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THE RELATIONSHIP BETWEEN COLLECTIVE ACTION AND INTENSIFICATION OF LIVESTOCK PRODUCTION: THE CASE OF NORTHEASTERN BURKINA FASO

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ABSTRACT

In this paper, we develop a simple game-theoretic model to explore the relationship between management of common pool resources used as an input in livestock production (common pastures) and the adoption of inputs associated with intensified per animal production (veterinary services, purchased fodder, feed concentrates, etc.). Theoretically, it is shown that better managed pastures should lead to increased adoption of complementary inputs but decrease adoption of substitute inputs; impacts on stock levels, however, are ambiguous. An empirical model is developed and applied to data collected in northeast Burkina Faso in 2000 and 2002. Results indicate that better managed pastures, proxied by community-level cooperative capacity indices, are indeed associated with lower purchases of substitute goods, e.g. purchases of low-value feeds and greater purchases of complementary inputs, e.g. high-quality feeds. However, purchase of vaccines, likely to be a compliment in livestock production, is not associated with cooperative capacity.

Keywords:

Burkina Faso; game theory; common property; livestock; collective action; pastoralism

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THE RELATIONSHIP BETWEEN COLLECTIVE ACTION AND INTENSIFICATION OF LIVESTOCK PRODUCTION: THE CASE OF NORTHEASTERN BURKINA FASO

Nancy McCarthy[1]

1. BACKGROUND

Burkina Faso is an agro-pastoral Sahelian country, where livestock production has always been an important component of agricultural activity. However, a number of factors led to a decline in livestock activity through the 1970's and particularly the 1980's. These included major droughts of the 1970's and 1980's, which induced estimated large losses of livestock, the importation of "cheap" livestock products from the European Union during the same period (ECA 2000), and an overvalued exchange rate. However, the 1990's have seen conditions improve for livestock producers because of a reversal of all three factors: the currency (F CFA) was devalued in 1994 leading to a 78 percent increase in producer prices for live animals between 1993 and 1996 (ECA 2000), rainfall has generally been more favorable, and anti-dumping restrictions have reduced importation of unfairly priced livestock products from the EU. The contribution of livestock products to GDP is currently about 12 percent, and these products also account for 25 percent of export income. In fact, it is the second most important source of export income (24 percent) after cotton (IMF[2]).

In the drier northern regions, livestock production is based on extensive and semi-extensive systems where access to common grazing lands and transhumance is heavily relied upon to provide forage resources. In such systems, there is wide scope for collective action and cooperation to influence land use and allocation patterns, resource management, investments in

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2 http://www.imf.org/external/NP/PFP/1999/Burkina/INDEX.HTM#IVB

and maintenance of community resources, and thus household incomes and wellbeing. In this paper, we consider the relationship between management of common pastures and household-level decisions to intensify livestock production at the household level – e.g. purchases of feeds, agro-industrial by-products, and veterinary services.

An analysis of the role of collective action and its impact on household production and income strategies is very timely to the situation in Burkina Faso. Surveys were undertaken in 2000, subsequently in 2002, the government began a process of implementing new rural land laws previously languishing on the books. Though the law itself is somewhat vague about practicalities involved in implementation, the goal is to decentralize responsibility for resource management– and hopefully authority and fiscal resources – to the community, and where relevant, supra-community levels. Unfortunately, this process got under way the year after the dataset used in this analysis was collected. Nonetheless, in this context of decentralization and devolution -- a context characteristic of many countries in sub-Saharan Africa -- an analysis of the intensification decision is required if effective programs and policies are to be designed and implemented that subsequently enable smallholders to take advantage of expanding markets for livestock products, and not be "left behind".

In the remainder of the paper, we first develop a simple-game theoretic model of the joint household decision on purchased inputs and the number of livestock to hold given that animals graze common pastures, under two assumptions: 1) a non-cooperative game is played over the use of common pastures, and 2) users jointly maximize total returns. These two assumptions generate different outcomes, and this difference defines the set of pareto-improving outcomes possible with effective collective action. Thus, we conclude this section by discussing the potential impact of community-level cooperation on the household-level decisions, and present results of an analysis of community-level cooperative capacity for the communities where study households reside. In section 3, we present the empirical model to be estimated, consider econometric issues, and present econometric results of the household-level decisions on livestock holdings and purchases of feed, agro-industrial by-products and vaccines. The final section gives concluding observations.

2. MODEL DEVELOPMENT

As discussed above, livestock owners make decisions on the purchase of inputs, in addition to the amount of stock to graze on common pastures. The industrial organization literature has considered similar problems; theoretically, the common pool resource problem, where average product is a function of total extraction rates, is akin to the duopoly quantity choice market where demand is a function of total output. Bulow et al. (1985) present a model where one firm produces outputs for two markets, costs of production of the two outputs are inter-related, and the firm is a monopolist in one market but a duopolist in the other. Using definitions found in Bulow et al. (1985) and Mas-Collel et al. (1995), conventional substitutes (complements) are defined by the cases where a "more aggressive" strategy by firm A increases or decreases (increases) firm B's profits. In our case, negative externalities arising from the use of the common pasture guarantee that the inputs are conventional complements. However, if two outputs are strategic complements (substitutes), then the marginal profits of one firm decrease as the output of the other firm decreases (increases). If marginal profits to selling in the first market decline due to an expansion of the second firm in the second market, then less will be sold in the first market. In our case, this means that if the marginal returns to using purchased inputs decline as others' increase their herd sizes grazing common pastures, then purchased inputs and others' livestock holdings are strategic substitutes.

With respect to use of a common pool resource, Lopez (1998) develops a general model of agricultural intensification, where households choose to allocate labor and/or land to either labor-intensive or land-intensive agricultural outputs, though the author essentially assumes open access (so that average revenue product is equated to marginal costs in equilibrium). Results indicate that exogenous parameter changes that favor labor-intensive production (e.g. an increase in relative price) increases labor-intensive production and reduces land-intensive production. Similarly, McCarthy et al. (1998) examine the case where producers can either allocate land to private crops or common pastures and also decide the stock densities on common pastures. In this case, any parameter change that increases overstocking on common pastures reduces marginal product to land allocated to pasture and thus lands are re-allocated to private crops, meaning that stock levels are higher and land allocated to common property lower than under joint maximization.

In this paper, we extend the general the theoretical models discussed above by developing a model of a two-player game where players' each simultaneously choose two input levels, allowing for inputs to be either traditional complements or substitutes in production (for the two-input case with constant marginal costs, this is equivalent to $\frac{\partial^2 F}{\partial x_1 \partial x_2} <=> 0$)[3], but strategic substitutes, using Bulow et al. (1985) terminology, which captures the negative externality arising form the use of common pastures (e.g. $\frac{\partial^2 F}{\partial x_1 \partial x_2} < 0$). We also compare outcomes from the non-cooperative game with those arising from joint-maximization. The latter is necessary so that

[3] see next section for variable definitions

we can evaluate the potential impact of cooperation on outcomes. In the context of management and use of common pool resources, many observers have noted that there is often evidence of some degree of cooperation leading to outcomes somewhere in between non-cooperation and joint-maximization (c.f. Baland and Platteau 1996; McCarthy et al. 1998).

LIVESTOCK PRODUCTION

Many of the game-theoretic analyses to date have continued to focus on production functions with one variable input used to exploit a fixed common resource (but c.f. Lopez 1996 and McCarthy et al. 1998). Here, we consider the case with two variable inputs, and one fixed common pasture.

