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Local Commons and Cross-Effects of Population and Inequality on the Local Provision of Environmental Services

Juan Camilo Cárdenas*

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Introduction

"It is unquestionably true, that in no country in the globe have the government, the distribution of property, and the habits of people, been such as to call forth, in the most effective manner, the resources of the soil. Consequently, if the most advantageous possible changes in all these respects could be supposed at once to take place, it is certain that the demand for labour, and the encouragement to production, might be such as for the short time, in some countries, and for rather a longer time in others, to lessen the operation of the checks to population which have been described."(Malthus, 1830, pp. 247).

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The majority of possible explanations for the tragedies of natural resources for which excludability and rivalry over their use are partial, focus on two major themes, the pressure from increasing population and the problem of assigning and enforcing property rights. On the first theme, there seems to prevail the almost unanimous notion that population growth is nothing less than one of the most crucial threats to maintaining the global and local commons. On the second topic, a vast portion of the literature has focused on the problems of defining and enforcing appropriate property rights over those natural resources under open access by users. But only until recently, less discussed and studied in this second theme is the problem of distribution of those property rights among the direct and indirect users of the commons.

Most agree that the definition and enforcement of property rights over the commons can be rather difficult and costly, which has brought back the interest on alternative forms of management such as community or collective arrangements, different than the conventional individual —private— or state management of resources.

I would like however to focus on the two other topics left, the population and the distributional problems. Furthermore, I will present the proposition that the "population evil" hypothesis about the environment only becomes important and valid when the asset inequality among the users of the commons is excessive, being the latter the real exogenous problem behind the degradation processes.

Moreover, if one looks at the social and economic processes currently affecting the most ecologically valuable areas in the planet —e.g. tropical forests— such claim becomes of central relevance. Natural areas in developing countries are witnessing an increase in population through migration and colonization while the agrarian structure of these countries and regions remain unequal, particularly in the regions more adequate for agriculture and exactly from all these migrants were expelled from by economic and political forces. However, there seems to be more research and policy questioning about the population increase towards tropical forests than on the institutional environment that has created such problems. If the claim that inequality plays a central role on the degradation of the commons, especially under higher population pressures, then redistributional policies should be part of the agenda about defining adequate institutions for managing the local and global commons.

After discussing the recent contributions of the literature on local commons I will develop further the idea that cross-effects between key factors for collective action such as population density and asset inequality may create a different set of predictions than what usually is proposed from a marginal analysis of each alone. In particular, I make the proposition that the effect of inequality on the level of conservation of the local commons is worse, the higher the level of population density in the village. Empirical econometric evidence from a set of 160 small villages in a rural Andean region in Colombia will study the cross-effect between population density and land distribution on the environmental externalities derived from the local commons in the village. The results may suggest a possible interaction between village population density and group heterogeneity in the possibility of cooperation for maintaining village commons such like productive soils, erosion control, natural vegetation, or water regulation.

The theoretical argument will be developed at two levels, one at the village level by looking at the effect of the village institutions in the choices by the group of farmers in technology and land use patterns and how these are affected by the level of population density and the distribution of land. At a micro —farm— level I will also discuss the rationality of the farmer with respect to these decisions —technology and land use— and their relation with the conditions on inequality and population in the village.

I. Population, Inequality and Cooperation for Local Commons Conservation

The fate of local commons such as remaining plots of forests or rural water resources has gone though an interesting variety of predictions from both theorists' models and factual experiences observed by field researchers. At every other moment in time the literature has provided some new specific variable to explain the future of a certain renewable natural resource that presents the possibility of congestion, over exploitation or extinction. From the very beginning with Malthus' predictions in the previous century until the recent works on game-theoretical models of local public goods and commons, certain factors have emerged as possible explanations to why a common pool of natural resources may be managed efficiently from a social view, or why it will be overexploited if agents behave rationally. Population pressures, lack of property rights, and group size, heterogeneity and inequality are the most salient factors in this literature. However, most analyses either from the theory or the empirical evidence discuss how one particular factor —holding all others constant, define if the local commons' fate is its over exploitation or a socially efficient management by its users.

Population pressure has been probably the most old and recurrent factor claimed by authors since Malthus (1798, 1830), but unfortunately it has been one with least innovative approaches,[1] showing the still polarized views between the so called Neo-Malthusians and what could be called the Boserupians[2] claiming that population growth may in fact enhance creativity and innovation for technological shifts to respond to scarcity and increasing demand for food. Notice, however, that Malthusians and the environmental Neo-Malthusians base their argument on aggregate variables and consider individuals as mere consumers of resources who grow exponentially in numbers. No coordination among the individuals to overcome the possible pressures is assumed by these sides.

Even more interesting is how those using the Malthus argument to blame population explosion for environmental destruction would not discuss the distributional element —See quotes in the first page— that Malthus himself mentions along his essay on population.

But other factors have appeared over time additional to the «population evil» hypothesis, attempting to predict the destiny of natural resources that are by nature indivisible, non-rival or non-excludable. The 1960's generated a great set of economic models and predictions on this particular issue, bringing along public policy proposals for natural resource management and externalities control. Property rights has been the focus of more than three decades since Coase (1960) offered a bargaining solution to the problem of externalities. His arguments created a wave of proposals for dealing with externalities derived from pollution and ecological public goods, reducing the solution to assigning private

1 In his most recent book on economic growth and the environment, Herman Daly (1996) states how "it is frankly discouraging to see how little the population discussion has advanced during the last thirty years."

2 From the well known work by Esther Boserup (1965).

property rights in the natural resources that had been under communal or public property. The great impact that Hardin's "Tragedy of the Commons" (1968) had over this debate was probably supported by the Coasian view that only individual —private— property rights could solve the externalities along with two important elements. One, the denial of a variety of other forms of property over natural resources such as communal property by assuming that the lack of individual private property rights meant open access to resources, and the proposition that state intervention most probably did not contribute but worsened the coordination problem.

A great portion of the collective action literature argues further that an increase in the size of the group facing a commons dilemma will reduce the possibilities of cooperation by the members. However, the debate on the role of group heterogeneity and inequality in particular shows more contrasting views. What this paper argues is that these elements combined produce relationships that may contribute to such inconclusiveness. During the same years, Mancur Olson (1965) contributed to the debate with his "Logic of Collective Action" by calling the attention that, under the impossibility to totally exclude and divide the benefits of a collective good, economic agents may cooperate for the socially efficient provision of the public good in a decentralized way. Olson's theoretical work generated a set of propositions and enough controversy to initiate a vast effort from both theoretical and empirical sides to test his predictions about the possibilities that collective action emerges, contrary to the free-riding prediction by conventional economics. Among the most important propositions laid by Olson where the negative effect of group size on the possibilities of collective action, and the more controversial one that group heterogeneity, inequality for instance, may increase the chances that collective action emerges. These arguments generated an immense research effort to develop models and gather empirical evidence to support or contradict such propositions (Sandler, 1992).

The period after Olson's contribution was characterized by a heated debate between the state and the market and private property rights as the only alternatives to solve the problems derived from externalities. The case of the environment and natural resources, probably because of the 1970's social and ecological movement in the industrialized nations, received special attention and a vast effort favoring state intervention, mainly through command and control measures and strengthening the national government control over natural resources gave the state solution a boost. The possibilities for collective action and community management of natural resources remained in the academic arena, and more attacked than blessed.

However, the 1980's and 1990's witnessed a reaction to the predominant views by offering the evidence, mainly empirical from case studies world wide, that Hardin's commons were not necessarily destined to tragic over exploitation, when collective institutions for managing common pool resources could design and enforce clear rules for excluding non group members and for controlling the members' use of the resource (Ostrom, 1990; Berkes (*ed.*), 1989). Furthermore, a revival of old themes and the rising new institutional economics bringing past topics such as inequality with new ones such as information asymmetry, principal-agent relations and game theoretic strategic behavior, opened the possibilities of expanding the debate further on the fate of local commons, and the actual potentials for state, market and community solutions.

A large proportion of the economic literature has resisted the crude separation between efficiency and distribution based on the fundamental theorems of welfare in the walrasian model. Such resistance has shown that when the economic problem presents problems of transaction costs in general —from which externalities and public goods are examples—, the information asymmetries do not allow for pareto efficient solutions. When the conditions for costless transactions are not met and contracts can not be perfectly enforceable, agency problems emerge and sub-optimal solutions result.

Such literature has found in the so called Coase theorem (1960) a challenge to the problem of solving these externalities. Coase suggested that if the affected parties could engage in costless bargaining, and the property rights to either the polluter or affected party were completely assigned, they would bargain over the optimal solution without need of a third party agent to enforce or correct the problem. Originally the Coasian solution would generate a pareto optimal outcome, but Farrell (1987) has proved that such is not the case; that although the parties could engage in bargaining over the externality, the outcome would not be pareto superior due to asymmetries.

