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PARTICIPATION IN THE CONSTRUCTION OF A LOCAL PUBLIC GOOD: A CASE STUDY OF WATERSHED MANAGEMENT IN THE ETHIOPIAN HIGHLANDS[1]

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Abstract

This paper is a query about the determinants of individuals contribution to the production of local public goods subject to important indivisibilities. It is based on an econometric study of factors accounting for variations in individual participation in the construction of a central drainage channel in Ghinchi watershed, Ethiopia. Using a tobit model, the paper is able to show that individual contributions are crucially influenced by the personal interests which local farmers have in the drain. These contributions have been sufficient to avoid the Pareto-inefficient outcome in what typically amounts to a coordination game.

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1. Introduction

Owing to pervasive market and state failures, an increasing role is being recognized to local groups and communities to perform a variety of tasks deemed essential for economic and social improvement, particularly in poor countries confronted with serious development challenges. This important policy trend noticeable among many national and international organizations involved in the financing of development projects and programmes is also reflected on the level of knowledge production. As a matter of fact, a growing body of literature dealing with so-called collective action problems has recently come to the forefront of development studies (Olson, 1965; Runge, 1986; Taylor, 1987; Elster, 1989; Ostrom, 1990; Sandler, 1992; Bardhan, 1993; Ostrom *et al*., 1994; Baland and Platteau, 1996a, 1996b). This literature actually covers a wide range of situations among which stand foremost those involving the creation of a local public good, those entailing appropriation problems in the presence of ecological externalities (most notably in the use of common property resource), and those concerned with the emergence of voluntary mechanisms for the provision of credit and insurance.

The main contention of a large number of these studies is that the pessimistic conclusion of the prisoner's dilemma story or mode is unwarranted in view of the many observed cases of successful cooperation among individual agents. On the theoretical plane, two lines of advancement have helped to resolve the intellectual puzzle thereby created. For one thing, the prisoner's dilemma has been refined by allowing repetition of the game, uncertainty regarding the agents' payoffs or the rationality of their behaviour, and sanctioning mechanisms (see, in particular, Kreps *et a*l., 1982; Hirshleifer and Rasmusen, 1989). For another thing, it has been admitted that people's interactions are not necessarily well described by the prisoner's dilemma. This is especially true when problems of coordination, trust and leadership are involved (Baland and Platteau, 1996a: chap. 4-5; forthcoming).

One may regret that the articulation between the available theory and empirical findings is often missing in case studies of cooperation. Analytical confusion often ensues, like when authors conclude from successful cooperation that "noncooperative free-riding, or defection is not a dominant strategy or an innate trait" of the local culture (White and Runge, 1990: 1690)[2]. It is not because an individual chooses to contribute in a situation akin to a coordination game or to a chicken game that he does not act strategically or that he has a different preference profile from that usually assumed in the prisoner's dilemma. His motives to cooperate may be as much tainted by opportunistic tendencies as those of the non-cooperating (free-rider) player in a prisoner's dilemma game. The fact of the matter is precisely that defection is not a dominant strategy in these other games.

[2] Statements that appear in the conclusion are still more confusing. This, the authors write: "the study results challenge the usefulness of the prisoner's dilemma and tragedy of the commons metaphors as conceptual bases for analysis. At least in Massaide, free-riding does not dominate. The study illustrates an inherent weakness of reductionist methods and models to assess individual behavior, and social interaction" (White and Runge, 1995: 1693). The first sentence of this excerpt may of course be entirely correct but the next sentencese do not follow from it.

Insufficient attention to the underlying structure of people's interactions in the situation concerned and the lack of use of regorous quantitative methods are largely responsible for the fact that our knowledge regarding individual motives for cooperation and conditions conducive to the emergence and evolution of cooperative behaviour is still in its infancy. This paper is a modest attempt to advance this knowledge by probing in a systematic manner into the determinants of participation in a collective action among farmers of a watershed is the construction of an indivisible public good, namely a central drainage channel, the structure of the game is that of a coordination game.

Date have been collected about the amount of time devoted to this collective task by the farm households of a small village known as Ginchi (situated at about 80 km west of Addis Ababa). The variance of their labour contributions is sufficiently large to suggest that no cooperative mechanism (in the game-theoretical sense) has been at work to coordinate individual household decisions to participate. We therefore want to test the following hypothesis: interhousehold variations in contributions to the public good can be largely explained by differences in the amount of expected benefits from its availability. In other words, the idea is to check whether and to what extent participation in the collective undertaking can be traced back to essentially self-interested motives (rather than to other-regarding norms of behaviour).

In a recent aforementioned paper, White and Runge (1995) have actually carried out a quantitative empirical analysis of cooperation in watershed management in Haiti. Collective action in this instance takes on the form of building checkdams in transboundary ravines with a view to controlling erosion. Having conducted their investigations in 22 watersheds, the authors are able to understand not only why individuals chose to participate (or not participate), but also why cooperative groups formed in some watersheds (in actually the majority of them) and not in others. Because our own data pertain to only the first question will be addressed in the following analysis. A significant result which comes out of White's and Runge's study is that practical knowledge of the potential gains from collective action is an important explanatory factor of the farmers' willingness to contribute labour to the construction of the local public good. Another factor also turned out to be important --membership in previously formed self-organized pre-cooperative groups. We will return to these results at the conclusive stage of the paper.

