HOW DOES COMMUNITY FORESTRY AFFECT RURAL HOUSEHOLDS? A LABOR ALLOCATION MODEL OF THE BOLIVIAN ANDES[1]

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I. Introduction

In rural areas of developing countries, farming systems tend to be household-based. These household production systems are also highly integrated with land-based natural resources such as forests, range areas and pasture lands. Households depend on these resources for fuels, animal food, building materials, fruits and medicines, and often these resources have ownership and control structures that are something other than private property. Forms of "common" ownership and control are by far the most important structures in which households access the land-based natural resources that support production by often poor, rural households. Indeed, common land areas can provide very significant portions of incomes for certain populations. For example, local commons contributed 15-25 percent of total income among households in eighty Indian villages (Jodha, 1986).

Because common lands are important for the poor of the world, and also because they may house significant biodiversity and other non-production oriented natural resources, their current and future status is important (World Bank 1992). Indeed, some have argued that community management of resources should be a critical component of strategies promoting sustainable development (Leach et al. 1999). Because we care about the status of common lands, the effectiveness with which these land-based, common natural resources are managed is of interest to us. An important goal of management should be to maximize the long run economic rents from natural resources, and it has been because of a belief that commonly owned and controlled natural resources generate little or no rents that researchers have long questioned the incentives for efficient use of common resources (Gordon, 1954; Scott, 1955; Crutchfield 1956; Hardin, 1968). These analysts argued that commons generate little or no value, because rents are dissipated due to poor or absent management. As a result, solutions were proposed such as command and control management (Hardin 1968) or privatization of the commons (Demsetz 1964).

More recently, however, an enormous literature has emerged which emphasizes the distinction between lack of ownership and control (open access) and community ownership and management (common property) (e.g., Wade 1988, Ostrom 1990, Bromley 1990, Baland and Platteau 1996). The impetus for trying to understand and in some cases advocating for community management often has something to do with reconciling the need to generate rents with the reality that natural resource rents should be distributed in a manner which recognizes the dependence of vulnerable groups on common lands . Due to work by Robert Wade, Elinor Ostrom, Daniel Bromley and others, it is now well accepted that natural resources do not have to be privately owned to be managed well. There therefore does not seem to be an inevitable

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contradiction between efficiency and non-exclusivity in the case of land resources (Baland and Platteau, 1996).

In the policy literature, the recognition that common management is strongly preferred to no management, and indeed can be efficient, has created a conventional wisdom which advocates for devolution of natural resources from central government owners to local groups. Devolution of forests has, for example, been underway in Nepal since the early 1980s and culminated in the transfer of all forest land to local forest users through the creation of forest user groups in 1993 (cited in Edmonds 1998). The FAO, for example, actively supports community forestry in several countries through its Forests, Trees and People Program.[2] Agrawal (2000), referring to a recent FAO survey, mentions that Governments in more than 50 countries are undertaking initiatives that would devolve some control over resources to local users.

Although local control over natural resources is now regarded as a win-win solution for both the environment and local development, the empirical evidence in its support is still rather thin. Case studies form the overwhelming majority of this material[3] and the results are perhaps still more suggestive than conclusive. In this paper we advance this line of research by formally modeling the household production system in the Bolivan Andes. This approach provides a sound theoretical framework to analyze household behavior in conditions where non-market goods are important (Bocksteal and McConnell 1981). We then attempt to estimate the importance of institutional effectiveness in natural resource management on households' use of the commons.

In particular, we seek to provide answers to the following question: *What are the local economic consequences of effective local management institutions?* Here, our working hypothesis is that better management and regulation translates into time saving for households engaged in forest-related activities. Such time saving can then be used in other productive activities (e.g., off-farm labor). We further hypothesize that such time-reallocation toward more productive activities and an increase in resource rents translates into increased household income.

Our focus on household labor allocations had the following motivations. First, household labor allocations provide a measure of household dependency upon access and use of the commons. Second, other things being equal, the time allocated to uses of the commons can be thought of as an indicator of the commons quality. High degrees of degradation of the common limit its supply of products. Thus, the time required to collect a given amount of these products increases with the degree of degradation. Finally, they are critical in assessing the productivity of labor and, through this, the adoption of input-saving and labor-saving technologies.

