

# Household Responses to Shocks in Rural Ethiopia

## Livestock as a Buffer Stock

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April 2015

## Abstract

This paper uses a stochastic dynamic programming model to characterize the optimal savings-consumption decisions and the role of livestock inventories as a buffer stock in rural Ethiopia. The results show that relatively land-rich households use accumulation and liquidation of cattle and other animal

inventories for partial consumption smoothing, while low-income households appear not to do so. The results highlight the need for improvement in livestock markets, which are often affected by high transaction costs and price risk, and for investigation of other approaches to risk management.

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# **Household Responses to Shocks in Rural Ethiopia: Livestock as a Buffer Stock<sup>¶</sup>**

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*JEL classification:* D91; O16

*Keywords:* Livestock; Consumption Smoothing; Savings; Risk

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<sup>¶</sup> The author would like to thank Stefan Dercon, Will Martin, Frans Spinnewyn, Bart Capéau and Marno Verbeek for their valuable comments and discussions.

# 1 Introduction

The capability of farm households to smooth their incomes through diversification heavily relies on the risk covariance between possible income sources. In subsistence economies, it is widely recognized that returns from various activities, particularly in rural areas, are to a great extent positively correlated. This significantly limits the efficacy of income diversification in achieving a smooth level of consumption across time and space. Therefore, the availability of sufficient *ex post* mechanisms is imperative for the survival strategy of farm households to prevent automatic translation of income variability into consumption variability. In this respect, a strategy worth considering is accumulation and liquidation of assets such as livestock, grain stocks, farm tools and implements, cash holdings and so forth. The study of the extent to which farm households use these assets, which are also directly employed in agricultural production, as a coping mechanism has recently become an important topic of analysis. The central focus of the analysis has been the investigation of the savings and portfolio choice of farmers.

Empirical studies on permanent income in poor agricultural societies (for example Bhalla, 1979; Wolpin, 1982; Deaton, 1992; and Paxson, 1992; Park, 2006) confirmed some but not all aspects of the traditional permanent income - life cycle hypothesis, i.e. farm households save a significant fraction of transitory income in order to stabilize their future consumption. In the same vein, Udry (1995) presented evidence from agricultural households in Northern Nigeria supporting the hypothesis that assets can be used as a buffer in *ex post* risk coping strategies. However, the analysis is based on the assumption that households are not constrained in their borrowings and the income process is given exogenously, independent from the decision of households to accumulate assets. Deaton (1991) partially addressed the problem by developing a theoretical framework for savings under uncertainty on the assumption that consumers are not allowed to borrow at any point in time. The predictions of the model highlight the role of liquidity constraints in providing additional incentives to hold assets as buffer stocks.

Furthermore, other studies have extended the framework by jointly considering consumption and production decisions under uncertainty and restrictions on borrowing. Rosenzweig and Wolpin (1993) consider investments in bullocks in India, which is the most important source of animal traction that can also be used for consumption smoothing. They find that sales of bullocks often serve as a buffer stock although substantial underinvestment in bullocks is observed due to the risk averse nature of farmers combined with their inability to borrow, which, in turn, lead to losses in output and further fluctuations in income. Dercon (1998) also finds similar results using data from Western Tanzania. In spite of its role in production as well as a buffer for future contingencies, investment in cattle is impeded by incomplete credit markets and the need for lumpy investments. As a result, poor households are forced to become involved in less risky

activities such as off-farm activities. In contrast, Fafchamps, Udry and Czukas (1998) find that livestock transactions play less of a consumption smoothing role in the face of rainfall shocks than often expected in West Africa, though their framework does not explicitly consider production decisions. Results from Burkina Faso also provide very little evidence for livestock to be used as an effective risk- coping strategy even in the face of idiosyncratic income shocks (Kazianga and Udry, 2006).

Ethiopia is a good country to test the hypothesis that assets, particularly livestock, are used as buffer stocks during bad years. The livelihood of the rural population in Ethiopia relies on rainfed subsistence agriculture. Animal husbandry is an important component of the farming system in the country. Livestock are highly integrated in the process of crop production as a source of draught power, to transport agricultural produce and inputs from farm to home and then to the market, as a source of food (meat and milk) and as a source of income from the sale of livestock products and live animals to cushion the effect of crop income shocks and to supplement the working capital needs of farm households (see Gryseels, 1988 and Mohammed and Abiy, 1996 for the details). Gryseels et al. (1984), quoted in Mohammed and Abiy (1996), indicate that the number of oxen owned by farmers influences their choice of crops as well as the size of their cultivated area. Farmers with less draught power cultivate relatively small areas in order to minimize losses in yields arising from a delay in the time of sowing. This problem is exacerbated due to the covariance in the timing of the demand for animal traction, which limits the rental market of oxen. Based on preliminary data analysis from the first round of the Ethiopian Rural Household Survey, Krishnan (1995) found that ownership of livestock is an important source of differences in cultivated land and invites tenancy arrangements. Also, there is evidence that tenant households possess more livestock, particularly oxen and bulls.

Livestock are not only important as an investment in production but can also serve as an alternative for insurance in the face of fluctuations in income. For instance, a study by Dessalegn Rahmato (1987) on the Northeastern part of Ethiopia clearly points out that the number of livestock marketed was extraordinarily high during the 1984 famine. The issue, however, has not so far been rigorously investigated, except the work done by Daniel (1995) using time-series, macro data. The results from the study show that marginal propensity to save from transitory income predicted by rainfall is far greater than savings out of permanent income. These findings imply that households on aggregate have been able to partially smooth their consumption in the face of rainfall shocks.

The aim of this study is, therefore, to test the hypothesis that households in rural Ethiopia keep livestock as a buffer stock. The study uses panel data collected by the Department of Economics of Addis Ababa University and the Centre for the Study of African Economies of Oxford University. For this purpose, we develop a dynamic intertemporal

model of consumption and asset accumulation that incorporates the important features of farm households: uncertain income, liquidity constraints and the use of livestock as investment in production and as a buffer stock for consumption smoothing. The empirical application addresses the issues of indivisibility, transactions costs and price uncertainty in the face of community-wide environmental shocks. This is done by disaggregating livestock into its different components and then examining if there is a clear hierarchy in selling these components for the purpose of consumption smoothing. Finally, we would like to point out that the available data do not permit to directly test the optimal savings behavior of farm households in Ethiopia.

The rest of the paper is structured as follows. In Section 2 a theoretical framework is constructed which is designed to capture the dynamic nature of livestock investment. Section 3 explains the data used and provides some descriptive statistics. Section 4 presents the estimating equation of net sales of livestock, identifying the econometric problems and the respective solutions. Section 5 presents the empirical results. The major findings are summarized in Section 6. Finally, an appendix with the algebraic details and tables is presented at the end of the paper.

## 2 A Model of Livestock Investment

The general framework is based on the standard assumption that farm households maximize a time-additive expected lifetime utility derived from consumption,  $c_t$ . The preferences of the household satisfy the basic assumptions of the von-Neumann-Morgenstern expected utility theory. The intertemporal utility function under uncertainty over a two-period<sup>1</sup> horizon is represented as

$$U = u(c_t) + E_t [\beta u(c_{t+1})], \quad (1)$$

where  $u : \mathfrak{R}_+ \rightarrow \mathfrak{R}$  is an increasing, strictly concave and at least thrice continuously differentiable function and  $\beta \in (0, 1)$  is a common discount factor and  $E_t$  is the expectation operator conditional on the information set available at time  $t$ . It is assumed that  $\lim_{c \rightarrow 0} u'(c) = \infty$  which satisfies the non-negativity condition of household consumption at each and every period. The concavity of the instantaneous utility function indicates risk aversion and an additional assumption for the convexity of the marginal utility function serves as a necessary condition for decreasing absolute risk aversion.

The above framework has been widely used to investigate the savings behavior of

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<sup>1</sup>The two-period problem is a good vehicle of analysis to derive empirically observable implications about the consumption and investment decisions of households. The results can be easily extended to a multi-period problem and hence the two-period model is hardly restrictive to the problem under consideration in this study.

households under uncertainty. The central idea of this study is, however, to analyze asset accumulation, particularly of livestock, as a substitute of insurance in the face of crop income shocks. This raises the need to investigate the portfolio decisions of households. Therefore, we first give some insights into the possible portfolio composition of rural households in Ethiopia.

Farmers in rural Ethiopia primarily hold their assets in the form of livestock, grain stocks, farm tools and implements, and so forth. For various reasons, it is very rare for these farmers to hold balances in the formal financial institutions.<sup>2</sup> First, the formal financial institutions are at rudimentary stages and they are hardly accessible to rural households. Second, farmers have little information about the terms and conditions of these institutions which are located in major urban areas of the country. Further, the transfer of rural land by sale, lease or mortgage has been prohibited since the 1975 proclamation that put rural land under the control of the government. The proclamation consequently abolished any form of private land ownership and replaced it by an arrangement that provides farmers only usufruct rights. In this situation land cannot be used either as a buffer stock or as collateral to borrow money in response to adverse income shocks. Nonetheless, the size and quality of land are identified as the second most important basis for wealth ranking, next to livestock, in the 15 villages covered by the rural household survey. This finding is based on the community wealth ranking exercise conducted in these villages (see Bevan and Bereket, 1996 for the details on the data based discussion of measuring wealth in rural Ethiopia).

