for land, however. This appears to contribute to the systematic variation in labor/land ratios across farms that affect land productivity as land and labor are likely complements rather than substitutes, and markets for both function imperfectly.

Monetary land productivity was significantly lower (30-40%) for non-cereal crops than for cereals[10]. The fact that households still preferred to grow these crops may be due to market imperfections causing a subsistence orientation of production, but may also partly be explained by positive crop rotational benefits on land productivity that is not captured in this short-run analysis. It is doubtful that these rotational benefits are larger than the 30-40% lower average land productivity for the non-cereal crops, however, lending support to the market imperfections hypothesis.

Village, household and farm characteristics variables were used to predict off-farm income[11]. We found no significant effect of off-farm income on land productivity. This in combination with the low level of fertilizer use may indicate that cash scarcity is not the primary constraint to fertilizer adoption.

Introduced conservation technologies did not increase short-term profits and this may be an important explanation why farmers in the area have started to remove these technologies (Shiferaw and Holden 1998). It is possible though that the positive long-term responses to conservation technologies appear through the positive effect on land productivity from the lower level of degradation.

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[10] Wheat was the reference crop. Two dummy variables were used, one for barley and one for other crops.
[11] These variables were not transformed into logarithmic form. Off-farm income was censored and a two-stage approach with a probit model, followed by a least squares model (Deaton's approach), was used.

We present the results of the normality tests for the least squares models in Table 5.

Table 5--Normality tests for residuals in models

Skewness/Kurtosis tests for Normality of error terms

Variable |	Pr(Skewness)	Pr(Kurtosis)	------- joint ------ adj chi2(2)	Prob>chi2
Deaton model	0.000	0.000	40.38	0.0000
All crops model +e	0.000	0.014	18.29	0.0001
All crops model -e	0.000	0.001	32.60	0.0000
Barley model +e	0.153	0.347	2.95	0.2286
Barley model -e	0.232	0.831	1.49	0.4754

Shapiro-Wilk W test for normal data

Variable |	Obs	W	V	z	Prob>z
Deaton model	481	0.96998	9.751	5.465	0.00000
All crops model +e	461	0.98508	4.665	3.688	0.00011
All crops model –e	461	0.97464	7.930	4.959	0.00000
Barley model +e	270	0.99347	1.268	0.551	0.28978
Barley model –e	270	0.99644	0.692	-0.860	0.80524

+e: includes potentially endogenous input variables
-e: excludes potentially endogenous input variables

We see that normality holds only in the barley model. The unobservability of error terms in the H model prevents testing for heteroskedasticity and normality in this model but the significance of the heteroskedasticity and non-normality in the least squares models gives reason to be cautious. Overall, the parameter values were not systematically different in the heteroskedasticity-robust D and P models. The main results are consistent and significant for the censored and uncensored least squares models.

6. CONCLUSIONS

We have used three different selection models and two least squares models with HCCME (HC3) correction of standard errors to test whether there are significant market imperfections affecting land productivity at the farm plot level in a degraded crop-livestock economy in the Ethiopian highlands. The persistence of heteroskedasticity and non-normality of error terms under different functional forms and the possibility of selection bias in the data created a need to test the robustness of the results to different econometric specifications. Based on a comparison of the results of the different models we derive the following conclusions.

The results indicate clearly that there are significant market imperfections in labor and land markets in the study area and that these imperfections affect plot level land profitability. A wide array of variables has been used to control for land quality that may have caused an overestimation of inefficiencies in other studies (Suleiman 1995; Bhalla 1988; Benjamin 1995). Household male and female labor per unit of land had a significant positive effect on land productivity, showing that the labor market and the rental market for land do not redistribute these resources efficiently. The econometric analysis provides no evidence of inefficiency in the oxen rental market as the oxen variable is insignificant, but additional data do so. An insignificant resource stock variable is a necessary but not sufficient indicator of efficient resource allocation for this resource. We should therefore be careful and not jump to the conclusion that oxen rental markets are functioning efficiently. There were signs of overstocking of oxen according to Holden and Shiferaw (2000), the primary source of traction power in the area.

Lumpiness of this factor of production, as a pair of oxen is required for ploughing, and imperfections in the rental market for oxen (Holden and Shiferaw 2000) may explain this inefficiency. Female-headed households faced special problems as their land productivity was much lower than that of male-headed households. Resource poverty and poor substitutability between factors of production may explain this discrepancy. Old age of household heads was also causing lower land productivity.

Shiferaw and Holden (1998) found that population pressure created incentives to remove externally introduced conservation structures in the study area. This study reveals no positive land productivity response to these conservation technologies and that land productivity declines with population pressure (consumer units/ha).

Even though land productivity increased with household labor force, we did not find a significant inverse farm size-land productivity relationship[12], as often has been observed in other studies. The reasons for this may be that farms managed by female headed households are smaller than average and with lower productivity and that population pressure had a negative effect on land productivity. The land redistribution policy in Ethiopia has also caused an egalitarian distribution of land resources, making it more difficult to find a significant inverse farm size-land productivity relationship because of the narrow range of farm sizes.

Policies that can improve the labor market and the rental markets for oxen and land may reduce the inefficiencies we identified in this study. There appears to be little to gain in terms of increased land productivity by continuing the land redistribution

[12] We tested this by leaving out the resource endowment variables in the analysis. The farm size variable remained insignificant (with a negative sign) when doing this.

policy. Female-headed households represent a vulnerable group that requires special attention.

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