Wealth Inequality and Overexploitation of the Commons: Field Experiments and Spatial Exercises in Colombia

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Abstract:

Wealth related differences within a group of agents that depend economically on their joint access to a commons may influence in various and simultaneous ways the individual user's benefits and costs of exploiting the commons. Wealth might also affect preferences not directly related to the extraction of the commons, but regarding social relations with others, particularly when users attempt to deal with the collective action dilemmas associated with such joint use. This paper deals with inequalities in the commons by drawing some lessons from two sources of field evidence from different regions and villages in Colombia. One, a set of group experiments conducted in the field with villagers who daily face commons dilemmas, and another, a cross-section analysis of a spatial village level database on economic and ecological conditions. Four major results emerge from the empirical evidence presented here: i) land inequality increased the negative effect of population pressure over the conservation of the village commons; ii) lower exit options outside the use of the experimental commons induced greater cooperation by those with poorer private options and higher dependence on the conservation of the commons; iii) actual assets inequality in a group of experiment participants induced greater wealth distance which reduced the possibility of cooperation via self-governed mechanisms; and iv) familiarity with commons dilemmas and lower levels of private assets were associated with higher levels of cooperation in the experiments. The results provide some parallels and methodological complementarities that could contribute in a rather inconclusive issue on the literature, and can also revisit the relation between poverty, inequality and conservation of natural resources.

"The lords woke up to hear their names pronounced
among the psalms of praise. And they looked to see
what had happened on earth while they were sleeping.
And they approved what they saw.
And from that moment they called the man of gold rich and
the man of flesh poor. And they ordered things in such a way
that the rich man should care for the poor and shelter him,
since it was the rich man who benefitted by the poor man's acts.
And the lords so ordered it that the poor should answer for the rich
before the face of Truth. That is why our law says that no rich man
can enter heaven if a poor man does not lead him by the hand".
Balún-Canán (The Nine Guardians), Rosario Castellanos. 1957.

1 Introduction.

Rural households produce private goods for the market and self-consumption by deciding daily over the use of land, labor and other inputs, by choosing technologies, and by extracting resources from local commons such as mangroves, watersheds, forests or fisheries. Further, their income and well-being depend not only on the allocation of their own assets but also on ecological goods and services that flow from the local commons they all use. This joint access to the commons creates problems of collective action among the users who face incentives for overexploitation, and where conservation measures are costly. These goods and services flowing from the local commons include not only excludable and rival goods like fiber, food or fodder, but also other public-good types such as water quality, biodiversity services like nutrients recycling, erosion control, up to leisure, religious and cultural values.

This paper starts discussing the different reasons why wealth and wealth heterogeneities within a group of commons users may have different effects in the way these resources are used and the outcomes resulting from it. I will present in section 2 a set of theoretical arguments on how the problem can be studied from the perspective of each individual user of the commons, given the different incentives the household faces regarding private and collective options. The individual behavior will then be aggregated (section 3) at the village level to discuss how inequality of different forms can create problems of overuse in the commons, particularly if the resources are scarce. Section 4 presents the sets of empirical evidence that support some of the arguments provided in the theoretical discussion based on the experimental and cross-section data gathered in different rural villages of Colombia. The last section is an attempt to find parallels among the results from these different methods, and to derive conclusions

2 Wealth and Commons Use.

Wealth can determine in various ways how people interact with a local commons and how they interact with other commons users. On the other hand wealth determines private alternatives for the household, and therefore the need for exploiting a resource for which there is joint access. Marginal returns on private alternatives increase with assets such as education, land, livestock or equipment. Meanwhile, marginal returns on local commons depends on the individual extraction of resources from the commons, but also from the flow of other goods and services which decreases with aggregate extraction. Wealth and inequality can affect the institutional setting, e.g, the rights one has to use a resource, or the set of rules and norms that govern how a group manages and uses the commons; in fact the level of enforcement of those rules, either endogenous or externally enforced and monitored, can vary depending on the wealth of the violator.

The field evidence presented here includes several cases in which rural villagers combine their income from private and collective alternatives, and where wealth and wealth inequality play a role in how the collective action dilemma of using the commons is solved. Through two different but complementary methods of gathering data, I explore some of these ways in which wealth can affect the level of conservation or over extraction of commons, particularly in rural areas.

In summary, the evidence presented here show certain parallels in the results of two rather different empirical approaches regarding the relations between wealth inequalities and commons conservation. The results expand the evidence on the negative effects that wealth inequality may have in the possibility of conservation of the commons. Further, the results may contradict those arguing that poverty in itself hinders collective action in the conservation of natural resources, and instead be more compatible with the positions by Wade (1984) or Boserup (1965) regarding the capacity of agricultural societies to adapt and respond to constraints in resources availability via institutional or technological change. The results could therefore help separating how poverty and wealth inequality play different roles, sometimes reinforcing, other cases opposing in decision ;making under group social dilemmas and incomplete contracts. The policy implications are central as increasingly public policies are moving towards poverty reduction and away from changes in the distributional structures.

2.1 A quick overview of the literature.

An obligatory reference on the role that wealth differences may play in groups facing a collective action dilemma is Olson's (1965) proposition that when privileged agents within a group benefit proportionally more from the provision of the public goods generated by the collective action, they will contribute to its provision proportionally more, and that the rest of the group will therefore free-ride on such provision. Such proposition was qualified later, among others, by Sandler (1992) who in fact argues that the direction of the relation between heterogeneity of agents and collective action can go either way depending on the specific parameters and form assumed for the production function of the public good. Another important point of reference in the role that inequality can play in the provision of public goods is Bergstrom, Blume and Varian (1986) more formal development of Olson's proposition. They study how the private income level of the individuals contributing to a public good affects aggregate contributions, yielding a similar conclusion to Olson, namely, that the wealthier will over contribute to the public good while those with lower income levels will free-ride by not contributing.

There are however important distinctions to be made between pure public good and common-pool resource social dilemmas. These key distinctions may play a role in explaining how wealth and wealth differences affect the individuals' levels of cooperation in such social dilemmas, eventually in different ways[1]. As Ostrom, Gardner and Walker (1994) clarify, while

[1] The two types of dilemmas show similarities in the sense that the individual action is a mirror image of the other, i.e extracting in the commons vs contributing in the public goods. In both cases there is a conflict between the individual and the group interests generated by the incentives where each individual sees her payoffs increased by her own extracting (not contributing or free-riding) but the group's payoffs decrease with aggregate extraction (aggregate free-riding). Main differences between the two types of dilemmas, however, emerge form having different structures of the MPCR (marginal per capita ratio between the public good and the private alternative). A careful inspection of the payoff structures of public good and common-pool resources will show that most public goods structures involve a constant MPCR while the commons involve MPCR that are variable on the aggregate level of cooperation in the collective action.

the characteristic of rather costly exclusion of beneficiaries may be shared with public good dilemmas, commons dilemmas share the attribute of high levels of subtractibility with private goods. Units extracted by a user are not longer available for others in the group, and therefore creating a set of incentives for free-riding which will vary on the aggregate level of use. Further extracted units may have different opportunity costs for some of the users, with respect to their other alternatives outside the use of the commons, and therefore make the picture more complex. As I will discuss later using theoretical models, the decision to therefore extract will depend on these opportunity costs which may be asymmetric within the group.

More recent surveys on the role of heterogeneity and inequality in fact show the inconclusiveness of the literature on this matter. Varughese and Ostrom (2001 forthcoming) and Bardhan and Dayton-Johnson (2002 forthcoming) list a vast series of factors associated with heterogeneity and inequality, involved in commons dilemmas.