The structure of the present work is as follows. In section 2, a simple game-theoretical model is proposed that offers a good description of the public good problem faced by the watershed farmers of Ginchi. Section 3 underlines the critical role of drainage systems as a means to relieve population pressure on land resources in Ethiopia, provides some relevant background information about the study area, and describes the methodology of data collection and the sample. Section 4 presents some descriptive statistics about the variables used and reports the results of an econometric analysis aimed at identifying the main determinants of individual labour contributions to the central drainage channel constructed in Ginchi watershed. In the final section (section 5), our main results are compared with those obtained in White and Runge's study.

2. An adapted theoretical framework

A problem of provision of a pure public good is modelled by a set N of agents ($\# N=n$), indexed by the positive integers, a utility profile (one utility function for each agent) and a production function turning labour services into an indivisible public good if the sum of individual contributions meets or exceeds a fixed cost k (nothing is produced if the sum of individual contributions is strictly smaller than k (nothing is produced if the sum of individual contributions is strictly smaller than k). Let σ take the value 1 if the public good is produced and 0 otherwise; the production function can be characterized as follows:

$$f: R_+ \rightarrow \{0,1\}: L \rightarrow \sigma = 1 \text{ if } L \geq \kappa \text{ and } \sigma = \text{ otherwise.}$$

The fixed cost κ is a parameter the value of which is known by every agent[3].

Preferences are assumed to be quasi-linear, so that utility representations are of the kind: $U_i = v_i \ \sigma - L_i$, *where* $i \in N$ $\sigma = f(\sum_{j \in N} L_j)$ and L_i is i's labour contribution to the production of the public good. The value v_i summarises all the relevant information about agent i's marginal rate of substitution between leisure and the public good. The quasi-linearity makes a surplus analysis possible: $\sum_{i \in N} (v_i - L_i)$ is the only criterion required for efficiency assessments. The vector $(v_i - L_i)_{i \in N}$ describes entirely the distributive implications of a particular allocation of labour $(L_i)_{i \in N}$.

Labour is voluntarily contributed, that is, worktime is the strategic decision variable; this model is therefore a particular case of Bergstrom, Blume and Varian (1986) 's study of subscriptions to public goods. The discontinuous character of the production function is justified by the particular situation that we try to model and examine empirically: it is not very useful to build a drain that would discharge only half the amount of excessive water accumulated in the watershed; the crop would be lost anyway. Some other public goods would be of a more divisible kind.

We assume that no agent would have an incentive to produce the public good alone (formally, $\forall i \in N: \ v_i < k$) , while the community as a whole would indeed benefit from the provision of the public good (formally, $\sum_{i:N} v_i > k$)). In this setting, Pareto-efficiency is simply equivalent to the fact that the public good is indeed produced ($\sigma = 1$).

We now proceed by computing the best response functions. An agent i will optimally contribute zero hour if either $\sum_{j*i} L_j \geq$ or $\sum_{j*i} L_j \leq k - v_i$. In the first case, the public good will in any event be produced and therefore agent i's contribution is not required. In the second case, agent i's utility is 0 if he does not work (because the public good is not produced), but if he works just enough so that the public good is produced[4] his utility is $v_i - (k - \sum_{j*j} L_j)$, which is negative by construction. It is clear that, in this case, agent i

[3] It is important to noitce that no common knowledge needs to be assumed in this king of game.

[4] Working more or less than this amount is of course pointless.

prefers not to work and not to enjoy the benefits of the public good given his preferences. The non-trivial part of agent i 's reaction function is thus in the interval $k - v_i \leq \sum_{j\neq i} L_j < k$. The best response is then $L_i = k - \sum_{j\neq i} L_j$, that is to say, agent i will work just enough to produce the public good, given the others' contributions.

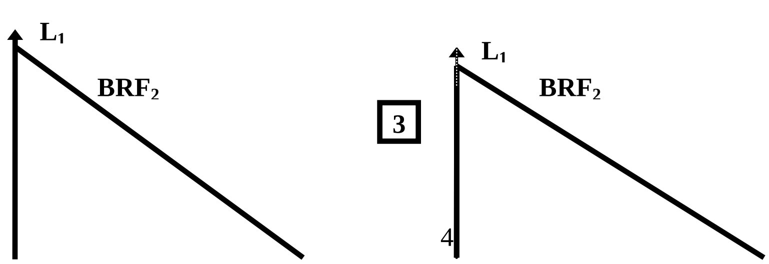
There are multiple Nash equilibria in this game (in fact, there is a continuum of Nash equilibria plus one). First, if nobody works, no agent has an incentive to deviate: (0,...,0) is a Nash equilibrium. Second, a strategy profile $(L^*_i..... L^*_n)$ is a Nash equilibrium if the two following conditions are met: (1) $\forall i \in N: L^*_i \leq v_i$ and (2) $\sum_i L^*_i = k$. One easily checks that there is no other Nash equilibrium. The set of Nash equilibria is therefore the disconnected union of a singleton {(0,...,0)} and a weakly convex hypersurface of dimension (n-1). Every equilibrium in the latter set is Pareto-efficient. This simple fact contradicts the "folklore" according to which the collective action problem represented by the above-described subscription game always "looks like" a prisoner's dilemma. Only one feature of this story is preserved: the existence of a Nash equilibrium which is Pareto-inefficient because of an insufficient provision of the public good. To illustrate this claim, we represent a two-player discrete version of the game where labour time can only take integer values. Assume $v_1 = 2$, $v_2 = 4$ and $k = 5$. The payoff matrix is then the following.