Inequality of wealth, income, information or access to certain resources in the economy has been then analyzed through the new 'information economics' paradigm (Stiglitz, 1994) using different approaches and models reviving old but unsolved political economy problems. Bargaining power, principal-agency problems, game-theoretical models have been used for explaining how distribution may affect efficiency in a direct way (Bowles and Gintis, 1996; Bardhan, Bowles and Gintis, 1997).

A. Inequality and the Environment

In the particular case of environmental problems, such models support several arguments where poverty and inequality may worsen pollution and natural resource degradation outcomes beyond the conventional approach of the pigouvian social cost difference.

The role of inequality, mainly wealth inequality expressed through land distribution, has appeared in the environmental debate. An important portion of the debate arises from the vicious cycle of poverty and degradation (Durning, 1989; Leonard, 1985, 1989). Inequality and poverty are closely related, including the rural setting, where landlessness, restricted credit markets and low provision of public services are associated with unequal distribution of land.

Boyce (1994) proposed a power-weighted model in which power differences between winners and losers from the economic activity causing the degradation will determine a different "optimal level of degradation" depending on the marginal benefits to the winners and the marginal damages to the losers. Under such explanation, a positive relation exists between power (associated with wealth) inequality and environmental degradation. Further, Torras and Boyce (1996) tested empirically some of these arguments in a cross-section analysis introducing non-linear relations between per capita income and emissions of several major pollutants. Initially the conventional inverted "U" hypothesis was discussed where income and pollution would increase in a first stage and after a certain point the further income growth would compensate for the excessive damages and will bring down the emissions. They then tested a cubic form relationship expanding the result by finding that eventually an even higher level of income growth —e.g. OECD countries— will cause a rise again in pollutant emissions and concentrations.

In a micro level analysis, Roemer (1994) has shown through a simple model how wealth inequality may increase such optimal level of pollution. His argument shows that the greater the share of an individual in the profits of the pollutant firm, the greater will be his optimal pollution —where marginal benefits from profits equate his marginal disutility from pollution—, and therefore his comparatively higher power in the decision making of the firm will induce such higher levels of pollution.

In a forthcoming volume (2005), Baland, Bardhan and Bowles compiled a set of papers where different mechanisms might be in effect, sometimes in opposite directions, on the relation between inequality and the environment. Policy biases, consumption effects, inadequate provision of environmental public goods in poorer societies, and social distances that impede solving in a self-governed manner the "tragedy of the commons" are examples of processes involved in explaining how inequality can affect environmental outcomes.

This brings us to the problem of solving a local environmental problem when the group externality is generated from the divergence between the individual and group incentives.

B. Local Commons Problems

So far I have discussed some of the arguments where inequality may affect the level of environmental degradation as an externality or public problem for one of the affected parties. However, there is a more complicated problem, traditionally labeled as either of the collective, commons, social, or prisoners' dilemma. In this case, the non-cooperative rational behavior of the individuals of a group will induce a socially sub-optimal outcome, despite them knowing that a coordinated effort would bring the entire group to a socially superior solution. Figure 1 illustrates such situation through a typical model where aggregate flow of benefits from the commons is a concave function of the aggregate effort to extract such benefits.[3] It is usually assumed from biological conditions that after a certain peak, the limited renewability of the natural resource cannot maintain its biological productivity and too much effort extracting products or services from it will reduce considerably its flow of benefits for the users group.

3 In the case of fisheries, total catch is a concave function on the total number of boats -or nets- put in the water for fishing. In the case of a forest, one could think of an aggregate flow of biomass appropriated by the village for energy, fodder, food, which is a function of the aggregate village effort, say, in total number of hours devoted to extract such biomass.

Figure 1 pictures such situation. Assuming increasing costs on effort, two extreme solutions can illustrate the "commons dilemma". On the one hand, the social maximization of aggregate net benefits will control aggregate effort at e_{opt}, by equalizing marginal benefits with marginal costs. In the other extreme there is the "open access" case where the non-cooperative actions by each individual user of the resources pool will find it still rational to add one unit to effort and extract additional benefits from the commons, up to the point where for each individual agent average benefits equal average costs. Obviously such solution will create too much aggregate effort (e_{oa}) and eventually too little aggregate benefits because the ecosystem is over exploited.

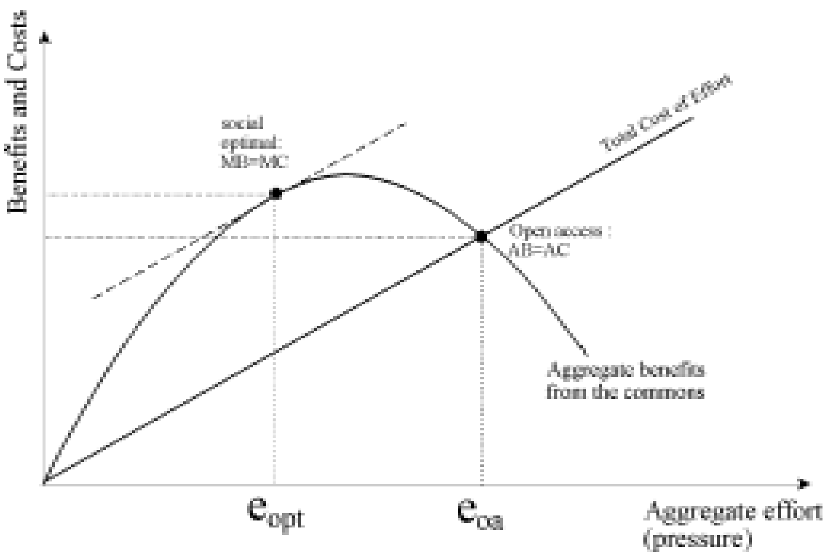

Figure 1. *Flow of aggregate ecological benefits from the local commons as a function of aggregate effort—pressure—*

Although still useful for the discussion, both extremes have proved to be unrealistic. The open access outcome predicts that individual behavior will exhaust a resource because it assumes that there are no social forces, norms or institutions —formal or informal— that protect the collective interest, at least partially. The social optimal solution, even if defended only through the private solution of assigning all property rights and residual claimancy on one authority is also unrealistic because the transaction costs and enforceability of such property rights will limit the possibilities to fully internalize the externalities.

In the environmental discourse the popular "Tragedy of the Commons" by Garret Hardin (1968) popularized this view through a situation where the users of an open access renewable natural resource would end up exhausting it due to their individual rationality. However the Hardin's situation was characterized by rather extreme conditions, namely that the users would not engage in any coordination actions to overcome the problem, and that the property rights were basically non existent over the resource. Most local commons problems, however, involve a certain level of exclusion for non-members of the group, and property rights are at least partially enforced. Cornes and Sandler (1983; 1986) and Cornes, Mason and Sandler (1986) have proved, however, that Hardin's tragedy will not result from his original prediction, yet, the over extraction of the commons will happen. In their model they show that an optimal number of firms or users will result, beyond which is not rational to assume the costs of extraction and benefit from the open access resource. Thus, exhaustion may not happen as predicted. However, these models mentioned, again, ignore the possibility of coordination of the local commons users to solve the dilemma.

Thus, our focus of interest in this paper is to study how inequality and population pressures may drive the level of aggregate effort and productivity from the commons closer to either the social optimum or the "open access" solutions.

C. Inequality and Local Commons

The recent developments on the possibility that groups using a common pool of resources may engage in collective actions to solve the coordination failure, has found in the group heterogeneity issue a source of thought for studying the problem of inequality among the members of the group. One starting point of such discussion is Olson's claim that group heterogeneity will increase the likelihood that collective action emerges. In the Olson's explanation, the argument is based on that in a privileged group the wealthier members who comparatively have more interests in the public goods from cooperation, will contribute more to its provision, and the less privileged will then be able to benefit from such cooperation.

However, there are contrasting views suggesting that asset inequality could diminish, rather than enhance, the provision of the public good by the individual contributions of the members of the group (Dayton-Johnson and Bardhan, 1996; Baland and Platteau, 1996; 1997; Bardhan, Bowles and Gintis, 1997).

Their response, in general, to the Olsonian prescription, is that the net effect of the privileged group in the final local commons outcome depends on several other factors, and that it may not be necessarily positive. Dayton-Johnson and Bardhan, for instance, raise the possibility that rich members may exit the group attempting to provide the public good rather than cooperate or free-ride on the provision by others. Baland and Platteau, on the other hand, argue that although the wealthier users may indeed have a greater incentive to cooperate, other issues involved in the problem may affect the net result. Not all the situations may be better expressed as PD games, they claim. Imperfect information and different forms of social regulation may change the rules of the game generating other types of results.

Bowles and Gintis (1996), and Bardhan, Bowles and Gintis (1997) argue that asset inequality undermines efficiency-enhancement possibilities because of the asymmetries and the costly enforceability of the contracts between the agents sharing the externality, being in this case a public good ecological externality among the local commons users. Furthermore, and as in the case of Dayton-Johnson and Bardhan, these works claim that different types of inequalities —e.g. assets, exit options, power to enforce, fallback position— generate different effects on the equilibrium result, and therefore different types of redistribution will be more effective than others in the social outcome, being in this case the achievement or failure on preserving the local commons resources.[4]

4 The rural inequality and poverty questions are then somehow relative. In a methodologically interesting paper in World Development, Reardon and Vosti (1995) —"Links between rural poverty and the environment in developing countries: Asset categories and investment poverty"— argue that there are several types or components of asset poverty in rural contexts, and each of them may have a different relation with possible environmental outcomes. Rural poverty could be in terms of natural resources assets, human resources poverty, on-farm, and off-farm assets — physical and financial—.