This paper examines these questions by looking at community management in the Bolivian Andes. In the Bolivian Andes local communities benefited from control over natural resources for several decades as a result of the 1952 Agrarian Reform. Yet, although relatively homogeneous in terms of cultural background and traditions and subjected to a similar policy and reform regime, communities across the Bolivian Andes exhibit different types of local common resource regulation with different effectiveness. This makes the Bolivian Andes an

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[2] See www.fao.org/waicent/faoinfo/forestry/ftpp for more information.

[3] Notable exceptions include Edmonds (1998) Foster et al. (1998), Otsuka (2000)

ideal setting for the study of which factors (e.g., demographic, environmental, and economic) affect the effectiveness of community forestry.

The paper is organized as follows: in section 2, the relevant literature is surveyed. In section 3 an overview of the Bolivian context is given and a model of household production systems in the Bolivian Andes is presented. Section 4 overviews the data from a survey in the 32 communities that were the focus of the empirical analysis and discusses the econometric model used. Section 5 presents the results of that analysis. Section 6 concludes the paper and suggests avenues for further research.

II. Selected literature review

There is a rich literature that focuses on the determinants and likely outcomes of collective action as the result of cooperative games in the presence of common property resources (CPRs). The "Comprehensive Bibliography of Common Pool Resources 1999" compiled by Charlotte Hesse at the Workshop in Political Theory and Policy Analysis lists more than 5,600 citations that focus on forest commons alone! This body of literature evaluates the incentives of individuals/communities to cooperate for the common good therefore preventing or favoring the realization of “tragedies of the commons.” The outcome of cooperative behavior can, in this case, been observed in the institutions (decision making processes, monitoring and enforcement mechanisms) that have been created to deal with appropriation and production activities Baland and Platteau 1996). Theoretical support often comes from game theory from which testable hypotheses are derived (see, for example, Sethi and Somanathan 1996). The incentives or disincentives to cooperate appear to play a major role in the development of institutions that relate to the management of CPRs.

A related important issue focuses on the effects that local management and institutions have on the common's use and users. Indeed, while environmental and economic benefits can be expected on the basis of theoretical models, empirical evidence is still limited. In Nepal, Edmonds (1990) estimates the impact of Government initiated community institutions on local resource use and finds that these institutions led to a statistically significant reduction in fuelwood extraction. Using a non-separable framework where the opportunity cost of labor is endogenous, the issue of fuelwood demand and its determinants has been analyzed econometrically by Amacher et al. (1996, 1999) and Heltberg et al. (2000). Similarly to Edmonds (2000) we look at resource use as it related to community management and institutions. However, we attempt to incorporate institutional and management variables into a formal model of household behavior. Some of these institutional variables include clarity of property rights (legal status, demarcation, etc.) and regulations, a condition that in the common property literature has been identified by many (e.g., Wade 1988, Ostrom 1990).

We attempted to incorporate also variables related to the size, age, and settlement pattern of community. Smaller groups, living in proximity, are more likely to cooperate and thus to develop institutional solutions (decision making processes, monitoring and enforcement mechanisms) that favor sustainable resource management (see Olson 1965). Because the transaction costs from finding cooperative solutions decrease with experience, the age of communities (or institution) should be positively related with cooperative outcomes (Agrawal and Goyal 1999)[4].

The study setting

Household and village surveys were carried out in 32 communities belonging to 8 municipalities concentrated in the Andean valleys (Departments of Cochabamba, Tarija and Potosi) and the northern altiplano (La Paz). These communities present different institutional characteristics (property rights and management norms, see for example Castro and Rist 1999; Moscoso and Villanueva 1997), ecological conditions, geographic and market features. A total of 378 households were interviewed.

The altiplano and the valley region differ in temperature, precipitation and elevation. Elevation is higher in the north (by about 500 m) and so are temperature and rainfall. Average rainfall in the north (around Lake Titicaca) is about 900 mm while at the Sajama it is only 300 mm. At southern locations it is even less. Thus, the north is higher, wetter, and warmer and consequently more fertile. This ecological gradient overlaps with the pattern of Spanish colonization (although a causal argument may be difficult to make) which concentrated in the valley region and the northern part of the altiplano. Thus, these regions were exposed to a culture of private ownership earlier than other areas.