In a very synthetic and illustrative exercise, Agrawal (2001) makes a comparative analysis of three influential works that were published within the last decade on the issue of natural resource management and rural sectors. Wade's (1988) "Village Republics", Ostrom's (1990) "Governing the Commons" and a more recent book "Halting Degradation of Natural Resources" by Baland and Platteau (1996). Agrawal identified a taxonomy of factors suggested by these authors to affect commons use and sustainability. In all three cases there are elements related to our present discussion, but those involving poverty, wealth and inequality are rather inconclusive. On the one hand most authors identify higher dependence on the commons as a key factor for the users group to device self-governed institutions to avoid the tragedy. On the other hand, heterogeneity seems to work in different but simultaneous ways. While more heterogenous endowments seem to be associated with a more sustainable commons management, interests, norms, identities and allocation of gains seem to contribute more too solve the dilemma when more homogenous and fair. In particular, the emergence of wealthier and innovative group members might be the key to the emergence of leaders that guide and promote the collective action (Baland and Platteau, 1996). It is, however, difficult to predict the net effect given that in the field most cases when there is a privileged subgroup, both processes of proportionally greater contributions by the wealthier, with more unfair outcomes, allocation rules and distribution of rights will emerge.

Regarding heterogeneities in particular, Bardhan and Dayton-Johnson propose a comprehensive taxonomy of at least six types of heterogeneities based on a survey of theoretical and empirical works. The types of heterogeneity suggested by them are **income, wealth, exit options, location with respect to the benefits of the collective good, ethnic and social heterogeneities, and asymmetries in the rules choosing system**. In various recent works, Baland and Platteau (1996, 1997, 1998) develop game theoretical models that explore how some of these factors may explain empirical evidence on an adverse effect of inequality in the management of common resources.

Much of the arguments for supporting the hypothesis that inequality may worsen the failures emerging from the commons dilemma emerge from the asymmetries in the information that the users have of the others' behavior, and the difficulty of monitoring and enforcing contracts (self-governed or externally enforced) that restrict the overuse of the commons to avoid the tragedy. Bardhan, Bowles and Gintis (2000) provide a more generalized explanation of why incomplete contracts and unequal rules in the opportunities of agents will generate outcomes socially inefficient, including a case for the use of local commons. Their argument is based on the proposition that once contracts become costly to enforce because of asymmetric information *"the distribution of wealth may affect allocative efficiency by its impact on:*

-residual claimancy over income streams and hence incentives for both an agent's own actions and the agent's monitoring of the actions of others;

-exit options in bargaining situations;

-the relative capacities of actors to exploit common resources;

-the capacity to punish those who deviate from cooperative solutions; and

-the pattern of both risk aversion and the subjective cost of capital in the population".

These factors can easily be identified within the structure of a commons dilemma, and the structure of incentives, rules, norms and restrictions for the users group. I will model some of these below in order to provide a theoretical prediction to compare to with the empirical evidence later on.

2.2 A simple model of individual use of the commons.

Assume a group of households surrounding an area (the commons[2]) with a certain set of attributes that provide ecological goods and services to society. Some of these household may have private control over certain assets such as livestock or land. Some may extract resources

[2] "Commons" will not be assumed here only as a common property resource, but in a more general way, as a resource area for which there is joint use by a group. Thus, state owned natural parks may fall within this definition, particularly if exclusion rules are very costly to enforce. Also, natural areas that provide congestible public good benefits to households in the form of non-extractive benefits will coincide with the definition used here.

from the commons such as firewood or water from it, but they might also be affected like the rest of the village by the level of erosion, sedimentation, water pollution or biodiversity levels directly related to the aggregate extraction of resources from the natural area being exploited by these households.

2.2.1 Household's utility function

Define $U_i(x_i, \sum x_j)$ as the level of utility for user i, with $i \in (1,n)$ and j=1,,,n, derived from the allocation of total effort e_i (e.g. total household labor) between private alternatives (e_i-x_i) and individual extraction (x_i) of resources from the commons. Individual extraction x_i generates direct benefits to the household, but on the other hand individual allocation of effort into private alternatives (e_i-x_i) will also increase i's well-being. Thirdly, aggregate allocation ($\sum x_j$) of effort by the group of households into extracting the commons will generate a negative externality to i and the rest of the households. If benefits to i are increasing in i's effort extracting the commons as well as in i's effort into her own private alternatives, and decreasing in aggregate extraction, we can define:

$$U_i = U_i(x_i, \sum x_j) = U_i[f(x_i), b(\sum x_j), w_i(e-x_i)] \qquad [1]$$

where

$f(x_i) = \gamma\, x_i - ½\, \phi(x_i)^2$, where γ and ϕ are strictly positive and are chosen in part to guarantee $f(x_i) > 0$, for $x_i \in [0, e]$. The strict concavity of $f(x_i)$ indicates diminishing marginal private returns to effort extracting resources;

$b(\sum x_j) = q^0 - ½\, (\sum x_j)^2$, where b is a quadratic function of the aggregate amount of time individuals in the community spend collecting firewood; q^0 is interpreted to be the maximum level of non-use benefits when the natural area is in its ecological climax. The concavity of g is based on the assumption that at low levels of aggregate extraction the ecosystem is able of providing most of its ecological benefits but after a certain level of extraction these capabilities begin to diminish at increasing rates.

And lastly, we can assume that the marginal return on the private alternative is a linear function, at a constant rate of w_i times the amount of effort not allocated into extracting resources from the commons. Therefore, we can express the utility function as:

$$U_i(x_i, \sum x_j) = U_i[q^o - ½ \sum x_j)^2 + (\gamma x_i - ½\, \phi(x_i)^2) + w_i \times (e_i - x_i)] \quad [2]$$

For each individual i, and for all j users of the commons.

2.2.2 Social vs individual efficiency in the use of the commons.

One of the simplest cases is when all households face the same utility function and have the same marginal returns from their private and collective alternatives. From [2] we can therefore express the joint welfare function as

$$W(x) = n[(q^0 - ½\, (nx)^2) + (\gamma x - ½\, \phi(x)^2) + w \times (e - x)]. \quad [3]$$

The first-order condition for the maximization of W(x) requires that $-xn^2 + \gamma - \phi x - w = 0$. Solving for x, the optimal individual level of extraction should be $x^{so} = (\gamma - w)/(\phi + n^2)$, which basically equates the marginal rate of gains from the private alternative to the sum of the marginal gains from extracting the commons and perceiving the other non-consumptive goods and services from extraction.

However, achieving such socially efficient outcome will require certain institutions if the individuals do not coordinate their actions. Due to the structure of the payoffs function, there is a group externality and a conflict between individual and collective use of the commons. Each individual benefits from increasing its extraction, but suffers the costs of aggregate extraction for which it has only partial control, in the baseline case where we assume the absence of institutions correcting the externalities. If for the moment we assume again symmetry in the payoffs structures of the n individuals, and symmetry in the assumptions about behavior of the individuals, we can derive the optimizing decision x^* by each player as a best response function of the others' expected behavior, and of the parameters in equation [1]. The symmetric Nash equilibrium where each individual, by choosing x, maximizes the utility function shown in [1], requires that:

$$x^{nash} = (\gamma - w)/(\phi + n). \qquad [4]$$

Clearly $x^{nash} = (\gamma - w)/(\phi + n) > (\gamma - w)/(\phi + n^2) > x^{so}$ as long as $\gamma > w$ which we will assume for purposes of simplicity[3]. Given that the individual payoffs function is increasing in x_i, at equilibrium, these n individuals will find themselves in a commons dilemma where individual and group interests are in conflict. For any specified number of households, n, and for any level q^0 of ecological services for an unexploited commons, the distance in aggregate payoffs between the two benchmarks depends on the marginal returns from extracting resources (determined by γ and ϕ), and on the marginal rate on the private alternatives, w.

In the particular case of the private alternative, w, clearly higher exit options should under this model induce a reduction in the individual extraction of the commons and -at equilibrium- a socially superior outcome given that the reduction in gains for less resource

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3 For $\gamma < w$, we would be assuming that the marginal return on the first unit of effort into extraction is less than the marginal return on a unit in the exit option which would make the commons not an option.

extracted is more than compensated by the increase in the outside option, and also by the increase in ecological benefits from a lower aggregate extraction. This would clearly suggest, for policy purposes and under the assumptions given here for the rationality and incompleteness of the contracts among the individuals, that improving the private alternatives of the commons users such as higher returns on land or labor, better crops prices, subsidies for education, and the like, should reduce the pressure over natural resources over which there is joint access and lack of institutions[4].