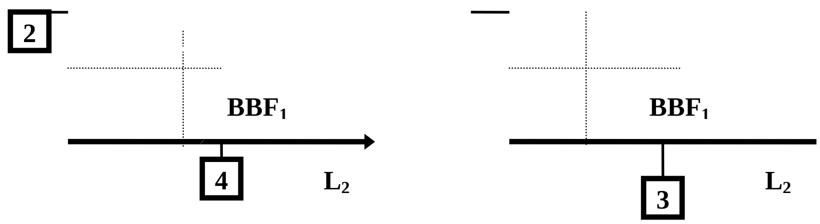
Table 1: The payoff matrix of a two-player, discrete subscription game

$L_1 \backslash L_2$	0	1	2	3	4	5
0	0, 0	0,-1	0,2	0,-3	0,- 4	2,-1
1	-1,0	-1,-1	-1,-2	-1,-3	1, 0	1,-1
2	- 2,0	-2,-1	-2,-2	0, 1	0, 0	0,-1
3	- 3,0	-3,-1	- 1.2	-1,1	-1, 0	-1,-1

The inefficient Nash equilibrium, in the upper left corner, is emphasized with a bold border. The two other Nash equilibria, also underlined with a bold border, are embedded in a chicken game matrix marked by a double line border. Below, we have drawn two graphs representing the continuous version of the game under concern; part (a) describes the best response function and the set of Nash equilibria when $v_1 = 2$, $v_2 = 4$, $k = 5$ (as in the discrete example), while part (b) is built on the alternative assumptions that $v_1 = v_2 = 3$, k = 5.

Figure 1: Reaction functions in a two-player subscription game under two sets of parameters





case(a): *vi = 2*, v_2 *= 4 and k = 5* *case (b):* $v_1 = v_2 = 3$; $k = 5$

It is evident that *i*'s best response curve coincides with *j*'s axis until L_j reaches k-v_i; it then jumps to v_i and decreases as L_j increases with a slope of -1. The best response curves intersect at (0,0) and in the intervals represented in bold grey on the graphs. The two extreme points on the segment correspond to the Nash equilibria in the (discrete) chicken game depicted in the above table. It is interesting to notice that the location of the set of Nash equilibria is influenced by the relative size of the v_i s: agents with a higher v_i may have to work more than others at a Nash equilibrium. More exactly, the interval of labour contributions that can be played at an equilibrium contains larger contributions for agents who have a higher $v_{i.}$

To attempt an explanation of the observed individual labour contributions to the drain in Ginchi watershed, an econometric model will be specified and tested. The selected explanatory variables are various factors that presumably bear upon the benefits which an individual can expect to derive from the public good. They are therefore linearly correlated with v_i. The choice of these variables, the estimation technique and the results of the estimation are described in detail in section 4.

The above theoretical insights, it must now be emphasized, only show the plausibility of a positive correlation between the v_i's and the actual amounts of labour at the observed Nash equilibrium. One might indeed construct examples (e.g., $v_1 = 4$, $v_2 = 6$, $k = 7$) that yield an equilibrium in which labour contributions are uncorrelated with the v_i's (take $L_i = L_2 = 3.5$) or even negatively correlated with them (take $L_i = 3.9$; $L_2 = 3.1$). This being said, if the equilibrium located at the middle of the Pareto-efficient segment were actually implemented and observed, the correlation would be unmistakably positive. Unfortunately, even though it is probably a focal point, there is no way of ensuring at a theoretical level that this will be the chosen equilibrium: hence the crucial role of empirical estimations to determine whether rural communities such as that of Ginchi farmers actually select equilibria characterised by a positive correlation between individual labour contributions to the public good and the private benefits that can be derived from it.

3. The setting of the case study and the stakes involved

The context of the study

Population pressure in Ethiopia is high compared to many countries of sub-Saharan Africa: in 1995, population density in this country reached around 50 persons per square kilometer, as against an average of 24 persons for the whole of Africa (World Bank, 1995). The pressure of numbers in Ethiopia is heavily concentrated in the highlands which represent only 40% of the total landmass but as much as 90% of all cultivated land and 80% of the total population (Saleem, 1995; Mamo *et al*., 1993)[5]. Soil characteristics in the highlands are not necessarily favourable to cultivation given other prevailing characteristics of the physical environment. More precisely, many soils in this area are vertisols, that is, heavily textured soils with a high content of clay. If these soils are potentially fertile, they are also seriously subject to the problem of waterlogging when they are found on terrains with poor drainage such as seasonally flooded depressions, or other kinds of bottom lands. Since they easily get flooded and waterlogged during the wet season, vertisols thus located remain uncultivated and used mainly for dry season grazing. In the present situation, only 25% of the vertisols in the Ethiopian highlands are cultivated (Mamo *et al*., 1993: 29).

To relieve demographic pressure in the highlands, the most obvious strategy therefore consists of removing constraints to crop production in vertisol areas, particularly in bottom lands. This is precisely the objective pursued by the programme of improved management of vertisols which has been initiated by JVP (Joint Vertisol Project) (International Livestock Consortium of international and national research institutions. There are various components in the vertisol technology package such as the introduction of the broadbed maker to drain the excess water that accumulates during the rainy season[6], the early planting of improved wheat varieties (or other crops such as maize with fertilizer to utilize moisture during the whole growing season, the planting of grass in gullies and of leguminous trees and forages on steeper slopes to control erosion and provide quality feed for animals, etc.