More recently, Cardenas (2003) and Cardenas *et al.* (2002) explored using experimental methods how heterogeneity among group members may have an effect in this endogenous solution to the collective action dilemma of an environmental problem at the group level. On the one hand these experiments found that social distance among players restrict the capacity to trust others in the group, being trust and reciprocity key engines of cooperation. On the other, when asymmetries exist among the group members, and contrary to the Bersgtrom, Blume and Varian (1986) prediction, we found, similarly to Chan *et al.* (1996, 1999), that those with poorer private options and whose income is more dependent on collective actions with others, were more likely to cooperate or provide the public good.

Baland and Platteau (1997) suggest a model to explain the collective action problem that a group of farmers may face when dealing with soil erosion control practices —e.g. anti-erosive barriers—.[5] Typically, an isolated contribution by investing in a barrier on one's farm will not contribute to increase the state of the local commons —soil quality—, unless a sufficiently large number of farmers in the village undertake such investment. Their results show that different Nash equilibria emerge depending on several assumptions in the model. A first result shows that the individual's incentive in investing in the local commons is an increasing function of the number of cooperators in the village. On the possible equilibria resulting from the model there is the tragedy of the commons outcome where non cooperation is a Nash equilibrium, yielding a pareto inferior result although the collective result of cooperation is pareto superior as in any PD game. However, the opposite extreme of the spectrum shows that when the individual investment cost is low enough, or the expected benefits from such cooperation are large enough for the smallest of the farmers, there will be sufficient incentives for individual —non-cooperative— cooperation and therefore individual and collective efficient outcomes result from all individuals building the erosion control barriers. The possible outcomes in between these extremes, coordination failures as they label them, will present different equilibria situations with respect

5 Other types of local commons are mentioned in the paper such as watershed management, wind erosion control, water erosion control, fishery management, forestry management, and weed and pest control management. All of these involve a typical collective action dilemma situation at the village level.

to the incentives required for individuals to cooperate depending on several factors modeled. Of particular interest for our discussion is the case where non-identical agents interact in the village. Their model shows that the net effect of land inequality in the incentives for landowners to invest will be the result of two effects working on opposite directions. The large landowners will have an extra incentive in conservation measures given their larger stake in the village local commons. However, such inequality also reduces the incentives by the smaller landholders who see their incentives to cooperate reduced. The result is then inconclusive, and therefore they argue that policy interventions in the agrarian structure would not have a definite effect on the incentives for village members to contribute to the conservation of local commons.

Baland and Platteau (1997) discuss the effect of population on the possibility of cooperation by community members. Compatible with the Neo-malthusian argument, their model shows that as the number of landowners increase in the village, the individual incentives to invest in the local commons are reduced. The argument they use is that the endowment by each farmer is reduced with the increased number of holdings, reducing the expected gains from the local commons, and therefore the equilibrium moves from the extreme of unconditional cooperation by all members to the extreme of the tragedy of the commons outcome —page 206—. In other words, an increase in the size of the village population is interpreted solely as a reduction of available per-capita land which in turn increases the pressure over the local commons.

However, this and other similar arguments under the "population evil" environmental argument, do not account for other processes involved in population sizes at village levels. Most of these views assume only the "demand" side of the village population size, i.e. the indisputable fact that greater populations demand more aggregate volumes of matter and energy from their surrounding ecosystems for food, fiber, firewood, inputs and other. However, there is a "positive" side to the problem, the possibility that larger groups of people can engage also in actions that reduce the negative effects of extracting matter and energy from the local commons. A partial or total equilibrium model of the village may look at the substitution effects between labor and capital in the farms village and how this has an effect, for instance, in the amount of soil or water contamination caused by manual weeding vs. pesticides use. Moreover, one can argue, for instance, that dense villages may have associated greater frequency of interactions among the village members rather than unpopulated ones. Therefore, eventually a positive relation between village population and frequency of interactions could increase the possibility of reciprocal behavior that usually results on choosing nice tit-for-tat as Nash strategy in repeated games, increasing the possibilities of cooperation for preserving the village local commons.

I shall discuss these issues in more detail when I introduce the theoretical discussion and empirical evidence that there might be some cross-effects between population side and land inequality that could improve and expand the results emerging from this literature.

Before doing that, however, it will be very useful for my argument to mention the important contribution that empirical work can make for the discussion. Although it seems widely accepted now that the conventional prediction of an unconditional free riding outcome resulting from public goods or commons type of problems is very unlikely in the actual world, the levels of non-free-riding and the conditions for individuals not to behave as such, are still under debate.

D. Field and Experimental Evidence on Cooperation, Commons and Collective Action

The observation of the behavior of people facing coordination failures in the real world has been made through two major strategies by economics and other social sciences. Field work usually through closer but descriptive and qualitative analysis of case studies on certain villages, or local commons situations; and economic experiments run in more controlled settings. Both of these have backed in a great deal the argument against the —homo-economicus— free-riding model. Some of the most important contributions from these empirical works can be briefly mentioned.

Ostrom (1990) and Berkes (1987) have been extensively cited for their collected evidence on several contemporary cases where communal management of natural resources has succeeded despite severe constraints from the nature of the local commons, constraints from the definitions and enforcement of rules by the user groups, or constraints from external conditions threatening a communal arrangement.

Another two widely known and cited works are Wade's "village republics" study in India (1988), and Putnam's (1993) study of the institutional performance on different Italian regions. Putnam's concept of Social Capital has expanded the possibilities of considering nonmaterial or intangible forms of productive capital in local levels, which plays important roles in the provision of public goods at local levels. These works have also opened the door to introducing the issue of community participation and involvement in the economic analysis of the provision of public goods which is extensively ignored by the fiscal and public policy literature, particularly on local public goods despite the empirical evidence showing the link between community involvement and the outcomes in terms of coverage and quality of the services.

The other important source of empirical evidence that strengthen the arguments for people being able to overcome Prisoners' Dilemma situations is the vast work with experimental economics, particularly public goods experiments, aimed at identifying the individual behavior of agents when facing coordination failure situations.

Ostrom, Walker and Gardner (1994) have compiled several years of empirical and experimental work on common pool resources and provide some suggestive conclusions about the conditions under which groups will be able to self-regulate in the use of a common-pool without over harvesting it. Among the most relevant results from this work is the enhanced role of communication among group members prior to the individual decisions, and beyond the "cheap talk" assumption (Ostrom, 1997). [6] "Exchanging mutual commitment, increasing trust, creating and re-enforcing norms, and developing a group identity appear to be the most important processes that make communication efficacious".

Other forms identified in these studies as explanatory of the capabilities of common-pool self-governed by groups are the innovation in the creation of a variety of norms and rules, and the use of resources for monitoring, punishing and rewarding individual behavior. Reciprocity norms, which appear to be central from the experimental evidence worldwide, are strong factors in determining the behavior of group members when facing a collective action dilemma.

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6 Ostrom (1997) mentions a "[...] meta-analysis of over 100 experiments involving over 5,000 subjects, [where] opportunities for face-to-face communication in one-shot experiments significantly raises the cooperation rate, on average, by more than 45 percentage points."

In a recent work, Moir (1997) has taken from Ostrom, Gardner and Walker (1994) to deepen into the issue of monitoring and sanctioning in common-pool resources. Within the same common-pool model, he compares the baseline model where no communication is allowed and a typical commons problem exists, with two alternatives, one, that group members may monitor the behavior of the others, and another, where members can sanction the non-optimal behavior of others. The main results suggest that monitoring alone may not help correct the coordination failure by reducing the aggregate level of extraction from the common-pool or by increasing the efficiency gains, but sanctioning involving the actual enforcement of rules is in fact effective in controlling extraction levels and increasing efficiency.

E. Emerging and Contrasting Elements: Population Pressure, Group Inequality and Group Composition

Bardhan (1993a, 1993b) discusses how the characteristics within the group have different effects on the possibility that local commons be wisely managed over time by rural communities, and the emerging evidence from experiments, the field and theory about cooperation or over-use of the local commons. I presented before an important portion of the literature on how inequality can affect the possibilities that communities, particularly rural, engage in collective actions to manage their local commons. Wealth or asset inequality makes part of the broader concept of *group heterogeneity*, which Olson (1965) has argued to increase the chances for collective action when the more privileged members of the group may have an additional incentive to invest in the local commons even of such action may generate positive externalities to the poorer members of the group. The contrasting literature on productivity enhancing redistributions has argued, however, that inequality can undermine such possibilities because of the nature of the possible contracts within the groups which includes costly enforcement and non-observability of some of the key variables.