However, recall that the symmetric Nash equilibrium that supports these conclusions assumes that the individuals are not devising any institution to correct the failures generated by the social dilemma. Rather they are following their Nash best responses given the assumption that everyone else in the users group will do so. Once external agents or self-governance institutions emerge that attempt to align the individual and collective goals, these predictions would just provide a set of benchmarks but not necessarily a prediction of actual behavior.

Secondly, the results are also based on the assumption of symmetry in both, outcomes and behavior, across decision makers. In reality, groups of commons users usually show various types of asymmetries, the central theme of this paper. In general, these asymmetries can be related to the different components of the individual payoffs function as we will discuss later on.

This particular model presented above was used to design an economic experiment to test the theoretical hypothesis and predictions previously presented and whose results will be

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[4] One could also make the argument that such improvement in household human and manmade capital could also improve the marginal returns on the individual extraction of the commons via changes in the parameters γ and ϕ. One clear example is better fishing or logging equipment that could increase the quantity of resources extracted per unit of labor.

presented in section 4.2 later on, where the theoretical benchmarks predicted by the model will be contrasted against the behavior of people facing such incentives and institutions.

Before presenting the empirical evidence, however, I would like to discuss also from a theoretical perspective how wealth inequality, associated with land ownership among a group of commons users, could affect the level of over exploitation of the resource when there are problems of population pressure and demand for agricultural land.

The next section will expand the analysis of the individual household decision making, and how changes in distribution of private alternatives may affect the individual use of the commons and therefore its aggregate extraction. The model will now incorporate how land and labor interact at the farm and the village levels to determine the use of the commons.

3 Private vs collective alternatives: the role of land ownership and distribution[5].

Dating back to the Malthusian argument combined with Hardin's (1968) tragedy of the commons, some could argue that higher levels of population pressure -or its equivalent, scarcity of land per household- could increase the risks of falling into the tragedy, particularly if the institutions that define the rules of access and ownership will not correct the failure. And further, could inequality play a role in mediating such relation? In fact Malthus offered some original hints on the idea by reflecting on the role of labor in the demand and supply of food: "*An unfavourable distribution of produce, by prematurely diminishing the demand for labour, might retard the increase of food at an early period, in the same manner as if cultivation and population had been further advanced;*" [Malthus (1830): pp. 239].

[5] See Weitzmann (1974) and Balland and Platteau (1996) for more detailed analysis of these ideas.

In our baseline model, individuals use their best response to allocate their effort (labor in our model) between the use of the commons and the private alternatives they have which generates income in the form of $w(e-x_i)$. Let us now expand the discussion to study how not only marginal returns on labor but also on private land may affect the use of the commons. In a next step, individual households have a fixed amount of labor (e) and an amount of land (t), and will allocate their labor between the private land and the commons alternative depending on their relative marginal productivities. The endowed labor e will be allocated between effort (x) extracting the commons and effort in the private alternative (e-x = L).

Borrowing from Weitzman (1974) and Baland and Platteau (1996), assume the average farmer for whom the production function depends on his own land (t, fixed) and available labor time (e). Let us assume further that Q = Q(t, e) where Q_t, $Q_e > 0$, and $Q_{te} > 0$. Thus, when looking

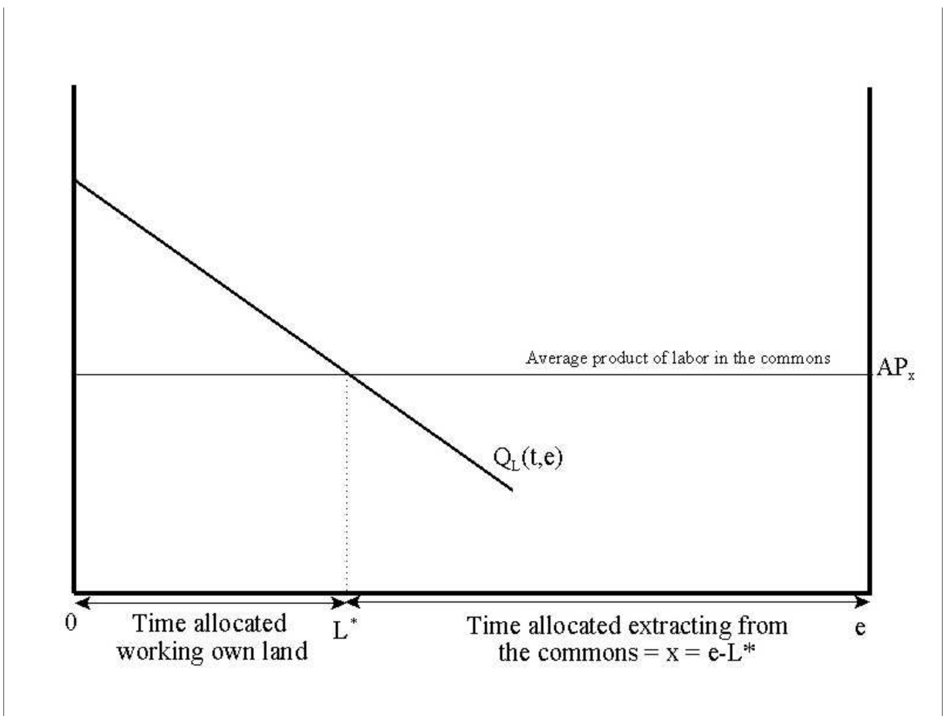

Figure 1 Optimal allocation of time between the commons and own land.

at her labor allocation problem (see Figure 1), she will allocate her time e at L^* where the marginal product of labor in her own land $Q_e = AP_x$, where AP_x is the average product of labor on the commons. The remaining amount of time ($e - L^*$) will be allocated to effort into extracting benefits from the commons, which we derived as a best response function earlier. Larger private land will shift the $Q_e(t,e)$ curve to the right (up), or conversely, as the farmer owns less land, its optimal allocation of time will induce him to increase its effort in extracting benefits from the commons. Notice also that a farmer could at some point own sufficient land that it is would not be necessary for her to dedicate time into the commons, that is when the marginal product of labor curve is high (to the right) enough that she will allocate all her time into her own land.

An increase in population in the village, with fixed total land, will decrease the average per household land and therefore reduce average t, shifting $Q_e(t,e)$ to the left[6]. This will add to the aggregate effort ($\sum x_i$) in extracting from the commons and therefore will decrease its aggregate flow of benefits for the households. Such situation will reduce the average product for users due to overcrowding of the resource and increasing extraction costs, shifting AP_x downwards. Thus, a reduction in per household farm size will create a net increase in the aggregate effort by farmers using the commons since the shift of AP would not overpower the shift in MP. The reason for this is that at optimality AP is flat (at maximum) and MP is decreasing, $\partial MP/\partial x > \partial AP/\partial x$ (Henderson and Quandt, 1980: 68).

Let us think now on the effects of a change in the land distribution in a village. Assume

[6] Notice that the inverse of population density (p) defined as number of households divided by the total village land is precisely $t = 1/p$.

the case of two farmers who initially own the same amount of land (T/2) of total village's land (T) and which will be sufficient for them to allocate all their time in the own land ($L^* = e$), i.e. they would not need to use the commons. Assume another case where one of the farmers ends owns 3/4 of the land and the other 1/4. While the average land per household remains constant at 1/2, the aggregate use of the commons changes from the smaller farmer (with t=1/4) allocating a greater part of her time in the commons which is shown by a shift of $Q_e(t,e)$ to the left.