In moderately sloped parts of a landscape a few field drains within lower slopes, however, the passage of water is usually more difficult and other more requiring methods must be applied. Use of the broadbed maker may be quite effective on a given plot, yet there is the awkward fact that it creates negative externalities by expelling excess water to nearby plots, particularly at the lower end of the landscape. The construction of a common drain across private landholdings provides an obvious solution to this externality problem arising at the plot level. This is actually one among many examples of local public goods the availability of which conditions growth of agricultural production and rural development in Third World countries.

[5] These are low-end estimates given that the highest cutting point of altitude has been chosen for defining highlands.

[6] The plough traditionally used for tillage in Ethiopia is called maresha and is pulled by a pair of oxen. It can not invert or shape the soil so that land tilled with the *maresha* remains covered with water during heavy rains. The broadbed maker (BBM) is made by joining two *mareshas* with a crossbar about 1.5 meter long, then attaching a metal wing on the outside of each *maresha* and link the two wings with a looping chain from behind. When operated by a pair of oxen, the two wings with a looping chain from behind. When operated by a pair of oxen, the two *mareshas* of the bbm create two furrows on two sides of a 1.5 meter bed, the chain levels the soil on the bed and covers seeds when sown or planted on the bed. At the time of heavy rain, the forrows allow escess water from the bed to be expelled to a field or main drain at the end of the plot. This drainage device allows early sowing and longer growing period. Absent this, crops have to be planted at the end of the main rain so that crops grow on residual moisture for a short duration and yields are consequently low (Saleem, 1995).

The Ginchi pilot watershed comprises about 350 ha which itself is part of a Peasant Association of about 250 households with about 800 ha of land area. Within the 350 ha watershed, a sub-watershed of about 50 ha held by a total of 57 households could be delimited and it was chosen in 1995 by the above programme for the purpose of along the things construction of a main common drain with the participation of landowners concerned (the beneficiary group). The possibility was explicitly envisaged of extending the drain to the whole watershed area in subsequent years if the experience was to prove a success.

The construction of a main drainage channel such as was proposed by JVP to Ginchi farmers clearly involves important indivisibilities. Unless a critical amount of labour input is allotted to this task, the channel will not yield any benefit in the form of increased land productivity. On the other hand, no additional labour contribution beyond that critical amount can give rise to productivity increments. Note also that since landholdings are widely dispersed across the sub-watershed of Ginchi, there is no possible sub-coalition of farmers with lands concentrated in a well delimited part of this area. As a result, it is not conceivable that only a portion of the drainage system be constructed to the benefit of a fraction of the farmers and at the expense of other farmers with their lands located down the drain. Either the channel is constructed across the entire sub-watershed area with the required technical specifications, or it is not produced at all. To put it in another way, due to scattered ownership, the channel within the sub-watershed area is not susceptible to being divided into several segments that could be the object of separate construction decisions.

Ginchi's central drainage channel has been built during the months of May and June 1995 by labour-intensive methods. Since the construction had to be completed before the starting of the rainy season, the work was accelerated during the last days with the help of mechanical equipment (tractors) provided by the Joint Vertisol Project. A pessimistic interpretation is that the critical mass of labour contributions has not been provided by the farmers and that, were it not for an external intervention, the public good would not have been crated given the above-emphasized indivisibility problem. An alternative, more optimistic interpretation is the following: there is a good measure of uncertainty regarding the exact amount of labour input required and the timing of the efforts involved. In other words, farmers may well have believed that their contributions were likely to be sufficient to complete the drain within the prescribed time given their initial expectations concerning the advancement of the work and the advent of the rains.

This last interpretation is actually correct. As a matter of fact, when the digging was started, it soon became clear that the soil was very hard for manual work. Progress was therefore much slower than expected. In consultation with the farmers and only after it made sure that the problem was real and serious enough to prevent completion of the drain during the season, the project's staff decided to use a tractor to loosen the soil and the farmers then removed the earth and shaped the drain.

Sources and characteristics of the data

In order to identify the farmers' attributes that motivate their individual choice of participation, data have been collected through two different methods. First, a number of crucial information have been obtained by measuring precisely and objectively the relevant characteristics. Two types of data fall into this category: (i) data measuring the exact number of days and hours allocated by each household to the public good construction (including participation in preparatory meetings) and (ii) data regarding the amount of land owned in the sub-watershed, the extent of subdivision of all such household landholdings and the exact location of the various land plots. Second, a household survey has been conducted in order to get information about various aspects of the demographic structure, the asset position and economic activities of the farming households of Ginchi's sub-watershed. Discrepancies have emerged from a comparison of size of landholdings in the sub-watershed as a measured by JVP experts with that stated by the households themselves, yet they are not very important. As far as lands owned in the sub-watershed are concerned, we have of course chosen to use the data obtained through the first method. Regarding lands owned outside the sub-watershed area (for which no objective measurement is available), given the absence of a strong bias in the farmers' answers regarding their land ownership situation within the sub-watershed, we may presume that the household survey data are sufficiently reliable to be used in the subsequently analysis.

Households owning land in Ginchi's sub-watershed number 57. Out of these 57 households, 53 (93%) could be interviewed. The remaining four households could not be covered because they were absent from Ginchi at the time of the survey (three cases) or because the interview was unexpectedly interrupted (one case). Since farmers were busy with harvesting operations during the survey period (in November 1995), interviews had to take place in the early morning or during the (numerous) days of religious feasts which they take as a holidays.

