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COLLECTIVE ACTION IN SPACE: ASSESSING HOW COLLECTIVE ACTION VARIES ACROSS AN AFRICAN LANDSCAPE

Brent M. Swallow, Justine Wangila, Woudyalew Mulatu, Onyango Okello, and Nancy McCarthy

CGIAR System-wide Program on Property Rights and Collective Action

Secretariat:

International Food Policy Research Institute
2033 K Street, N.W.
Washington, D.C. 20006 U.S.A.

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ABSTRACT

This paper develops and applies a new approach for analyzing the spatial aspects of individual adoption of a technology that produces a mixed public-private good. The technology is an animal insecticide treatment called a "pouron" that individual households buy and apply to their animals. Private benefits accrue to households whose animals are treated, while the public benefits accrue to all those who own animals within an area of effective suppression.

A model of household demand for pourons is presented. As ~~for~~ a private good, household demand for the variable input depends upon output price, input cost, and household characteristics. Input costs for pouron treatments include both the market price of the pourons and the transaction costs that the household must incur to obtain the treatments. Demand also depends upon the way that each household expects its neighbors to respond to one's own behavior. Free-riding is expected in communities with no tradition or formal organization to support collective action. Greater cooperation is expected in communities that have organizations that reward cooperative behavior and punish deviant behavior.

Data for estimation of the model were collected for all of the 5,000 households that reside within the study area of 350 square kilometers in southwest Ethiopia. Geographic reference data were collected for every household using portable Geographic Positioning System units. GIS software was used to generate spatial variables. Variables for distance from the household to the nearest treatment center and number of cattle-owning neighbors within a 1-kilometer radius of the household were created. The density of cattle-owning neighbors was

used as a measure of the potential benefits from cooperation; this variable was expected to have a positive effect on household pouron demand in communities able to support effective collective action and a negative effect in communities not able to support effective collective action. A set of community binary variables was interacted with the density variable to capture differences between communities. The results confirm the importance of the household-level variables. The results also indicate large differences in ability to cooperate between local administrative units. Everything else equal, the areas least able to cooperate were located farthest from the treatment center, were ethnically heterogenous, and had a different ethnic composition than areas around the treatment centers.

CONTENTS

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Brent M. Swallow[*,H], Justine Wangila[H], Woudyalew Mulatu[I]
Onyango Okello,[*] and Nancy McCarthy[*,']

1. INTRODUCTION

Economists are beginning to show more interest in the spatial aspects of economic relationships. Spatial patterns of prices and land use have perhaps received most attention to date. Jayne (1994) and Omamo (1995) have analyzed spatial patterns of crop choice in Zimbabwe and Kenya. Bockstael (1996) studied spatial patterns of land use and land prices in the Patuxent Watershed in the state of Maryland. Chomitx and Gray (1995) analyzed the spatial patterns of land use conversion resulting from road construction in Belize.

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[*] Brent Swallow, Onyango Okello, and Nancy McCarthy are associates from International Livestock Research Institute, Nairobi, Kenya.

[H] Brent Swallow and Justine Wangila's present address is: ICRAF, P.O. Box 30677, Nairobi, Kenya.

[I] Woudyalew Mulatu is from the International Livestock Research Institute, Addis Ababa, Ethiopia.

['] Nancy McCarthy is a joint appointee with International Food Policy Research Institute, Washington, D.C.

Collective action for natural resource management also has important spatial aspects. The location of individuals relative to each other and the collective good determines both the benefits and costs of collective action. Consider, for example, a collective good available at a single fixed location, for example, a water well managed by collective. Households located near to the well incur relatively low transaction costs to participate in the maintenance of the pump and low transaction costs to collect water from the well. Households located near to the well, or near to roads leading to the well, could also incur relatively high costs from the disturbance caused by neighbors walking past. Aggregate benefits and costs also depend upon the spatial distribution of individuals and resources. The more densely populated the area served by the well, the lower the monitoring costs per individual, the greater the total transaction costs associated with queuing, and the greater the incentive to free-ride on others' cooperative behavior.

The focus in this paper is on individual adoption of a technology that produces a mixed public-private good. The technology is a formulation of insecticide called that is applied to cattle as a "pouron". The mixed public-private good is control of external parasites and animal disease vectors. Household demand for pourons is hypothesized to depend upon three spatial factors: (1) distance from the household to the place where the cattle treatments are sold; (2) density of cattle owners in the neighborhood around each household; and (3) ability of the local administrative unit to foster collective action. Distance to the treatment center determines transaction costs incurred to obtain treatments. Density of cattle owners in the neighborhood affects both the opportunities for collective action and the incentives to free-ride on neighbors' use of the cattle treatments. The ability of the local administrative unit to foster collective action determines the incentives to free-ride or cooperate in provision of the public good.

Those hypotheses are tested through an analysis of individual use of cattle treatments in a study site in the Ghibe Valley of Ethiopia. The behavior of individual households regarding the use of cattle treatments is related to the characteristics of the households themselves and the characteristics of their neighbors. Neighbor variables are created using Geographic Information Systems (GIS) software and brought into a logistical regression model.

The next section provides some background on the technical and economic aspects of the problem and the particular case study. Section 3 presents a model of household demand for pouron treatments. That model provides a mathematical definition of the three spatial dimensions of demand for the mixed public-private good. Section 4 discusses the methods used to collect, process and analyze household-level census data. The econometric results are presented in Section 5. The econometric results led to a subsequent qualitative study of the ability of local communities to cooperate in the use of the pourons. Both the methods and results of that phase of the research are described in Section 6. Section 7 is a discussion and conclusion.