There is however a third element in which both the Olsonian view through the concept of group size, and the game-theoretical approaches such as Baland and Platteau with the number of land owners, could agree on its effect on collective action. Most approaches have been arguing that an increase in population and therefore an increase in the number of members of the community would undermine the chances of collective action. The population issue in the collective action problem is therefore one more variable in the even broader concept of *group composition*.[7] Inequality within the group and the size of the group, relative to the resources available to them, make part of the group composition. As I will argue later, the interaction of population and inequality factors in the group composition may have different effects on the potentials for cooperation from within the group members.

One clarification should be made at this point. Although related, group size and population pressures are by definition different concepts. While a large portion of the collective action literature on the commons focuses on the limits that group size impose in creating conditions for voluntary cooperation by members, I would rather focus on the problem of population pressure.[8]

It is important at this point to highlight that most of the models have a micro level of analysis and the incentives for conserving or overexploiting the local commons are looked at from the perspective of each individual household in the village. Although the recent literature has made a great step by introducing the strategic behavior by the individual and therefore be able to model the prisoners' dilemma situation in a more realistic manner, the net result on the superior level, the village, is still inconclusive from micro models as Baland and Platteau (1997) argue when closing their paper. The effect of individual actions on a village local commons is looked from the perspective of each of the village members but not on the net effect of the aggregate of the village members. The same argument would apply to the case of Roemer's model (1994). Although the willingness to control the public bad —erosion— by the landowner is reduced by his share in the sharecropping contract, one could not derive the conclusion that villages that have sharecropping contracts giving greater shares to landowners will necessarily have higher levels of "equilibrium erosion".

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7 Sandler (1992) has suggested that future research on the role of group composition in collective action; Dasgupta and Itaya (1991) cited by Sandler, and Schwab and Oates (1991) have provided some first steps in such modeling when community members are heterogeneous.

8 Sam Bowles -personal communication- provides a useful separation by suggesting that while population density reflects the degree of the environmental challenge, group size relates to the political challenge for collective action.

Other factors that are played at the village level —group effects— may intervene also in the landowner's contribution to the conservation of the local commons and are not necessarily captured in these models. In the case of heterogeneous groups with asset inequality, for instance, one could not look at the net impact of the positive and negative effects at the village level in the local commons, because the winners and losers of inequality will have different incentives in conservation measures, and the net effect on the village local commons will be the aggregation of the effects of the actions by each type, and the number of members on each group in the village.

Thus, the final effect of the actions by the members of a group in the conservation or degradation of the village local commons could not be entirely looked from the standpoint of one member's optimization problem if one does not look at the aggregation of the net effects by the different sub-groups in the community, particularly if group heterogeneity is higher. The net effect of individuals' actions in the local commons is a village —meso-economics?— problem. Therefore, the specific condition of a local commons is the result of both the individual rationality of the members, which in part depends on their strategic behavior with respect to the rest of the group members, but it is also the result of the aggregation of the effects from each of the sub-groups that compose the heterogeneity of the village.

The question then is whether the conservation of the village commons is the result of autonomous individuals' cooperation —non-cooperative—, or the result of stronger village effects —e.g. social norms—, or the unintended effect of the sum of benefits and costs imposed by each of the subgroups whose decisions affect its conservation. This question I do not pretend to respond, but it seems that both processes play an important role, and probably a complementary one. Villages where individual's preferences involve certain type of cooperative or communal traits may find it easier to maintain group norms that are beneficial to the conservation of the local commons. Such norms, however, would find it better to survive in villages where individuals' utilities involve only selfish elements.

The recent empirical study by Sampson *et al*. (1997) on the Chicago neighborhoods would be compatible with such argument in the sense that both individual and neighborhood level factors determine the public goods outcomes, being in that case the neighborhood public safety. In their study, social norms and social capital, along with individual socio-economic conditions, explain the levels of cooperation by the individuals in self-governing some of the local related violence.

A key element of the discussion that remains to be clarified is the causality of these individual and group factors. At a first glance it seems that some vicious or virtuous cycles may arise between individuals' preferences and community social norms. However it does not explain the direction that the system would take if one of the factors is changed. It seems that an evolutionary theory may contribute in this area by studying, for instance, if a more individualistic strategy of free-riding on a local commons attempted to invade a community with strong village values regarding the conservation of their watershed or forests.

Finally, it is important to highlight that most of the models studying the incentives for collective action from the individual perspective need for tractability purposes to assume certain variables to be exogenous to the individual's choices. In the case of agriculture, for instance, technology expressed in terms of land use patterns —crops, pastures or forests— or in terms of production relative inputs is generally assumed as constant. However, field observation of rural villages shows how decision making at the household level regarding both the portion of the land for different land uses and inputs use greatly changes across time and villages and in many cases as response to several exogenous changes in prices, climate or other social conditions. The empirical evidence presented later shows such a case, and further, it explains an important portion of the status of each local commons in each village.[9]

II. Farm and Village Models: Why There Might be Some Cross-Effects Between Population Density and Group Heterogeneity in the Village?

The argument will be presented initially by the discussion of theoretical elements from prior models, and then supported empirical evidence. To develop

9 Water, soil and forest resources are directly affected by the farming system decision by the household. The relative shares of land devoted to pastures, crops or natural vegetation, as well as the use of certain inputs and byproducts from agriculture and livestock have severe on-farm and off-farm impacts in the village.

this hypothesis I will use the case of a rural village that shares certain local commons resources expressed through the status of forest, soil and water resources combined. Group heterogeneity will be associated to the distribution of land, and population density to the number of households in the village, relative to land available.

The basic notion of the cross-effects developed here is that the marginal effect of population density on the conservation of local commons is determined by the group heterogeneity, or conversely, the relation between group heterogeneity and conservation of the local commons is mediated by the size of the population in the village, relative to the quality of land. In particular I propose that villages with more equal access to land should make the population pressure effect have a lower association with the degradation of the local commons.

In order to develop the argument I shall start at the farm level by looking at the decision making by any farmer in the village who has access to the local commons. Then I will look at the village level and discuss some implications of the farm-level results.

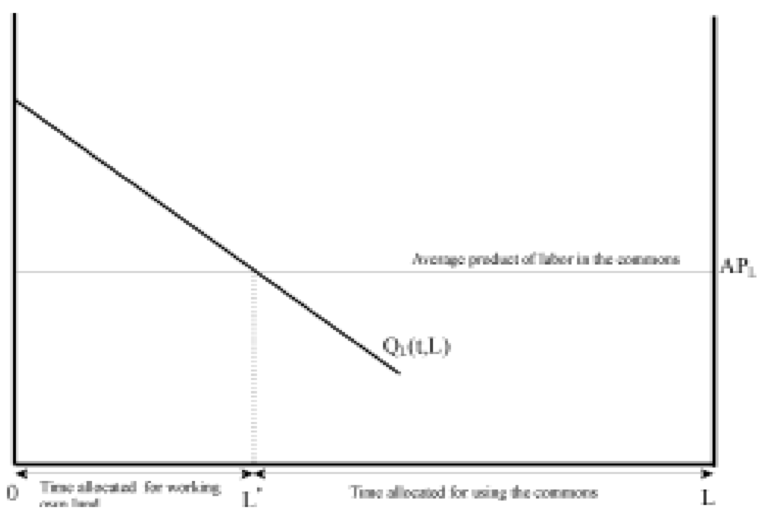

Figure 2. *Optimal allocation of time between the commons and own land*

A. The Farm-Level Decision Making[10]

For the analysis to follow, and for purposes of simplicity I will assume the baseline scenario where the commons or common-pool resource level of excludability and rivalry reflects the case for an open access resource rather than a community-managed resource, closer to the —OA— solution in Figure1, i.e. at zero rents. However, a more realistic analysis should be aware of institutional forms of regulation where farmers can be restrained from the open access solution and allow for coordinating the community's aggregate effort to manage the resource.

Assume an average farmer for whom the production function depends on his own land (t, fixed)[11] and available labor time (L). Let us assume further that $Q = Q(t, L)$ where Q_t, $Q_L > 0$, and $Q_{tL} > 0$. Thus, when looking at the time allocation problem —see Figure 2—, the farmer will allocate his time at L^* where the marginal product of labor in his own land $Q_L = AP_L$, where AP_L is the average product of labor on the commons. The remaining amount of time $(L - L^*)$ will be allocated to effort into extracting benefits from the commons. Notice that the larger private land will shift the $Q_L(t,L)$ 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 may have enough land that it is not necessary for her to allocate 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 $Q_L(t,L)$ to the left. This will add to the aggregate effort (e) in using the commons and therefore will decrease its aggregate flow of benefits. Such situation will reduce the average product for users due to overcrowding of the resource, shifting AP_L 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

10 See Weitzmann (1974) and Baland and Platteau (1996).

11 The inverse of population density (p) defined as number of households divided by the total village land is precisely $t = 1/p$.

AP is flat—at maximum—and MP is decreasing, $\partial MP/\partial L > \partial AP/\partial L$ (Henderson and Quandt, 1980, pp. 68).