Consider the profit function, $\pi_i = F_i\left(k_i, x_i, \sum_{i \neq j} x_j; P, Z\right) - c_k k_i - c_x x_i$, where output price is normalized to 1, k_i is the variable input of the i'th player, the use of which does not affect others' profits, x_i is a variable input whose use does affect others' profits, x_j is variable inputs used by the j-th player, P is the fixed pasture resource, and Z is a vector of both household- and community level characteristics that affect the profitability of livestock production, and c_k and c_x are the unit costs of the two variable inputs, respectively. Essentially, we can think of k_i as purchased feeds or veterinary inputs, and x_i as livestock.

We assume that $\frac{\partial F_i}{\partial x_i} > 0$, $\frac{\partial F_i}{\partial k_i} > 0$, $\frac{\partial F_i}{\partial x_j} < 0$, $\frac{\partial F_i}{\partial x_i} > \frac{\partial F_i}{\partial x_j}$, $\frac{\partial F_i}{\partial k_j} = 0$; and $\frac{\partial^2 F_i}{\partial x_i^2} < 0$, $\frac{\partial^2 F_i}{\partial x_i \partial x_j} < 0$, $\frac{\partial^2 F_i}{\partial k_i^2} < 0$ and $\frac{\partial^2 F_i}{\partial k_i \partial k_j} = 0$. These conditions ensure that there is a negative externality generated by the use of x_i, but not by the use of k_i, and that the individual's profit function is quasi-concave. Suppressing fixed pasture resources and household and community characteristics in the production function, each individual maximizes the following:

$$\max_{k_i,x_i} \pi_i = F_i\left(k_i, x_i, \sum_{i\neq j} x_j; P\right) - c_k k_i - c_x x_i$$

which results in the following first order conditions (FOCs):

$$\frac{\partial \pi_i}{\partial x_i} = \frac{\partial F_i\left(k_i, x_i, \sum_{j\neq i} x_j\right)}{\partial x_i} = c_x \qquad [1]$$

$$\frac{\partial \pi_i}{\partial k_i} = \frac{\partial F_i\left(k_i, x_i, \sum_{j\neq i} x_j\right)}{\partial k_i} = c_k \qquad [2]$$

and similarly for each player.

Next consider the social optimizer's problem, which given that agent's are homogenous, is the same as joint-maximization. This is written as follows:

$$\max_{k_i,x_i} \pi_i = \sum F_i\left(k_i, x_i, \sum_{i\neq j} x_j; P\right) - c_k k_i - c_x x_i$$

This yields the following FOCs:

$$\frac{\partial \pi_i}{\partial x_i} = \frac{\partial F_i\left(k_i, x_i, \sum_{j\neq i} x_j\right)}{\partial x_i} + \frac{\sum_{j\neq i} \partial F_j\left(k_i, x_j, \sum_{k\neq j} x_j\right)}{\partial x_i} = c_x \qquad [3]$$

$$\frac{\partial \pi_i}{\partial k_i} = \frac{\partial F\left(k_i, x_i, \sum_{j\neq i} x_j\right)}{\partial k_i} = c_k \qquad [4]$$

and similarly for each *i*.

Comparing the derivatives with respect to x_i for the individual vs. the social optimizer (comparing equations [1] and [3]), we immediately note that [1]>[3] when evaluated at the same x_i, k_i pair, since $\frac{\partial F_i}{\partial x_j} < 0$. In other words, the following holds when evaluating the FOC's at the same x_i, k_i pair:

$$FOC_{x1}^{NC} > FOC_{x1}^{SO}$$

$$FOC_{k1}^{NC} = FOC_{k1}^{SO}$$

where *SO* and *NC* in the superscript refer to the inputs resulting under the social optimum and non-cooperative game, respectively.

In order to evaluate the comparison between non-cooperative outcomes and joint maximization, we need to consider additional assumptions on whether or not private inputs and livestock levels are traditional gross complements or substitutes and whether or not they are strategic complements or substitutes. Given that we assume that there is a negative externality generated in using common pastures, $\frac{\partial^2 F_i}{\partial x_i \partial x_j} < 0$, then player i's stock levels and player j's stock levels are always strategic substitutes – increasing total stock levels on the commons reduces the marginal value of livestock grazing on those commons. With $\frac{\partial^2 F_i}{\partial x_i \partial k_i} > 0$ and $\frac{\partial^2 F_i}{\partial x_j \partial k_i} < 0$, then purchased inputs are traditional complements with own stock levels, but other players stock levels are strategic substitutes for player i's purchased inputs. Essentially, this means that whenever the marginal product of cattle grazing commons increases, the marginal impact of purchased inputs increases; alternatively, increased externalities on the commons reduces the marginal product of cattle in common, and thus the marginal product of the purchased input. Similarly, $\frac{\partial^2 F_i}{\partial x_i \partial k_i} < 0$ and $\frac{\partial^2 F_i}{\partial x_j \partial k_i} > 0$, imply that marginal product of livestock increases as externalities increase, and thus that the marginal product of purchased inputs increase.

In the first scenario, we consider equilibrium outcomes when we assume that $FOC_{k1}\big|_{x_1^{NC} > x_1^{SO}} < FOC_{k1}\big|_{x_1^{NC} = x_1^{SO}}$ and $FOC_{k1}\big|_{x_1^{NC} < x_1^{SO}} < FOC_{k1}\big|_{x_1^{NC} = x_1^{SO}}$; this captures the cases where the marginal product of the private variable input is reduced by both over-use and under-use of the common resource; we consider the case where $FOC_{k1}\big|_{x_1^{NC} < x_1^{SO}} \geq FOC_{k1}\big|_{x_1^{NC} = x_1^{SO}}$ at the end of the section. First, we evaluate whether $x_i^{NC} > x_i^{SO}$ and $\sum x_j^{NC} > \sum x_j^{SO}$ is possible. Greater input levels on the common resource reduces FOC_{x1}^{NC}, as required. And, given $FOC_{k1}\big|_{x_1^{NC} > x_1^{SO}} < FOC_{k1}\big|_{x_1^{NC} = x_1^{SO}}$, then $FOC_{k1}^{NC} < FOC_{k1}^{SO}$ when evaluated at the pair: $x_i^{NC} > x_i^{SO}$, $k_i^{NC} = k_i^{SO}$. This implies that $k_i^{NC} < k_i^{SO}$ to ensure that $FOC_{k1}^{NC} = FOC_{k1}^{SO}$. With $k_i^{NC} < k_i^{SO}$ FOC_{x1}^{NC} is further reduced, so that the combination $x_i^{NC} > x_i^{SO}$, $k_i^{NC} < k_i^{SO}$ is possible.

Next, we evaluate whether $x_i^{NC} < x_i^{SO}$ and $\sum x_j^{NC} < \sum x_j^{SO}$ is possible. In this case, FOC_{x1}^{NC} increases still further; meaning that $k_i^{NC} < k_i^{SO}$ would be required in order to equate the first-order conditions. Since $FOC_{k1}\big|_{x_1^{NC} > x_1^{SO}} < FOC_{k1}\big|_{x_1^{NC} = x_1^{SO}}$ at $k_i^{NC} = k_i^{SO}$, this would require $k_i^{NC} < k_i^{SO}$, which is consistent with the required change in FOC_{x1}^{NC}.