INDIVIDUAL AND COLLECTIVE ACTION FOR TSETSE CONTROL BY USE OF POURONS

Background

African animal trypanosomosis is an animal disease that constrains livestock productivity and agricultural development across much of sub-Saharan Africa. Trypanosomosis is caused by parasitic protozoa and transmitted by several specie of tsetse fly (*Glossina* spp.). Trypanosomosis is particularly important in Ethiopia where about 7 million cattle are at risk of contracting the disease and cattle are the main source of traction for crop cultivation.

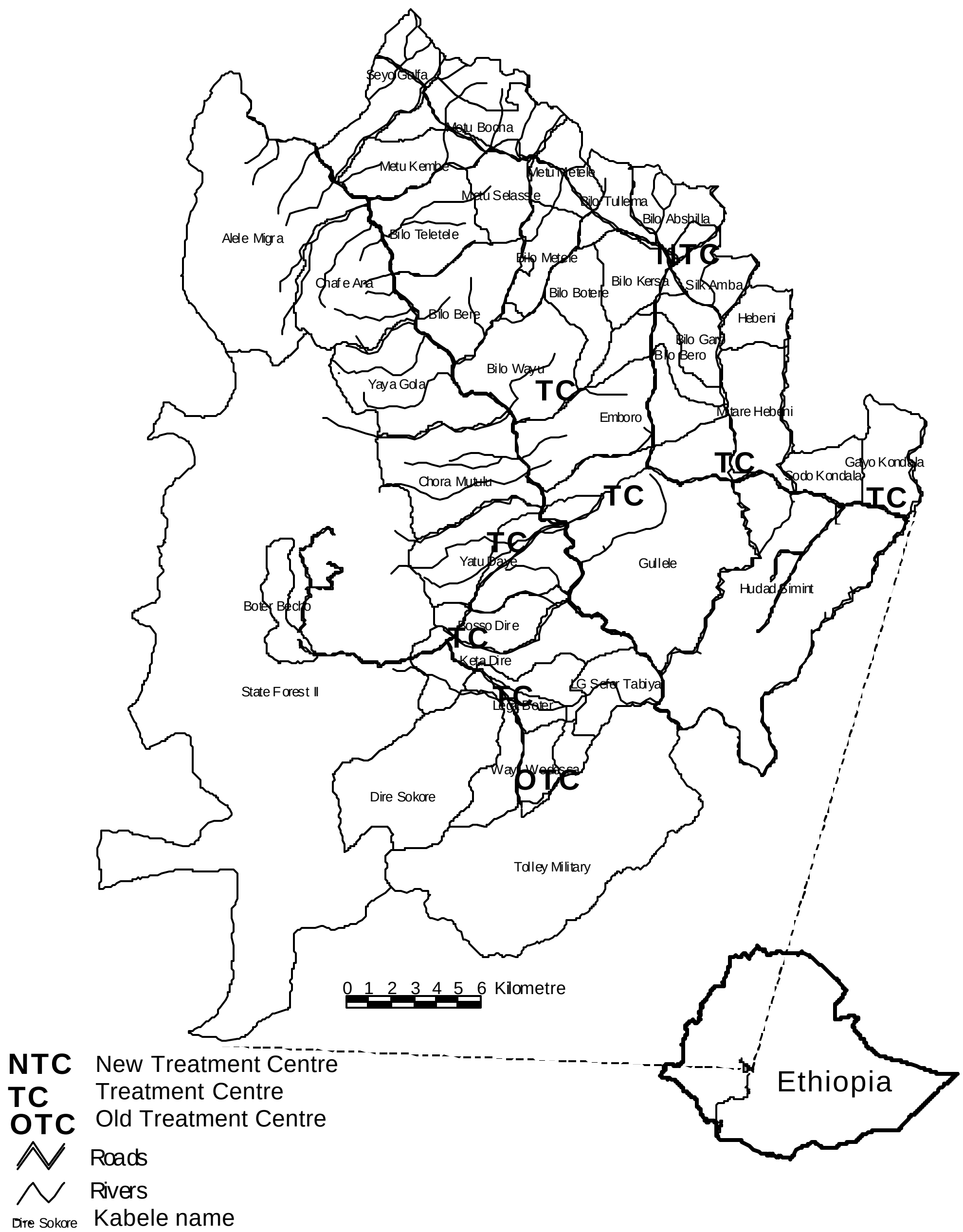
Since January 1991 the International Livestock Research Institute (ILRI) has been conducting a tsetse control trial using a cypermethrin high-*cis* pouron (ECTOPOR, Ciba-Geigy, Switzerland) in the Ghibe Valley (Gullele area) of Southwest Ethiopia (Leak et al. 1995; Swallow et al. 1995). Most cattle owners in the Ghibe Valley are sedentary agropastoralists who rely heavily on cattle for the production of traction power. Indeed, 51 percent of all cattle in the area are oxen, that is, male animals over the age of five years whose primary purpose is to provide traction power. Most cattle are grazed in village herds of less than 100 cattle. Village herds are formed each morning in the village area, and then taken to graze on fallow land and crop residues within two-four kilometers of the village. Other research conducted by the authors shows that there is relatively little overlap between the grazing territories used by communal herds. Individual households have use rights to land, with the local government unit (Kabele) having the authority to reallocate land among local residents.

In the pouron trial, a solution of insecticide is applied directly to cattle as a pouron. Tsetse flies and other external parasites that attempt to feed on the treated animals contact the insecticide and die. The pouron treatments were cost free until December 1992 when a cost recovery scheme was introduced. Thereafter individual cattle owners have been charged 3 Ethiopian Birr (about US$ 0.50) for each animal treated (Swallow et al. 1995). Any farmer who wishes to have animals treated can present their animals at one of the nine treatment centers where ILRI makes the pourons available one day each month. Figure 1 is a map of the study site.