Taking the above facts into account, we consider only two assets, namely, a risky and a safe asset. The availability of a safe asset with a known rate of return has been challenged in the literature on the basis of its lack of realism even in economies with a high degree of price predictability (Sandmo, 1969). The problem is much more critical in countries like Ethiopia where economic activities are highly risky. Analytically, however, it is perfectly plausible to assume the existence of assets which are relatively safe and assets which are relatively risky, which provides a sound justification for the setup of our model with only two assets. The risky asset is cattle that are directly used in agricultural production while the relatively safe asset with a known rate of return includes grain stocks or small animals such as sheep and goats. This classification is quite realistic taking the settings of the rural areas into account, i.e., a mixed farming system that mainly incorporates subsistence crop production and livestock rearing.

Let us now introduce additional assumptions that give more structure to the analysis. We assume the existence of food and livestock markets, but an absence of insurance and credit markets. This implies that households cannot trade risks among themselves

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<sup>2</sup>For example, only 12 out of 1477 households reported that at least one household member had a bank account at the first round interview of the rural household survey.

and that they face stringent borrowing constraints, implying the non-negativity of the different asset holdings. It has been clearly observed that prices of different commodities and assets are possible sources of uncertainty. Nonetheless, we assume that all prices are given and constant just for expositional simplicity.<sup>3</sup> Randomness in the future income of the household, therefore, emanates from uncertainty in crop yields and cattle returns. There is a general consensus that weather variability leads to significant fluctuations in agricultural production in developing countries. This type of shock, indeed, affects current crop yields and returns on cattle in the same direction, allowing for contemporaneous positive correlation between variations in crop income and variations in cattle returns. To make the model as simple as possible we assume the absence of serial correlation in the distribution of both variations; hence the innovations in crop income and cattle returns are assumed to be identically and independently distributed.

The return from cattle is mainly based on their use in agricultural production. The traditional agricultural system in rural Ethiopia depends on animals for draught power to cultivate and to transport farm produce. Gryseels and Anderson (1983) indicate that the most important contribution of livestock, particularly in the Ethiopian highlands, stems from the use of oxen and bulls as draught power. Crop production can thus be expressed as a function of, *ceteris paribus*, the value of cattle ownership allowing the return from cattle to be approximated by its marginal productivity. The expression takes the form as

$$\tilde{y}_t = f(L_t) + \underline{y}, \quad (2)$$

where  $\tilde{y}_t$  is crop output,  $L_t$  is the value of cattle in monetary terms at time  $t$  and  $f : \mathbb{R}_+ \rightarrow \mathbb{R}_+$  is continuously differentiable, strictly increasing and strictly concave with

$$f(0) = 0, \quad f'(\cdot) > 0; \quad \forall L_t > 0.$$

Crop output,  $\tilde{y}_t$ , is a stochastic variable arising from crop failures as a result of various types of idiosyncratic and community-wide shocks.<sup>4</sup> The idiosyncratic shocks consist of those risks that affect individual households such as sickness during the work season, animal trampling of specific plots, localized flooding or infestation of pests while community-wide shocks represent mainly weather related anomalies that affect mem-

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<sup>3</sup>This assumption will not be satisfied in reality. There are inter-year as well as seasonal variations in prices, which, in turn, influence the decision of households in different perspectives. During the community level research, all villages reported sharp declines in livestock prices at times of drought and famine and then steep increases afterwards (Pankhurst, 1995). In the empirical part of the paper, the panel data estimation with time-varying community effects is expected to overcome some of the problems associated with this assumption.

<sup>4</sup>Note that the stochastic element in the production function is not explicitly defined. The production function is implicitly assumed to be stochastic due to the interaction in response between the decision and random variables. It will thus take only multiplicative and not additive shocks, implying a stochastic marginal physical return of cattle.



bers of the community simultaneously. And  $y$  is an exogenously given minimum level of income. For simplicity milk production is subsumed under the crop production function.

Research on farm and livestock productivity in the central Ethiopian highlands indicates that livestock other than poultry are only occasionally slaughtered for home consumption (Gryseels and Anderson, 1983). The model, therefore, incorporates physical returns from cattle herding in the form of offspring, weight gains, by-products<sup>5</sup> and loss through death as well as the contribution to agricultural and milk production. Let us denote the net marginal physical returns from this asset at time  $t$  as  $\eta_t \in [-1, \infty)$  with a positive expected rate of return.<sup>6</sup> We consider net returns although it is possible to explicitly model costs of herding (see Fafchamps, Udry and Czukas (1998) for a case where labor cost is expressed proportional to the number of livestock). The model can otherwise be further simplified to gross returns using an assumption that livestock are herded on common land and that, in most cases, child labor is used in keeping livestock (see for example Gryseels, 1988). Note that this specification does not affect the results of the model.

For seasonal as well as inter year transfers households also hold a relatively safe asset in the form of grain stocks and/or small animals such as goats and sheep (Dercon, 1998).<sup>7</sup> It should be noted that grain stocks serve as insurance against food price risks most notably during across-the-board harvest failures. This is because harvest failure will lead to an instantaneous increase in food prices in a country like Ethiopia with very limited integration into regional food markets within the country. But the subsistence nature of the agricultural sector in Ethiopia compels households to hold grain stocks mainly for home consumption rather than for sale in response to future increases in grain prices. In this study we keep the model as simple as possible by considering a fixed rate of return  $r > -1$  with constant prices for all commodities and assets. Finally, the expected return from cattle herding has to exceed the return on the safe asset in order that risk averse agents should not avoid the risky asset in their optimal decision, i.e.,

$$E_t [f'(L_{t+1}) + \eta_{t+1} - r] > 0.$$

The total resource of the household, therefore, depends on a process that combines savings in the safe asset and returns from a productive, but risky asset. The cash-on-hand,  $A_t$ , in the first period is divided between consumption,  $c_t$ , savings in the safe asset

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<sup>5</sup>In rural Ethiopia manure is used as natural fertilizer and as a major household fuel source. There are also other important livestock by-products (see Tilahun, 1995).

<sup>6</sup>For sake of simplicity a technology of constant returns to scale is used to model physical returns to herding. It is, however, clear that returns to cattle may decline beyond a certain herd size given a fixed supply of grazing land that results in an outcome of optimal herd size.

<sup>7</sup>Small animals are relatively safer than cattle. A study on arid and semi arid lands in East and Southern Africa shows that losses of livestock during drought time can be massive: upto 50-80 percent for cattle and 30 percent for sheep and goats (Lybbert, et al., 2004).

transferred into the second period,  $S_{t+1}$ , and investment on cattle,  $L_{t+1}$ . This relationship can be represented as

$$c_t + S_{t+1} + L_{t+1} = A_t, \quad (3)$$

where  $A_t = (1+r)S_t + (1+\eta_t)L_t + f(L_t) + \underline{y}$ . Assuming that households do not derive utility from leaving a bequest, second period consumption is defined after some rearrangements as

$$c_{t+1} = f(L_{t+1}) + \underline{y} + (A_t - c_t)(1+r) + L_{t+1}(\eta_{t+1} - r). \quad (4)$$

There are non-negativity restrictions on asset holdings because households do not have access to outside funds, i.e.,

$$L_{t+1} \geq 0, \text{ and} \quad (5)$$

$$(A_t - c_t - L_{t+1}) \geq 0. \quad (6)$$

The objective of the farm household is to maximize (1) by choosing consumption and portfolio policies,  $(c_t, L_{t+1}, S_{t+1})$ , subject to the budget constraint (3), and the non-negativity constraints (5) and (6) given the initial cash-on-hand,  $A_t$ . Substituting (4) into (1), the problem of the household can be written as

$$\max_{c_t, L_{t+1}} \left\{ u(c_t) + E_t \left[ \beta u(f(L_{t+1}) + \underline{y} + (A_t - c_t)(1+r) + L_{t+1}(\eta_{t+1} - r)) \right] \right\}, \quad (7)$$

subject to the non-negativity constraints (5) and (6). The first-order conditions for  $c_t$  and  $L_{t+1}$  are

$$u'(c_t) - \beta(1+r)E_t[u'(c_{t+1})] - \lambda_t = 0, \text{ and} \quad (8)$$

$$\beta E_t[(f'(L_{t+1}) + \eta_{t+1} - r)u'(c_{t+1})] + \mu_t - \lambda_t = 0, \quad (9)$$

respectively; and  $\mu_t$  and  $\lambda_t$  are Lagrange multipliers associated with the non-negativity constraints (5) and (6) in the same order.

The last two expressions are the usual Euler equations of intertemporal optimization under liquidity constraints that provide the rule for consumption-investment trade-off and portfolio decisions of the farmer. Assuming an interior solution ( $\mu_t = \lambda_t = 0$ ), so that the liquidity constraints are non-binding, the interpretation of these conditions is straightforward. Equation (8) says that  $c_t$  is chosen at the point where current marginal utility of consumption is equal to the discounted value of future expected marginal utility of consumption. Condition (9) states that the optimal value of investment on cattle,  $L_{t+1}$ , is chosen in such a way that the discounted expected marginal utility of savings in the form of either of the assets are equated, and hence at the margin the household is indifferent in which asset purchasing power is transferred to the next period. These first-order conditions clearly show the interdependence between consumption and portfolio decisions and the optimal investment on cattle is a function of the expected profitability

of cattle herding vis-à-vis returns on the safe asset, its riskiness and other individual constraints and factors.

If both constraints are binding then current consumption will exactly be equal to the value of total liquid wealth or cash-on-hand. As a result, no asset will be carried over to the next period and in fact the household would have been willing to borrow if there existed a credit market for consumption purposes. There are also other behavioral regimes depending on which constraint is binding. If the constraint on the safe asset is binding then it will result in under investment in cattle and the farm household would have increased both current consumption and investment in cattle if it were allowed to hold a short position in the safe asset.