In both cases, $k_i^{NC} < k_i^{SO}$, but $x_i^{NC} <=> x_i^{SO}$. The impact on stock densities is ambiguous, and depends on the marginal impact of over- or under-use on the marginal product of livestock vs. the marginal impact of purchased inputs. Whenever the marginal impact of externalities on pasture is greater on the marginal product of livestock vs. purchased inputs, then stock levels will be higher and input levels will be lower under non-cooperation. Finally, if there are no possibilities of under-use, e.g. $FOC_{k1}\big|_{x_1^{NC}<x_1^{SO}} \geq FOC_{k1}\big|_{x_1^{NC}=x_1^{SO}}$, then the only equilibrium combination is $k_i^{NC} < k_i^{SO}$, $x_i^{NC} > x_i^{SO}$.

In the second scenario, we assume that the individual's livestock and his purchased inputs are gross substitutes and that $FOC_{k1}\big|_{x_1^{NC}>x_1^{SO}} > FOC_{k1}\big|_{x_1^{NC}=x_1^{SO}}$ and $FOC_{k1}\big|_{x_1^{NC}<x_1^{SO}} > FOC_{k1}\big|_{x_1^{NC}=x_1^{SO}}$, which captures the cases where both over- and under-use of the commons increases the marginal product of the private variable input. Following the process developed above, it is straightforward to show that $k_i^{NC} > k_i^{SO}$ and $x_i^{NC} > x_i^{SO}$ or $x_i^{NC} < x_i^{SO}$ are the only possible equilibrium combinations. Again, if the impact of externalities generated from grazing common pastures has a greater impact on the marginal product of livestock versus the marginal product of purchased inputs, then $x_i^{NC} > x_i^{SO}$, $k_i^{NC} > k_i^{SO}$ will result. And, if $FOC_{k1}\big|_{x_1^{NC}<x_1^{SO}} \leq FOC_{k1}\big|_{x_1^{NC}=x_1^{SO}}$, then the only $k_i^{NC} > k_i^{SO}$ and $x_i^{NC} > x_i^{SO}$ is possible.

Summarizing the results, when outcomes lead to lower marginal returns on the pastures (either over- or under-grazing), use of inputs that are "traditional" gross complements in production – i.e. those that are gross complements when all inputs are private – will be lower than the corresponding equilibrium under the social optimum. We expect, then, that purchase of inputs such as vaccines, feed concentrates, and high value agro-industrial by-products will be lower where stock densities on pastures do not coincide with the social optimum, all else equal. On the other hand, bulky low-value feeds such as hay and stover may well substitute for misuse of common pastures, and so we would expect that purchase of such inputs increases.

From the above model, we can write the optimal input demands as follows:

$$x_i^* = f\left(\sum_{j \neq i} x_j^*, k_i^*; P, Z, Coop\right)$$

$$k_i^* = f\left(\sum_{j \neq i} x_j^*, x_i^*; P, Z, Coop\right)$$

We have introduced a new term, *Coop*, which captures the extent to which community members can engage in collective action and manage use rates on the commons in order to attain outcomes closer to, or equal to, those obtaining from joint-maximization. We discuss our empirical strategy for measuring *Coop* below.

3. EMPIRICAL MODEL

To test model hypotheses, data were collected at a number of different levels – market, community, institutions, and household level. Surveys were undertaken for 48 communities and 400 households located in northeastern Burkina Faso. The inputs to be estimated below include size of the household's livestock herd, measured in tropical livestock units (TLU), and the total number of cattle held. We also estimate household purchases of millet and sorghum residues and grains, which is an adjusted aggregate quantity. The sale unit of millet and sorghum stalks was in "bottes", which weighs roughly 5 kgs[4]; units of grain were in kgs. Using a conversion figure of 5 kg. of stover = 3 kg. of grain, we added the four types of purchased feed to get a total quantity in grain equivalents. We expect that purchased crop residues and grain are substitutes for grazing pastures[5]. We also estimate the quantities of high-valued feed purchased and whether

[4] Though we did not weigh purchased "bottes", team members assessed that the botte sizes were roughly uniform and that they weighed approximately 5 kgs., similar to a study undertaken by IITA in West Africa, c.f. www.iita.org/info/crop-livestock/arti18.pdf.

[5] Residues and grain themselves have different nutrition and caloric attributes, and grain in particular, may be a complement to residues and pasture. We nonetheless consider both types of crop by-products as relatively low-value in terms of impact on overall livestock productivity. We tried a number of specifications, including using just

or not a household purchases vaccines (a discrete variable); we hypothesize that these inputs are complements with forage from common pastures. We estimate tropical livestock units and cattle separately, since all ruminants can be fed with crop residues and high-value feed, but vaccines are purchased only for cattle.

Below, we first consider household and community characteristics that affect livestock production, and consider the likely impact that each variable has on input demands, taking into consideration strategic effects as well as whether inputs are gross complements or substitutes in production. Second, we discuss the empirical strategy for recovering estimates of cooperative capacity and thus the extent of externalities generated in the use of common pastures. We then derive the equations to be estimated, and present descriptive statistics for the variables used.

LIVESTOCK PRODUCTION

While the main hypothesis to be tested in this paper is the impact of cooperation on livestock input demands, clearly other factors will also influence the decision. Input decisions are expected to be a function of a number of household- and community-level variables. Yet, comparative statics are based on the 4x4 matrix for each of two players' two input choices; in this case, impacts of changes in exogenous variables, other than cooperation, is in general ambiguous, and depends on the relative strength of direct vs. strategic impacts. As long as strategic effects are relatively weak, e.g. $\frac{\partial^2 F_i}{\partial x_i \partial x_j} < \frac{\partial^2 F_i}{\partial x_i^2}$ and $\left|\frac{\partial^2 F_i}{\partial x_i \partial k_j}\right| < \left|\frac{\partial^2 F_i}{\partial x_i \partial k_i}\right|$, then changes in certain exogenous variables will have the same impacts as those arising if N=1 (e.g. an increase in output price would increase use of all inputs; an increase in the costs of animals would lead to

grain (31 observations) or just stover (39 observations). Since the number of non-censored observations are quite a bit lower, however, explanatory power and efficiency is lower. Coefficients, however, are similar to those for the crop by-product variable.

a decrease in number of animals stocked, an increase low-value substitutes and a decrease in high-value complements).

Consider first the total size of the pasture. Unfortunately, it is quite possible that the allocation of land to common pastures vs. private croplands may itself be a function of unobserved community characteristics that may also affect household livestock production decisions, leading to potential problems of endogeneity. Also, given thin and localized markets for crop residues with seasonality in demand, we could not recover a community level price for crop residues. Thus, we use the fixed total land endowment at the community-level (cropland plus common pastures) to capture both pasture resources and the availability of crop residues. We expect that a greater land endowment at the community level will increase stock levels, and also lead to greater complementary input use (agro-industrial by-products and vaccines). The impact on crop residues is ambiguous, and depends on whether resulting land allocation patterns make pasture or crop by-products less costly.