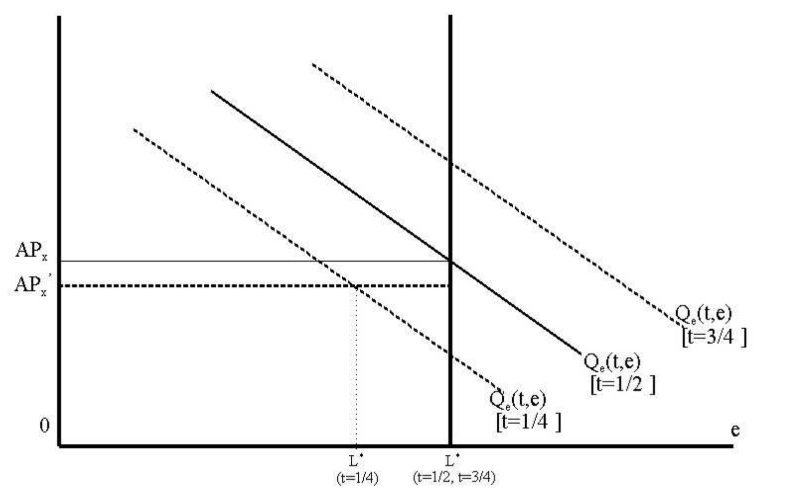

Figure 2 Changes in commons use from a change in distribution of land.

3.1 Ecological consequences at the village level.

Recall that our original model of household utility (Equation [1]) included a component $b(\sum x_j)$ for the set of ecological goods and services that the commons provides to every household in the village, apart from the direct use from extraction. Such flow of benefits to a specific user -which take the form of a public goods case- are decreasing and concave in the aggregate extraction ($\sum x_i$) by all users. The reason for the concavity of this function is mainly ecological. For a certain level of extraction, the ecosystem is capable of providing the same goods and services without its diversity, biomass productivity and resilience being affected. However, after a certain threshold, ecosystems show a much rapid decrease in its ecological functions and capacity.

Let us define first the aggregate (village) flow of ecological goods and services as $B(\sum x_i) = n\, b(\sum x_j)$. $B(\sum x_i)$ could be affected by individual actions in several ways. First aggregate extraction of resources such as water, fish, firewood, logging, reduces the levels of biodiversity and biomass available. But also, actions made within the farms may as well affect other elements of the village commons. In particular, changes in land use from vegetation covered to crops and specially to pastures affect negatively the ecosystem's productivity, biodiversity and resilience by increasing deforestation and the levels of sedimentation in the watershed[7].

Thus, let us expand the expression for $B(\sum x_i)$ as a function also of the land use decisions by the households in their own land. Thus, let us define

$B = B[C(g,t), P(w)]$, with $B_C < 0$, $B_P < 0$[8],

and where $C(g,t)$, is the village aggregate level of effort put into extracting resources from the commons, which is a decreasing function of t, the mean farm size in the village as discussed earlier, ($C_t<0$), and an increasing function of g, the level of inequality ($C_g > 0$) as

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[7] Other ways land use decisiones affect the commons ecosystems are the use of pesticides, fertilizers or soil erosion practices that increase biodiversity loss, pollution and sedimentation.

[8] The marginal effects B_C and B_P can be thought as *marginal damages to the ecosystem* from an additional unit of resource extraction and an additional unit in pastures expansion respectively.

discussed in Figure 2.; P(w), the village's area in pastures as land use, to be assumed as increasing in wage (P_w >0) based on the assumption that as labor becomes more expensive, farmers should shift from crop land uses to less labor intensive land uses such as pastures and livestock[9].

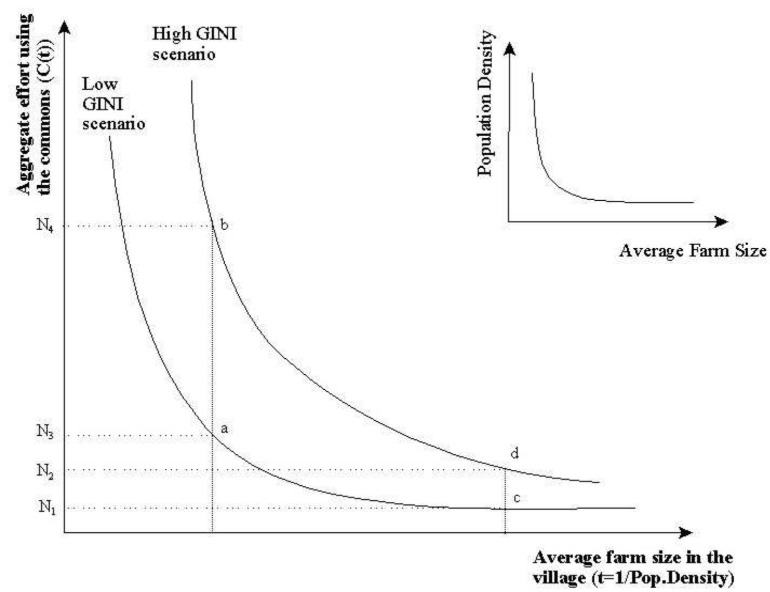

Figure 3 Average farm size and level of pressure into the commons.

If one assumes that the village's wage w depends in the village population density (p=1/t) and the village's distribution of assets, w = w(g,t), with $w_g < 0$ and $w_t > 0$, then we have,

$$B = B[C(g,t), P(w(g,t))]. \quad [5]$$

The next step in the analysis is to introduce a change in population level in the village and see how that affects the flow of benefits from the commons. Thus,

[9] For analytical purposes one should assume that the function P(w) is increasing and convex on w, therefore reflecting the notion that for a certain portion of wages increases the level of pastures land use by farmers should not change by much and farmers mostly use crops as the main land use given the high labor supply an demand for staple crops. However, after a certain point in the curve, a change in wage will create a much larger effect in land use inducing a greater switch from crops to pastures, after which the function P(w) becomes now concave, yielding therefore an S-shaped function.

$$\partial B/\partial t = B_C \cdot C_t + B_P \cdot P_w \cdot w_t \qquad [6]$$

$$= (-) \cdot (-) + (-)\ (+)\ (+) = \leq\ ?\ \geq 0$$

From which no unique sign can be derived. The reason for this result is that two opposing effects ($B_C{\cdot}C_t$ and $B_P{\cdot}P_w{\cdot}w_t$) are interacting when the average per family farm size t (inverse of population density) changes. According to [6], as the average farm size increases (from a population density reduction) less effort is put into using the commons; but on the other hand, it increases the village's wages inducing farmers to switch to less labor intensive but more damaging activities such as soil erosive livestock and capital (chemical) intensive crops which generate damages to the local commons.

Let us then look at the cases where $\partial B/\partial t$ might be positive and negative respectively. When $\partial B/\partial t > 0$ the Neomalthusian argument prevails, i.e. that when the average per household farm size increases (that is, when the population density decreases) the pressure over the environment should be reduced. In our model, that would happen when $B_C \cdot C_t > B_P \cdot P_w \cdot w_t$. Likewise, having $\partial B/\partial t < 0$ (that when population density increases a net positive effect over the local commons results) would be consistent with the Boserupian argument that an increase in population may induce technological changes and adaptation to the constraining conditions. In such case $B_C \cdot C_t < B_P \cdot P_w \cdot w_t$.

In order to study the conditions under which each possibility may emerge, we introduce the inequality effect, g, which will decide the net effect. The basic intuition is that at high inequality levels the indirect effects from farming practices into the commons ($B_P \cdot P_w \cdot w_t$) get overpowered by the population pressure effect ($B_C \cdot C_t$). The reason for this is that at high inequality, as we proved before, the landless and nearlandless farmers will increase their labor allocated into the commons (Figure 3), while the change into more sustainable farming practices from lower wages by fewer landholders will not compensate for the damages created by the overuse of the commons.

For equation [6] to be negative, that is, that a population density increase does not reduce but increase the flow of benefits from the commons we need that $B_C \cdot C_t < B_P \cdot P_w \cdot w_t$. This result holds for cases where the distribution of land is equal enough that C(g,t) is very small, which we proved before for the case where farmers would allocate most of their labor into their own land. In such case, an increase in the population density, by increasing the supply of labor, would induce a shift by farmers to more sustainable (labor intensive) practices usually associated with labor intensive activities such as manual weeding, crop rotation, and reduction in chemical intensive inputs use such as fertilizers and pesticides.