As was pointed out, this study focuses on the link between total wealth and portfolio choice of farmers for a given distribution of income and returns on the risky asset. Accordingly, we proceed to derive the relationship among these variables. In this respect, it is important to investigate how farmers will respond to negative crop income shocks. An intuition for this question can be derived by undertaking comparative statistics on the first-order conditions. It should, however, be noted from the outset that the analyses given in the following subsections are valid only for an interior solution in which the non-negativity constraints are not binding.

## 2.1 Change in Liquid Wealth

Empirical studies from developing countries (Dercon, 1998; Morduch, 1993) indicate that relatively poor households specialize in low return, low risk activities as compared to relatively wealthy households. The model in the previous section, however, cannot be solved analytically and the policy functions depend on the assumptions on the degree of convexity of the marginal utility function, the correlation between the income process and the returns on the risky investment and so on. Here we derive conditions that determine the relationship between initial wealth and investment in the risky asset.

By implicit differentiation of the first-order conditions, the wealth derivative of investment in cattle becomes

$$\frac{\partial L_{t+1}}{\partial A_t} = \frac{-(1+r)\beta u''(c_t)E_t[(f'(L_{t+1}) + \eta_{t+1} - r)u''(c_{t+1})]}{H}, \quad (10)$$

where

$$\begin{aligned} H = & \beta E_t \left[ (f'(L_{t+1}) + \eta_{t+1} - r)^2 u''(c_{t+1}) \right] \times \{u''(c_t) + (1+r)^2 \beta E_t[u''(c_{t+1})]\} \\ & - \{\beta(1+r)E_t[(f'(L_{t+1}) + \eta_{t+1} - r)u''(c_{t+1})]\}^2. \end{aligned}$$

It is easy to see that  $H > 0$  if the second-order sufficient condition of the optimiza-

tion problem is satisfied. The sign of expression (10) thus depends on the sign of  $E_t [(f'(L_{t+1}) + \eta_{t+1} - r) u''(c_{t+1})]$  which depends on the risk-aversion parameter of the utility function. Lemma 1 of Sandmo (1969), which can be easily adapted to the setup of our model, implies that this expression is positive if the utility function of the household exhibits decreasing absolute risk aversion and  $L_{t+1} \geq 0$  (see Appendix A.1 for the proof of the Lemma). The latter condition is automatically satisfied due to the non-negativity constraint on investment in cattle holdings and the fact that crop income is endogenously determined does not affect the result. Therefore, if at the optimum  $L_{t+1} \geq 0$  then decreasing absolute risk-aversion is a sufficient condition for investment in cattle to be a normal good.

If Ethiopian farmers have decreasing absolute risk aversion, cattle holdings increase with liquid wealth. This implies that farmers respond to crop income shocks by divesting cattle. But this result alone will not tell us more about the rate at which they are divesting cattle as compared to the safe asset. This issue is dealt with in Section 2.3.

## 2.2 Change in Expected Return on Cattle

The solution of the maximization problem makes it possible to evaluate the effect of a change in the expected return of the risky asset, with its distribution remaining unchanged. This can be done easily by analyzing the effect of an additive shift in the distribution of the random returns in the risky asset. Specifically, let the physical return on cattle be  $\eta_{t+1} + \theta$ , which can be interpreted as an additive increase in the expected yield of investment in cattle by a magnitude equal to  $\theta$ . Implicitly differentiating the first-order condition with respect to  $\theta$  and evaluating at  $\theta = 0$  provides the expression

$$\frac{\partial L_{t+1}}{\partial \theta} = \frac{L_{t+1}}{(1+r)} \frac{\partial L_{t+1}}{\partial A_t} - \frac{\beta u''(c_t) E_t [u'(c_{t+1})] + (1+r)^2 \beta^2 E_t [u'(c_{t+1})] E_t [u''(c_{t+1})]}{H}, \quad (11)$$

where the first term of the right hand side is the income effect and the second term is the substitution effect. The substitution effect is always positive, as the utility function is assumed to be concave. Therefore, if investment in cattle is a normal good and  $L_{t+1} \geq 0$ , then an increase in its expected return will lead to an increase in cattle investment. Once again decreasing risk aversion is a sufficient condition for an increase in investment in cattle due to an increase in its expected return.

## 2.3 Factors for Slow Adjustment in Cattle Investment

How does a change in wealth affect the portfolio composition of a risk averse agent? This question has been widely investigated in the finance literature, but the results are by and large inconclusive. They depend on several factors including the assumptions on the

properties of the utility function and the relationship between the income process and the returns on the risky asset.

To examine the portfolio selection of farm households, let us first denote the proportion of wealth invested in cattle as  $\alpha_{t+1} = \frac{L_{t+1}}{A_t - c_t}$ . Note that it lies within the unit interval due to the non-negativity constraints of asset holdings. The effect of a change in total wealth on the portfolio composition of households is then found by differentiating the above expression with respect to  $A_t$ . After some rearrangements, this gives

$$\frac{\partial \alpha_{t+1}}{\partial A_t} = \frac{A_t}{L_{t+1}} \frac{\partial L_{t+1}}{\partial A_t} - \frac{A_t}{S_{t+1}} \frac{\partial S_{t+1}}{\partial A_t}. \quad (12)$$

From (12) it can be easily seen that the proportion invested in cattle depends on the wealth elasticity of investment in the risky asset and the wealth elasticity of investment in the safe asset. An increase in total wealth will increase the proportion invested in cattle if the wealth elasticity of demand for cattle is greater than the wealth elasticity of demand for the safe asset, will decrease if the reverse is true and will leave it unchanged if the two elasticities are equal. It is clear from the expressions (10) and (12) that the relative strength of these elasticities mainly depends on the degree of convexity of the marginal utility function and the correlation between the crop income process and returns on the risky asset.

A good benchmark for the analysis is the case where the utility function displays constant relative risk aversion (CRRA) and the crop income function is represented by a linear specification. These specifications simplify the programming problem so that it can be solved analytically for the choice variables. In such a framework, Samuelson (1969) has shown that the choice of optimal portfolio is independent of the consumption-savings decision and the holding of the risky asset is a constant proportion of savings given the total supply of liquid wealth. This result thus implies that households will divest cattle proportional to their wealth when they encounter an income shock.

Empirical analyses of livestock as a buffer stock, however, provide mixed results. Rosenzweig and Wolpin (1993) find that the sale of bullocks often serves to smooth consumption in semi-arid India. On the other hand, Udry (1995) finds no evidence that livestock holdings are affected by adverse shocks in Northern Nigeria. Similarly, results from West Africa show that livestock marketing is very limited in response to crop income shocks (Fafchamps, Udry and Czukas, 1998). These varying results might be explained by factors that characterize the milieu of rural economies in developing countries.

To start with, cattle are directly used in crop production and hence cattle holdings may be subject to diminishing marginal returns. It is unrealistic to assume a linear crop production function. If this is the case and other assets are not subject to diminishing marginal returns, then households might deplete their cattle stock proportionally less than its share in total wealth in response to bad income draws.

Secondly, transactions costs might impose restrictions on the marketing of cattle. Cattle are also to some extent illiquid, indeed, for the reason that distress sales, particularly in the face of community-wide shocks, would lead to a much more reduced price than the normal value of the animal (Fafchamps, Udry and Czukas, 1998). These circumstances make investment in cattle partially irreversible which, in turn, compels farmers to trade cattle less frequently at the expense of an increase in consumption volatility.

The other factor worth considering is the issue of indivisibility as cattle transactions take place in discrete units. This imposes additional restrictions on the liquidity of cattle in comparison with other assets. Nonetheless, households could mitigate this problem by adjusting the age and weight composition of their herd. Although farm households could apply this strategy, it can only be effectively used once they meet the minimum threshold,  $\underline{L}$ , required to enter the cattle rearing activity. If the optimal value of investment in cattle is between zero and the minimum threshold level,  $\underline{L}$ , then the agents should compute their expected utility under two scenarios: with or without the investment. If the expected utility with the investment is greater than the expected utility without the investment, the farm household will find it optimal to keep cattle as part of the portfolio. If the opposite holds then the farmer will not undertake the investment and keeps zero units of cattle, but saves more in other assets at a lower rate of return. The implication is that a negative shock in income would result in over or under investment in cattle when the lumpiness constraint is binding. Besides, relatively poor households might find it difficult to enter into this activity due to the required minimum threshold level of investment even though it is profitable to do so.

Finally, community wide climatic shocks affect both crop production and cattle prices. Negative common shocks lead to a dramatic decline in the current price of cattle and then a sharp increase afterwards; this type of price fluctuation has been observed in livestock markets in Ethiopia (Pankhurst, 1995). As a result, the expected return from surviving animals will increase although a fall in current income is the immediate outcome. Therefore, community-wide shocks will have two opposing effects on cattle holdings: the fall in current income tends to decrease investment in cattle, while the increase in expected return to the surviving animals tends to increase cattle holdings. The total effect is thus indeterminate; nevertheless, one can still conclude that the existence of the latter effect dampens the use of cattle transactions in response to common climatic shocks.

## 2.4 Increase in Risk

The fact that farm households face different degrees of income uncertainty has important implications on their consumption and portfolio decisions. In the absence of a risky asset, Leland (1968) and Sandmo (1969) have shown that convexity of the marginal utility function is a sufficient condition for the realization of precautionary savings. However,

the model considered in this study is too complex given the interaction of the crop income risk and the cattle holding risk to provide clear theoretical results on consumption and portfolio composition. To deal with this indeterminacy, we control, in the empirical application, for the differences in the degrees of income uncertainty using a vector of household characteristics. The panel data also allow us to further control the effects of precautionary savings.