THE PRIVATE AND LOCAL PUBLIC BENEFITS OF POURON USE

Previous studies in the Ghibe Valley show that farmers perceive three main benefits from use of the pouron: (i) less trypanosomosis in cattle; (ii) fewer problems with biting flies; and (iii) fewer problems with ticks (Swallow *et al*., 1995). Leak *et al*. (1995) have confirmed these perceptions: use of the pouron was associated with large reductions in trypanosomosis prevalence in cattle and in the relative densities of 3 species of tsetse and 2 species of biting flies. Farmers who treat their cattle with pourons obtain private benefits. Animals that receive treatments carry fewer ticks and may receive fewer bites from tsetse and other biting flies. Private treatment of animals with the pourons also generates local public benefits, namely suppression of the numbers of tsetse and other biting and nuisance flies in the local area. Given the dispersal patterns of the species of tsetse flies found in the study site, most of the benefits of tsetse suppression in one location likely accrue to people keeping cattle within a 1-kilometer radius of that location (Leak, personal communication, 1997).

Figure 1 Study site in the Ghibe Valley of Ethiopia



Pourons are thus described in economic terms as mixed public-private goods or impure public goods (Cornes and Sandler 1986). Individual farmers will purchase pouron treatments on the basis of their expectations of the marginal costs, marginal private benefits and marginal benefit from the public good. The marginal costs will be of two types: (i) cash cost of the treatment (standard cost of 3 Ethiopian Birr or $0.50 per animal treated) and (ii) transaction costs associated with procurement of the treatments. A priori, we assumed that transaction costs would be completely determined by distance from the homestead to the treatment center.

The marginal private benefit will depend upon the productivity effects of biting flies and ticks and the efficacy of the pourons in alleviating those effects. The public good benefit will depend upon the strength of the local institutions governing pouron use and the way that neighbors are expected to respond to changes in others' behavior. A priori, we assumed that these expectations would vary from one Kabele to another. Kabeles are the lowest level of government administration in rural Ethiopia and are responsible for a wide range of public services and local organization. Farmers from 23 Kabeles obtain pouron treatments at the nine treatment centers (see Figure 1). Kabeles contain an average of 200-250 households.

2. A MODEL OF HOUSEHOLD DEMAND FOR POURON TREATMENTS

This section presents a model of household demand for pourons that considers the private and local public benefits that they generate. Equation (1) defines the profits from cattle keeping for individual i as the difference between expected revenues and costs. We assume that livestock producers will choose the level of pouron use (Poi) that maximizes profits. Revenues are defined as the product of an aggregate product price (P) and the productive capacity of individual i's cattle herd (Hi). The productive capacity of a herd is a function of the number of cattle in the herd (Li), the composition of the herd, the level of pouron use by individual i (Qi), the expected level of pouron use by others who raise livestock in the area (QJ = n Qj\i) and the attributes of the herd owner. Two variables were used to measure herd composition: LOi is the proportion of oxen in the herd and LCi is the proportion of cows in the herd. Age and gender of the household head were the two attributes of the herd owner that were considered. Herd size (Li) and herd composition (LOi, LCi) are assumed to be quasi-fixed assets that are unaffected by pouron use in the short term. Thus the only costs associated with the pouron use are the costs of the pourons themselves (c) and the transaction costs associated with the pouron treatments (ti). Here it is assumed that the costs of the pourons are constant for all individuals, while transaction costs vary across individuals. A priori, we assume that the main determinant of transaction costs is distance from the homestead to the treatment center (ti(di)).

ð i = E [P * Hi (Qi, QJ; Li, LOi, LCi, Agei, Sexi)] - (c + ti(di)) * Qi (1)

Differentiation of equation (1) with respect to Qi produces the first order condition given by equation (2) and the implicit demand function given by equation (3). The explicit demand derived is given by equation (4). We assume that the function H is concave and continuously differentiable.

ä ð i / ä Qi = E [P (ä H/ ä Qi + (ä H/ ä Qj) * (ä Qj/ ä Qi)] - c - ti = 0 (2)

ä ð i / ä Qi = P ä H/ ä Qi + P ä H/ ä Qj E (ä Q/ ä Qi) - c - ti = 0 (3)

Qi^D = f (P, c, ti, ä H/ ä Qi, ä H/ ä Qj * E (ä Qj/ ä Qi); Li, LOi, LCi, Agei, Sexi) (4)