The relative price of livestock: grain is used as a measure of the output price relative to opportunity costs of increased grain production. We expect stock levels to increase with higher relative livestock prices, and also for purchases of high-value feeds and vaccines to increase. Use of crop inputs, however, may well be lower. Distance to the livestock market captures lower transactions costs of selling animals, and also lower transactions costs of purchasing feeds and potentially vaccines. Thus, we expect stock levels and purchase of feeds and vaccines to be higher, the lower is the distance to market – that is, we expect the direct impact via lower costs will outweigh lower marginal returns due to higher stock levels. Since most crop inputs are purchased within the village, we expect no direct impact on these inputs; to the extent that higher stock levels drive down marginal returns to pastures, however, we expect greater use of crop inputs. We also expect that the stock of infrastructure within a village – whether or not there is a community granary or vaccination park, the numbers of transport vehicles available, etc. – will increase all inputs. This stock of village infrastructure is a simply a sum of all such infrastructure found in the community. The final community-level variable we consider is the coefficient of variation in rainfall. We use secondary data from Hutchinson (2001), and use the coefficient of variation instead of the mean and variance of rainfall, since these latter two measures are very highly correlated. We expect that in high rainfall, low variability areas that stock densities will be greater, and that purchases of high-valued feeds and vaccines will be higher. We also expect crop inputs to increase since crop yields themselves should be higher and less variable in these environments.

Household-level factors include age of the household head (in natural logarithms), the number of adults in the household who have had any public education (either regular schooling or adult education classes), whether or not the head of household comes from a traditionally pastoralist tribe and the stock of agricultural assets. It is hypothesized that all four of these factors will increase total factor productivity, and thus lead to increased levels of all inputs. Given relatively thin agricultural labor markets, household size is expected to capture the opportunity costs of agricultural labor. In the current case, the "household" was defined by those who either shared ownership rights to the household herd and/or were dependent on the household head, who is considered the primary herd owner. To the extent that the (fixed) household labor endowment increases the marginal product of all inputs, we expect stockholdings and purchased inputs to increase with the stock of labor. Similarly, total cropland under the control of the household is expected to decrease purchase of crop residues; we use total cropland per household adult to reduce collinearity with household size. We also consider how many grain storage facilities the household has (only four households have no storage); this would decrease the cost of feeding grains and residue to livestock. We expect such facilities to reduce purchase of crop inputs. On the other hand, we expect that greater cropland and greater storage capacity will lead to higher stockholdings and purchases of high-valued feeds, as well as the probability of vaccination. Finally, we consider the ownership structure of the herd. We hypothesize that the greater the proportion of animals owned by the individual (as opposed to being part of a share-contract arrangement), the more likely it is that the individual will purchase any inputs. We do not include this variable in the stock levels decisions. Descriptive statistics for these variables are presented in Table 1 below.

Table 1—Descriptive Statistics

	Mean	Std.	Minimu	Maximu
Dependent				
TLU	13.4	19.0	0.00	157.0
Cattl	11.4	17.9	0.00	149.0
Crop	94.4	416.7	0.00	4800.0
High-Value	228.4	444.4	0.00	3700.0
Vaccine	0.40	0.49	0.00	1.00
Explanatory				
Community -				
Total Land Endowment	3262.4	2308.7	586.0	9058.5
Price of Cattle:Grain; (kg. Liveweight: kg.	2.32	0.15	2.11	2.56
Distance to Livestock	21.1	15.7	0.00	63.0
Community	1.23	1.24	0.00	4.00
Coefficient of Variation in	0.22	0.02	0.18	0.24
Household-				
Age of Household	50.5	15.3	17.0	100.0
Number of Adults with	0.14	0.45	0.00	4.00
Head, Traditionally	0.52	0.50	0.00	1.00
Number of Agricultural	0.22	0.51	0.00	4.00
Number of Household	5.82	3.20	1.00	20.0
Total Cropland per	0.80	0.53	0.00	3.62
Storage	2.14	1.46	0.00	16.0
Proportion Herd	0.90	0.25	0	1

Number of observations: 402

TLU = tropical livestock units
Distance to market (km)
Total cropland per adult (ha)

Mean tropical livestock units are just over 13, most of which are accounted for by cattle holdings; not reported are mean sheep and goat holdings of 6 and 12, respectively. On average, households purchase 28 kgs. of crop input equivalents, though the average for those households who purchase these inputs is 178 kgs. Of the 402 households in the survey, 63 purchase these crop inputs. In fact, many more households purchase high-value feed (204 vs. 63); the average kgs. purchased by those households who purchased any at all is 450 kgs. Finally nearly 40 percent of households vaccinated either part or all of their herds.

COLLECTIVE ACTION AND COOPERATION

In the above theoretical analysis, input decisions are a function of the management of common pastures. While there were no formal rules on livestock levels or pasture use rates in the study area, this does not necessarily mean that community members aren't aware of pressures on the common resource and that informal mechanisms to reduce the tendency to overstock do not operate. In a separate paper, McCarthy et al. (2003) construct two indices of community-level cooperative capacity, using such variables as the density of community institutions that directly engage in natural resource management, the density of other formal organizations, the proportion of households participating in these two types of institutions/organizations, the total number of rules and activities operating within a community with respect to the natural resource base (including water point maintenance, erosion control and reforestation activities, etc.), monetary and labor contributions to resource management activities and active participation by households at meetings. A factor analysis of these variables, shown in Appendix 2, yielded two factors – one whose scoring coefficients were quite high on organization density and meeting participation, and the second whose scoring coefficients were negative for organization density, but high on number of rules and activities and active participation by households in terms of labor and monetary contributions to local public goods. We will use these capacity indices in the household-level input equations below; and hereafter refer to the first as the index of network capacity and the second as the index of implementation capacity, respectively. These indices were then normalized to lie between 0 and 1. Table 2 below presents descriptive statistics for the two cooperative capacity indices.

Table 2--Descriptive Statistics, Cooperation Variables

Cooperation Variables	Mean	Std. Deviation	Minimum	Maximum
Index of Network Capacity	0.22	0.16	0.00	1.00
Index of Implementation Capacity	0.66	0.23	0.00	1.00

ECONOMETRIC ISSUES

Full data on all variables is available for 397 of the 402 households. We observe zero values for all of our dependent variables; though 96 percent of observations have TLU > 0,75 percent (300 households) hold cattle. Following the Cragg test described in Greene (2000), we test whether factors affecting the decision to hold animals are statistically different from those affecting the decision on how many animals to hold (e.g. testing the sample selection vs. tobit specifications)[6]. For both TLU and cattle holding, we reject the tobit specification. We thus use two-stage Heckman regressions for the animal holding equations. Furthermore, purchase of feeds will be conditional on holding livestock and purchase of vaccines will be conditional on holding cattle. However, purchases can be zero even when households hold animals. We use the inverse Mills ratio from the TLU Heckman equations to test the tobit vs. sample selection specification, and in this case, we accept the tobit model as the appropriate specification[7]. Note that, given that purchases themselves are incidentally truncated at zero, we cannot then use a standard Heckman for the crop by-product and high-value feed equations. For vaccines, because it is a dichotomous variable, we can run a two-stage Heckman, with probit equations in the first stage estimating whether or not the household holds cattle, and the second stage estimating

[6] All regressions were performed in STATA 8.0

[7] We actually use the interval regression model to reproduce the tobit specification, but which, using STATA, allows us to correct for clustering on community-level variables.

whether or not the household purchases vaccines. This allows us to adjust errors for both selection and clustering. In this case, we conclude that the equations are in fact independent, and present results for the probit on vaccination for the subset of cattle owners.