Let us think now on the effects of a change in the land distribution in a village. Assume 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 ($L^* = L$), i.e. they would not need to use the commons. Assume then that after a redistribution of land, one of the farmers ends up with 3/4of the land leaving the other with 1/4. While the average land per household remains constant at 1/2, the aggregate use of the commons changes because now the smaller farmer (with t=1/4) will allocate part of her time in the commons which is shown by a shift of $Q_L(t,L)$ to the left.

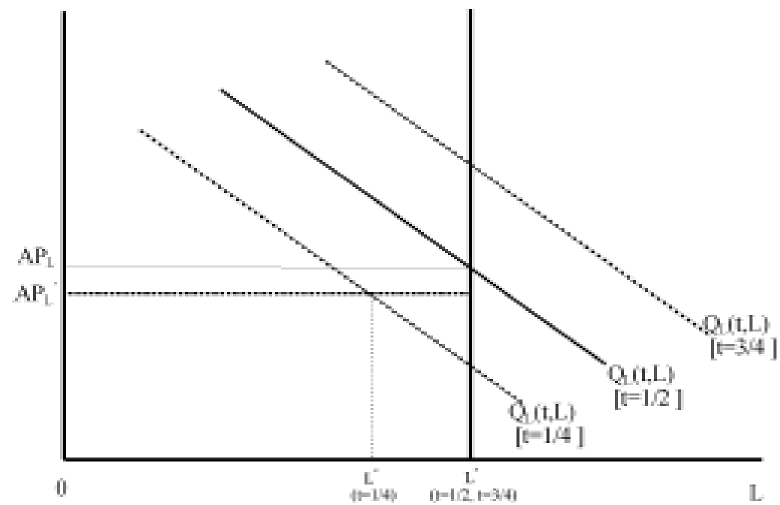

Figure 3. *Changes in commons use from a change in distribution of land*

The basic notion that inequality increases the negative diseconomies created by larger use of the commons is compatible with other works earlier discussed such as Boyce (1994), Roemer (1994), Bardhan, Bowles and Gintis (1997), Dayton-Johnson and Bardhan (1996), Baland and Platteau (1996, 1997).

B. The village-level effects

The results above lead us to an expression of the village common's production of environmental goods and services (B) as a function of the actions taken by the farmers in both their own land and the open access commons, and the institutions in the village. The individual farmer's actions affect B in several ways, for instance, through their direct effort in extracting from the commons (C) biomass —firewood, logging, food, fodder, etc.— and water, among others. On the other hand, the farmer's actions in their own land affect the local commons water and soils, for instance, by increasing their use of fertilizer and pesticides, or by causing soil erosion through intensive crops and livestock land uses (P). Meanwhile, institutional parameters such as inequality will determine those technological choices through relative input prices and access to land.

For simplification purposes let us define B as:

1. $B = B[C(g,t), P(w)]$, where $B_C < 0$, $B_P < 0$,[12] where:

$C(g,t)$, is the village aggregate level of effort put into extracting 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 discussed in Figure 3.

$P(w)$, the village's area in pastures as land use, which is increasing in wage ($P_w >0$) based on the assumption that as labor becomes more expensive, farmers should shift from land uses like crops to less labor intensive land uses such as livestock.[13]

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:

2. $B = B[C(g,t), P(w(g,t))]$

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:

12 The marginal effects BC and BP can be thought as marginal damages to the ecosystem from an additional unit of resource extraction and an additional unit in pastures expansion respectively.

13 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 the curve a change in wage will create a much larger effect in land uses inducing a major switch from crops to pastures, after which the function P(w) becomes now concave, yielding therefore an S-shaped function.

$$3.\ \partial B/\partial t = B_C . C_t + B_p . w_t$$
$$= (-)(-) + (-)(+)(+) = ?.0$$

From which no unique sign can be derived. The reason for this result is that two opposing effects ($B_{C'''}C_t$ and $B_{p'''}P_{w'''}w_t$) are interacting when the average per family farm size t —inverse of population density— changes. According to (3), 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 Neo-Malthusian 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 $B_C C_t > B_P P_w w_t$. 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 $B_C C_t < B_P P_w w_t$.

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 ($B_P P_w w_t$) get overpowered by the population pressure effect ($B_C C_t$). The reason for this is that at high inequality, as we proved before, the landless and near-landless 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 (3) 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 $B_C C_t < B_P P_w w_t$. 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 fertilization and pesticides.

Graphically, the argument can be presented through the following figure (4) 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—.

Summarizing the results, 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. The next step should be to test these hypotheses econometrically and discuss the implications in the next section.

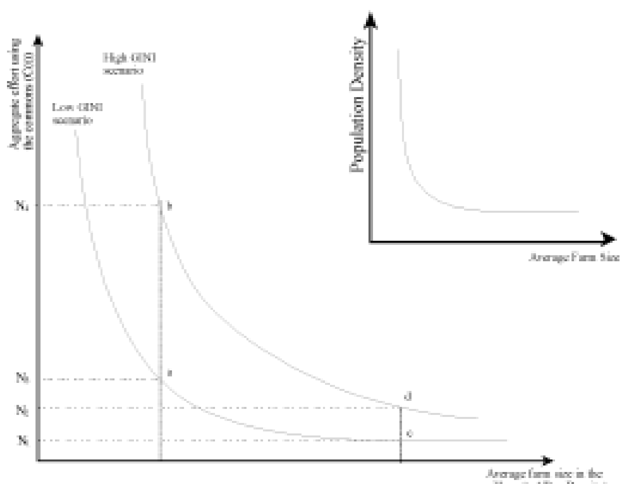

Figure 4. *Average farm size and level of pressure into the commons*

Table 1. *Cross-effects of inequality and average farm size — population density*[1] —
Basic equation: $B = B[c(g,t), P(w(g,t)]$

Increase in population density (decrease in t, t= Population Density^{-1}	Low Inequality (g) $\delta B/\delta t<0$	High Inequality (g) $dB/dt<0$
Dominant Effect	$Bc\ Ct<Bp\ Pw\ Wt$ Shift to sustainable farming practices and land uses from higher use of labor.	$Bc\ Ct>Bp\ Pw\ Wt$ Increase in the aggregate use of the commons.

III. Empirical Evidence of the Cross-Effects of Inequality and Population Density in the Andes

A first observation of the variability across villages within a rural region in Colombia will yield some first ideas of how the variables involved at household and village levels interact and affect the village commons.[14] Why a region with similar bioregional characteristics, ecological carrying capacity, common historical process and macroeconomic policies and constraints, and relatively homogeneous ethnic background, may present across villages a high variability in environmental degradation, farming systems, population density and land distribution? This is the case —and not an exception— of a rural Andean region in Colombia, the Chicamocha region, consisting of 17 municipalities and around 160 *veredas* —villages— for which a comprehensive ecological and socio-economic study was undertaken between 1990 and 1994 (Baptiste *et al.*, 1993; IDEADE, 1995; Cardenas, 1994).

Several explanations for having different levels of environmental degradation across villages could emerge from several sides of the environmental discussion. Many may argue that the higher population density creates pressure over the ecosystems, usually within the Neo-Malthusian argument. As I will later show, there is not a monotonic negative relation between these variables for the region studied, and consistent with the model developed earlier. Others would claim

14 This in fact, the personal experience of the author visiting several of the villages in this region, originated the ideas behind this research. The ecological diversity found in the tropical Andes is complemented with a social diversity in terms of the variety of institutions defining the technology, population and land distribution across villages, even within a same municipality.

that the change in technology towards more "green revolution" farming systems creates greater degradation, which, however, does not explain entirely the results for this region. Some could even offer an ecological explanation through the carrying capacity of the specific ecosystems. However, different environmental outcomes coexist for ecologically similar areas.

At the village level, the following villages —See Table— show the variability of technological, institutional and environmental outcomes. A comparison of how land use patterns (PCROPS, PPAST) vary along with the population density (POPDEADJ) and the distribution of land (GINIADJ) may explain the adoption of more or less sustainable practices (SPRINDX). The dominant farming systems are also dissimilar. Notice for instance the cases of CUCO and DIMISA, two villages within the same municipality. With opposite situations with respect to population density and distribution of land, the quality of their commons varies considerably, and it is related to the technological choices in farming systems and land use patterns. The econometric evidence to be presented later on will clarify such relations with stronger and more comprehensive evidence.

A closer look inside the village should help clarify these situations. Notice that the indicators being used are village level variables, and as such are the net result of different types of farming systems and land uses within the village. In fact, the observation of these variables led the IDEADE research then to lower the level to the household and the farming system to understand the logic of these ecological, technological and institutional factors.

A first approach to the interaction of the variables suggested that the choice of farming practices and land use patterns is determined by the available natural capital in the farm, and institutional factors such access and tenure of land, labor and other inputs availability, determined also by income. Such decisions should then generate different effects into the off-farm and downstream components of the village commons. Examples are water and soil contamination and erosion, loss of natural vegetation, among others. These side effects from the farming systems determine then the level of sustainability at the village level in terms of a reduction of the available natural capital for present and next generations on the one side, and the reduction of land productivity, income or malnutrition on the community members.