The expected signs of five of the variables follow from the standard model of variable input demand: (1) ä Qi^D / ä P > 0—demand is increasing in the price of the aggregate output; (2) ä Qi^D / ä c < 0—demand is decreasing in the cost of the pouron; (3) ä Qi^D / ä ti < 0—demand is decreasing in transaction costs; (4) ä Qi^D / (ä H/ ä Qi) >0—demand is increasing in the marginal contribution of the pouron to herd productivity; and (5) ä Qi^D / ä Li >0—demand is increasing in herd size. The expected signs on both of the herd structure variables, ä Qi^D / ä LOi and ä Qi^D / ä LCi, are positive since oxen and cows are the most preferred age-sex cohorts in the cattle herds. This hypothesis is supported by the earlier analysis by Swallow et al. (1995). ä Qi^D / ä Agei is expected to be positive since the pouron is a risk-reducing input and households whose heads are older are expected to be more risk averse. ä Qi^D / ä Sexi (Sexi = 1 if the household head is male and 2 if the household head is female) is also expected to be positive since female-headed households are expected to be more risk averse. This hypothesis is supported by the findings of Echessah et al. (1997) that female-headed households in the Busia area of Kenya were willing to contribute a significantly higher proportion of their income to tsetse control than male-headed households. The component of equation (4) that relates to collective action is (ä H/ ä Qj * E (ä Qj/ ä Qi). We assume that ä H/ ä QJ is always positive: the marginal benefits derived from additional units of the pouron are positive for all relevant levels of pouron use. E (ä Qj/ ä Qi) may be positive or negative. With no cooperation between neighbors, E (ä Qj / ä Qi) would be negative. That is, individual i would expect his/her neighbors to free-ride on their use of the pouron by reducing their own level of use. The more pouron used by i, the less pouron used by i's neighbors. This free-rider effect might be dampened, or even reversed, however, if there is some type of collective action to support collective action among farmers. In such a case E (ä Qj/ ä Qi) might be positive. That is, the more pouron used by i, the more pouron used by i's neighbors. We therefore re-define E(ä QJ/ ä Qi) as ë i, the index of expected cooperation held by individual i. Following the discussion in Section 2.2, we hypothesize that ë i will vary from Kabele to Kabele.

3. DATA COLLECTION, GENERATION AND ANALYSIS

GEO-REFERENCED HOUSEHOLD CENSUS

A geo-referenced census of all households in the 'market shed' of the 9 supply points for the pouron was undertaken between March and July 1996. Administration of the census questionnaire began with the villages immediately adjacent to the supply points and moved from village to village in all directions away from the distribution points until the enumerators came to villages that reported no use of the pourons during the previous year. A village was judged to be within the market shed if more than 2 households in the village reported having cattle treated with pourons during the previous year. A village was judged to be outside of the market shed if less than 2 households reported having cattle treated during the previous year.

The census questionnaire was prepared in English, translated into Amharic, pre-tested with 20 households, modified, and administered by enumerators during personal interviews with household heads. The census questionnaire was brief and took an average of 10 minutes to administer to each household. Data were collected on livestock ownership, use of pouron treatments, crop production and migration. Almost all of the questions were pre-coded closed-ended questions. Enumerators carried portable global positioning system (GPS) units and recorded the longitude and latitude co-ordinates for each household.

GENERATION OF NEIGHBOR AND NEIGHBORHOOD VARIABLES USING GIS

After translation into English, all data were entered using *Visual Dbase* (Borland, 1995) and verified in *SPSS* 6.1 (Norusis 1994). Data were then moved into *PCARC/INFO* (ESRI, 1996) GIS software, for creation of the spatial variables. The *PCARC/INFO* POINTDIST command was used to create a Point Attribute Table (PAT) file on neighbors in the 1-kilometer radius neighborhood. Microsoft FoxPro Version 3.0b (Kennamer, 1995) was used to sort the PAT data file created by the POINTDIST command and to generate attribute data on neighbors within a radius of 1 kilometer of each household. The NEAR command was used to calculate the nearest treatment center for each household. *ArcView* (ESRI 1995) was used to map the locations of households and treatment centers. The augmented data set was then brought into *SPSS* for econometric analysis.

In this analysis we relate the behavior of households to the characteristics of neighbors within a 1-kilometer radius. The 1-kilometer radius was chosen for two reasons. First, group interviews show that farmers appreciate the fact most of the benefits of tsetse suppression in a particular location will accrue within 3-4 km^2 of that location (Stephen Leak, personal communication, 1997). Second, people are able to easily monitor the tsetse control actions of households located within 1 kilometer of their homesteads. Farmers likely interact less with neighbors living more than 1 kilometer away.

A LOGISTICAL MODEL OF POURON DEMAND

Equation (4) specifies a general version of the pouron demand function. In the empirical analysis we have focused on the probability that a household treated some of their animals with pouron during the previous wet season. While there were direct measures for most of the household-level variables that would affect that probability, an instrumental variable needed to be constructed to represent collective action (or collective inaction in the case of non-cooperation). As a measure of the effects of others' pouron use on the productive capacity of the individual household (ä H / ä QJ), we use the number of cattle-owning households within a 1-kilometer radius. The higher the number of cattle-owning households in that area, the greater the potential gains from cooperation in pouron use and also the greater the incentive to free-ride on others' behavior.

A priori, we hypothesized that the degree of cooperation or non-cooperation (E(ä Qj / ä Qi)) would depend upon the Kabele in which the household is located. That is, the demand of households living in Kabeles with low cooperation would be negatively influenced by the density of cattle-owning households, while the demand of households living in Kabeles with high cooperation would be positively influenced by the density of cattle-owning households. In Ethiopia, the Kabele is the smallest unit of local administration and the smallest socio-political unit whose boundaries are fixed. While there are other social-spatial units that affect cooperation, none are observed across the study area, none are mutually exclusive, and none have fixed boundaries.

Binary variables were created to represent the 23 Kabeles in which the households were located. The population density and Kabele variables were multiplied together to create a set of 23 new variables, CGNL = CGNL1, CGNL2, ..., CGNL23, measuring the gains from cooperation or loss from non-cooperation. CGNL stands for cooperation gain or non-cooperation loss. For each household 22 of the 23 variables were equal to zero and one was equal to the number of households within the 1km radius around the household. A negative sign on a CGNL variable will indicate that households in that Kabele were generally less likely to treat their own animals when they had more cattle-owning neighbors. A negative sign indicates a group that did not overcome the incentives for free-riding. A positive sign on the CGNL variable will indicate households in that Kabele were generally more likely to treat their own animals when they had more cattle-owning neighbors. A positive sign indicates a group that was able to overcome the incentives for free-riding.