Another possible econometric problem concerns potential endogeneity of the cooperative capacity indicators with the household input demand equations. Fortunately, we have available a number of potential instruments with which to test endogeneity. In a previous study of community-level collective action (McCarthy et al. 2003), the authors regressed the cooperative capacity indices on a number of explanatory variables hypothesized to affect collective action in found in the general literature on cooperation and resource management[8]. Variables used in that analysis included the total number of households and the square of households to test the hypothesis that cooperation is more difficult both with few households and with many households (Ostrom 1990; de Janvry et al. 1998). Social heterogeneity, measured by the number of quarters within a village and the number of ethnic groups, is expected to reduce cooperative capacity since such heterogeneity is posited to make establishing and enforcing agreements more costly. Similarly, the coefficient of variation in cattle holdings – used as a proxy wealth differentiation – is expected to decrease cooperative capacity, again because such heterogeneity makes negotiating mutually acceptable agreements more difficult. To capture the opportunity costs of engaging in collective action, the authors used the percentage of households with at least one member engaged in migration for wage work (Dayton-Johnson and Bardhan 2002; Bardhan 2000). The proportion of adults who have attended public school is hypothesized to favor cooperative capacity by increasing individuals' capacity to acquire information and transform such information into practical knowledge.

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8 In McCarthy et al. (2003) the authors give a more detailed literature review and of variables hypothesized to affect collective action.

Community-level variables included the coefficient of variation in rainfall, and relative livestock:millet prices, distance to market and distance to the regional capital. The hypothesized sign of rainfall variability is ambiguous, whereas more favorable livestock prices and shorter distances to market are expected to increase cooperative capacity by increasing returns to livestock production, which relies more heavily on common pool resources than does crop farming. Also included was information on the extent to which community resources are shared with either neighboring communities, it being hypothesized that resources shared with outsiders reduces cooperative capacity by making communication and enforcement more costly. This subset of community-level variables, however, enter into the household input decisions, and thus cannot serve as instruments.

Also included were a set of variables capturing the structure of the organizations in the community. Two indicators of the degree of "democratization" were used, the dominance of the village chief's role across formal and informal organizations within the community and the extent to which other community members participate in rule-making; the hypothesis being that democratization increases cooperative capacity. Finally, information on the presence of external programs/projects (mainly international NGO's) and the duration of these programs, was included to test their impact on cooperative capacity. The number of programs in existence since before 1993 and those beginning after 1993 were included separately. According to project personnel with long experience working in the area, there was a distinct change in the development paradigms (Grell, personal communication). In general, most programs/projects beginning before 1993 had an overwhelming focus on technical solutions to crop production and NRM, whereas those beginning after 1993 began adopting the "terroir" approach, with a focus on specific resources within given boundaries but also the institutions charged with managing those resources, and more recently, considering the pastoral system as a whole, including community members' use of non-community resources and vice-versa. It is generally supposed that projects begun in the latter period should increase cooperative capacity the most.

Results of the analysis of factors affecting implementation capacity show that such capacity is in areas with higher and less variable rainfall, in communities with less heterogeneity in wealth, where fewer people migrated for wage work, where there is more collaboration between the chief and community members in rule-making, and where more external projects began in the latter period. These results coincide well with factors expected to positively affect collect action for the management of common resources. On the other hand, network capacity was in general higher in areas characterized by lower and more variable rainfall, in communities with greater heterogeneity in wealth and ethnicity, where more people migrated for wage work, but that were located closer to the regional capital. This index appears to be capturing the capacity of individuals to join networks to exploit potential gains from heterogeneity in terms of information flow, increased access to migration networks, and perhaps more importantly, in spreading risk.

For all five household input decisions – total cattle holdings, tropical livestock unit holdings, purchases of high-value agro-industrial by-products, purchase of low-value crop by-products, and purchase of vaccines – we used the instruments identified above to test whether or not the cooperative capacity indices were statistically exogenous. Following the Hausman-Wu test, we regress cooperative capacity on all exogenous explanatory variables identified immediately above plus the household-level factors expected to affect input demand. We conclude that the indices are indeed statistically exogenous for cattle and livestock holdings, purchase of agro-industrial by-products, and vaccines. However, we reject the hypothesis of exogeneity for implementation capacity in the equation estimating purchase of low-value crop by-products. Thus, we must instrument the implementation capacity index in this regression. Below we show results of two specifications. In the first, we use predicted values of the implementation capacity index in a interval regression model correcting for clustering on the capacity indices; in this case, we use predicted values of the implementation capacity based on regressions found in McCarthy et al. (2003). Though this specification enables us to correct for clustering, it is still inefficient due to the use of the predicted values. In the second specification, we use an instrumental variables tobit, which gives correct standard errors for the instrumented variables, but may be inefficient due to the fact that clustering is not taken into account. As shown below, results are quite robust to these alternative specifications.

INPUT PURCHASE DECISION

Tables 3 and 4 present results for the two-stage Heckman regressions for livestock holdings in tropical livestock units and cattle holdings; *** indicates significant at the 1%, ** at 5% and * at the 10% level, respectively.

Table 3—Dependent variable, total livestock units; Heckman

	Coefficient	**Std. Error**	**z-stat**
Age, Household Head (in natural logs)	0.67	1.93	0.35
Head – Ethnicity, Pastoralist	10.43***	2.20	4.74
# of Adults in HH, (in natural logs)	7.30***	2.24	3.26
# of Adults, Public or Adult Schooling	-0.73	0.83	-0.88
Total Cropland per Household Adult	4.54	2.21	2.05
# of Agricultural Implements	5.23**	2.31	2.26
# Crop Storage Facilities	1.46	0.79	1.86
Price of Livestock: Millet (kg. Liveweight: kg. Millet in natural logs)	0.14	16.91	0.01
Distance to Market	0.00	0.07	0.06
Total Land Endowment of Community	0.74	1.39	0.53
Coefficient of Variation of Rainfall (in natural logs)	10.23	15.70	0.65
# of Infrastructure in Community	-1.82	1.22	-1.49
# of Neighbors Sharing Pastures	-3.25**	1.66	-1.96
Network Capacity	-2.77	7.04	-0.39
Implementation Capacity	7.96	5.78	1.38
Constant	8.05	25.32	0.32
First State			
TLU Holdings (1=positive)			
Age, Household Head (in natural logs)	-0.85**	0.35	-2.41
Head – Ethnicity, Pastoralist	-0.02	0.29	-0.07
# of Adults in HH, (in natural logs)	0.11**	0.06	1.93
# of Adults, Public or Adult Schooling	-0.18	0.24	-0.77
Total Cropland per Household Adult	0.37	0.34	1.12
# of Agricultural Implements	0.08	0.34	0.24
# Crop Storage Facilities	0.64***	0.21	3.07
Price of Livestock: Millet (kg. Liveweight: kg. Millet in natural logs)	0.30	2.49	0.12
Distance to Market	-0.01	0.01	-1.46
Total Land Endowment of Community	0.14	0.23	0.58
Coefficient of Variation of Rainfall (in natural logs)	-1.56	1.62	-0.96
# of Infrastructure in Community	0.21**	0.10	1.99
# of Neighbors Sharing Pastures	0.11	0.26	0.41
Network Capacity	0.53	0.73	0.72
Implementation Capacity	-0.33	0.63	-0.52
Dummy, Permanent Water Source	0.55**	0.25	2.20
Constant	-0.81	4.20	-0.19
rho	-0.36	0.13	-2.87
Insigma	2.85	0.12	22.86
lambda	-6.01	2.26	

Wald test of indep. eqns. (rho= 0); chi2 (1) = 8.23 Prob>chi2 = 0.0041
Prob>chi2=.0000
Number of Observations = 397