Table 2. *Selected village's different combinations of land distribution, population density and quality of their local commons*

Variable *	Variable range	Region means	id=169 Vereda CUCO 83 households	id= 258 DIMISA 223 households	id= 32 CARRASPOZAL 16 households	id= 32 CORTADERA 112 households
Population density Households/ha.-adj (POPDENAD)	> 0	0,0923 0,2170 (adj)	0,1460 0,2745 (adj)	0,5718 1,0502 (adj)	0,0398 0,0859 (adj)	0,0234 0,0538 (adj)
Land inequality (GINI adjusted) (GINIADJ)	(0,1)	0,541	0,7272	0,3527	0,2579	0,6762
Land tenure Index (TENUINDX)	(0,1)	0,5133	0,0003	0,4599	0,6004	0,516
Farming system's technological sustainability (SPRINDX)	(0,1)	0,2468	0,109	0,4064	0,2584	0,2575
Land use pattern —Crops area %— (PCROPS)	(0,1)	0,1856	0,192	0,7498	0,2163	0,0394
Land use pattern —Pastures area %— (PPAST)	(0,1)	0,4343	0,61	0,1907	0,7836	0,1907
Natural Capital Index (NKINDX)	(0,1)	0,4379	0,4739	0,4956	0,4554	0,4389
Index of invironmental goods and services (BSAINDX)	(-1,1)	-0,1286	-0,6447	-0,0558	-0,1149	-0,0566

*See the table's footnote in page 105 (lower section)

A. Population and land distribution in the Chicamocha region

The following table introduces part of this argument by suggesting first that households may choose different farming systems —sustainable or unsustainable ones— depending on the institutional setting they are facing in their villages. Moreover, certain institutional variables may be more compatible with some farming systems than others. For instance, farming practices that enhance the long-run soil productivity by controlling erosion may be more compatible with villages where land tenure and access can be secured and less likely in villages with absentee large landholders fearing that environment enhancing practices by sharecroppers may undermine the owner's property rights over the land. Another case is when the local labor market may interact with the farming practices.[15] More populated villages will create a higher supply of labor, reducing the use of chemical inputs for fertilization and pest control and increasing labor intensive practices —e.g. manual weeding— that cause much less impacts on the ecosystems.

In general, according to the argument in the table, farmers will find it more adequate to choose farming practices, inputs use, and land uses, more compatible with the type of institutions in the village and therefore stable scenarios would be me more likely to be A and D in the diagram.

Although it might be clear how wealth inequality may undermine the possibilities for conserving the local commons, it does not necessarily mean under this argument that villages with greater inequality will have proportionally lower levels of conservation of their ecosystems. In fact the observation of the data from this region does not support this claim. Moreover, it does not support either the Olsonian claim that inequality improves the level of conservation through the privileged group effect.

* NOTE FOR TABLE 2 (PAGE 104): Later on I will introduce in detail the variables of the model, but for clarity purposes some short definitions may be useful. The Natural Capital Index reflects the status of biodiversity, resilience and biological productivity of the village ecosystems. The Land Tenure Index measures the degree of ownership by the operator of the farm, and at the village level a area-weighted average. The Farming system's technological sustainability measures the degree of sustainable practices within the farms. The Index of environmental goods and services (BSAINDX) measures the state the village "local commons" through a degree of environmental goods or bads from the conservation or degradation of water, soil and forest resources respectively

15 Daily labor mobility across municipalities and even villages is unlikely due to geographical and infrastructure conditions. Except for specific harvesting and planting peaks, most labor supply within villages comes from the existing households

Following the table and diagram above, I should be able to introduce in more detail the argument that population density and land distribution —or group heterogeneity— may interact in determining the individual effect that each of these have on the level of conservation or degradation of the local commons in the village.

The following Table 4 provides some of the ways that these two variables seem to interact in these villages. Assuming only two options or extremes —low and high— for both variables, we could combine some of the most important contributions from empirical and theoretical works.

Therefore, introducing the possibility of these cross-effects, several of the alternative explanations may still be valid, but under more specific conditions. For instance, the privileged group explanation by Olson (1965) could accepted for cases where the population to land ratio is low enough that the negative effects from inequality on the commons be overpowered by the positive investments by the privileged ones. Without invalidating such possibility, a severe inequality when the population size is greater would create through the same balance, a net negative effect on the commons due to the greater effect of the poorer pressuring over the natural resources for subsistence.

Table 3. *Interaction between institutions and farming systems*

Institutions	Farming systems (imputs, outputs, practices, land uses)		
	Weak- unequal: -Unclear definition of property rights -Unequal distribution of land and landlessness -Restricted access to rural credit -Free riding yields high individual benefits	*Scenario A —Stable—* "Tragedy-of-the-Commons" or "Prisoners' Dilemma" "Tragedy of the Commons" - Prisoners' Dilemma scenario: -Property rights undefined or unclear -Free riding on public —open access— lands to over extract forest products and services. -Low use of local labor inducing migration	*Scenario B —Unstable—* -Sustainable farming systems cannot persist since restricted access to land and other resources induce shifts to technologies that yield short run returns for subsistence May evolve to scenario A

Continue...

Table 3. *Continuation*

	Farming systems (imputs, outputs, practices, land uses)		
Institutions	Strong-Egaliatirian: -Access to land and credit -Cooperation and community participation is socially valued and recognized -Free riding is socially punished	*Scenario C —Unstable—* -Higher —cheaper— supply of community labor induce substitution of external —chemical— inputs for labor and other local resources. -Social valuation of cooperation and access to resources may induce a shift to technologies that encourage conservation and higher provision of environmental goods and services. May evolve to scenario D	*Scenario D —Stable—* "Cooperation-Collective Action" -Conservation of water, soils and forests. -Common Property Regimes evolve and succeed. -Social and biological diversities empowered. -Higher use of community labor -People's cooperation for conservation offsets pressures over environment from people's needs for food, fiber and energy

Table 4. *Cross-effects between population pressure and inequality —group heterogeneity—*

		Population density	
		High	Low
Community Inequality (Group Heterogeneity)	High GINI	Tragedy of open access resources: —Bardhan, Bowles and Gintis; Baland and Platteau— -Demand pressures from the powerless and landless prevails —needs for fiber, food and energy—. -Less village area under sustainable farming systems. - Land constraints induce higher pressure over scarce soils, water and vegetation.	Privileged effects —Inputs prices hypothesis—: Low wages paid by landlords allow them to substitute capital for labor. Less us of chemicals, higher use of labor. —Olson hypothesis—: -Powerful landholders derive greater benefits from conservation, and depend less on land under agriculture production. -Smaller pressure from fewer landless farmers over commons. -Lower wages paid by landlords increase labor intensive practices, lower capital —chemical— intensive farming systems.
	Low GINI	Cooperation-adaptation-Innovation —Boserup hypothesis; Efficient redistribution Bardhan, Bowles and Gintis— -More village area under more sustainable practices. -Higher —cheaper— supply of village labor required for sustainable practices.	Higher cooperation Inconclusive zone? —Baland and Plateau—

B. Econometric Evidence of the Cross-Effects

The econometric analysis could be performed by using the spatial data set constructed during the mentioned study in a rural Andean region in Colombia, in the middle of the Chicamocha (Boyacá) watershed (IDEADE, 1994, 1995). A general model was developed to explain, through a system of equations, how rural institutions, farming systems technology and land uses interacted with natural capital determining the level of conservation or degradation of a village. The statistical unit was the village, and the data set was constructed using Geographical Information Systems —GIS— in order to overlap different layers of ecological and socio-economic data collected through an exhaustive field work and the use of remote sensing techniques —aerial and satellite images—.[16]

Such systemic approach inspired the following system of equations that could allow a statistical analysis of these relationships. The system of equations Table 5. Variables description and statistics (n=161 villages —*veredas*—)I, IIa, IIb, IIc,IIIa, IIIb— corresponds to a recursive system, and therefore could be estimated using ordinary least squares for each equation independently. The last equation (IV) is then the reduced form of the system and can also be estimated using OLS. The description of the variables used in the estimation is presented in Table 5.

Table 5. *Variables description and statistics (n=161 villages —veredas—)*

Description	Data sources and method	Mean	Standard Deviation
BSAINDX: Index (-1,1) of the net state of the village local commons in terms of water, soil and forest resources. It reflects the level of environmental goods or bads either downstream or on-site within the village.	Map of environmentally critical and valuable areas based on the "landscape ecology" approach (IDEADE, 1992).	-0,1286	0,3859

Continue...