4. Determinants of individuals contributions: an econometric analysis

The main variables used and the hypotheses tested in the analysis

The dependent variable measuring the extent of participation of households in the construction of the drainage channel is defined in terms of working hours. As explained in the previous section, these labour contributions to the earth work have been observed on the spot by an external observer. Note that the number of hours of labour was the same for all participants on any given day, yet it could vary from one day to another according to circumstances. As a result, the number of days of participation does not represent an exact measure of the extent of involvement in construction operations: households which contributed the same number of days are likely to have put in varying amounts of labour input (in terms of working hours) because they did not necessarily come to the building site on the same days. This said, since work duration varied from 2-3 hours per day only, measuring participation by the number of days contributed provides a reasonable approximation.

Moreover, in addition to contributing to earth work, households may have assisted in the collective action by attending preparatory meetings during which JVP experts explained to the farmers the usefulness of the persons who attended these meetings, but in the household survey respondents have been explicitly asked to state the number of meetings in which any member of the household participated. Counting three hours per meeting attended, we are able to construct a new measure of participation in which allowance is made not only for contribution with the drain construction project. We call this measure the comprehensive index of household participation in the collective action.

A last methodological point concerning the dependent variable needs to be made. While recording labour contributions on the building site, the household was taken as the unit of analysis. In other words, if several persons belonging to the same household turned up for work, their labour contributions were added up under the name of the corresponding household. This was done with respect not only to members of the owner's family but also to any other person whom the household head may have chosen to send to the site, including sharecroppers to whom land had been rented out and friends or neighbours to whom land had been rented out and friends or neighbours involved in labour exchange agreements with him or her.

Out of the 53 sampled households owning land in Ginchi sub-watershed, 33 (62%) participated in the drain project. Among these 33 households, 13 (about 40%) attended at least one preparatory meeting while the remaining 20 households contributed to earth work yet did not participate in any meeting. (Note that no household participated in meetings without contributing to earth work). From observation of actual contributions on the building site, it is evident that 40 households were involved at one point or another during the course of operations. The difference between this objectively measured number of participating households (40) and the number inferred from the household survey (33) can be accounted in the following way. On the one hand, two owner households which could not be interviewed (see supra) actually contributed to the drain construction and, on the other hand, five households participated which own land outside the sub-watershed but very close to one extremity of the drainage channel under construction. Incidentally, the head of one of these five households is the chairman of the local Peasant Association. As will become apparent when our econometric results are presented, these five cases, although excluded from our empirical analysis (since, not owning any land in the sub-watershed, they have not been covered in our household survey), can be used to reinforce our conclusions regarding the incentives to participate.

Overall, if we use the comprehensive index of household participation, 137 person days have been contributed by the sampled households to the drain construction project and they correspond to 397.12 person hours (thus indicating an average of 2.9 hours per day of participation). The frequency distribution of households according to the number of days of participation (whether in earth work or in preparatory meetings) is displayed in column 2 of Table 2 while the corresponding labour contributions measured in hours are given in the third column. From cumulative relative frequencies given in column 4, it is evident that two-thirds of the total time allocated to the drain have been provided by households which participated at least five days in the collective project. Moreover, as can be inferred from the figures between brackets in column 3, about 70% of the total amount of time contributed has been used to construct the drainage channel *stricto sensu* (277.12) while the remaining 30% (120 hours corresponding to 40 days) has been spent in preparatory meetings).

Table 2: Frequency distribution of landowning households according to the total number of days contributed to the drain construction project (comprehensive definition) and corresponding aggregate labour input contributions (in hours) --- Ginchi sub-watershed (1995)

Total No. of days contributed to the drain construction project	Absolute frequency (No. of households)	Corresponding aggregate contributions (in hours)*	Cumulative relative frequency in terms of hours (in percent)
0	20	0.00 (0)	0.0
1	5	14.84 (0)	3.7
2	3	15.27 (0)	7.5
3	8	66.57 (0)	24.3
4	3	36.85 (0)	33.6
5	4	53.96 (0)	47.2
6	3	61.86 (0)	62.8
7	5	102.16 (0)	88.5
8	1	19.68 (0)	93.5
9	1	25.93 (12)	100.0
Total	53	397.12 (120)	

* Between brackets are indicated the total times (in hours) spent by the corresponding size class in attending preparatory meetings on the assumption that each meeting takes three hours to attend.

One could a priori think that those households which attended preparatory meetings were more strongly motivated to participate in the actual construction work than those who never appeared in such meetings. This hypothesis is borne out by the facts since the former worked for an average time of 9.52 hours on the building site while the latter's average working time was only 7.6 hours. However, the difference between these two means is not statistically significant at the 5% confidence level (using a student's test for difference of two means with small sample distributions)[7]. It is therefore meaningless to include attendance at preparatory meetings as an explanatory variable in an equation purported to explain participation in the construction of the drain. In fact, this operation would create strong multicollinearity among regressors.

Independent variables mainly include factors hypothesized to bear upon the task which households can have in the project. These variables are: the amount of land owned that

7 The t-observed value is 1.39 with 31 degrees of freedom.

is situated in the sub-watershed; the locational characteristics of the land parcels; the wealth of the household as assessed from the number of animals owned or the total amount of land owned (whether inside or outside the sub-watershed); the amount of capital owned or operated in the form of draught animals; the available workforce; and the type of crop cultivated; the availability of alternative income-earning opportunities as measured by the percentage of land owned that is located outside the sub-watershed or by engagement in non-agricultural occupations. Membership in the committee of the local Peasant Association, an institution directly inherited from the previous regime of socialist Ethiopia and often acting as a catalyst for the production of local public goods[8], may facilitate understanding unrelated to self-interest may well drive village leaders to participate in collective actions intended to benefit the local community.