Table 4—Dependent variable, cattle-holdings; Heckman

	Coefficient	Std. Error	z-stat
Age, Household Head (in natural logs)	2.56	2.45	1.05
Head – Ethnicity, Pastoralist	8.58***	2.63	3.27
# of Adults in HH, (in natural logs)	8.00	2.43	3.30
# of Adults, Public or Adult Schooling	-0.53	0.84	-0.63
Total Cropland per Household Adult	5.85**	2.72	2.15
# of Agricultural Implements	1.85	2.03	0.91
# Crop Storage Facilities	0.73	0.58	1.26
Price of Livestock: Millet (kg. Liveweight: kg. Millet in natural logs)	-6.54	18.41	-0.36
Distance to Market	0.00	0.08	-0.04
Total Land Endowment of Community	0.51	1.70	0.30
Coefficient of Variation of Rainfall (in natural logs)	-3.09	17.26	-0.18
# of Infrastructure in Community	-0.96	1.30	-0.74
# of Neighbors Sharing Pastures	-3.09*	1.92	-1.61
Network Capacity	-5.45	8.29	-0.66
Implementation Capacity	4.82	7.58	0.64
Constant	-10.35	28.63	-0.36
Cattle Holdings (1=positive)			
Age, Household Head (in natural logs)	-0.59**	0.20	-2.93
Head – Ethnicity, Pastoralist	0.49	0.19	2.64
# of Adults in HH, (in natural logs)	0.05	0.05	1.10
# of Adults, Public or Adult Schooling	-0.07	0.11	-0.65
Total Cropland per Household Adult	0.01	0.16	0.06
# of Agricultural Implements	1.09***	0.21	5.14
# Crop Storage Facilities	0.30	0.09	3.16
Price of Livestock: Millet (kg. Liveweight: kg. Millet in natural logs)	0.59	1.64	0.36
Distance to Market	0.00	0.01	-0.67
Total Land Endowment of Community	0.07	0.11	0.62
Coefficient of Variation of Rainfall (in natural logs)	1.85	1.16	1.60
# of Infrastructure in Community	-0.15**	0.07	-2.29
# of Neighbors Sharing Pastures	-0.02	0.12	-0.18
Network Capacity	-0.09	0.65	-0.14
Implementation Capacity	0.60	0.39	1.54
Dummy, Permanent Water Source	-0.02	0.15	-0.12
Constant	4.01*	2.38	1.68
rho	-0.28	0.07	-3.85
Insigma	2.89	0.14	21.85
lambda	-4.98	1.64	

Wald test of indep. eqns. (rho= 0); chi2 (1) = 14.83 Prob>chi2 = 0.0001
Prob>chi2=.0000
Number of Observations = 397

For both total tropical livestock units and cattle holdings, and for both the discrete decision to hold animals as well as how many to hold, the cooperative capacity indices have no statistically significant impact. According to the theory described above, hypothesized impacts are ambiguous – though we hypothesized that stock levels would be lower where cooperation is higher on the assumption that the marginal impacts of increased stock densities on the livestock production would be relatively stronger than marginal impacts of purchased inputs. The ambiguous results also provide evidence consistent with the hypothesis that stock levels that are either higher or lower than those arising from joint-maximization lead to an overall decline in profits[9]. For both cattle and TLU, larger households where the household head comes from a traditionally pastoralist tribe hold larger herds, as do those households with more cropland per adult located in villages who share pastures with fewer neighboring villages. For TLU, households with more crop storage facilities hold more TLU. In both cases, age of the household head has a negative impact on whether or not to hold TLU or cattle. Having more agricultural assets are increase the probability of having cattle, though, interestingly, village infrastructure has a negative impact on the discrete decision to hold cattle. On the other hand, having access to a permanent water source as well as more village infrastructure leads to an increase in the probability of holding TLU, so in this case in holding small ruminants.

In Table 5 below we present the results for the tobit regression of the quantity of agro-industrial by-products purchased, with errors corrected for clustering on community-level variables.

Table 5—Dependent Variable, Quality of agro-industrial by-product

	Coefficient	Std. Error	z-stat
Age, Household Head (in natural logs)	-35.07	104.65	-0.34
Head – Ethnicity, Pastoralist	270.18***	88.85	3.04
# of Adults in HH, (in natural logs)	14.02	15.28	0.92
# of Adults, Public or Adult Schooling	69.59**	32.22	2.16
Total Cropland per Household Adult	34.73	69.63	0.50
# of Agricultural Implements	366.59***	77.06	4.76
# Crop Storage Facilities	44.57	25.64	1.74
Proportion of Herd Owned	-191.48	173.61	-1.10
Price of Livestock: Millet (kg. Liveweight: kg. Millet in natural logs)	782.81	573.23	1.37
Distance to Market	3.78	2.54	1.49
Total Land Endowment of Community	-58.55	56.61	-1.03
Coefficient of Variation of Rainfall (in natural logs)	-843.97*	521.39	-1.62
# of Infrastructure in Community	-84.82	59.49	-1.43
# of Neighbors Sharing Pastures	-125.21*	76.93	-1.63
Network Capacity	60.72	257.20	0.24
Implementation Capacity	315.37*	184.39	1.71
Inverse Mills Ratio, TLU	-738.68**	330.73	-2.23
Constant	-1640.45*	976.68	-1.68
/lnsigma	6.41	0.11	59.00
sigma	607.79	66.03	

Prob>chi2=.0000
Maximum Likelihood R2=.21
Number of observations=371

First, we note that both network and implementation capacity have positive coefficients, though only implementation capacity is statistically significant. Of the household-level variables, coefficients are positive and significant for households where the head is traditionally pastoralist, where household adults have more education, and where the household holds more agricultural assets and crop storage facilities. The coefficient on the inverse mills ratio is negative and significant, implying that errors associated with selecting to hold cattle and the purchase decision are negatively correlated. Of the community–level variables, we note that in communities with lower and more variable rainfall, households purchases of high-valued feed will be lower; purchases are also lower where community members share common pastures with a greater number of neighboring villages. Size of the household, age of household head, the household's land endowment, distances to market and relative livestock prices, and community infrastructure have no impact on the purchase decision. Interestingly, the proportion of the herd owned also has no impact on the purchase decision, although we note that in our sample, most households owned a very high share of livestock in their herd. It may be the case that share-contracts are made between community members, relatives or close friends, such that the moral hazard problems associated with lower incentives to invest simply do not arise. Unfortunately, we do not have data to further test whether the relationship with the owner and/or monitoring costs for the owner (e.g. if the owner lives in the community or in a distant town) affects this choice of additional inputs into livestock production. Nonetheless, our results do not support the contention that such contracting arrangements reduce purchase of high-value feeds. To summarize, purchase of high-value feeds is greater in communities with better agro-climatic conditions, where common pastures are shared with fewer neighbors and where cooperative capacity is high, and in households wealthier in terms of agricultural assets and human capital, and where the ethnicity of the household head is traditionally pastoralist.

In Tables 6a and 6b below, we present the results for the purchase of low-value crop-based feeds, under the two specifications described above.