16 The spatial unit used for the analysis is the “vereda”(village) assumed as a group of households with similar bioregional conditions. Traditionally the boundaries of veredas have corresponded due to historical reasons in these Andean regions to watershed features, namely, water streams or mountain peaks and ridges. Many of these villages emerged after the breakdown of larger feudal forms of land control during the Colony period. Using such spatial unit, and with the help of GIS, the different data layers —ecological and economic— could be made comparable

Table 5. *Continuation*

Description	Data sources and method	Mean	Standard Deviation
NKINDX: Index (0,1) of natural capital based on the ecological health of the ecosystem, where factors such as diversity, stability and ecological productivity of the ecosystems were weighted.	Map of landscape ecology units. Based on biodiversity, productivity and resilience factors.	0,4380	0,0472
SPRINDX: Technological sustainability Index (0,1). Based on rankings for the 42 different types of farming systems and subsystems found in the region. The factors consider inputs use, process and outputs for each farming system and gives greater weights to practices friendlier with natural resources.	Rapid Rural Appraisal interviews. Map of farming systems.	0,2468	0,0560
PCROPS: Percentage (0,1) of the village area in crops production, calculated using remote sensing and GIS techniques.	GIS interpretation. Farming systems map	0,1856	0,1400
PPAST: Percentage (0,1) of village area in pastures land use and also calculated using remote sensing and GIS techniques.	GIS interpretation. Farming systems map	0,4342	0,2000
POPDEADJ: Population density adjusted by land quality. —Households per ha., POP>0—. The estimation of households was based on photo interpretation —remote sensing— with aerial photography and field work verification. Land has been adjusted for slope, water and roads access for comparability purposes.	GIS-Remote sensing of rural households.	0,2170	0,2018

Continue...

Table 5. *Continuation*

Description	Data sources and method	Mean	Standard Deviation
GINIADJ: Adjusted gini coefficient (0,1) of land operation. Based on the distribution of the number of farms among different —adjusted— size ranges, and using the Lorenz curve model. Farm areas were estimated using the thiessen polygons method and areas were adjusted using a 'land potential' set of factors including soils quality, slope, and roads access.	GIS-Remote sensing. Thiessen polygons method and covariance method for estimating the Lorenz curve.	0,5410	0,543
P102: Percentage (0,1) of the total area of the vereda —village— with land holdings greater that 10 has. —here assumed as "larger farms"—.	GIS-Remote sensing. Farm sizes adjusted for biophysical factors.	0,6698	0,2493
TENUINDX: Land tenure index (0,1) based on the farming systems analysis and based on the degree of ownership of the land by the farmer —operator—.	Farming systems analysis, interviews, visits.	0,5133	0,1439

Note: Areas for calculating population density and land distribution (gini) have also been adjusted for slope, roads, and water access to the household using GIS techniques, in order to allow comparisons between different qualities of land.

In order to test for the possible cross-effects, a variable is included for the OLS estimations, where POPINE = POP * GINI. Therefore, the system of equations and the respective estimation coefficients is:

(I) $\text{BSAINDX} = \alpha_1 + \alpha_2(\text{NK}) + \alpha_3(\text{SPRINDX}) + \alpha_4(\text{PCROPS}) + \alpha_5(\text{PPAST})$

(IIa) $\text{SPRINDX} = \beta_1 + \beta_2(\text{NK}) + \beta_3(\text{POP}) + \beta_4(\text{GINI}) + \beta_{34}(\text{POP} * \text{GINI}) + \beta_5(\text{P102}) + \beta_6(\text{TEN})$

(IIb) $\text{PCROPS} = \gamma_1 + \gamma_2(\text{NK}) + \gamma_3(\text{POP}) + \gamma_4(\text{GINI}) + \gamma_5(\text{P102}) + \gamma_6(\text{TEN})$

(IIc) $\text{PPAST} = \delta_1 + \delta_2(\text{NK}) + \delta_3(\text{POP}) + \delta_4(\text{GINI}) + \delta_{34}(\text{POP} * \text{GINI}) + \delta_5(\text{P102}) + \delta_6(\text{TEN})$

(IIIa) $\text{P102} = \phi_1 + \phi_3(\text{POP}) + \phi_4(\text{GINI}) + \phi_{34}(\text{POP} * \text{GINI})$

(IIIb) $\text{TENUNIDX} = \psi_1 + \psi_3(\text{POP}) + \psi_4(\text{GINI}) + \psi_{34}(\text{POP} * \text{GINI})$

Thus, the marginal effect of inequality on BSA in the reduced form, due to the cross effects between population and land distribution, $(\partial \text{BSA}/\partial \text{INE})$ is as follows

Reduced Form:

$$\text{(IV) BSAINDX} = \rho_1 + \rho_3(\text{POP}) + \rho_4(\text{GINI}) + \rho_{34}(\text{POP} * \text{GINI})$$

Where ρ_3 and ρ_{34} depend on the values of several coefficients in the system of equations. However, the reduced form allows us to estimate directly such net effect. If ρ_{34} results significant, the hypotheses if the cross-effects would be confirmed from the empirical evidence. Moreover, if ρ_3 and ρ_{34} have opposite signs, there would be a threshold level for inequality (GINI) where the marginal effect $\partial \text{BSA}/\partial \text{POP}$ changes from one sign to the other. In fact, this is the result found. The next table presents the estimated system of equations with their coefficients, t-values, and the standardized coefficients for comparisons across variables.

Table 6. *Regression results, OLS*
—n=160 villages—

Equations in the system and the reduced form equation (IV)					
Explanatory variables and coefficients in each equation	Equation (I) BSA	Equation (IIa) SPRINDX	Equation (IIb) PCROPS 18	Equation(IIc) PPAST	Equation (IV) Reduced form: BSAINDX
SPIDE (α 3) (Tech. sustainability)	2,7323 (6,469)* 0,3961	---	---	---	---
PCROP (α 4) (Area% in crops)	-0,7205 (-4,977)* -0,2614	---	---	---	---
PPAST (α 5) (Area% in pasture)	-0,3357 (-3,032)* -0,1743	---	---	---	---

Continue...

17 The PCROPS equation with cross-effects did not pass a Chow test to perform better than the linear one.

Table 6. *Continuation*

Equations in the system and the reduced form equation (IV)					
	3,9059	0,3393	-0,0017	-0,5738	5,2795
NK($\alpha 2$, $\beta 2$, $\gamma 2$, $\delta 2$, $\rho 2$)	(8,354)*	(4,521)*	(-0,010)	(-2,038)*	(11,875*
(Natural capital)	0,4781	0,2865	0,0003	-0,1353	0,6463
		0,2434	0,3254	-0,5246	0,9023
POPDENAD ($\beta 3$, $\gamma 3$, $\delta 3$, $\rho 3$)	---	(3,154)*	(6,139)*	(-1,812)*	(2,042)*
(Population density)		0,8782	0,4691	-0,5285	0,4719
		-0,0113	-0,1499	-0,5537	0,7382
Inequality (GINIADJ)	---	(-0,370)	(-2,658)*	(-4,822)*	(4,002)*
($\beta 4$, $\gamma 4$, $\delta 4$, $\rho 4$) (Land inequality gini)		-0,0312	-0,1652	-0,4265	0,2952
		-0,4988	---	1,5539	-3,2564
POP*GINIADJ	---	(-3,005)*		(2,495)*	(-3,299)*
($\beta 34$, $\gamma 34$, $\delta 34$, $\rho 34$)		-0,749		0,6516	
		0,023	-0,1287	0,0578	---
P102 ($\beta 5$, $\gamma 5$, $\delta 5$, $\rho 5$)	---	-1,272	(-3,210)*	-0,85	
(Village area% in large farms)		0,1028	-0,2292	0,0172	
TENUINDX	---	0,1744	-0,0179	0,6498	---
($\beta 6$, $\gamma 6$, $\delta 6$, $\rho 6$)		(6,975)*	(-0,322)	(6,930)*	
(Land tenure)		0,4484	-0,0184	0,467	
n (No. villages)	160	160	160	160	160
Adjusted R2	0,5656	0,3884	0,5126	0,3289	0,5318
Equation F-test	53,087	17,933	34,659	14,067	46,43

Note: Each cell presents the estimated coefficient, its t-ratios in parenthesis, and the standardized coefficient; * One-tail statistically significant at 95%.

The overall performance of the estimation can be verified through the percentage of variability in the dependent variables explained by the right hand side for each equation, the F-test for each equation, and the significance of most variables. Most of the expected signs were obtained. The model estimated here performed better than the simple linear one, giving therefore statistical support for the cross-effects model. The non-significance of some of the right hand variables in some of the equations, although the signs correspond to the expected ones, may be caused by multiple collinearity among the institutional variables.[18]

Let us see in detail how the estimation provides some evidence of the theoretical argument. As discussed earlier, the ecological quality of the local commons is determined by forces working in opposite direction, all related to the decisions by farmers within their own land and decisions when using the local commons. Those decisions then are determined by the institutions that determine the availability or access to inputs such as land, labor and capital.