A logistical regression model was estimated to investigate factors affecting the probability that a household treated any cattle with pourons during the previous wet season. A Heckman's two-step model will also be estimated in future studies in order to test hypotheses about factors affecting the level of demand. Given space limitations here, however, we focus on the probability that a household treated any cattle.

Five versions of the logistical regression model were estimated. Version 1 included only characteristics of the household and its herd. The explanatory variables included age of household head, sex of household head, total number of cattle held, proportion of herd that was oxen, and proportion of herd that was cows. Version 2 included those household and herd characteristics and a variable measuring distance from the household to the nearest treatment center. Version 3 considered household and herd characteristics, distance to the nearest treatment center, and the 23 variables that measure the gains from cooperation or losses from non-cooperation. Version 4 was the same as Version 3, with the addition of 8 binary variables to allow for differences between the 9 treatment centers (crushes). None of those crush variables was statistically significant. Version 5 was the same as Version 3, plus 23 more variables to capture possible interactions between Kabele and distance to the treatment center.

Probi=f (household attributes—age and sex of the household head (5)

herd attributes—herd size, proportion of oxen, proportion of cows, distance to the treatment center—including the square to allow for diminishing marginal costs associated with distance;

composite variables of number of animals in 1km radius and Kabele binary variables—CGNL1, CGN2, ... CGNL23).

4. STATISTICAL RESULTS

About 5,000 households were enumerated during the census, two-thirds of which owned cattle (3,267). The average cattle-owning household held 4.7 cattle at the time of the survey, 51% of which were oxen and 17% of which were cows. Ten percent of cattle-owning households were headed by women. Ninety percent were headed by men. Seventy percent of cattle owners treated some cattle during the previous wet season (June-August 1995), 46% treated some cattle during the dry season, 44% treated some cattle during both the dry and wet season, and 1.6% treated some cattle during the dry season only.

The average cattle-owning household in the area was located 2.5 km from the nearest treatment center and had 53 cattle-owning neighbors within a 1-kilometer radius. Neighbors of the average cattle-owning household treated 59 cattle during the previous dry season and 102 cattle during the previous wet season. The average household owned 3.8% of all cattle within the 1km radius of their household. There was large variation in these spatial variables between households. One household had 143 cattle-owning neighbors within a 1-kilometer radius; others had no cattle-owning neighbors within a 1-kilometer radius. Some households resided in places where within a 1-kilometer radius, 301 cattle were treated during the previous wet season and 240 cattle were treated during the previous dry season. Other households resided in places where no other cattle were treated within a 1-kilometer radius in the previous dry season or wet season (Table 1).

Households in the market-shed of the 9 treatment centers resided in 23 Kabeles. The average Kabele had 142 cattle-owning households and 216 total households. Kabeles ranged in size from 27 to 317 households.

Several findings stand out from the results of the logistical regression model of wet-season demand presented in Table 2. First, neither the age nor sex of the household head were significant in any of the models. Second, the coefficients on the herd size and herd structure variables were significant in all versions of the model ($p < 0.001$). The relative size of the estimated coefficients indicate that large holdings of oxen are more likely to prompt farmers to treat some animals than equally large holdings of cows. Third, the results from Version 2 of the model indicate a significant non-linear relationship between distance to the crush and the probability that a household treated any animals. The finding that the probability of treatment actually increases for some distance, then decreases, might indicate that the relationship is non-linear but poorly represented by the quadratic, since the coefficient for the squared distance is non-significant. It might also indicate that proximity to the crush provides people with a stronger incentive to free-ride; this incentive might outweigh the difference in transaction costs.

Table 1 Descriptive statistics on household population included in household census (data for 3,267 cattle-owning households)

Variable name deviation	Mean	Standard	Minimum	Maximum
Use of pourons				
–proportion households in dry season	0.46			
–proportion households in wet season	0.70			
–cattle treated in dry season	1.38	1.95	0	25
–cattle treated in wet season	2.16	2.36	0	30
Household characteristics				
–Age (years)	41.50	14.60	16	111
–Sex (1=m, 2=f)	1.10	0.30	1	2
Herd characteristics				
–number cattle	4.70	4.60	1	56
–proportion oxen	0.51	0.36	0	1
–proportion cows	0.17	0.20	0	1
Distance				
–Kilometers to crush	2.50	3.10	0	19.8
Neighbor traits				
–number cattle owners in 1 km	52.67	33.23	0	143

Table 2 Results for versions 1, 2 and 3 of the model of pouron demand, estimated for 3,221 cattle-owning households in the Ghibe Valley of Ethiopia

Variable	Version 1		Version 2		Version 3	
	Coef.	P-value	Coef.	P-value	Coef.	P-value
Constant	-.8919	.0000	-.2936	.0000	-1.3841	.0000
Household traits						
–age of hh head	.0006	.8336	.0013	.6520	.0013	.6644
–sex of hh head	-.1135	.3881	.0247	.8538	-.0319	.8253
Herd traits						
–number cattle	.1889	.0000	.1820	.0000	.1858	.0000
–proportion oxen	1.8617	.0000	1.7873	.0000	1.8571	.0000
–proportion cows	.7935	.0006	.8185	.0004	1.1066	.0000
Distance						
–meters			.0003	.0000	7.6E-5	.0750
–meters squared			-.2E-8	.0000	-3.0E-9	.4829
Kab1*cattle hhs in 1km					.0188	.0002
Kab2*cattle hhs in 1km					-.0002	.9641
Kab3*cattle hhs in 1km					.0152	.0042
Kab4*cattle hhs in 1km					.0070	.0358
Kab5*cattle hhs in 1km					-.2441	.0000
Kab6*cattle hhs in 1km					-.0077	.1657
Kab7*cattle hhs in 1km					-.0050	.4738
Kab8*cattle hhs in 1km					-.0994	.0008
Kab9*cattle hhs in 1km					.0156	.0182