Table 6a—Dependent variable, quantity of crop by-products purchased; Tobit specification using predicted cooperative capacity indices

	Coefficient	Std. Error	z-stat
Age, Household Head (in natural logs)	237.84	237.87	1.00
Head – Ethnicity, Pastoralist	-6.65	206.31	-0.03
# of Adults in HH, (in natural logs)	-71.57**	32.62	-2.19
# of Adults, Public or Adult Schooling	119.42	100.32	1.19
Total Cropland per Household Adult	-37.92	144.23	-0.26
# of Agricultural Implements	-9.07	184.76	-0.05
# Crop Storage Facilities	218.78**	73.24	2.99
Proportion of Herd Owned	-291.28	306.47	-0.95
Price of Livestock: Millet (kg. Liveweight: kg. Millet in natural logs)	4996.82**	2198.32	2.27
Distance to Market	-26.93***	10.15	-2.65
Total Land Endowment of Community	-29.79	135.83	-0.22
Coefficient of Variation of Rainfall (in natural logs)	-1672.90	1153.83	-1.45
# of Infrastructure in Community	30.78	94.94	0.32
# of Neighbors Sharing Pastures	-221.50	144.20	-1.54
Network Capacity	-289.35	476.10	-0.61
Implementation Capacity	-1047.20	657.03	-1.59
Inverse Mills Ratio, TLU	-2380.09*	1307.60	-1.82
Constant	-6810.93**	2694.74	-2.53
/Insigma	7.11	0.20	35.89
sigma	1224.76	242.65	

Prob>chi2=.0001
Maximum Likelihood R2=.10
Number of Observations = 371

Table 6b—Dependent variable, quantity of crop by-products purchased; Instrumenting for capacity indices

	Coefficient	Std. Error	z-stat
Age, Household Head (in natural logs)	255.49	333.90	0.68
Head – Ethnicity, Pastoralist	54.91	232.46	0.24
# of Adults in HH, (in natural logs)	-66.40	44.57	-1.49
# of Adults, Public or Adult Schooling	135.39	126.07	1.07
Total Cropland per Household Adult	-73.03	193.96	-0.38
# of Agricultural Implements	-45.61	199.89	-0.23
# Crop Storage Facilities	228.33**	82.55	2.77
Proportion of Herd Owned	-331.29	379.55	-0.87
Price of Livestock: Millet (kg. Liveweight: kg. Millet in natural logs)	5554.08**	2242.02	2.48
Distance to Market	-29.19***	9.63	-3.03
Total Land Endowment of Community	8.79	168.79	0.05
Coefficient of Variation of Rainfall (in natural logs)	-1973.87	1259.56	-1.57
# of Infrastructure in Community	102.45	111.23	0.92
# of Neighbors Sharing Pastures	-297.02**	165.14	-1.80
Network Capacity	-277.65	645.58	-0.43
Implementation Capacity	-1886.74**	973.34	-1.94
Inverse Mills Ratio, TLU	-2113.50**	1103.65	-1.92
Constant	-7388.47**	3013.92	-2.45

Prob>chi2=.0001
Number of Observations = 371

As shown in Tables 6a and 6b, the cooperative capacity indices are negative as expected, but network capacity is never significant. In the first specification which uses predicted values for implementation capacity, the coefficient is just shy of significance at the 10 percent level; the coefficient is negative and significant in the instrumental variables equation shown in 6b. Of the household-level variables, household size is positive and significant in the first specification, and crop storage facilities are positive and significant in both specifications, both as expected. In an interesting contrast with purchase of high-value feed, higher livestock prices and lower distances to market both contribute to higher household purchases of crop-based feeds. Certainly a positive sign on the relative livestock: grain price coefficient is expected – since this indicates both higher output price and lower input costs. However, a priori, we assumed that distance to market would be more important not only for sales of livestock products, but also for purchase of high-valued feed and vaccines, but less important for grain and crop residues, since the market for residues in particular tend to be more localized due to the low feed value but relative bulkiness. Neither cropland per household nor total land endowment at the community level affect purchase of these feeds. Sharing pastures with neighbors is negative in both equations, as is the case with purchase of high-value feeds. This effect likely comes from the negative impact on livestock and cattle holdings indicated in Tables 3 and 4. The impact of the coefficient of variation of rainfall is again negative, as in the high-value feeds equation, though it is not significant in either equations. To summarize purchase of low value crop-based feeds are higher in communities with low implementation capacity facing high livestock prices relative to grain prices, and for households with greater storage capacity.

In table 7 below, we present results of the probit for purchasing vaccines.

Table 7—Dependent variable, purchase of vaccines; probit

	Coefficient	Std. Error	z-stat
Age, Household Head (in natural logs)	-0.053	0.26	-0.2
Head – Ethnicity, Pastoralist	-0.157	0.21	-0.77
# of Adults in HH, (in natural logs)	0.125	0.20	0.63
# of Adults, Public or Adult Schooling	0.001	0.09	0.01
Total Cropland per Household Adult	0.115	0.16	0.74
# of Agricultural Implements	0.244*	0.14	1.78
# Crop Storage Facilities	0.148**	0.07	2.02
Proportion of Herd Owned	0.003	0.26	0.01
Price of Livestock: Millet (kg. Liveweight: kg. Millet in natural logs)	3.493**	1.57	2.23
Distance to Market	-0.001	0.01	-0.13
Total Land Endowment of Community	-0.022	0.14	-0.16
Coefficient of Variation of Rainfall (in natural logs)	-1.374	1.12	-1.22
# of Infrastructure in Community	0.063	0.11	0.58
# of Neighbors Sharing Pastures	-0.281	0.14	-2.01
Network Capacity	-0.322	0.52	-0.62
Implementation Capacity	0.176	0.45	0.39
Constant	04.996**	2.53	-1.97

Prob>chi2=.0000
Maximum Likelihood R2=.10
Number of Observations = 296

As noted above, we conclude that the decision to purchase vaccines is independent of the decision to hold animals. First we note that neither cooperative capacity index is statistically significant in this equation. Households with more agricultural assets and storage facilities are more likely to purchase vaccines, as are those living in communities with higher relative livestock:grain prices and where there are fewer neighbors sharing pastures. Interestingly, community infrastructure is not significant – if we substitute infrastructure with a variable that takes the value of one if the community has a vaccination park, results are quite similar.

In summary, econometric results are consistent with the hypothesis that substitute inputs, such crop-based feeds, are more likely to be purchased by households located in communities with less cooperative capacity; whereas evidence for one of the complementary inputs, high-valued feeds, is more likely to be purchased where cooperative capacity is higher. Household wealth in terms of agricultural assets increases livestock owned as well as the purchases of any input; whereas own cropland only increases livestock holdings. Whether or not the household head comes from a traditionally pastoralist group – used to proxy experience and knowledge of livestock production – leads to greater stock levels and also higher purchases of high-value feeds, with no impact on the purchase of crop-based feeds or vaccines. Education levels within the household have a positive impact on purchase of high-quality feeds. Thus, it appears that wealthier households – in terms of human and physical capital – not only hold more animals, but also are more likely to purchase additional inputs – either low-value feeds, high-value feeds, or vaccines. Communities facing higher and more variable rainfall are less likely to buy any inputs – though, while the coefficient is consistently negative, it is only significant for high-value feeds. Finally, relative market prices and distances to markets do not affect either livestock holdings or purchased inputs, save for the crop-based feeds.