Graphically, the argument can be presented through the following figure 3 where the slope of the relation between the average farm size (inverse of population density) and the aggregate (village) effort for using the commons is steeper for the cases where the inequality is higher. Thus, a reduction in the average farm size from a population increase will have a stronger effect on the aggregate level of extraction from the commons when the village distribution of land is more unequal, or conversely, a worsening in the distribution of land will have a more damaging effect when the population density is higher(segment ab), i.e. at a village's lower average farm size than at less population pressure (segment cd).

The following table shows the two possible outcomes for the sign of $\partial B/\partial t$ depending on the level of inequality and the prevailing or dominant effect in each case. It summarizes the predictions on how an increase in population, i.e. a decrease in farm size, will have different effects depending on the level of inequality. The next section will present the empirical evidence to test these predictions, and later I will address the possible parallels of these results with the experimental results.

Basic equation: $B = B[C(g,t), P(w(g,t))]$ = flow of ecological goods and services to the village.		
Effects of a change in population density (decrease in t, $t = \text{Pop.Density}^{-1}$)	Low Inequality (g)	High Inequality (g)
	$\partial B/\partial t < 0$	$\partial B/\partial t > 0$
Dominant effect	$B_C \cdot C_t < B_P \cdot P_w \cdot w_t$	$B_C \cdot C_t > B_P \cdot P_w \cdot w_t$
	Shift to sustainable farming practices and land uses from higher use of labor.	Increase in the aggregate use of the commons
Table (???). Cross-effects of inequality and average farm size (population density^{-1})		

4 Two very different exercises in the field.

The following sections explore empirically these possible relations of wealth and conservation of the commons, using two rather different techniques. One the one hand, an econometric exercise using a spatial cross-section database for 160 villages in a region located in the Andes of north east Colombia[10] (Baptiste et.al., 1993; IDEADE, 1995). Using such

[10] The Chicamocha middle basin region of analysis is formed by 17 municipalities. The unit of analysis is the "vereda" or village. A municipality is composed of "veredas" (about 10 in average for each municipality). Each "vereda" can be considered as a homogeneous area in

database, I will present regression results on how wealth inequality and population density, can help explain variations in the level of conservation of the local commons of these villages.

The second empirical exercise consists of a series of economic experiments conducted in the field during 1998 in three different villages in Colombia using a simple common-pool resources experimental design (Ostrom, Gardner and Walker, 1994; Cardenas, 2000) and different treatments for self-governed and externally imposed regulations.

Empirical analysis of these two sources will allow us to test the hypotheses discussed earlier on how wealth and inequality may affect the individual use of the commons and the collective outcome expressed in the aggregate level of conservation or overexploitation.

4.1 A spatial cross-section Geographical Information Systems exercise.

The spatial database used different remote sensing techniques using interpretation of aerial photographs and satellite images, along with field work for validation of photo interpretation. Such study generated a set of maps with different environmental topics, and that could be overlaid. The maps included the location of households, municipality and village boundaries, land use and farming systems, water streams, types of vegetation and coverage, and geomorphological units for elevation, soils types and slopes.

The analysis of the spatial data, based on the landscape ecology approach (IDEADE,

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social, cultural, economic, and ecological terms. Most "veredas" are located within the same micro-watershed, therefore, the "veredas" boundaries have been historically defined either by streams or mountain peaks. This causes high interdependencies within a village such as downstream effects in terms of hydrological regulation or soils erosion. The entire database includes 160 villages. Using various remote sensing and field work techniques, a comprehensive ecological and socio-economic study was undertaken between 1990 and 1994 (Baptiste et.al., 1993; IDEADE, 1995; Cardenas, 1994) and in which the author participated.

1993; Zonneveld, 1979; Etter, 1990), then identified the features that expressed the most critical and valuable areas in the territory in terms of ongoing ecological processes, and based on the interpretation of natural aspects and human intervention processes. The criteria used was to identify salient features, positive or negative, associated with soils, forests, and water resources in the territory, and for each type of ecosystem identified.

To value the degree of conservation or degradation of each area the team of biologists and agronomists assigned values, from -1 to 1, to each of the identified polygons in the map according to the severity of the degradation or the value of the conserved areas. Those areas that did not show a salient process of degradation or conservation were assigned a value of zero. The following table shows the criteria and the values assigned. The exact value assigned to each polygon depended on the severity of the observed phenomenon and its ecological potential given by ecosystem, elevation, and climate.

CRITICAL AND VALUABLE AREAS (Summary Table) LANDSCAPE ECOLOGY ANALYSIS (IDEADE, 1993; Zonneveld, 1979; Etter, 1990)	
NEGATIVE EXTERNALITIES:	Range of values assigned to areas
Soils erosion, degradation (landslides, soil runoff, pollution)	(-1.0 ; -0.5)
Vegetation loss (deforestation, loss of native species)	(-0.8 ; -0.6)
Water degradation (hydrological imbalance)	(-0.3)
POSITIVE EXTERNALITIES:	
Soil and Vegetation conservation	(0.75 ; 0.80)
Water hydrological cycle balance	(0.5 ; 0.7)
Soils + Vegetation + Water conservation	(0.9 ; 1.0)
Other areas	0

The resulting map presented for the entire region a valuation of the most valuable and critical areas, which was then overlaid, using GIS techniques, with the village boundaries map. Then, we could calculate for each village an index as a weighted average of the points and the percentage of the village under each category, that is:

$BSAINDX_j = \sum (area_{ij} * points_{ij}) / \sum (area_{ij})$, where j is the village, and i is the category of critical and valuable zones, based on the table above.

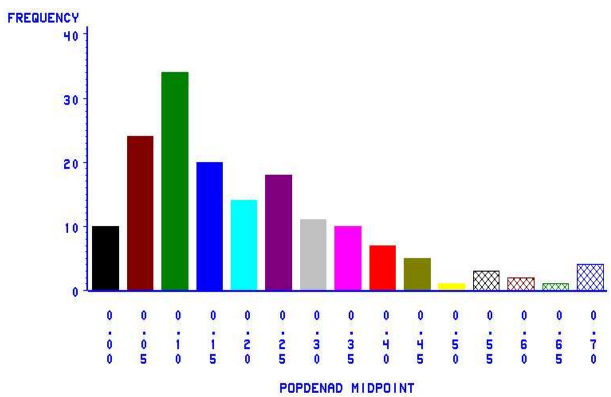
The index BSAINDX will be used as an expression of the level of conservation or degradation of the natural resources that the village uses collectively, i.e the level of conservation of the commons, and will be the result of interactions and decisions by the households which affect the capacity of each village commons to provide ecological goods and services for the community. Greater levels of the index represent the net result of decisions by the households in the village and will imply a higher level of ecological services for the community such as water regulation, erosion control, and biodiversity conservation.

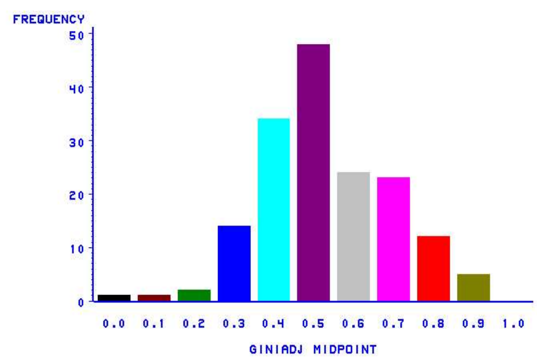
It is clear why such index represents the result of collective action in the village. Given that most decisions, even within the farm, affect ecological aspects of the village (e.g. downstream effects, soil erosion, vegetation loss), there are group externalities that generate a social dilemma. Undertaking measures to reduce such external effects is costly for each household, but aggregate external effects induce a collective outcome that is undesirable.

4.1.1 Land distribution and population density.

Two more variables are of interest in our village level analysis. On the one hand, the distribution of land within a village, which can be calculated by heterogeneity of farm sizes within a village using the map with the exact location of households, and the population density estimated by calculating the number of households per hectare in each village.

However, farm sizes are not comparable within a village because of other factors that make a hectare of land more valuable due to location, water access, slope or soils type. Using a cadaster land valuation system (available from author), and using the data on roads, water streams and precipitation, and geomorphological units, the farm sizes were adjusted to allow for comparisons[11]. With such adjustments, an estimation of land distribution based on adjusted farm sizes would be a more accurate reflection of land (wealth) value. We calculated the gini land inequality index, using the lorenz curve method, and based on the distribution of the number of farms among different (adjusted) size ranges. The covariance method (which better performs for individual data) was used for calculating the gini coefficient.