Table 2 Results for versions 1, 2 and 3 of the model of pouron demand, estimated for 3,221 cattle-owning households in the Ghibe Valley of Ethiopia (continued)

Variable	Version 1		Version 2		Version 3	
	Coef.	P-value	Coef.	P-value	Coef.	P-value
Kab10*cattle hhs in 1km					-.0268	.0000
Kab11*cattle hhs in 1km					-.0046	.2353
Kab12*cattle hhs in 1km					.0071	.0171
Kab13*cattle hhs in 1km					-.0170	.0000
Kab14*cattle hhs in 1km					-.0072	.0000
Kab15*cattle hhs in 1km					-.0135	.0435
Kab16*cattle hhs in 1km					.0072	.0072
Kab17*cattle hhs in 1km					.0177	.0012
Kab18*cattle hhs in 1km					.0165	.0001
Kab19*cattle hhs in 1km					.0459	.0000
Kab20*cattle hhs in 1km					.0030	.7334
Kab21*cattle hhs in 1km					.0053	.4043
Kab22*cattle hhs in 1km					-.0145	.0000
Kab23*cattle hhs in 1km					-.0130	.0000
Chi-square	367.8		410.6		804.1	
% correct predictions	75.8		75.4		77.6	

Results from Version 3 of the model indicate large differences between Kabeles in their ability to capitalize on the gains from cooperation or suffer losses due to non-cooperation. The estimated coefficients on the CGNL variables were negative for about half of the Kabeles, indicating overall free-riding behavior, and positive for the other half, indicating overall cooperative behavior. Seven of the negative coefficients are statistically significant at $p < 0.001$, three of the positive coefficients are statistically significant at $p < 0.001$. It would appear that in the remaining 13 Kabeles the incentive to free ride was roughly offset by incentive to cooperate.

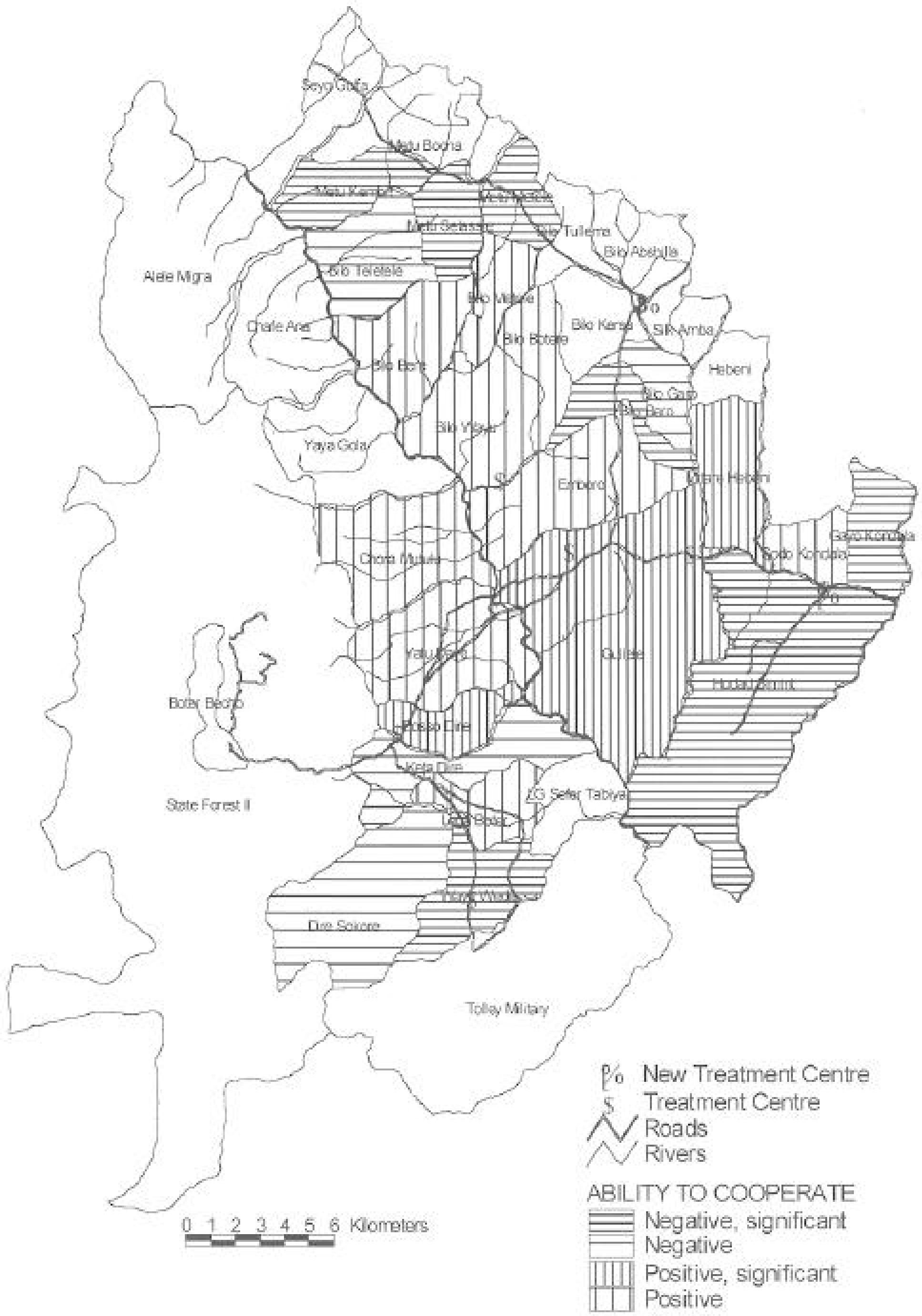
Another intriguing result from Version 3 of the model is that the distance variables were statistically insignificant, in contrast to the results from Version 2. This suggests that the distance variables were capturing the effects of the cooperation variables in Version 2, so that their significance disappeared when the cooperation variables were included in Version 3. Apparently distance had important effects on the ability to cooperate, but no other effect on household demand.