The first equation simply explains how the local commons proxy (BSAINDX) is mostly determined by the available stock of natural capital (NKINDX) and the technology choices by the farmers through land uses and farming practices. In general two types of decisions by farmers affect the commons, one, their choice of farming practices (SPRINDX) which is a composite of choices with respect to inputs use, production practices, and by-products of agriculture. We will assume that capital intensive technologies are less appropriate for the environment than labor intensive ones, and also that crops tend to be more labor intensive than livestock farming systems. The second type of decision is the distribution of their own land in crops (PCROPS), pastures (PPAST) and natural vegetation (PNATU). According to our definition of the commons, SPRINDX should have a positive impact on BSA; and with respect to land use patterns, some inconclusiveness remains except for PNATU which we could expect to have a positive association with BSAINDX. Regarding pastures and crops land uses, one could argue in both signs of the relation depending basically on then type of crops and livestock practices.

Equations (IIa, IIb, IIc) then reflect how the institutional variables affect the technological choices which in turn determine the effect on the village ecosystems as expressed in the reduced form equation. However, reducing the attention to the reduced form may ignore the effects that operate in opposite directions, for instance, from the population density. As can be verified through the results, while population density increases the village area in crops and pastures which in turn reduce BSA, population density also increases the amount of more

18 For instance, one should expect land tenure and inequality combined with population density to be related. Although single correlations are not strong enough, linear combination of the three could create collinearity problems.

sustainable farming practices (SPRINDX) which has a positive effect on BSA. Moreover, as discussed before, the net effect estimated through the reduced form may suffer from statistical error from several coefficients in the system.

In order to concentrate on the cross-effects of population and inequality on the village environmental outcome, the following three dimensional surface illustrates how the level of one variable determine the marginal effect of the other on BSA. Clearly, the slope of population density (POPDEADJ) on BSA decreases as inequality (GINIADJ) increases and eventually becomes negative. Such claim is supported by the regression results. If using the estimated coefficients in the reduced form, after the GINI level passes a threshold level of GINI $= \rho_3 / \rho_{34} =$ 0,9023/3,2564 = 0,277. Notice also that from the data descriptive statistics and the distribution graphs in the appendix, the mean for GINI is 0,541 with a standard deviation of 0,1543, suggesting that for a large portion of the region inequality is creating more harm than good to the local commons.

Finally, the evidence of the cross-effects can be also found in the rest of the estimation results through the structural equations given that in most cases the variables were found significant. The interpretation of similar surfaces such as the one shown can be derived for the equations (IIa and IIc). For instance, $\partial \text{SPRINDX} / \partial \text{POPDEADJ}$ becomes negative for GINIADJ > 0,488. Thus, for high inequality levels, an increase in population density reduces the adoption of sustainable farming practices, or, for villages with better distribution of land population density provides incentives and possibilities for farms to shift to labor intensive land uses and technologies.

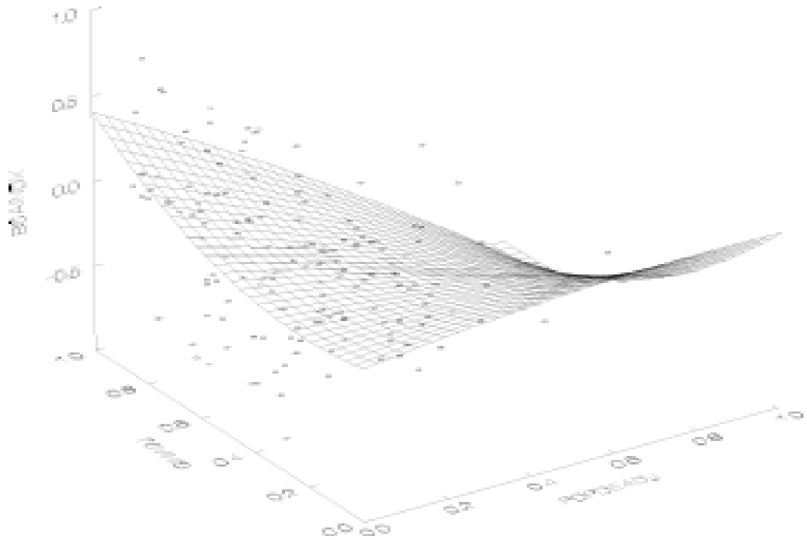

Figure 5. *Three-dimensional surface generated with the data to illustrate the cross-effects of population and inequality on the local commons.*

IV. Final Discussion: Natural and Social Capital, Natural and social Resilience

In another passage, Malthus insists on the problem of distribution and how it may affect the outcomes with respect to his main point on the different rates of agriculture production and population growths:

> "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)

What could be better than Malthus himself to revisit with more complexity the problem of population pressures on the environment? «Population pressure» is the term mostly used in the so called Neomalthusian literature to express that larger population and a limited amount of resources in the ecosystems —land originally— will result in the exhaustion of the ecosystem because its renewability is overpowered by the exponential growth of population, while agricultural growth increases at lower rates. Thus, two villages with similar area and natural base but one with double the population would indistinctly make the latter end up in ecological collapse more rapidly under such argument.

However, and consistent with Malthus, this is relative to the institutional setting —land distribution, tenure among others—, and also relative to the technological systems the farmers choose given the ecological and institutional constraints they face. In our case, it is not the retard in the increase of food production but in the provision of the public goods that the local commons generate for the community. As I argued before, the population issue has two sides, the 'pressure' side where people's needs for products from those local commons are taken as proportional to the number of people, and an ignored related to people's capacity to overcome the coordination failures from such demand.

The theoretical discussion and the evidence above provide new elements to bring together the importance of several elements recently emerging from the social and ecological sciences. While social diversity and social capital have been increasingly recognized in the literature as key explanation for the success of collective action and cooperation within communities, ecology and systems approaches have been providing the basis for understanding the economic importance of natural capital and the main factors for healthy ecosystems. In general natural capital, and local commons would be an example, benefits more communities when their biological productivity, resilience and biodiversity are greater. With similar arguments we could state then that villages and communities with greater levels of social diversity, productivity and resilience will present better conditions for overcoming prisoners' dilemma situations and be able to cooperate for providing these and other local public goods. Diverse and therefore resilient communities rely on more equal institutions to be able to overcome challenges from increasing population and scarcity of natural resources. More equal distribution of the land, as in the case discussed here, provides the incentives in the village for adopting more sustainable farming practices and land use patterns that balance the need for food, fiber and energy, while preserving the biodiversity, resilience and biological productivity of the local commons of the village expressed in the stock and relations between land, trees and water. Socially diverse and resilient communities are made of diverse and resilient ecosystems and farming systems. That is the value of group heterogeneity and an alternative approach to this problem in collective action.

After reviewing some of the reasons why inequality may affect the conservation or mismanagement of village level commons such as water, soil and forest resources, I have attempted to go further in the discussion and explore the possibility that cross-effects between population density and land inequality may alter slightly the predictions that the recent literature is providing on these issues. Recent developments (Bardhan (1993), Baland and Platteau (1996), Bardhan, Bowles and Gintis, 1997) have been counter arguing the Olsonian prediction that group heterogeneity —inequality— will increase the likelihood that collective action emerges. Meanwhile the Neo-malthusian environmental argument persists compatible with Olson's claim that group size will reduce the possibility of such collective action. The basic argument I have developed is that the impact that population size has on the level of conservation of the local commons is mediated by the level of village inequality in several ways. Highly populated villages will be more likely to manage sustainably their local commons if the distribution of land is more equal; and unequal villages could generate conditions for local commons conservation under low population pressures. In other words, this claim would be consistent with the old —but less publicized— argument by Malthus that the distribution of property may indeed retard or accelerate the operation of the population checks on production and land productivity in particular.

The econometric evidence presented confirms these predictions through the estimation of such cross-effects by creating a three-dimensional surface relationship in which the slopes of both population density and land inequality on the status of the village local commons are mediated by each other.

In fact, when looking at the estimated surface from a two dimensional perspective, it may in fact be misinterpreted as an inverted "U" curve where the environmental quality of the local commons decreases with inequality to a certain point and eventually catches up. Interestingly, some of these arguments have been emerging as plausible explanations of relations between inequality and environmental quality, including empirical evidence using cross-country data. Moreover, some of these arguments have been proposed as extrapolations of the so called "Kusnetz" curve to the environmental discourse.

A three dimensional explanation of the empirical results changes dramatically the interpretation of inequality and local commons. Under the two dimensional explanation the gainers from inequality would lead the local commons conservation and the poorer will benefit, even free-ride, from such efforts. In our 3D world, this explanation would happen only for villages with low population sizes. But the more populated villages, where in fact dependence on their local commons is even more crucial, the effect of inequality can be quite opposite.

The argument here defended results even more interesting when one looks at the recent demographic trends in Third World countries where the rural migration to new agricultural frontiers has been increasing the population densities of settlements with key but fragile ecosystems —e.g. tropical rainforests, humid forests, high cloud forests, paramos—. Given that the land productivity of these new regions is much lower under conventional agriculture, and that the flow of environmental services of such local commons is highly dependant on the possibility of collective action within their communities, a call for sound policies for land distribution seems more urgent, and eventually more cost-effective, that costly attempts by governments to establish exclusion of local users from national conservation parks which have proved ineffective.

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