So far we have theoretically clarified the role of livestock in consumption smoothing. We are now set to test the implications of the theoretical model by looking at actual sales and purchases of different types of livestock. We have not considered slaughtered animals in the analysis. This is mainly because livestock are rarely slaughtered for home consumption in rural Ethiopia (Gryseels and Anderson, 1983). This fact is supported by the data we use in this study. The following sections provide the details of the data and the empirical application to rural Ethiopia.

### 3 Description of the Data

This study is based on a longitudinal survey of 1,477 farm households from 15 villages in rural Ethiopia conducted jointly by the Department of Economics of Addis Ababa University and the Centre for the Study of African Economies of Oxford University. The first three waves were carried out during 1994 and 1995. The survey was designed to produce comprehensive data on various socio-economic characteristics of farm households. Information is thus available on different variables related to household demographics, assets and income, consumption, health, education and participation in informal as well as formal markets. Besides, it includes information on the incidence of household specific random production and livestock shocks.

The villages were selected using a cluster sampling technique that incorporated the main agro-ecological zones as its basic element so as to capture the various farming systems of the country. Households from each village were chosen randomly proportional to the population size of their respective region with respect to the national population. However, we do not claim that these villages would represent rural Ethiopia at large. The whole idea is rather to get an insight into the behavior of farm households particularly on their investment decisions by exploiting the relatively large size of the data set.

For this study we need data on livestock transactions, production, livestock and health related shocks, individual and household level characteristics. Differences in the timing of the survey rounds and lack of comparable data on all variables, however, do not allow us to use the information from all three rounds. The empirical application is thus based on data solely from the first and third rounds which had exactly the same set of questions on the variables of interest.

The farming system in Ethiopia tightly integrates subsistence crop production with animal husbandry. Farmers use traditional technologies where livestock play an important role as a source of draft power and a means of transferring wealth through time. Descriptive data given in Table 1 show that farm households from the surveyed villages accumulate assets predominantly in the form of livestock. As can be seen, livestock are very popular in terms of mean value as well as number of households (78 percent) who reported that they owned livestock at the time of the survey. Almost all the households had farm tools and implements and wooden and other furniture (85 and 75 percent, respectively), but their mean values are by far smaller than that of livestock (Birr 49 and Birr 112 vs. Birr 2,181). The other forms of assets (such as radio, tape and jewelry as a group) are held by about less than a quarter of the sampled households. However, only a few households (less than 1 percent) reported that at least one household member had a bank account. In general, the figures would appear to suggest that farm households have hardly any linkages with the formal financial sector. Information from the third round showed that only a fifth of the surveyed households kept savings in the form of cash; of whom about a fifth were not willing to specify the amount of their cash holdings reflecting the sensitivity of the issue in rural areas.

It is widely accepted that markets are thin in rural areas of developing countries for various reasons depending upon the settings of the countries under consideration. The most commonly cited reason is large transactions costs relative to the income of market participants. Along with this, information asymmetry about product and factor quality also restricts market participation (see Dasgupta, 1993 for a detailed discussion of imperfect and incomplete rural markets in poor countries). Nevertheless, small holder farmers in the Ethiopian highlands regularly visit local markets to sell and/or purchase items such as grains, livestock, livestock products and manufactured products (Gryseels, 1988). There is at least one market day per week for each small town and the surrounding rural villages which to some extent ensures interlinkages between the inhabitants of rural villages and nearby small towns. These facts together with the ability to move on the hoof clear some of the hurdles of the marketability of live animals. The panel data set shows a certain degree of participation in the livestock market as a seller and/or buyer; on average, more than a third of the surveyed households had been involved in this market (see Table 2).

Table 3 presents the reported reasons for the sale of livestock. It can be seen that over and above its role as a source of draft power, livestock might serve as a buffer stock for the purpose of consumption smoothing. Slightly more than half of the reported sales were used to pay for consumption-related expenditures. Sale of livestock and animal products also supplement the cash needs of farm households to pay for farm-related expenditures. Similar results are found in the case of other physical assets and loan transactions (see



Table 4). It is, however, difficult to compare the incidence of livestock transactions with those of other physical assets because the data for the latter is over five years preceding the first round while the recall period for livestock is only four months before the first round.

## 4 Estimating Equation for Net Sales of Livestock

As indicated earlier the focus of this study is to investigate the hypothesis that households smooth their consumption in the face of income shocks using livestock as a buffer stock. It should, however, be noted from the outset that livestock transactions alone do not fully represent net savings even if livestock accounts for a large proportion of the portfolio of households. There are other forms of savings, but we do not have a reliable time series data on other assets and grain stocks due to some shortcomings in the frame of the questionnaire administered on the survey sites. It is, therefore, impossible to estimate a model of optimal savings and portfolio selection.

As shown in the previous section more than 60 percent of net livestock sale observations are zero. This implies that the decision to participate in the livestock market is nonlinear, signalling the possible presence of transactions costs that, in turn, limit the role of livestock as a buffer stock in response to income shocks. This calls for the use of a friction model to account for the possible impact of transactions costs on livestock transactions.

The limited dependent panel data model that we estimate distinguishes between desired and actual net sales of livestock. Due to the presence of transactions costs, not all desired net sales are realized, resulting in three distinct observations: positive, negative and zero net sales of livestock. The model that takes these three observations into account can be written as

$$\begin{aligned} y_{it}^* &= x_{it}'\alpha + u_{it}, & i &= 1, \dots, N, \\ & & t &= 1, \dots, T, \end{aligned} \tag{13}$$

with a two-threshold Tobit specification characterized by the following censoring rules

$$y_{it} = \begin{cases} y_{it}^* - \tau_1 & \text{if } y_{it}^* < \tau_1 \\ 0 & \text{if } \tau_1 \leq y_{it}^* \leq \tau_2 \\ y_{it}^* - \tau_2 & \text{if } y_{it}^* > \tau_2, \end{cases} \tag{14}$$

where  $y_{it}^*$  is desired or latent net sales of livestock per adult equivalent units<sup>8</sup> of household  $i$  in period  $t$ ,  $y_{it}$  is observed net sales of livestock per adult equivalent units,  $\tau_1 < 0$  and  $\tau_2 > 0$  are threshold values reflecting the unobserved transactions costs that relate the

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<sup>8</sup>Adult equivalent units are calculated using World Health Organization (WHO, 1985) codes. The codes were constructed based on nutritional equivalence scales on data specific for East Africa.

latent variable to the observed variable, and  $x_{it}$  is a vector of regressors that are chosen based on the empirical implications of the theoretical model. Finally,  $\alpha$  is a vector of constant parameters and  $u_{it}$  consists of the unobserved individual specific effect and the reminder error component that are both assumed to be identically and independently distributed.

The vector of regressors,  $x_{it}$ , that are listed in Table 5 consists of a set of household characteristics ( $H_i$ ), indices of self reported random shocks ( $Z_{it}$ ) and time varying village dummies ( $V_t$ ). The set of household characteristics includes factors such as demographic structure and land holdings that determine the level and variance of the household's expected income and that indicate the stage of the household in the life cycle. They might also control for the effect of precautionary demand for savings.

The data set consists of household level information on the receipt of random production, livestock and health related shocks over the production cycle. The availability of these direct measures of agricultural shocks resolves some of the measurement problems related to the use of the residual between observed income and some measure of permanent income to gauge transitory shocks. These shocks are represented by indices of negative events for each household in each period.<sup>9</sup> The use of these shocks in the analysis of livestock transactions heavily relies on the assumption that the negative events are exogenously given to the individual agents.<sup>10</sup> The first index measures farm-specific adverse events with respect to the timing and variability of rainfall at different stages of the crop production cycle. The second index is a measure of events such as flooding, animal invasion, insect attacks as well as possible wind, bird and weed damages with a negative effect on crops. Thirdly, an index of whether livestock are affected by lack of grazing land, drinking water and diseases is constructed.<sup>11</sup> To capture family labor supply shocks we use the number of working days lost by male and female adults due to illness as a percentage of male and female adults in the household. The differential effect for shocks to male and female labor is for the apparent reason that agricultural and other

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<sup>9</sup>There are no information on the positive shocks of households in the survey data set. That is why our empirical analysis is limited only to the negative shocks.

<sup>10</sup>It should, however, be noted that the self reported shocks reflect the subjective experiences of farmers and hence capture only their evaluation of different negative events that adversely affect crop production and livestock.

<sup>11</sup>The indices are averages of the number of events for each category, namely, farm-level rain shocks, crop shocks and livestock shocks. In the case of farm level rain and crop shocks, the responses to the negative events are coded as either the household encountered no shock (a value of 0) or encountered adverse shock (1). The code is a bit different in the case of livestock shock: not at all affected (0), moderately affected (1) or severely affected (2). The responses to the negative events in each category are combined using the following formula

$$Index = \frac{Score - Min\ Score}{Max\ Score - Min\ Score}.$$

The index varies from 0 to 1. It takes a value 0 if the household had not faced any negative event at all and 1 if the household had faced all the negative events with a maximum score.

activities are segmented by gender in subsistence economies. Finally, dummy variables are used to capture imperfections in the oxen market and its effect on farm outputs.