Version 4 of the model included all of the same variables as Version 3, plus an additional 8 binary variables to allow for differences between the 9 treatment centers. None of those binary variables were significant. Version 5 of the model was the same as Version 3, with 23 more variables included to capture possible interactions between Kabele and distance to the treatment center. None of those interaction variables were significant.

Figure 2 illustrates these results on a map of the Kabeles in the study area. The Kabeles indicated by vertical hatched lines have positive coefficients on the ability-to-cooperate variable. The 3 Kabeles with the narrowly-spaced vertical lines have significant positive coefficients, while the 9 Kabeles with the widely-spaced vertical lines have insignificant positive coefficients. On the other hand, Kabeles indicated by horizontal lines have negative coefficients on the ability-to-cooperate variable. The 4 Kabeles indicated with widely-spaced horizontal lines have insignificant negative coefficients, and the 7 Kabeles indicated with narrowly-spaced horizontal lines have significant negative coefficients.

The spatial distribution of the 4 types of Kabeles indicates that the ability of the Kabele to cooperate is at least partially related to distance from the treatment centers. Kabeles with low cooperative abilities tend to be on the peripheries of the overall study area, while Kabeles with high cooperative abilities tend to be in the center of the area. Three clusters of Kabeles suggest that there are other important factors at play. In the south-west of the study area, there are 4 neighboring Kabeles with the different levels of cooperative ability, despite the fact that all are located near to treatment centers. There are similar clusters of Kabeles in the south-east and northern parts of the study area.

Figure 2 Index of cooperation for 23 Kabeles in the ectopor area, Ghibe Valley, Ethiopia


Metu Bocha
Alele Migra
Bio Abshilla
Bio Kersa
Sill Amba
Hebeni
Bio Botale
Chafe Ana
Yaya Gola
Emboro
Bio Gara
Gullele
Boter Becho
State Forest II
Keta Dire
ZG Sefer Tabiya
Dire Sokore
Tolley Military
New Treatment Centre
Treatment Centre
Roads
Rivers
ABILITY TO COOPERATE
Negative, significant
Negative
Positive, significant
Positive
0 1 2 3 4 5 6 Kilometers

5. GROUP INTERVIEWS: WHAT CAUSED DIFFERENCES IN COOPERATION?

The results from Version 3 of the model indicate significant differences between Kabeles in their abilities to foster cooperation in pouron use among neighbors. These results raise additional questions. First, do the results capture real differences in cooperation or some other phenomena that is only statistically related? Second, are Kabeles important in their own right, as assumed a priori, or are Kabeles spatially correlated with some more important social groupings? Third, why is it more difficult to undertake collective action in Kabeles close to the treatment centers than in Kabeles further away from the treatment centers?

Follow-up research was conducted to answer those questions. Results from the econometric analysis were used to select three pairs of Kabeles. Each pair included one Kabele with a high ability to cooperate and another nearby Kabele with a low ability to cooperate. In the southwest part of the study area, Wayu Wedessa was selected as an area of low cooperation and Bosso Dire was selected as an area of high cooperation. In the southeast part of the study area, Mitare Hebeni was selected as an area of low cooperation and Bilo Mero as an area of high cooperation. And in the northern part of the study area, Metu Selassie was selected as an area of low cooperation and Bilo Metele as an area of high cooperation. Interviews were held in each of the 6 Kabeles during a 3-day period in February 1998. Between 5 and 30 livestock owners participated in each group interview. About 10-12 open-ended questions were asked during interviews lasting 1 to 2 hours. Participation in the group interviews was the first indication that the statistical results were accurate. No more than 10 livestock owners attended the group interviews in the low cooperation villages. Twenty to thirty livestock owners attended the group interviews in the high cooperation villages.

The results provided answers to the three questions posed above. The econometric results were indeed consistent with large differences in actual cooperation between the Kabeles. All three Kabeles that were identified through the econometric analysis as having low ability to cooperate did indeed report low levels of pouron use and little or no active collective action to support pouron use. Alternatively, the three Kabeles that were identified as having high ability to cooperate indeed reported much higher levels of pouron use and very active collective action at the level of the Kabele.

Examples of active and deliberate cooperation were found in the Kabeles identified through the statistical analysis as having high ability to cooperate. For example, the livestock owners and Kabele officials that we interviewed in Bilo Metele reported several forms of active cooperation, most of which was led by the Kabele officials: 1) People in the Kabele have formed groups for disseminating information about upcoming meetings and important events. The head of each group is a contact point for receiving information and he is responsible for disseminating the information to other group members. Information about the dates when pouron treatments are available is disseminated through these groups. 2) People help each other by taking each other's animals to the treatment center. They do this despite the difficulties of handling others' animals in strange places. 3) The Chairman of the Kabele has met with nearby Kabeles to organize joint work to clear the road along which they walk their animals to the crush where treatments are available. 4) A village of recent immigrants who live farther away from the crush are allowed to graze their animals around the village en route to getting treatments.