A few comments are in order at this stage. First, it is assumed that the large the amount of land owned in the watershed the greater the incentive to make an investment that is designed to increase land productivity. True, the land rental market is rather active in Ginchi ___31% of the whole land area in the sub watershed were actually rented out at the time of the survey[9] ___ but, since land rental contracts are generally of one-year duration (and are not automatically renewable), there is not much reason to believe that holders of land rented can have sufficient incentives to participate in collective efforts to improve the watershed.

Second, the location of the parcels can be though to bear upon the benefits derived from the drainage infrastructure in two different ways. On the one hand, the gradient of the parcels may matter since drainage intervention is likely to be less and less needed as lands are located higher up the watershed's foothill. On the other hand, proximity of the parcels to the drain may be expected to bring large benefits if water is more effectively drained away close to the central channel. Moreover, it can be presumed that when a farmer owns a large compact landholding formed by a set of contiguous parcels having a border along the drainage channel, he is able to organize at lower costs a system of secondary drains connected to this channels.

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[8] Peasant Associations (PAs) were created after the 1974-75 revolution and were conceived as the lowest-level administrative unit of socialist Ethiopia. They are composed of 500-700 households, depending on population concentration in various parts of the country. The land area covered by a PA was about 600-1,000 ha. In addition to assuming responsibility for the allocation of land use rights (transfer rights were strictly forbidden), the PA's committee was also in charge of a variety of other functions, such as receiving loans from bans, receiving seeds and fertilizers from the Ministry, collecting foodgrain from members to meet compulsory delivery requirements set by the government, organizing members to build local roads, arbitrating local disputes, etc. Basically, the PA was a political body and the committee's members had substantial political clout. Under the post-socialist regime, the PA continues to exist but some of its powers or prerogatives have been curtaild, particularly those of allocating land and monitoring land use, and those of acting as agent of an intervenionist government. Yet, the PA's role as a catalyst for the production of local public goods has remained and, as expected, its influence on that score varies from place to place according to the quality of committe's members.

[9] The quasi-totality of the land rental contracts are sharecropping contracts.

Third, it is noteworthy that the labour market is rather thin in the area: only five of the sample households have reported the hiring of agricultural labourers during the peak season. (Bear in mind that the hiring of labour was illegal until 1992). The size of the workforce available of work the land can therefore be approximated by the number of family members able to perform agricultural tasks.

Fourth, given the great difficulty of collecting reliable data about the cash incomes earned by households in non-agricultural occupations (cattle trade, carpentry works, house construction, and sales of wood), we have to content ourselves with a simple binary information regarding whether the household has access to outside income opportunities or not. As it turned out, only ten households (less than 20% of the sample) benefit from access to supplementary incomes. It bears emphasis that the expected impact of the availability of such opportunities is *a priori* ambiguous since two opposite effects are presumably at work. For one things, households with more income possibilities may be facing higher opportunity costs for their labour, as a result of which they ought to be more reluctant to allocate time to the construction of an infrastructure that determines only a fraction of their incomes. For another thing, there is an income or wealth effect: the richer a farmer the more time he can devote to operations that do not bring immediate returns since his subsistence constraint is not liable to be violated (whether the investment is private or concerns a public good does not matter here). Obviously, the influence of wealth as assessed by the number of animals owned should involve only the latter effect.

Fifth, as suggested above, we want to test the hypothesis that knowledge of the potential gains from collective action may be more easily forthcoming when farmers are members of the executive committee of the local peasant association (there are four such farmers in our sample). This would work through the following screening effect: farmers who are more aware of potential gains from cooperation in general tend to assume responsibilities and leadership roles in peasant organizations. The impact of membership in such organizations could admittedly work the other way around if the fact of having responsibilities in them exercises moral pressure on members to set an example of good behaviour and act as a model for other farmers.

Finally, it is useful to have some idea of the distribution of total lands owned by the sample households (whether inside or outside the sub-watershed) as well as about the distribution of draught animals. The Gini coefficient for the former distribution is 0.3 (note that only 9% of the sample households own less than one ha while, at the other end of the egalitarian distribution of land assets (no doubt a result of the 1974-75 revolution). The critical role of draught animals in Ethiopian agriculture has often been emphasized (see, e.g., Krishnan, 1996). It is therefore interesting to look at their frequency distribution, as is done in Table 3.

As is apparent from the figures, more than one-third of landowners in Ginchi sub-watershed do not own any pair of oxen. When due allowance is made for the possibility of hiring such animals in the corresponding market, this proportion decreases only slightly (down to 28%), a clear evidence that the rental market in oxen is rather thin. Differences in endowments of labour (if only because households are at same technology imply that marginal productivity must vary between households. Since both labour and oxen markets are highly imperfect, inter-household exchange contracts. k It can therefore be concluded that, in spite of a relatively egalitarian distribution of land assets (see supra), construction of a drainage channel. This should be reflected in a positive impact of capital-labour endowment (where capital is measured by draught animals) on participation to the creation of this public good. We now turn to an empirical test of whether there is a positive relationship between the size of expected benefits and active participation in this collective undertaking.