In these areas, indigenous communities use forests primarily to collect fuels, construction material, medicinal plants, and food. In the highlands forest use for medicinal plants is apparently very important. Forest use for food and medicines, however, has a negligible impact on the resource, largely because of its non-destructive nature. Because resource degradation appears to be driven primarily by fuelwood extraction, our survey focused on this use.

Among the Aymara (predominant ethnic group in the altiplano), the land falls into roughly three forms of ownership. Private land (*sayañas*), communal land (land that is worked collectively, but whose products belong to specific households) and common land (where access is open to all

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[4] Other hypotheses include (Agrawal (2000): *Inequality within community.* Income and assets inequalities make some elements of the community more influential in public decisions. Dayton-Johnson (2000) found that land holding inequalities can partly explain why in certain cases "congruent" outcomes (benefit sharing are proportional to cost-sharing) are not attained. (See also Baland and Platteau 1999). *Resource abundance and productivity*. The more productive the resource, and the easier its management, the higher the incentives to find a cooperative solution (Dayton-Johnson 2000). It is not clear how the incentives work with resource abundance. Abundance should increase the gains from cooperation. Yet, at the same time, it makes cooperation less crucial (cooperation also involves costs). *Resource dependency*. The higher the village dependency from the resource, the higher the incentives to cooperate. Thus, the higher the economic alternatives in other sectors, the lower the incentives to cooperate for rationale resource management. *Resource proximity*. Increased control over resources (through institutional changes) benefits who is "closer" to the resource (Wade 1988, Baland and Platteau 1996). It may be marginalized groups or large concession holders. *External shocks and threats*. Communities' ability to respond to external threats varies. Sporadic threats (e.g., drought) motivate cooperation while constant heavy threats (e.g., illegal logging, encroachment by outside farmers, etc.) encourage "defection" (a shift toward appropriation). Type of management problem. Other interesting results deal with the capacity of communities to deal with "allocative" as opposed to "conservation" decisions (read static v. dynamic allocation decisions.). Apparently, communities can deal more effectively with the former than with the latter. (Baland and Platteau 1996)

community members.) Communal lands (*aynocas*) are often located on the most fertile land (even if one would expect that the most fertile land would be on private ownership [Demsetz 1964]) which is managed on a rotational basis. Each community has several *aynocas*, distributed across the landscape to reflect various crop requirements and to minimize the risk of crop losses (due, for example to frost or drought). What is planted in any one *aynoca* is decided collectively and usually follows a pattern. Households may also own animals, such as cows, llamas (common at high altitudes and dry conditions), donkeys, pigs, and sheep. Animals graze on pasturelands and on *aynocas* during the fallow years. Pasturelands are typically on common land. Communities in the valleys' region are primarily ethnic Quechua but possess similarly complex system of commons ownership and use.

III. Analytical Model of Households in the Bolivian Andes

This section presents a model of a representative household in the Bolivian Andes. This model builds on the work of Singh, Squire and Strauss (1986) and Bluffstone (1995) by attempting to at least partially integrate the household modeling literature with the recent findings on the components and determinants of effective common property management.

The theoretical and applied literatures suggest that effective common property management should result in higher quality forests. In the model, forest quality (Q) is hypothesized to be a function of three categories of variables. Environmental variables (E), such as altitude and rainfall, alter the productivity of forests and affect Q at any point in time. The structure (Σ) of forest management is also believed to be important. For example, perceptions of fairness , democratic management, the setting of clear resource boundaries and participation requirements, as well as active involvement by group members should result in a higher level of Q over time. Finally, the existence of several instruments (I) is also believed to be important for forests. These instruments include clear quotas in which group members know how much of key products can be taken, appropriate penalties (whether social or monetary) for transgressions are applied, monitoring by officials and villagers and the mobilization of reasonable levels of village labor in support of group management.