In contrast, in Wayu Wedessa, farmers interviewed during the group interview were ready to admit that they had deliberately discouraged their neighbors from receiving pouron treatments. Their logic was this: if they told their neighbor that pouron treatments will be available on a certain day, that neighbor will ask them to take their animals when they go. The strange animals may be difficult to handle and cause crop damage along the way.

An answer to the second question is supported by both the econometric analysis and the group interviews. In Version 4 of the model none of the coefficients on the treatment center binary variables was significant, implying that cattle owners do not group around the treatment centers. The groups of farmers interviewed in the three Kabeles with high levels of cooperation mentioned examples of collective action at the Kabele level, but did not mention examples of collective action for pouron use around any other social group. This suggests that the Kabele is a locus of collective action for tsetse control in some of the areas. No other social group was identified as playing that role.

The group interviews also provided a possible answer to the third question about the reasons why it appears to be more difficult to sustain collective action in Kabeles farther from the treatment center? The types of collective action that the farmer groups mentioned involve transaction costs. Gathering and disseminating information about the dates when pouron treatments will be available is costly. Taking neighbors' animals to and from the treatment centers is costly. Maintaining a clear walking path through intensively-used farmland is also costly. All of these transaction costs are positively related to distance to the treatment centers. The greater the distance, the higher the transaction costs associated with cooperation, and thus the less likely was cooperation.

Transaction costs are also positively related to ethnic heterogeneity. We propose two hypotheses that are consistent with this result. First, the greater the ethnic heterogeneity within a Kabele, the greater the transaction costs associated with collective action. This is consistent with both theory and other case study evidence (see Baland and Platteau, 1994). Second, the greater the ethnic difference between the Kabele that hosts a treatment center and another outlying Kabele, the greater the transaction costs associated with the collective action in the outlying Kabele. Two of the non-cooperative Kabeles were populated by mixtures of Oromo-speaking and Amhara-speaking people, while the third was mostly populated by Oromo speakers. The pattern of settlement in the study area is such that all of the crushes are located in areas where Amharic-speaking persons predominate. Because they don't interact as freely with Amhara speakers, the Oromo speakers had to bear more costs in order to obtain information about the treatment dates. In addition, Oromo speakers do not feel welcome to walk their animals through the Amhara areas en route to the crushes or to wait around the crushes to have their animals treated. Crop damage cases would be more costly and difficult to resolve.

6. DISCUSSION AND CONCLUSIONS

THE CASE STUDY

Several of the results from the case study warrant further discussion. Consider first the result that the gender of the household head has no effect on the probability that a household will give pouron treatments to its animals. This result is consistent with an earlier analysis of pouron demand in the Ghibe Valley that found no household characteristics to have significant effects on pouron demand (Swallow et al. 1995). It appears inconsistent, however, with the findings of Echessah et al. (1997) that female-headed households in the Busia District of Kenya were willing to contribute significantly more money to tsetse control than male-headed households. The differences may be due in part to the difference in disease risk. Both people and livestock are at risk of contracting trypanosomosis in Busia, while in Ghibe only livestock are at risk. In both sites men have primary responsible for animal health, while women have primary responsible for family health.

The results from Version 3 of the model indicate significant differences between Kabeles in their abilities to foster cooperation in pouron use among neighbors. The group interviews conducted in the three pairs of Kabeles confirmed these findings and provided three important insights. First, Kabeles are an important locus of cooperation even though Kabeles were not formally involved in the control program. Second, cooperation is costly. It is costly to acquire and exchange information and both costly and risky to move animals to the treatment centers. Third, anything that increases the costs or risks of cooperation will reduce the likelihood of successful cooperation. Differences in ethnicity and distance to the treatment center increase those costs.

The pilot tsetse control trial was changed in two ways because of the insights obtained from this study. First, two new treatment centers were opened in low cooperation areas that are mostly populated by Oromo speaking people. This should make the treatments more easily accessible to Oromo-speaking people in the area and increase cooperation. Second, the dates when pouron treatments will be given are now announced at least a month in advance. This should make information more easily and cheaply available. These lessons will extend to other locations where this approach to pouron delivery and utilization is attempted.

IMPLICATIONS FOR ANALYSIS OF THE ECONOMICS OF SPACE

Several things about this study distinguish it from most other studies of economic behavior and economic activity in developing countries. First, the large number of observations (5,000 households, two thirds of which owned cattle) allowed more accurate estimation of parameters than is usual. The costs per household of data collection and data processing were very low because there were no costs associated with sampling (e.g. compilation of an accurate sampling frame, location of selected households) and because the questionnaire was very focused.

Second, the large number of observations allowed the accurate estimation of the parameters and thus more complete testing of hypotheses. Version 3 of the model included 31 variables, over half of which were statistically significant at $p < 0.001$. Two additional versions of the model, not shown here, were run with several more variables.

Third, the geo-referenced census yielded information about all of the neighbors of every household. Manipulation of the census data with the GIS tools allowed the creation of the neighbor variables and the tests of hypotheses about ability to cooperate. This approach could be extended to the many other types of economic behavior and economic outcomes that are related to space. In this case, this approach was possible because of close contact and collaboration between economists and geographers and the availability of computer software and hardware for GIS and econometric analysis.

Fourth, the geo-referencing of the census data allowed us to create several new spatial data layers that can be used for other purposes. For example, we now know the location of all households in our study area, the year that they established their homestead in its present location, and from where they originated. Those data are being used to estimate the temporal and spatial patterns of in-migration into the study area and the effects of tsetse and trypanosomosis on those patterns.

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