In rainfed agriculture, the influence of negative events on farm income depends on land size and ownership status. Land is, however, a state property in the Ethiopian context and farmers have only usufruct rights. As a result, this variable becomes exogenous to the behavior of farmers and hence their investment and savings decision do not directly influence landholdings. But Dercon and Krishnan (2000) found out that land is highly correlated with other measures of wealth. Based on this fact they hypothesize that land could be used as a good proxy for liquidity constraints. This study closely follows their approach. Specifically, the indices of self reported shocks are interacted with dummy variables indicating whether the household is in the lower or upper half of the per capita distribution of land. Interaction of the shock variables with the per capita distribution of land also addresses the fact that returns to land depend on environmental factors.

The time-varying village dummies capture seasonality and community-specific effects. These variables account for social and infrastructural differences that affect the marketability of livestock in the respective villages. Besides, they capture the effect of village level shocks, and hence there is no need to look for other exogenous variables to proxy village average unanticipated income component in the estimation.

The model presented in equations (13) and (14) shows that net sales of livestock respond only to large changes in the exogenous variables because of transactions costs. As a result, the usual fixed and random effects panel data methods yield biased and inconsistent estimators. One approach to deal with this problem is the Maximum Likelihood Estimation (MLE) with an appropriate likelihood function to obtain consistent and asymptotically efficient estimators. A likelihood function is, therefore, constructed assuming a random error component model

$$u_{it} = v_i + \epsilon_{it}, \quad (15)$$

where

$$\begin{aligned} v_i &\sim iid N(0, \sigma_v^2), \text{ and} \\ \epsilon_{it} &\sim iid N(0, \sigma_\epsilon^2). \end{aligned}$$

The individual specific random component,  $v_i$ , controls household specific heterogeneity and, in turn, the demand for precautionary savings. The likelihood function conditional on  $v_i$ , derived in Appendix A.2, can thus be written as

$$\Pr(y_i|x_i) = \int_{-\infty}^{\infty} \frac{e^{-v_i^2/2\sigma_v^2}}{\sqrt{2\pi}\sigma_v} \left\{ \prod_{t=1}^T F(x'_{it}\alpha + v_i) \right\} dv_i, \quad (16)$$

where  $F$  is a generic notation for a probability or cumulative density function given by

$$F(\Delta_{it}) = \begin{cases} 1/\sigma_\epsilon \phi\left(\frac{y_{it} + \tau_1 - \Delta_{it}}{\sigma_\epsilon}\right) & \text{if } y_{it}^* < \tau_1, \\ \Phi\left(\frac{\tau_2 - \Delta_{it}}{\sigma_\epsilon}\right) - \Phi\left(\frac{\tau_1 - \Delta_{it}}{\sigma_\epsilon}\right) & \text{if } \tau_1 \leq y_{it}^* \leq \tau_2, \\ 1/\sigma_\epsilon \phi\left(\frac{y_{it} + \tau_2 - \Delta_{it}}{\sigma_\epsilon}\right) & \text{if } y_{it}^* > \tau_2, \end{cases} \quad (17)$$

where  $\phi(\cdot)$  and  $\Phi(\cdot)$  are, respectively, the standard normal density and cumulative distribution functions. Note that  $\tau_1$  and  $\tau_2$  are themselves unknown parameters to be estimated jointly with  $\alpha$  and the  $\sigma$ 's. The estimation is done based on Maximum Likelihood with the above probabilities entering into the likelihood function. Assuming that the model is correctly specified,  $E(v_i|x_{it}) = 0$  and  $E(\epsilon_{it}|x_{it}) = 0$ , it gives us consistent and asymptotically efficient estimators for the unknown parameters.

There is, however, a problem of identification<sup>12</sup> if we try to estimate the unobserved threshold values jointly with the other unknown parameters. This requires the introduction of normalization constraints in such a way that all the parameters of the model are identified. We circumvent this problem by setting the threshold values exogenously taking the distribution of net sales of livestock into account. In setting the two-threshold values, symmetry is not imposed on the data as transactions costs should not necessarily be symmetric for sales and purchases of livestock.<sup>13</sup> We, therefore, consider net sellers and net buyers separately to fix the lower and upper limits of the censored observations. Accordingly, we construct different measures of censored net sales of livestock corresponding to the sample's 10<sup>th</sup> and 20<sup>th</sup> percentiles. This helps us to compare the parameter estimates at different censoring points. The unobserved net sales of livestock are thus those within the samples 10<sup>th</sup> and 20<sup>th</sup> percentiles. After generating a censored net sales data with the predetermined threshold values, the parameters are estimated following the procedure of random effects interval data regression technique. In this procedure, the integral over  $v_i$  is approximated using a Gauss-Hermite quadrature.<sup>14</sup>

## 5 Results

As discussed in the previous section, a random effects interval data regression procedure is adopted to estimate the parameters of the friction model presented in equations (13) and (14). The dependent variable is net sales of livestock (also disaggregated into its different components) per adult equivalent units converted into monthly observations,

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<sup>12</sup>This refers to the case where different combination of parameter values might lead to the same likelihood value and hence there would be no unique maximum.

<sup>13</sup>Schineller (1997) followed similar approaches to fix adjustment costs of capital flight and reversals.

<sup>14</sup>See Stata Longitudinal-Data/Panel-Data Reference Manual, Release 13 for a comparison of the likelihood function of the two-threshold Tobit model of this paper with the random-effects interval-data regression model.

in order to adjust for the discrepancies in the recall periods between rounds. The unobserved threshold values are fixed corresponding to the 10<sup>th</sup> and 20<sup>th</sup> percentiles of the dependent variable. We use homogeneous thresholds across villages. This may not lead to misspecification of the estimated equation, as the time-varying village dummies account for village level differences in the marketability of livestock.

Recall that the explanatory variables include interaction terms between the per capita distribution of land and the indices of the self-reported shock variables. This raises an important econometric issue in the interpretation of the coefficients of the interaction terms. In a recent paper, Ai and Norton (2003) have criticized most applied researchers for wrongly interpreting the coefficients of interaction terms in nonlinear models. Ai and Norton (2003) have shown that the magnitude of the interaction effect is different from the marginal effect of the interaction term. The two effects can even be of opposite sign and the former cannot be tested with a  $t$ -test on the coefficient of the interaction term. Besides, the interaction effect may have different signs for different values of the independent variables. It is thus difficult to interpret the magnitude and sign of the interaction effect without any ambiguity. Therefore, we have to be careful in interpreting the coefficients of the interaction terms in our models.

In this study, the coefficients of the shock variables are allowed to be different across land-poor and land-rich households. For example, we estimated two parameters for livestock related shocks: one for the land-poor and another one for the land-rich households. As shown in Appendix A.3, the sign of these parameters can be easily interpreted. The sign of the coefficient of the interaction term of any of the shock variables corresponds to the marginal effect of the original variable on the dependent variable given the respective group of households. To wit, if the coefficient of livestock related shocks interacted with land-rich dummy is positive then livestock related shocks will have positive marginal effect on net sales livestock for the land-rich households. Also note that the statistical significance of the marginal effect of the original variable can be tested with a single  $t$ -test on the coefficient of the interaction term of each group of households.

The empirical estimates of the determinants of aggregate net sales of livestock are given in Table 6, but the specification does not take the size of animals and their role in crop and milk production into account. The Wald test for the overall performance of the model shows the joint significance of the estimates; they are also robust to the different measures of censoring points. The panel error component significantly contributes to the overall variance of the model which, in turn, signals the importance of household heterogeneity in the decision of farm households. Similarly, time-varying village dummies are jointly significant although the estimates are not reported for the sake of brevity. This shows the influence of village level factors on livestock transactions which are basically reflections of the sharp differences in the agro-ecological zones of the surveyed villages.

As can be seen, relatively land-rich households have been induced to increase the sale of their livestock in response to crop related shocks (such as waterlogging, insect attacks and animal trampling) among the set of adverse idiosyncratic events. In contrast, the significant negative coefficient of adverse female labor supply shocks affecting female adults is unexpected and difficult to explain. In general, there is limited evidence on the relationship between adverse idiosyncratic shocks and livestock transactions although farm households keep their wealth mainly in the form of livestock.<sup>15</sup> This very weak relationship is in agreement with previous studies that employed data from other Sub-Saharan African countries (examples are Udry, 1995 in Nigeria and Fafchamps, Udry and Czukas, 1998 and Kazianga and Udry, 2006 in Burkina Faso).

There was, however, a general a priori expectation that livestock to a large extent would serve as a buffer stock, being at the center of the portfolio of farm households in Ethiopia. This expectation in contrast with the obtained results necessitates further investigation particularly taking some of the features of live animals into consideration. In this regard, we have discussed in the theoretical part of this study that there might be a hierarchy in the sale of different types of livestock in response to adverse events for reasons related to the size of live animals and their direct role in agricultural production. To be more specific, cattle are directly used in crop production and they are most likely subject to diminishing marginal returns. Over and above, the degree of indivisibility and transactions costs required in marketing livestock may differ significantly across different types of live animals. In view of this, we estimate the friction model separately for cattle and other animals including calves. The estimates are given in Tables 7 and 8, respectively.

Let us first consider cattle excluding calves. The results are quite similar to those for aggregate net sales of livestock, except that here the panel-level variance component is insignificant, suggesting that the panel estimator is not different from the pooled estimator. The weak relationship between cattle sales and adverse shocks might be explained by their direct role in crop production and their sheer size as compared to other animals.<sup>16</sup>

The estimates for the alternative live animals are different from those for cattle transactions. To start with, household heterogeneity plays a role in the case of the alternative live animals. In addition, the shock variables that explain net sales of other animals – primarily of small ruminants – are not the same as those explaining net sales of cattle. Farm-specific rainfall shocks are compensated by an increase in the sale of other animals, but this applies only to households in the upper half of the per capita land distribution.