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[11] Each farm area was estimated from the location of each house, and using the thiessen method which distributes polygon areas around points. The adjustement system used slope (-), soil pH (+/-), soil depth (+), rainfall (+), number of dry months (-), and distance to main and secondary roads (-). The signs indicate how the factor affected the valuation of a plot.

The histograms show the distribution of the population density (households/ha.) and the Gini coefficient for land distribution for the sample of 164 villages, and adjusting land areas by the factors mentioned before.

If the arguments used in section 3 are valid, we could explain part of the variation of BSAINDX, our proxy for the level of conservation or degradation of the commons, as a function of population density and land distribution for the average village in the sample. It is of particular interest to test the hypotheses presented in Table (???), that the net effect of population density or the farm size on the ecological outcome at the village level, is the result of land distribution.

The spatial database included data for 164 villages, and estimation of the indices mentioned for them. The regression results are presented below after showing the descriptive statistics of the variables. The model that will be estimated is:

$$BSAINDX_i = \alpha + B_1(POPDENAD_i) + B_2(GINIADJ_i) + B_3(POPGINAD_i) + \varepsilon_i$$

where,

BSAINDX: Index of environmental conservation or degradation of the commons in each village (can range from -1 to +1).

POPDENAD: Population density (adjusted) = Number of households per hectare, adjusting land areas by productivity and value factors.

GINIADJ: Gini coefficient (from 0 to 1) based on adjusted farm sizes.

POPGINAD: POPDENAD * GINIADJ

If the cross-effects variable POPGINAD shows to have a significant and relevant magnitude and sign, it would be plausible to support the hypothesis of a cross-effect of inequality in the way population density affects the level of environmental conservation or degradation of the commons.

The descriptive stats for the n=164 villages observations and variables are shown in Table (???):

Variable	Minimum	Maximum	Mean	Std Dev
BSAINDX	-0.9810000	0.9419000	-0.1241866	0.3929625
POPDENAD	0.000796557	1.5916826	0.2136661	0.2016112
GINIADJ	0	0.8902000	0.5338726	0.1631213
POPGINAD	0	0.5741199	0.1019632	0.0843384

Table (???). Descriptive statistics for variables in spatial village level model.

Partial correlation coefficients for the variables are shown in Table (???):

Pearson Correlation Coefficients / Prob > |R| under Ho: Rho=0 / N = 164

	BSAINDX	POPDENAD	GINIADJ	POPGINAD
BSAINDX	1.00000	-0.27063	0.24846	-0.27154
	0.0	0.0005	0.0013	0.0004
POPDENAD	-0.27063	1.00000	-0.37041	0.95141
	0.0005	0.0	0.0001	0.0001
GINIADJ	0.24846	-0.37041	1.00000	-0.18811
	0.0013	0.0001	0.0	0.0159
POPGINAD	-0.27154	0.95141	-0.18811	1.00000
	0.0004	0.0001	0.0159	0.0

Table (???). Simple Pearson Correlation coefficients among model variables.

The estimated model using OLS procedure is in the next Table (???):

Model: Dependent Variable: BSAINDX

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	3	3.19256	1.06419	7.747	0.0001
Error	160	21.97782	0.13736		
C Total	163	25.17038			

Root MSE	0.37062	R-square	0.1268
Dep Mean	-0.12419	Adj R-sq	0.1105
C.V.	-298.44039		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|	Standardized Estimate
INTERCEP	1	-0.388957	0.13485718	-2.884	0.0045	0.00000000
POPDENAD	1	0.921977	0.60398994	1.526	0.1289	0.47302476
GINIADJ	1	0.719099	0.23405390	3.072	0.0025	0.29850261
POPGINAD	1	-3.100449	1.36551759	-2.271	0.0245	-0.66542422

Table (???). OLS estimation results for spatial village level model.

According to these results, there seems to be in fact a cross-effect between gini (inequality) and population density. In fact, the sign of POPGINAD, opposite to the signs of POPDENAD and GINIADJ, and the magnitude of the coefficients would suggest that for highly equal cillages, an increase in population density could in fact be associated with an increase in the environmental outcome. Notice also in the stimation results the weights of the variables (last column with standardized coefficients, and in particular the greater value of the cross-effects coefficient. Therefore, and according to the estimated coefficients, we could predict the marginal change in the dependent variable, BSAINDX by calculating:

dBSAINDX/dGINIADJ = 0.719099 - 3.100449*(POPDENAD),

which changes signs, from positive to negative, when population density is equivalent to 0.2319 households per hectare, a point in the distribution of this variable quite close to the mean (see table with descriptive statistics). Thus, for an important fraction of more populated villages, the marginal effect of a change in the gini coefficient f land would be a decrease in the level of conservation of the village commons.

4.2 An economic experiment in the field.

Without much detail on the experimental design[12] let me summarize the basic components of the experiments conducted in the field. Twenty sessions of 8 person, 20 rounds, were conducted during the summer of 1998 in three rural villages of Colombia. In all three cases the villagers faced a similar dilemma: a forested area from which several products were extracted and from which other types of ecological services were generated for the community.

Through a simple decision-making exercise, eight participants in each group had to make repeated economic decisions that had salient economic incentives (in kind and cash) and with the kind of externalities common to these commons dilemmas. The average earnings, about two minimum wage days of work, at the end of the sessions compensated for their time participating in the experiment and in a community workshop held at the end in each village.

In brief, during the experiment each participant had to decide in each round the number of months (from 0 to 8) that she would allocate to extract resources from a jointly used forest. The net earnings from such decision, which she could view in a payoff table, based exactly on the payoffs function in equation [2], which increases with individual extraction, but decreases with total group's extraction, giving rise to the commons dilemma. To complete the earnings structure, any month not allocated to extract from the forest would yield a constant marginal private return equal to all players. We chose the parameters of the payoffs structure such that if

[12] A detailed analysis of the experimental design can be found at Cardenas (2000), Cardenas, Stranlund and Willis (2000).

every player choose 1 month in the forest, for a maximum of 8, the group would achieve the social optimum solution where group earnings would be maximized. And if each player chose 6 months, they would find themselves in the Nash sub-optimal equilibrium at about 24% of social efficiency. The participants in all cases had to make a series of decisions (rounds) under no possibility of interaction among themselves, and then depending of the sample, they would face a different institution either face-to-face communication among the players, or an external regulator that would enforce a certain social norm aimed at improving social efficiency. Also we introduced for some cases a payoff structure to emulate the case of asymmetric incentives where two of the players had a much better opportunity cost of time not allocated extracting the forest, while the other six a much worse than the baseline symmetric case. The design had therefore two benchmarks described earlier, the social optimal solution when each player chooses 1 month (i.e. 8 months group total) and social efficiency is at 100%, and the Nash solution where each player chooses 6 months (i.e. 48 months group total) where efficiency for the group is only at 24%. The summary of the predicted benchmarks for the Nash outcome and the social optimum case are included in the following table (???).

Two Benchmarks for equilibria in the commons game		Symmetric game (All 8 players)	Asymmetric game	
			Two H players	**Six L players**
Social optimal solution (GroupMax strategy)	Individual decision (X^{opt})	$X_S^{opt} = 1$	$X_H^{opt} = 0$	$X_L^{opt} = 1$
	Yields ($) per round per player	Y_S^{opt} = $645	Y_H^{opt} = $801	Y_L^{opt} = $602
	Group yields	$SUMY_S^{opt}$ = $5,160	$SUMY_{HL}^{opt}$ = $5,214	
Nash solution (IndivMax strategy)	Individual decision (X^{nash})	$X_S^{nash} = 6$	$X_H^{nash} = 0$	$X_L^{nash} = 8$
	Yields ($) per round per player	Y_S^{nash} = $155	Y_H^{nash} = $117	Y_L^{nash} = $191
	Group yields	$SUMY_S^{nash}$ = $1,240	$SUMY_{HL}^{nash}$ = $1,380	

For fifteen of these groups (10 under the symmetric payoffs table, and 5 under the asymmetric ones), in the second stage we introduced a new rule where they could have a five minutes conversation before each round decision. Such conversation would be free but would not permit any threat or promise of transferring earnings after the session. They would make choices for another set of around 9-10 rounds under this new treatment. As in previous studies (Ostrom, Gardner and Walker, 1994) face-to-face communication has proved to be a powerful mechanism for inducing more cooperative behavior. The results reject in general the "cheap talk" argument that when agents make promises with no enforceable consequences, such promises remain as such and moves towards cooperative choices do not happen. Our results showed that in average the ten groups improved social efficiency by about 10% thanks to the communication. Although the result may seem small, it should be noted that this is the resulting social efficiency at the end of stage 2, and that during some rounds the average was above that.