Table 3: Frequency distribution of households according to the number of draught animals owned and operated in Ginchi watershed

No. of draught animals	According to Absolute frequency	animals owned Percentage	According to or Absolute frequency	animals owned operated Percentage
0 or 1	19	35.8%	15	28.3%
2 or 3	26	49.1	30	56.6
4 or 5	8	15.1	7	13.2
6	0	0.0	1	1.9
Total	53	100.0%	53	100.0%

Econometric results

As we have seen above, an important feature of the dependent variable which we want to use is that there are many zero observations. In this case, applying standard OLS to all the available observations is an unsatisfactory procedure because this would yield inconsistent estimators of the population regression function. Dropping the observations for which the dependent variable is equal to zero is not a more acceptable approach since least squares estimators will then be biased and inconsistent. The correct procedure is to use the censored regression or limited dependent variable model known as the tobit model. In this model, we have observations on the explanatory variables for all individuals in the sample and it is only the dependent variable that is missing (equal to zero) for some individuals, hence the name “limited dependent variable” chosen to denote it. Estimators are obtained by maximizing a likelihood function which has two components, the “usual” component for the observations that are positive and one for those that are zero. The maximum likelihood estimators for the tobit model are consistent and asymptotically normal. The t-values for testing the significance of the estimated parameters are often called “asymptotic t’s” since they are the ratio of the parameter estimates to their estimated asymptotic standard errors. Unfortunately, the estimated coefficients cannot be used directly to assess the impact of a unit change in the value of the regressors on the regressand (Judge *et al*., 1982: 795=801; Maddala, 1992: 338-44; Greene, 1993).

Mathematically, the tobit model can be expressed as

$$Y_i = ß_1$$

where RHS = right-hand side.

In our estimations, we have adopted two different definitions of the dependent variable. In the first case, participation is measured by the comprehensive index (which includes attendance at meetings) whereas, in comprehensive index (which includes attendance at meetings) whereas, in the second case, participation is taken in the more restricted sense of time devoted to earth work only. Nevertheless, since both estimations yield rather similar results, only those pertaining to the comprehensive definition of participation will be presented here.

In the specification finally retained are included the following independent variables: the number of *kerts* owned in the sub-watershed area *(LAND)*[10]*;* the proportion of land parcels owned in the sub-watershed that form a compact set with at least one parcel bordering on the drainage channel (*PROX*); the ratio of number of draught animals owned to adjusted size of the family workforce (*CAPL*), where the adjustment is made by giving an unitary weight to all members aged between 15-59 years while children aged between 6-14 years receive a weight of only one-third; a dummy variable (*LEAD*) representing leadership qualities (it is equal to 1 if the household head is a member of the executive committee of the local Peasant Association and to zero otherwise); a dummy variable (*YALT*) representing access to non-agricultural incomes (it is equal to 1 if any member of the household earns incomes from a non-agricultural occupation, and zero otherwise); the proportion of land owned by the household which is located outside the sub-watershed (*LOUT*); and the proportion of land allocated to wheat growing the sub-watershed (*CROP*).

A number of variables have been dropped because they were too strongly correlated with some of the above variables and the estimated $ß^1$s obtained for them were smaller. This applies to the following variables: the total amount of land owned inside and outside the sub-watershed; the total family workforce; the labour-land ratio; the total number of animals owned (draught animals only or all animals together); and the gradient of the lands owned in the sub-watershed[11].

[10] The *kert* is the traditional unit of measurement in Ethiopia which is equivalent to one-fourth of an hectare.

[11] We strongly suspect here that gradient variations between different parcels of land are not large enough to determine different attitudes towards the drainage system. This is all the more so as farmers tend to

The estimated equation is then

$$PART = 5.8250 + 1.6144LAND + 9.4763PROX + 6.2326\ CAPL + 22.5350\ LEAD$$
$$\qquad (-1.060) \qquad (2.420) \qquad (3.262) \qquad (3.194) \qquad (5.814)$$

$$- 1.5591\ \mathrm{YALT} - 5.6335\ \mathrm{LOUT} + 0.4382\ CROP$$
$$(-0.475) \qquad (-1.134) \qquad (0.126)$$

Log-likelihood: - 126.53

where *PART* stands for the comprehensive index of household participation and where the t-statistics are given between brackets below the corresponding coefficients. Except in the vicinity of a zero value for the predicted participation, the marginal impact of a unit change of a regressor is equal to the estimated coefficient of this regressor.

It is evident from the results that four variables are highly statistically significant: *LAND* (at 1.6% level of significance); *PROX* (at 0.11%); *CAPL* (at 0.14%); and LEAD (at close to 0.00%). The aggregate goodness of fit for the specification is measured by the likelihood-ratio test statistic, which is equal to twice the difference between the log-likelihood reported for our estimation and the log-likelihood reported for a regression of the dependent variable on a constant only. This aggregate measure of goodness of fit is equal to 119 for our specification. This figure can be compared to the corresponding goodness of fit for the uncorrected OLS estimation, which is equal to 42 (the adjusted R-square for the OLS estimation is as high as 49%).

All the coefficients are of the expected sign. In particular, the intensity of participation in the construction of the drainage system is directly related to the amount of land owned in the watershed; to the relative number of parcels owned that form a compact set with one border along the channel; to the potential effectiveness of cultivation measured by the capital/labour intensity of owned factors; and, finally, to it is noteworthy that members of the executive committee of the local Peasant Association have contributed an average of 22 hours, compared with 12 hours for all participating households and with 7.5 hours for all sample households (whether they have participated or not).