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<sup>15</sup>In the sample villages close to 80 percent of the households held part of their wealth in the form of livestock. But the mean value of livestock for the land rich is greater than that of the land poor. The mean values are found to be statistically different from each other between the two groups of households.

<sup>16</sup>Webb and von Braun (1994) reported that less than 1 percent of the sampled households in the seven villages covered by the Ethiopian Rural Household Survey sold an oxen and productive cow during the 1984 severe drought and famine that had affected most parts of the country.

Interestingly, there is a possible partial adjustment in the composition of livestock in response to illness shock on female adults of land-rich households. This shock decreases net sales of cattle while it increases net sales of other animals. An exceptional result is that constraints in the oxen market increase net sales of other animals by households with small landholdings in contrast to households with large landholdings.

The observed results establish a clear distinction between land-poor and land-rich households in marketing livestock. It seems that land-rich households use a combination of cattle and other animals to insure against the effects of some idiosyncratic shocks. Similarly, households with more land have better access to the informal credit market and access is significantly improved by their participation in various small-group networks (Daniel, 2003).

Finally, we turn to the sale of animal products (Table 9). Once again the distribution of land matters; the only significant shock variables are those interacted with the upper half of the per capita distribution of land. Farm-level crop related shocks lead to an increase in the sale of animal products while livestock related shocks and shortage of oxen lead to a decrease in income from livestock products. The negative coefficient of livestock-related shocks is a sensible result as these shocks refer to shortage of grazing land, lack of water and the effect of animal diseases that might result in a decrease in the productivity of live animals. A possible approach might, therefore, be first to look at the effects of these shocks on the income of farm households.

## 6 Conclusions

This study aimed at providing some empirical evidence on the role of livestock in general and its components in particular as a buffer stock. For this purpose we use a theoretical model that incorporates the salient features of rural Ethiopia and then characterize the properties of the solutions to evaluate the effect of different types of shocks on the portfolio composition of farm households. The discussion pinpoints the most important factors that might lead to a slow adjustment of large animals particularly cattle as compared to other alternative animals. The direct role of cattle in crop production and the issues of indivisibility and transactions costs are some of the key reasons in this respect.

The empirical application, using a two-threshold extension of the Tobit model, provides weak evidence with regard to the relationship between idiosyncratic shocks and the marketability of livestock. It appears more likely that relatively land-rich households use a combination of cattle and other alternative animals for consumption smoothing although full insurance is far from achieved particularly for asset-poor households. It is worthwhile to underscore that household heterogeneity and time-varying village dummies determine livestock transactions.

Given credit transactions and participation in small group networks were not effective in sharing risks especially for poorer households in the studied villages (Daniel, 2003), the results suggest the need to improve the functioning of livestock markets that are riddled with inefficiencies created by high transaction costs and price risks that lead to price collapses at the time of distress sales. High expected returns of livestock after a drought (both from rapid increases in prices and returns in crop production) amplify the illiquidity of livestock markets that perform poorly with inadequate marketing infrastructure, facilities and price information. As a result, improvements in domestic trade and market structure, price information and marketing infrastructures will likely lead to a better functioning livestock market that would benefit the rural poor (Ayele et al., 2003). Moreover, it is crucial to investigate a wide range of risk coping and management strategies such as income diversification and grain stock management for a better understanding of the environment in which small, subsistence farm households operate.



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## A Appendix

### A.1 Proof of Lemma 1 of Sandmo (1969) Adapted to the Set-up of our Model

**Lemma 1** *Decreasing absolute risk aversion implies that*

$$E_t \left[ (f'(L_{t+1}) + \eta_{t+1} - r) u''(c_{t+1}) \right] \geq 0$$

if  $L_{t+1} \geq 0$ .

In order to prove the Lemma, we first define

$$c_{t+1}^0 = \underline{y} + (A_t - c_t)(1 + r),$$

representing the case where the household invests only in the safe asset. And we know that  $\underline{y}$  is an exogenously given, deterministic component of crop income. We can rewrite the budget constraint using the above expression as

$$c_{t+1} = c_{t+1}^0 + f(L_{t+1}) + (\eta_{t+1} - r)L_{t+1}.$$

Since decreasing absolute risk aversion is assumed, we have

$$\frac{-u''(c_{t+1})}{u'(c_{t+1})} \leq \frac{-u''(c_{t+1}^0)}{u'(c_{t+1}^0)} \text{ if } f'(L_{t+1}) + \eta_{t+1} \geq r \text{ and } L_{t+1} \geq 0. \quad (\text{A1})$$

It is trivial that

$$u'(c_{t+1}) (f'(L_{t+1}) + \eta_{t+1} - r) \geq 0 \text{ if } f'(L_{t+1}) + \eta_{t+1} \geq r. \quad (\text{A2})$$

Multiplying (A1) by  $-u'(c_{t+1})(f'(L_{t+1}) + \eta_{t+1} - r)$ , we have the following inequality

$$u''(c_{t+1})(f'(L_{t+1}) + \eta_{t+1} - r) \geq \left( \frac{u''(c_{t+1}^0)}{u'(c_{t+1}^0)} \right) u'(c_{t+1}) (f'(L_{t+1}) + \eta_{t+1} - r), \quad (\text{A3})$$

$$\text{if } f'(L_{t+1}) + \eta_{t+1} \geq r \text{ and } L_{t+1} \geq 0.$$

Now suppose that  $f'(L_{t+1}) + \eta_{t+1} \leq r$ , then the inequalities (A1) and (A2) are both reversed and hence (A3) holds true for all values of  $(f'(L_{t+1}) + \eta_{t+1})$ . As  $\frac{u''(c_{t+1}^0)}{u'(c_{t+1}^0)}$  is not

a random variable, the expectation of (A3) becomes

$$E_t \left[ (f'(L_{t+1}) + \eta_{t+1} - r) u''(c_{t+1}) \right] \geq \left( \frac{u''(c_{t+1}^0)}{u'(c_{t+1}^0)} \right) E_t \left[ (f'(L_{t+1}) + \eta_{t+1} - r) u'(c_{t+1}) \right]. \quad (\text{A4})$$

The right hand side of (A4) equals zero by the first-order condition (9) with non-binding constraints and hence the Lemma is proved. Note that the endogenous nature of crop income does not affect the intended result. ■

## A.2 Derivation of the Likelihood Function

In the likelihood function for the random effects Tobit model, the contribution of individual  $i$  is conditional on the individual specific random component,  $v_i$ . Using  $F$  as a generic notation for a probability or cumulative density function, the likelihood function is of the general form

$$\Pr(y_i|x_i) = \int_{-\infty}^{\infty} \left\{ \prod_{t=1}^T F(y_{it}|x_{it}, v_i) g(v_i) \right\} dv_i, \quad (\text{A5})$$

where  $g(\cdot)$  is the probability density function of  $v_i$ . Given the usual random effects assumption that  $v_i$  and  $\epsilon_{it}$  are i.i.d. normally distributed with zero means and variances  $\sigma_v^2$  and  $\sigma_\epsilon^2$ , the above expression can be rewritten as

$$\Pr(y_i|x_i) = \int_{-\infty}^{\infty} \frac{e^{-v_i^2/2\sigma_v^2}}{\sqrt{2\pi}\sigma_v} \left\{ \prod_{t=1}^T F(x'_{it}\alpha + v_i) \right\} dv_i. \quad (\text{A6})$$

In the case of two-threshold Tobit model, there are three distinct observations: net sellers, net buyers and zero net sellers. Based on this observation rule,  $F$  is given by

$$F(\Delta_{it}) = \begin{cases} 1/\sigma_\epsilon \phi\left(\frac{y_{it} + \tau_1 - \Delta_{it}}{\sigma_\epsilon}\right) & \text{if } y_{it}^* < \tau_1, \\ \Phi\left(\frac{\tau_2 - \Delta_{it}}{\sigma_\epsilon}\right) - \Phi\left(\frac{\tau_1 - \Delta_{it}}{\sigma_\epsilon}\right) & \text{if } \tau_1 \leq y_{it}^* \leq \tau_2, \\ 1/\sigma_\epsilon \phi\left(\frac{y_{it} + \tau_2 - \Delta_{it}}{\sigma_\epsilon}\right) & \text{if } y_{it}^* > \tau_2, \end{cases} \quad (\text{A7})$$

where  $\phi(\cdot)$  and  $\Phi(\cdot)$  are the standard normal probability and cumulative density functions, respectively. The integral in (A6) has to be computed numerically. In the empirical application, a Gauss-Hermite quadrature is used to integrate over  $v_i$ .

## A.3 Interpretation of the Coefficients of the Interaction Terms

In nonlinear models the interpretation of the coefficient of the interaction of two variables is not as straightforward as the case of linear models. Ai and Norton (2003) has shown

the difference between the magnitude of the interaction effect and the marginal effect of the interaction term in nonlinear models. In this appendix, we derive a simple way to interpret the sign of the coefficients of the interaction terms in the context of the models of this study.