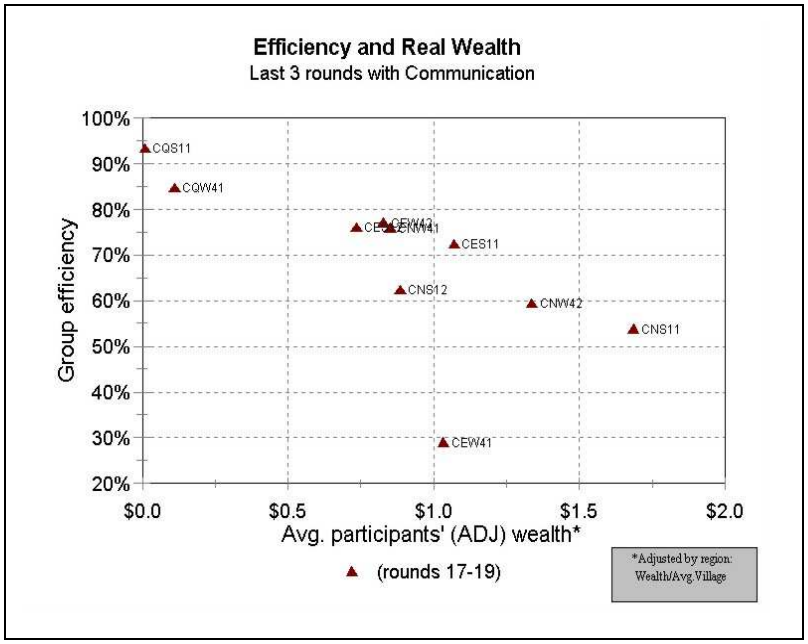

Figure 6. Average wealth of eight participants vs group efficiency at the end of experiment.

Secondly, and maybe more important, some of the groups achieved levels of almost maximum social efficiency, while others achieved almost no improvement despite all groups facing the exact same incentives and laboratory environment and rules. This point will be discussed next.

The wide variation of behavior and outcomes across and within the groups is very much consistent with the rest of evidence in the literature (Ledyard, 1995; Ostrom, Gardner and Walker, 1994). It can not be explained by changes in the lab institutions and environment since they are all the same in all groups. It might be explained by the individual data and the specific conditions in each round in terms, for instance, of reciprocity and learning effects determined choices in one round as a function of choices in previous rounds. But also, the time allowed for the discussion allowed each group in particular, and each individual, to construct a new image of the game, that is a new set of internal payoffs now in terms of utility and not necessarily of monetary values. Guilt, respect, spite, could all be now affecting the choice after a few minutes of debate over what should be a better choice to make in the next round.

Given the non-observability of such values, we wondered if certain variables about the demographic, economic and social characteristics of the players and the others in their group might explain such variable behavior. Indeed it did -at least statistically- in several ways. One of them, group composition, seem to determine how effective the communication could be to improve cooperation and social efficiency. We estimated the material wealth in terms of land, livestock and equipment) of each player and estimated also some indicators of wealth inequality for each group. The results of the implications are discussed in detail in Cardenas (2001) but the following graph (Figure 4) can describe one of the main points. Of the 10 groups we separated the 3 more and 3 least homogenous in terms of the standard deviation of individual wealth for the 8 participants in the group[13]. While the least homogenous groups barely improved efficiency through communication, around 3% gains, the three more homogenous or equal groups achieved levels of 85-90%, that is an improvement of almost 30% at the end of the communication rounds. In a related study, Alesina and La Ferrara (1999) showed from a General Social Survey (1974-94) sample from U.S. citizens that the participation in social activities as contributions to their neighborhoods, decreased for more unequal and more racially or ethnically heterogenous groups.

Further, in Cardenas (2001) it is shown econometrically that at the individual level, players chose during the second stage lower levels of months in the forest if the difference between their wealth and the average of the wealth of the other seven players was smaller, other things held

[13] Other measures of heterogeneity like the Gini of wealth, Herfindhal and the log of the variance of wealth all yield similar results.

constant. Also, those players whose real life income was less dependant on private assets like land, and more dependent on the use of a commons behaved in the lab more cooperatively. Interestingly no statistical significance was found on possible explanatory relations between lab behavior and demographic variables like age, education, or gender at individual or group levels.

4.3 Asymmetric payoffs: Different exit options.

The results above showed how voice and loyalty within the group improved outcomes through communication and through self-governed ways, and that besides the pure material incentives, who is in your group along with your own experience in similar dilemmas determine your choices. Your exit options should also affect the choices, and in fact this is how much of the theoretical literature has dealt with the problem of inequality. Asymmetric payoffs create different incentives to contribute to the public good or refrain from doing so. Olson's argument of the privileged group goes along these lines, that if a privileged member of the group individually benefits from providing the public good, she might provide it despite the free-riding of the others in the group. That is, if the marginal returns from contributing to the collective action are higher for some, they are more likely to cooperate[14]. However there is another side to this problem. It might be the case that the marginal return from not contributing is also asymmetric, that is, that the opportunity cost of allocating effort into the private next best alternative is different for some in the group. In other words, that some may depend more on the commons because their marginal return on their private alternative is much lower due to wealth

[14] Sandler (1992) develops the Olsonian propositions in detail and shows that depending on the production function for the public good, such claim may or may not hold.

effects. We introduced such case into our field experiments in five new groups of eight people by assigning different payoff tables to the eight participants in the following way: Two of them, randomly chosen, would receive payoff tables (H) that included a much higher marginal return on months not allocated to the forest, while six of them would receive tables (L) that would get tables where the earnings included much lower marginal returns on the months not allocated in the forest. The Nash theoretical equilibrium for this game would predict that those players with the L tables should allocate their entire eight months in the forest, and therefore those with H tables should not use the forest (i.e. choose zero months) since their best alternative is much better at such point. These asymmetric (HL) groups went through the same two stages as the symmetric baseline groups (S), that is, stage 1 where no communication is allowed, and stage 2 where five minutes of group discussion was allowed before each round decision.

Once again the experimental results would not confirm any of this behavior and provided another interesting sets of results described in detail in Cardenas et.al. (2001) and summarized in the following graph (Figure ???).

The first observation results from comparing the end of the Non cooperative game (end of stage 1) for the two types of payoffs structures. By the end of stage 1 we already noticed a difference that at first glance would confirm Olson's proposition that heterogeneity increases collective action. Drove by the payoffs incentives we could conclude that the asymmetric groups achieved higher levels of efficiency (around 72% for HL groups vs 60% for S groups). However, these outcomes did not result from the privileged group argument, but from a rather opposite effect. The six players that had the L tables by the end of the stage 1 deviated further from the expected Nash behavior and towards more cooperative behavior, and this happened without any institution or coordination among themselves. Clearly from the tables one could observe that at the levels of high extraction predicted by the Nash equilibria, earnings were quite low and any reduction in individual choices would bring improvements to the group and to each individual.