4. CONCLUSION

This paper uses data collected in northeastern Burkina Faso, and we can compare the results obtained here with other analyses of the same dataset. For instance, McCarthy (2003) investigates the impact of cooperative capacity, using the same indicators used in the above analysis, on stock densities, herd mobility and lands allocated to common pasture. Network capacity had no statistically significant impact on any of the endogenous variables, but higher implementation capacity led to lower stock densities, greater herd mobility (which also relieves pressure on community-based pastures), and to more lands being allocated to common pastures vs. individually cropped fields. Dutilly-Diane et al. (2002) also used the same data set and indicators on cooperative capacity to estimate total household income, total livestock, crop, and non-farm income, and the income shares coming from crop production, livestock production and non-farm income. The results show that implementation capacity increases livestock income, the share of livestock income and total incomes, whereas network capacity leads to higher crop and non-farm income, but no change in total incomes. The results of this study is consistent the results from both the McCarthy (2003) and Dutilly-Diane et al. (2002) studies – implementation capacity is associated with lower purchases of low-value substitutes (the need for which should be lower where common pastures are better managed, all else equal), and higher purchases of high-value complements to common pasture, but network capacity has no statistically significant impact on any household-level input decisions.

The paper is of direct policy relevance for a number of reasons. The goals of the new resource management and land use laws is to devolve both rights and responsibilities for NRM to the community level, with the objective of promoting efficient and sustainable resource use in order to alleviate poverty and to reduce the vulnerability of rural households to income fluctuations. Given the continual increase in population pressure and increased sedentarization of the pastoral population, it is strongly felt that intensification of both crop and livestock production must occur in order for households to lift themselves out of poverty.   At the same time, the impact of resource management at the community level on the household level decision to intensify production via private inputs has been nearly completely neglected.

Empirical results from this study indicate that in communities with better managed natural resources, including common pastures, households are more likely to purchase high-value feeds. On the other hand, households in villages with poorly managed pastures have a greater probability of purchasing low-value crop residue, a substitute for forage. As noted above, Dutilly-Diane et al. (2002) show that households in villages with poorly managed pastures not only have lower livestock incomes, but lower total incomes. The implications are far-reaching. Policies and projects that promote intensification of livestock production are quite likely to fail in non-cooperative communities simply because the marginal returns to adopting high-value inputs will be much lower in areas where ranges are overstocked. Instead, households will spend their money on purchasing substitute feeds. In well-managed communities, however, adoption of high-value products is likely to be successful.

There is no reason to suppose that the difference between adopters and non-adopters is a function of whether or not pastures are held in common (the property rights structure) per se, but rather how well-managed are the common lands. There are many benefits associated with common pastures that are lost under individual privatization, perhaps the most important being the reduction in spatial and temporal variation in forage (due to fluctuating rainfall, for instance). Reduced access to grazing resources increases riskiness of production, which in turn is likely to lead to lower purchase of inputs. In such semi-arid environments, then, promoting technology adoption may well begin with promoting collective action.

REFERENCES

Baland, J-M. and, J.-P. Platteau. 1996. *Halting degradation of natural resources: Is there a role for rural communities?* New York, USA and Oxford: Food and Agricultural Organization and Clarendon Press.

Bardhan, P. 2000. Irrigation and Cooperation: An Empirical Analysis of 48 Irrigation Communities in South India. *Economic Development and Cultural Change*, 48(4): 847-856.

Bulow, J.I., J.D. Geanakoplos and P.D. Klemperer. 1985. Multimarket oligopoly: Strategic substitutes and complements. *Journal of Political Economy*, 93(3): 488-511.

Dayton-Johnson, J., and P.K. Bardhan.2002. Inequality and conservation on the local commons: A theoretical exercise. *Economic Journal*, 112(481): 577-602.

Dutilly-Diane, C., E. Sadoulet, and A. de Janvry. 2002. How Improved Natural Resource Management Improves the Livestock Economy in the Sahel. *Economic Development and Cultural Change*, submitted.

Economic Commission for Africa (ECA). 2000. Globalization, regionalism and Africa's development agenda. Paper presented at the United Nations Conference on Trade and Development (UNCTAD) X, Bangkok, Thailand, February 12-19.

Greene, William H. 2000. *Econometric analysis*. Upper Saddle River, N.J.: Prentice-Hall (4 ed.).

Hutchinson, M.F. 2001. *Topographic and climate database for Africa*. Version 1.0. Centre for Resource and Environmental Studies. The Australian National University, Canberra.

de Janvry, A., McCarthy, N. and Sadoulet, E. 1998. Endogenous provision and cooperation on the commons. *American Journal of Agricultural Economics*, 80(3):658-664.

López, R. 1998. Agricultural intensification, common property resources and the farm-household. *Environmental and Resource Economics***,** 11(3-4): 443-458.

Mas-Collel, A., M.D. Whinston, and J.R. Green. 1995. *Microeconomic theory*. New York: Oxford University Press.

McCarthy, N. 2003. Resource management in erratic environments: An analysis of pastoral systems in Ethiopia, Niger and Burkina Faso. Draft Research Report, Washington, DC: International Food Policy Research Institute.

McCarthy, N., C. Dutilly-Diane, and Drabo Boureima. 2004. Cooperation, collective ction and natural resources management in Burkina Faso. *Agricultural Systems*, in press.

McCarthy, N., E. Sadoulet, and A. de Janvry. 2001. Common pool resource appropriation under costly cooperation. *Journal of Environmental Economics and Management*, 42(3): 297-309.

McCarthy, N., de Janvry, A. and Sadoulet, E. 1998. Dual individual – Common property rights and land use in Mexico. *Journal of Development Economics*, 56(2): 239-264.

Ostrom, E. 1990. *Governing the commons: The evolution of institutions for collective action.* Cambridge: Cambridge University Press.

APPENDIX 1--COOPERATIVE CAPACITY AT THE COMMUNITY LEVEL, AND ITS DETERMINANTS

Table A1--Scoring coefficients for first two factors of community level cooperative capacity indicators

Variables	Network	Active
Network NRM	**0.241**	-0.065
Membership NRM	**0.355**	0.087
Network others	**0.300**	**-0.291**
Membership others	**0.168**	**-0.175**
# Meetings	0.032	0.071
# Activities	0.058	**0.207**
# Rules	-0.013	**0.101**
Participation in meetings	0.028	0.091
Participation in work	**0.132**	**0.422**
# Days of work	0.087	**0.223**

Table A2--Determinants of Cooperative Capacity

	Network Capacity		Active Capacity	
	Coef.	t-stat	Coef.	t-stat
Demographic				
Size community	-4.77	-2.97**	1.35	0.65
Size community sq.	0.01	2.43**	0.00	-0.27
# Quarters	33.68	2.18**	8.23	0.48
# Ethnic groups	-7.35	-0.44	32.47	1.22
Heterogeneity in cattle holding	16.38	3.27**	-15.66	-1.89*
% Adults migrating	578.05	1.30	-1083.70	-2.19*
% Households w/ public education	325.47	1.91*	404.69	1.37
Institutions structure				
Chief Dominant	25.09	0.45	-5.46	-0.08
% rules made in collaboration	276.41	3.11**	10.41	0.04
# Projects				
Before 1986	37.65	2.22**	-6.91	-0.26
1986-1993 (Terroir approach)	23.35	1.27	98.59	3.81**
1993-2001 (NRM approach)	29.77	0.89	80.45	1.67*
Distance to regional capital	-0.03	-2.16**	-0.03	-0.99
External pressure				
# Village sharing past.	5.16	0.14	-65.89	-0.94
Transhumants using past.	-29.23	-0.54	179.08	1.48
Market and Agro-Ecological				
Relative Livestock:Grain Price	-50.49	-0.12	474.88	0.84
Distance to Livestock Market	-6.49	-0.30	20.06	0.82
Coefficient of Variation, Rainfall	524.14	1.73*	-734.04	-1.89*
Constant	1141.13	2.18**	-1277.14	-1.83*
Number of observations		48		48
R^2		0.59		0.57

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