Using the notations of Appendix A.2, the conditional mean of the dependent variable is given by

$$\begin{aligned} E[y_{it} | x_{it}] &= \int_{-\infty}^{\infty} [(\Delta_{it} - \tau_1)\Phi(\varpi_1) - \sigma_\epsilon \phi(\varpi_1)] \frac{1}{\sigma_v} \phi\left(\frac{v_i}{\sigma_v}\right) dv_i \\ &+ \int_{-\infty}^{\infty} [(\Delta_{it} - \tau_2)(1 - \Phi(\varpi_2)) + \sigma_\epsilon \phi(\varpi_2)] \frac{1}{\sigma_v} \phi\left(\frac{v_i}{\sigma_v}\right) dv_i, \end{aligned} \quad (\text{A8})$$

where  $\varpi_1 = \frac{\tau_1 - \Delta_{it}}{\sigma_\epsilon}$  and  $\varpi_2 = \frac{\tau_2 - \Delta_{it}}{\sigma_\epsilon}$ . Let  $x_{kit}$  is one of the shock variables,  $D_i$  is a dummy variable which takes a value of 1 if the household is land-poor and 0 otherwise, and  $X$  is a vector of additional independent variables including the constant term. Hence,  $\Delta_{it}$  takes the form

$$\Delta_{it} = \alpha_{k1}x_{kit}D_i + \alpha_{k2}x_{kit}(1 - D_i) + X\alpha + v_i, \quad (\text{A9})$$

where  $\alpha_{k1}$  is the coefficient of the interaction term if the household belongs to the land-poor category and  $\alpha_{k2}$  the coefficient of the interaction term if the household belongs to the land-rich group. Substituting equation (A9) into (A8), the marginal effect of the shock variable  $x_{kit}$  is given by the first derivative of the conditional mean of the dependent variable

$$\begin{aligned} \frac{\partial E[y_{it} | x_{it}]}{\partial x_{kit}} &= \int_{-\infty}^{\infty} [(\alpha_{k1}D_i + \alpha_{k2}(1 - D_i))\Phi(\varpi_1)] \frac{1}{\sigma_v} \phi\left(\frac{v_i}{\sigma_v}\right) dv_i \\ &+ \int_{-\infty}^{\infty} [(\alpha_{k1}D_i + \alpha_{k2}(1 - D_i))(1 - \Phi(\varpi_2))] \frac{1}{\sigma_v} \phi\left(\frac{v_i}{\sigma_v}\right) dv_i. \end{aligned} \quad (\text{A10})$$

It can be seen from expression (A10) that the sign of the marginal effect of the shock variable  $x_{kit}$  depends on the sign of the interaction coefficients  $\alpha_{k1}$  and  $\alpha_{k2}$ , because  $\Phi(\varpi_1)$ ,  $(1 - \Phi(\varpi_2))$  and  $\phi\left(\frac{v_i}{\sigma_v}\right)$  are always nonnegative. More specifically, the sign of the marginal effect of  $x_{kit}$  for the land-poor households,  $D_i = 1$ , corresponds to the sign of the coefficient  $\alpha_{k1}$ . For the land-rich households,  $D_i = 0$ , it corresponds to the sign of the coefficient  $\alpha_{k2}$ . The statistical significance of the marginal effect can be tested by a simple  $t$ -statistic on either of the two coefficients depending on the group in which the household belongs.

Table 1: Asset Composition of Households in 1994

Assets	Mean Value in Birr <sup>a</sup>	Number of Households	Percentage of Sampled Households
Livestock	2181	1154	78
Farm Tools and Implements	49	1307	89
Wooden and Other Furniture	112	1100	75
Cooking Materials	140	345	23
Radio, Tape, Jewelry, Watch	66	305	21
Guns, Spear, etc.	158	186	13
Cart	535	18	1.2
‘Gotera’ (Grain Storage Basket)	391	6	0.4
Others	120	22	1.5
Sampled Households in 1994		1477	
Holders of a Bank Account		12	0.8
Keep Savings in Cash <sup>b</sup>		<sup>c</sup> 278	18.7
Cash Holdings	383	<sup>c</sup> 221	14.9

Source: Ethiopian Rural Household Survey

<sup>a</sup>The exchange rate at the time of the survey was 5 Ethiopian Birr per US dollar.

<sup>b</sup>This information is available only in the third round which was conducted in 1995 and the number of surveyed households 1483.

<sup>c</sup>The discrepancy in the number of households is because about a fifth of them were not willing to specify the amount of their cash holdings.

Table 2: Households Involved in the Livestock Market by Village  
(Both as a Buyer and Seller)

Village	First Round		Second Round		Third Round	
	Number	Percent	Number	Percent	Number	Percent
Harresaw	14	16.7	31	36.9	15	17.9
Geblen	11	16.7	9	13.6	4	6.1
Dinki	27	31.0	13	14.9	11	12.6
D. Birhan	121	65.8	135	73.4	118	64.1
Yetemen	19	31.1	23	37.7	24	39.3
Shumsha	59	39.9	75	50.7	72	48.6
S. Godeti	26	26.8	31	32.0	31	32.0
A. Keke	25	25.8	18	18.6	38	39.2
K.degaga	80	73.4	67	61.5	75	68.8
Tirufe K.	47	46.1	56	54.9	55	53.9
Imdibir	14	20.9	16	23.9	18	26.9
A. Deboa	19	25.3	37	49.3	25	33.3
Adado	27	20.8	53	40.8	33	25.4
G. Godo	43	44.8	31	32.3	42	43.8
Doma	17	23.0	27	36.5	21	28.4
Total	549	37.2	622	42.1	582	39.4

Source: Ethiopian Rural Household Survey



Table 3: Reasons for the Sale of Livestock

Reason	First Round		Second Round		Third Round	
	Number	Percent	Number	Percent	Number	Percent
(1) Consumption Related	303	54.7	278	51.0	253	44.8
Food and Other Goods	268	48.4	243	44.6	216	38.2
Health and Education	26	4.7	26	4.8	28	5.0
Travel Expenses	5	0.9	4	0.7	1	0.2
Help Relatives	4	0.7	5	0.9	8	1.4
(2) Farm Expenditures	164	29.6	199	36.5	184	32.6
Buy Livestock	103	18.6	103	18.9	112	19.8
Buy Farm Implements	22	4.0	39	7.2	33	5.9
For Seeds and Fertilizers	25	4.5	32	5.9	13	2.3
To Pay for Labor	6	1.1	10	1.8	4	0.7
Rent and Taxes	8	1.4	15	2.7	22	3.9
(3) Building Materials	10	1.8	10	1.8	16	2.8
(4) To Repay Loans	9	1.6	12	2.2	26	4.6
(5) Others	68	12.3	46	8.5	87	15.2
Total	554	100	545	100	565	100

Source: Ethiopian Rural Household Survey

Table 4: Reasons for the Sale of Other Assets and Taking Loans

Reason	Other Assets <sup>a</sup>		Loans	
	Number	Percent	Number	Percent
(1) Consumption Related	147	78.2	457	53.2
Food and Other Goods	132	70.2	292	34.0
Health and Education	13	6.9	63	7.3
Travel Expenses	2	1.1	12	1.4
Ceremonial			90	10.5
(2) Farm Expenditures	20	10.7	280	31.3
Buy Livestock	6	3.2	52	6.1
Buy Farm Implements	8	4.3	37	4.3
For Seeds and Fertilizers	5	2.7	160	18.6
To Pay for Labor	1	0.5	11	1.3
Rent and Taxes			9	1.1
(3) Off-farm Business	2	1.1	20	2.3
(4) Building Materials	6	3.2	41	4.8
(5) To Repay Loans			8	0.9
(6) Others	12	7.0	65	7.6
Total	188	100	860	100

Source: Ethiopian Rural Household Survey

<sup>a</sup>Over five years preceding 1994.

Table 5: Variables Used in the Regression

Variable	Definition
Dependent Variable	
Net Sales	Net sales of livestock per adult equivalent units.
Animal Income	Income from the sale of animal products per adult equivalent units.
Self-Reported Household Level Shocks	
Rain Shock	Index of farm specific negative shocks related to the timing and variability of rainfall at different stages of the crop cycle. The higher the worse.
Crop Shock	Index of farm level adverse events, such as waterlogging, insect attacks, animal trampling, etc. The higher the worse.
Livestock Shock	Index whether livestock are affected by lack of grazing land and drinking water, and animal diseases. The higher the worse.
No Oxen	Dummy variable. 1 if the household could not obtain oxen at the right time for plowing.
No Labor	Dummy variable. 1 if the household could not obtain outside labor at the right time.
Family Labor Supply Shocks	
Lost Working Days by Male/Female Adults	Number of male/female adults working days lost due to illness in the last 28 days preceding the survey as a percentage of male/female adults in the household. The higher the worse.
Household Demographics	
Age	Age of the household head.
Age Squared	Age squared of the household head.
Children <5	Number of children less than 5 years old.
Children 5-15	Number of children aged between 5 and 15.
Male Adults	Number of male adults.
Female Adults	Number of female adults.
Skill	Dummy variable for the presence of a member of the household with a professional job.
Household Assets	
Land	Land per adult equivalent units.
Land Poor	Dummy variable. 1 if household owns less than the median land per capita.
Land Rich	Dummy variable. 1 if household owns more than the median land per capita.