The introduction of communication in stage 2 then reinforced this process. The discussions

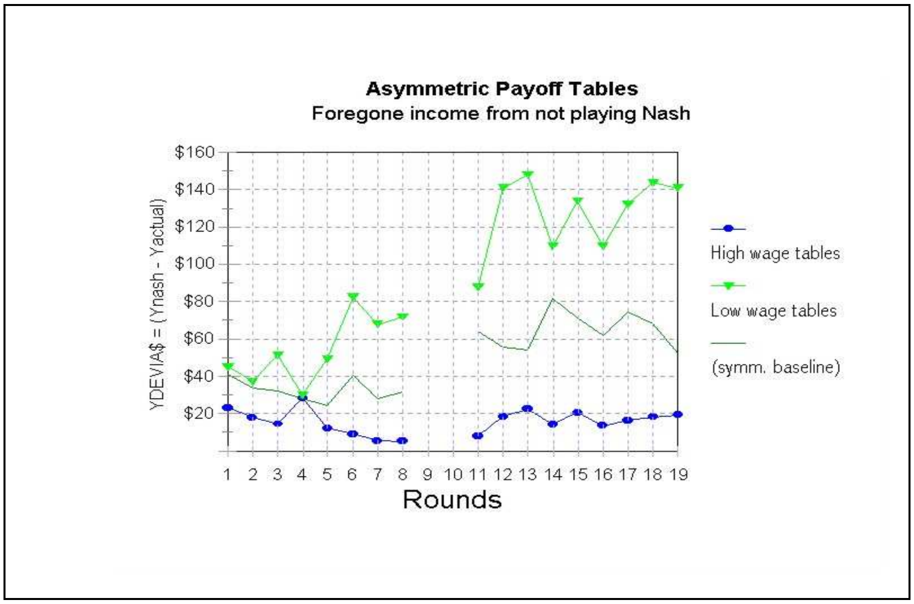

Figure 7. Foregone earnings from not playing a Nash best response.

called for reducing the individual months in the forests, but it was only the L players who showed statistically significant changes towards even more cooperative behavior while the two H players remained within the same individual levels they were choosing before communication. This combination of factors induced a group increase in earnings and therefore in social efficiency as shown in Figure 5. Chan et.al. (1996) have shown similar results from a pure public goods experiment, but direct comparisons must be made carefully because the CPR and public goods incentives are different in nature. Nevertheless, they found that when they introduced asymmetric income distributions within groups, aggregate contributions increased but because of a comparatively higher contributions by those endowed with higher income levels.

5 Results: parallels in models, variables and results.

The two empirical exercises presented, a geographical information systems (GIS) cross-section spatial analysis, and a set of economic experiments conducted in the field both attempted to explain conservation of a commons as a function of wealth and wealth distribution characteristics at individual and group levels. The index BSAINDEX in the GIS exercise has an equivalent in the experimental design, namely, the GROUP EFFICIENCY[15] in the experiment. Households cooperation in both cases is expressed by the individual level of economic activity that does not harm the commons provision of ecological benefits to the group and maximizes the net flow of extracted goods and non-extractive ecological benefits. Individual actions were for obvious reasons more observable in the experiments. However, land uses can be along with farming practices could reflect part of the individual actions by the household.

In the case of individual wealth, we measured in both exercises different variables that are comparable. Wealth associated with exit options can be expressed in the experiments by the wage, w, varied across different treatments. We also measured wealth in terms of the actual assets (land, livestock and equipment) that participants in the experiments had. In the case of the GIS exercise, we measured wealth in terms of the land, adjusted by factors that add value to the land such as access to roads and water, soils and slope.

Regarding the distribution of wealth in a group, we used different measures of

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[15] Defined as the actual group payoffs obtained / group payoffs at the social equilibrium prediction.

heterogeneity and inequality. For the experimental exit options, we compared groups with asymmetric payoff tables with symmetric ones. We also compared the heterogeneity in the actual wealth of the participants using different inequality measures. And in the case of the GIS exercise, a measure of inequality in land distribution was estimated based on the adjusted farm areas for each village.

In all exercises we could observe, or create, enough variation in the levels of wealth and inequality, and observe possible statistical relations with the environmental outcome, namely, the conservation of a commons. Section 4 before presented four major empirical results regarding the relation between wealth, inequality and conservation of the commons that may suggest some generalizations. These results can be summarized as follows:

Result 1: Land distribution inequality was associated with greater negative impacts of population pressure on the conservation of the commons, by increasing the negative effects of changes in farming systems towards less conserving land uses, and by decreasing the positive effects of more sustainable practices due to cheaper supply of labor (See section 4.1 on GIS exercise).

Result 2: Lower exit options, measured by the marginal value from effort not allocated into exploiting the commons, induced greater cooperation within a group given the higher dependence of income on the conservation and use of the commons (See section 4.3 on Experimental asymmetric payoffs exercise).

Result 3: Group heterogeneity based on wealth differences within the group reduced the possibility of devising and sustaining self-governed solutions to commons dilemmas (See section 4.2 on experimental symmetric payoffs exercise).

Result 4: Higher familiarity of an individual with commons use and extraction, associated with lower levels of wealth and exit options, induced a more cooperative behavior under self-governed attempts to solve the commons dilemma (See section 4.2 on experimental symmetric payoffs exercise).

The following table classifies these results by the type of wealth effect, and by the empirical approach:

	Method 1: Spatial Village Cross-section	Method 2: Experiments in the Field Lab
About Individual Wealth	N/A	Result 2: $WTC_L > WTC_S > WTC_H$ Result 4: $WTC_{RealPoor} > WTC_{RealRich}$
About Wealth Inequalities	Result 1: $\partial(SocEfic)/\partial(Ineq) = \alpha + \beta$ (pop.density), $\alpha>0$, $\beta<0$ => at High pressure, $\partial(SocEfic)/\partial(Ineq) < 0$	Result 3: $\partial(SocEfic)/\partial(Variance_{RealWlth}) < 0$

Table (???). Summary of findings by method and wealth factor.

6 Conclusions.

From these results one could infer that poverty in itself is not a limitation to cooperation in the commons. Further, poorer but homogenous groups seem to be willing to cooperate in order to increase their collectively generated individual benefits, even if at personal cost. This however does not invalidate the necessity for addressing problems of poverty and lack of freedoms (Sen, 1999) which affect other issues of well-being, including, eventually the use and management of natural resources. The only claim from these results is that blaming on the poor and not on other institutions that create poverty and mismanagement of commons might deviate the attention away from structural problems, such as inequality.

Inequality, however, does seem to affect cooperation. Heterogeneous groups can find it more difficult to cooperate if, for instance, there are wealth distances in the group that limit the possibility of getting group communication to be effective to build trust, cooperation and a commonly shared goal. Even if all agents depend equally from the commons, inequality and wealth distance within a group can limits cooperation, at least for the case when groups were allowed to communicate and devise a self-governance solution.

Public policy regarding the agricultural sector in much of the developing world has reduced its attempts in directly changing the distribution of wealth towards more equal institutions. A greater attention is being paid to progressive policies focused on the poorest, and on the creation of safety nets. Such strategy surely can change the equality of opportunities and freedoms (Sen, 1999) of the rural people, particularly for the case of the components of their income and well-being that depend on more complete market transactions where the marginal returns on human and man-made capital improve income. However, there is still an important share of their well-being and income that depends on solving collective action dilemmas such as in the case of resources from the commons (e.g. food, energy, water); further, other cases where contracts and incomplete (e.g. rural credit) are still relevant and critical to well-being in the agricultural sector. In these cases inequality in general can have a significant and negative effect in solving the failures and therefore attention to public policies that are aimed at the distribution of wealth should persist, in this case over efficiency grounds besides equity and justice.

The results here presented suggest that the ratio of income sources coming from collective to individual activities does not necessarily explain the emergence of collective action in cases of overuse of the rural commons. Although poverty increases the marginal relative value of a unit of the resource extracted from the commons, the poor can also compensate their less advantageous private alternatives with more effective community institutions to reduce the losses from the collective action dilemma. Through more effective, adaptive, local and self-governed institutions, they leave less money in the table at the moment of confronting the free-riding incentives within their group. However, when inequality is present in the group, other types of difficulties emerge for making these self-governance mechanisms effective and then the gains from cooperation are reduced giving way to the losses from lack of opportunities.

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