It is also interesting to bear in mind that when the capital/labour ratio is computed by taking the number of draught animals operated rather than owned by the households concerned, the significance of the corresponding coefficient does not improve. For another thing, the landscape variable has no significant influence when it is measured as the proportion of land parcels adjoining the channel: it does not seem to be the case that gains are larger for lands situated closer to the drainage system. Contrariwise, the significant impact of the landscape variable defined as *PROX* suggests that farmers can benefit from scale economies when they can construct and maintain secondary or tertiary drains on a large compact landholding bordering on the channel (see supra).

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have their parcels scattered across the watershed so that nobody has all his land concentrated in a topographically disadvantaged area.

As can be seen from the results displayed above, a number of explanatory variables have no significant impact on participation. Thus, the type of crop has not been found to influence participation even though it is a well-acknowledged fact that drainage is more effective for wheat, a crop that is not as water tolerance as other crops such as *teff* (the traditional mainstay of subsistence in Ethiopia). The reason for the insignificant result is probably that farmers vary their crops from year to year so that it is difficult to differentiate them neatly on the basis of their crop choice.

Furthermore, there is no significant relationship between availability of outside income-earning opportunities and participation. There are two possible explanations for this inconclusive result, one empirical and the other theoretical. On the one hand, the variable is not measured in a satisfactory manner since it is constructed as a dummy variable taking the value one when the household has access to such opportunities and zero when it does not. Access to non-agricultural incomes can cover a wide range of very different situations and, as long as we cannot get even rough information about the size of the incomes at stake, it is difficult to expect significant results. On the other hand, we have earlier explained that, regarding this explanatory variable, there are actually two effects working in opposite directions. As a consequence, the absence of any significant net impact on the rate of contribution to the drain is not an odd result from a theoretical standpoint. We have tried to isolate wealth effects by assessing the influence of the total number of animals owned (whether draught animals or not) or the size of the total landholding, but, as has been already pointed out, no significant result emerged because these variables are strongly correlated with other variables in the model (the size of landholding inside the sub-watershed and the capital/labour ratio).

The proportion of land owned outside the sub-watershed has no significant impact on participation either. It seems that people in the sub-watershed do not regard outside opportunities as substitutes for their activity in the sub-watershed and that opportunity costs of labour are therefore uncorrelated with landowning outside the sub-watershed. The high frequency of religious holidays suggests that a situation of disguised unemployment is indeed likely and that opportunity costs of labour only reflect a taste for leisure.

In the end, beyond the particulars of given explanatory variables, what bears most emphasis is that, with the exception of the leadership factor, individual labour contributions to the public good are well explained by factors which clearly determine the potential interest individuals can have in it. In other words, participation rates are largely influenced by the personal benefits which different community members can expect to draw from the creation of the drainage infrastructure. As explained in section 2, the pattern of interactions among Ginchi farmers when contemplating the possibility of producing this infrastructure is appropriately described by a (non-cooperative) coordination game. Our empirical exercise shows that the Nash equilibrium actually selected by them in the set of multiple possible equilibria confirms the conventional or plausible expectation that individuals who have larger stakes in a collective endeavour should contribute more to make it succeed.

5. Conclusion

This paper was pursuing two aims, one of analytical clarification and another of empirical validation. First, we wanted to clarify the structure of the problem facing farmers who see the possibility of constructing a collective good that is susceptible of increasing the productivity of their lands. An important (but quite common) characteristic of the good in question that helps shape this problem is that it is subject to indivisibilities. The underlying game is a coordination game that yields multiple equilibria, including the Pareto-inefficient equilibrium in which no agent contributes. If a critical mass of contributions is achieved, as was apparently observed in the case of Ginchi watershed, an interesting question arises as to what are the characteristics of the agents who chose to contribute. Here, the predictive power of theory is noticeably weak.

Second, we therefore wanted to find out to what extent individual contributions to the local public good are influenced by the personal stakes they can have in it. As our results show, the answer to that question is somewhat mixed in so far as leadership qualities appear side by side with more materialistic considerations for personal interest in the equation explaining variations in participation rates. Even though, taken singly, the leadership factor is the most statistically significant independent variable, taken together, it is self-interested considerations that play the major role.

In fact, our results are quite close to those arrived at by White and Runge (1995) in a similar context (watershed management). On the one hand, these authors found that cooperation emerges in many cases: “Within two years of activity, principal ravines were completely treated in 10 watersheds, partial treatment was achieved in seven and scant treatment was achieved in five”. On the other hand, they reached the conclusion that, within a given watershed, motivations associated with practical knowledge of the potential gains from collective action (in this case, the building of a soil conservation infrastructure to prevent externalities in the form of water spillover) and membership in indigenous peasant organizations are the best predictors of landholder choice to cooperate (ibi: 1697-89). In fact, as a careful examination of the significant variables reveals, it is not only awareness of potential benefits but also the ability to draw those benefits that motivate landholders to cooperate (in this study, the choice is binary and the econometric method used is the logit model). As a matter of fact, it turns out that cooperating landholders had adopted contour soil conservation techniques in the past and built private checkdams on their parcels, which is not only conducive to better learning of the advantages of the new collective infrastructure but also liable to increase the actual benefits that can be derived from it[12].

[12] As the authors themselves admit, privately checkdams installed independently of upstream proteciton would be eventually destroyed with rainfall (White and Runge, 1995: 1687).

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