Table 6: Maximum Likelihood Estimation of Two-Threshold Tobit Model  
Dependent Variable: Net Sales of Livestock

Variables	Coefficient	<i>t</i> -Value	Coefficient	<i>t</i> -Value
Threshold Values	10 <sup>th</sup> Percentile		20 <sup>th</sup> Percentile	
Upper	1.8805		3.5452	
Lower	−1.5009		−2.8412	
Constant	.8404	.29	1.1214	.38
Village Dummies <sup>a</sup>	Included but not shown.			
	Farm Level and Livestock Shocks			
Land Poor ×				
Rain Shock	−.8980	−.53	−.7712	−.44
Crop Shock	−.0912	−.04	−.2415	−.09
Livestock Shock	−2.3028	−1.23	−2.5197	−1.30
No Oxen	1.3480	1.25	1.5201	1.35
Land Rich ×				
Rain Shock	1.1233	0.74	1.5118	0.96
Crop Shock	5.9386	2.53**	6.0794	2.50**
Livestock Shock	−3.1925	−1.63	−3.3330	−1.64
No Oxen	−1.1226	−1.03	−1.2890	−1.14
	Labor Supply Shocks			
Land Poor ×				
Male Adult Working Days Lost	.0003	.00	.0026	.02
Female Adult Working Days Lost	.0198	.15	.0193	.14
Land Rich ×				
Male Adult Working Days Lost	.0829	.59	.0911	.62
Female Adult Working Days Lost	−.2141	−1.83*	−.2192	−1.80*
	Household Characteristics			
Age	−.0144	−.12	−.02182	−.18
Age Squared	.0001	.05	.0001	.10
Children <5	.4027	1.10	.4409	1.16
Children 5-15	.1919	.83	.2134	.89
Male Adults	−.0241	−.07	−.0005	−.00
Female Adults	.1511	.39	.1605	.40
Skill	−1.1379	−.93	−1.2510	−.99
Land	1.7597	1.89*	1.9148	1.97**
Number of Observations	2901		2901	
$\sigma_v$	3.5646	3.31***	3.7919	3.47***
$\sigma_\epsilon$	16.5802	53.43***	17.1603	53.27***
Likelihood Ratio Test of $\rho = 0$ : <sup>b</sup> $\bar{\chi}^2(01)$	2.75	$p=.049$	3.02	$p=.041$
Log Likelihood	−10133		−9091	
Joint Significance Wald $\chi^2(38)$	126.36	$p=.0000$	131.42	$p=.0000$

\* significant at 10 percent level,

\*\* significant at 5 percent level,

\*\*\* significant at 1 percent level.

<sup>a</sup>The time-varying village dummies are jointly significant for both specifications.

<sup>b</sup> $\rho$  is the fraction of variance due to the panel-level variance component. If  $\rho = 0$ , the panel-level variance component is unimportant and the panel estimator is not different from the pooled estimator.

Table 7: Maximum Likelihood Estimation of Two-Threshold Tobit Model  
Dependent Variable: Net Sales of Cattle, Excluding Calves

Variables	Coefficient	<i>t</i> -Value	Coefficient	<i>t</i> -Value
Threshold Values	10 <sup>th</sup> Percentile		20 <sup>th</sup> Percentile	
Upper	3.9477		6.6739	
Lower	-4.5699		-7.1878	
Constant	-1.1769	-.44	-1.2142	-.42
Village Dummies <sup>a</sup>	Included but not shown.			
	Farm Level and Livestock Shocks			
Land Poor ×				
Rain Shock	-1.1051	-.69	-1.0275	-.59
Crop Shock	.0350	.02	-.1129	-.05
Livestock Shock	-1.5525	-.88	-1.7172	-.90
No Oxen	.6235	.61	.7953	.72
Land Rich ×				
Rain Shock	.0678	.05	.1975	.13
Crop Shock	5.5016	2.49**	5.9759	2.49**
Livestock Shock	-2.6780	-1.45	-2.9190	-1.46
No Oxen	-.7427	-.73	-.8535	-.77
	Labor Supply Shocks			
Land Poor ×				
Male Adult Working Days Lost	.0315	.26	.0410	.31
Female Adult Working Days Lost	-.0579	-.47	-.0624	-.47
Land Rich ×				
Male Adult Working Days Lost	.0805	.60	.0925	.64
Female Adult Working Days Lost	-.2601	-2.35**	-.2842	-2.37**
	Household Characteristics			
Age	.0373	.34	.0350	.29
Age Squared	-.0002	-.22	-.0002	-.17
Children <5	.3380	.99	.3712	1.00
Children 5-15	.0888	.41	.1154	.49
Male Adults	-.1380	-.44	-.1140	-.33
Female Adults	.1152	.32	.1445	.37
Skill	-.9045	-.80	-1.0147	-.82
Land	1.3793	1.59	1.5968	1.69*
Number of Observations	2904		2904	
$\sigma_v$	.4615		2.3896	1.43
$\sigma_\epsilon$	15.8804	76.08***	16.8378	52.33***
Likelihood Ratio Test of $\rho = 0$ : <sup>b</sup> $\bar{\chi}^2(01)$	.04	$p=.423$	.51	$p=.238$
Log Likelihood	-7254		-6340	
Joint Significance Wald $\chi^2(38)$	120.80	$p=.0000$	125.94	$p=.0000$

\* significant at 10 percent level,

\*\* significant at 5 percent level,

\*\*\* significant at 1 percent level.

<sup>a</sup>The time-varying village dummies are jointly significant for both specifications.

<sup>b</sup> $\rho$  is the fraction of variance due to the panel-level variance component. If  $\rho = 0$ , the panel-level variance component is unimportant and the panel estimator is not different from the pooled estimator.

Table 8: Maximum Likelihood Estimation of Two-Threshold Tobit Model  
Dependent Variable: Net Sales of Other Animals

Variables	Coefficient	<i>t</i> -Value	Coefficient	<i>t</i> -Value
Threshold Values	10 <sup>th</sup> Percentile		20 <sup>th</sup> Percentile	
Upper	1.3107		2.2092	
Lower	−.9523		−1.7014	
Constant	2.3103	2.13**	2.5190	2.20**
Village Dummies <sup>a</sup>	Included but not shown.			
	Farm Level and Livestock Shocks			
Land Poor ×				
Rain Shock	.2145	.34	.2798	.42
Crop Shock	−.2165	−.24	−.2514	−.26
Livestock Shock	−.9372	−1.35	−1.0324	−1.40
No Oxen	.7779	1.92*	.8472	1.98**
Land Rich ×				
Rain Shock	1.1933	2.11**	1.4061	2.36**
Crop Shock	−.0432	−.05	−.0694	−.08
Livestock Shock	−.3698	−.50	−.4098	−.53
No Oxen	−.7162	−1.76*	−.8047	−1.88*
	Labor Supply Shocks			
Land Poor ×				
Male Adult Working Days Lost	−.0183	−.38	−.0200	−.39
Female Adult Working Days Lost	.0601	1.24	.0598	1.17
Land Rich ×				
Male Adult Working Days Lost	.0093	.18	.0105	.19
Female Adult Working Days Lost	.0761	1.74*	.0808	1.75*
	Household Characteristics			
Age	−.0762	−1.70*	−.0816	−1.72*
Age Squared	.0005	1.15	.0005	1.17
Children <5	.1819	1.32	.2055	1.41
Children 5-15	.1328	1.52	.1466	1.59
Male Adults	.1386	1.09	.1457	1.08
Female Adults	.0441	.30	.0418	.27
Skill	−.3567	−.77	−.3820	−.78
Land	.8106	2.30**	.8630	2.31**
Number of Observations	2904		2904	
$\sigma_v$	1.7055	5.37***	1.8415	5.61***
$\sigma_\epsilon$	6.0767	52.93***	6.3626	52.51***
Likelihood Ratio Test of $\rho = 0$ : <sup>b</sup> $\bar{\chi}^2(01)$	7.24	$p=.004$	7.92	$p=.002$
Log Likelihood	−7682		−6628	
Joint Significance Wald $\chi^2(38)$	105.44	$p=.0000$	108.09	$p=.0000$

\* significant at 10 percent level,

\*\* significant at 5 percent level,

\*\*\* significant at 1 percent level.

<sup>a</sup>The time-varying village dummies are jointly significant for both specifications.

<sup>b</sup> $\rho$  is the fraction of variance due to the panel-level variance component. If  $\rho = 0$ , the panel-level variance component is unimportant and the panel estimator is not different from the pooled estimator.

Table 9: Tobit Estimates of the Determinants of Income from the Sale of Animal Products  
Dependent Variable: Animal Income

Variables	Coefficient	<i>t</i> -Value
Constant	−15.6426	−4.85***
Village Dummies <sup>a</sup>	Included but not shown.	
	Farm Level and Livestock Shocks	
Land Poor ×		
Rain Shock	.3430	.25
Crop Shock	.6640	.33
Livestock Shock	1.8012	1.27
No Oxen	.1748	.21
Land Rich ×		
Rain Shock	.1640	.17
Crop Shock	6.0482	3.81***
Livestock Shock	−2.3115	−1.80*
No Oxen	−1.2354	−1.65*
	Labor Supply Shocks	
Land Poor ×		
Male Adult Working Days Lost	−.0242	−.26
Female Adult Working Days Lost	.0667	.75
Land Rich ×		
Male Adult Working Days Lost	.0808	.94
Female Adult Working Days Lost	−.0731	−.93
	Household Characteristics	
Age	.0393	.30
Age Squared	−.0001	−.10
Children <5	.2082	.70
Children 5-15	.9312	4.41***
Male Adults	.2273	.78
Female Adults	.2279	.69
Skill	−.6769	−.60
Land	9.5731	12.00***
Number of Observations	2905	
$\sigma_v$	12.1634	
$\sigma_\epsilon$	5.6782	25.65***
Likelihood Ratio Test of $\rho = 0$ : <sup>b</sup> $\bar{\chi}^2(01)$	266.1	$p=.000$
Log Likelihood	−4015	
Joint Significance Wald $\chi^2(38)$	303.48	$p=.0000$

\* significant at 10 percent level,

\*\* significant at 5 percent level,

\*\*\* significant at 1 percent level.

<sup>a</sup>The time-varying village dummies are jointly significant for both specifications.

<sup>b</sup> $\rho$  is the fraction of variance due to the panel-level variance component. If  $\rho = 0$ , the panel-level variance component is unimportant and the panel estimator is not different from the pooled estimator.