The vectors Σ and I also depend on basic village-level variables. Of particular interest are factors that are expected to be positively related with effective management, including length of time participants interact with each other (λ), proximity of households to each other (π), ethnic homogeneity (η), and productivity of ecosystems (ε). A hypothesized negative relation is competition for resources, perhaps proxied by population per hectare.

Given these hypotheses, we construct a two equation system that is purported to explain observed differences in forest quality

Equation 1 $Q = Q(\mathrm{E}, \Sigma, \mathrm{I})$

Equation 2 $E, \Sigma, I = \phi(\lambda, \pi, \eta, \varepsilon)$

From the contemporary perspective of household members, it is supposed that these direct and indirect determinants of forest quality are taken as given when villagers make their day-to-day decisions. This situation can be thought of as a two period game where in period 1 decisions about forest quality are made and in period 2 villagers make decisions about the allocation of their productive resources.

Village households are assumed to maximize utility, which is a function of cooked starch crops ("grains") (g_c), cooked meat (m_c) and other goods (X) that must be purchased. This specification is broadly in line with the work on peasant households, but includes the important component that meat is a higher quality food than grains. To facilitate a neater set of solutions, the utility function is assumed to be linear and additive. This specification captures the low consumption levels in the Bolivian Andes by not incorporating diminishing marginal utility, but of course imposes constraints that will have implications for the comparative statics. This utility function is presented in Equation 3.

Equation 3

$$U = ag_c + bm_c + cX$$

Cooked grains (g_c) are produced in a production function that combines fuel, raw grains, a stove technology and household labor. Fuels are assumed to be biomass fuels, such as fuelwood, branches and *thola*, a shrub indigenous to the region, because the use of commercial fuels is still limited to particular localities. These fuels may be collected by the household (f) or purchased in the market (F). Households may also sell fuelwood (f_s), and this amount is netted out of the production function. Raw grains can be produced on-farm (g) or purchased in the market (G). Households may also sell grains (g_s), which are, of course, netted out of the production function. The cooking technology (s) affects the efficiency with which cooked grains are produced. In particular, if a household has an improved cooking stove, such as a *lorena* stove, a higher value of g_c is produced per unit of fuel used. This variable can be thought of as an efficiency parameter. These physical inputs are combined with effort in the home (E_H) to produce cooked food. It is supposed in the model that cooking is strongly correlated with the overall level of home production, but because activities such as cleaning, child care, etc. are not of interest for the analysis they are ignored. These assumptions are summarized in Equation 4.

Equation 4

$$g_c = g_c\{s(f + F - f_s),(g + G - g_s),E_H\}$$

Cooked meat (m_c) is produced in a production function similar to cooked grains. The only difference of note is that meat is not purchased. This assumption was made because meat is an inherently heterogeneous good. Gathering data on "the" price of meat in a way that is not overly complex is therefore difficult. Furthermore, meat purchases are believed to be relatively insignificant in much of the Bolivian Andes. Raw meat used as an input into m_c is assumed to be a positive, linear function of the animals (A) households hold, and all animals are assumed to provide meat. Examples of such animals are cattle, llamas, goats, and sheep. Ignoring the parameter on the linear function, this production function is given in Equation 5

Equation 5

$$m_c = m_c\{s(f + F - f_s), A, E_H\}$$

Raw grains are produced on farm in a production function using household labor (E_g) and hired labor (E_h). Tasks performed include plowing, planting, weeding and harvesting. Hired labor may be wage labor or it may be part of reciprocal labor sharing arrangements in which no money or goods actually change hands. Such mechanisms are common in the Bolivian Andes (Castro and Rist 1999:60). Labor is complemented by agricultural land (L), which is assumed to be fixed; land is therefore considered to be predetermined. Animals (A) provide dung fertilizer that is important for maintaining soil fertility. Some of these animals also provide traction power, the timely application of which is important for productivity. Grain production is also a function of chemical inputs (C), such as fertilizers and pesticides, though the use of these inputs is relatively rare in the region. First derivatives are all positive and second derivatives are all negative. These elements are given in Equation 6.

Equation 6

$$g = g\{E_g, E_h, A, C, L\}$$

Biomass fuel is produced using household labor (E_f), common forests and trees on farm. Common forests are merely the variable Q presented in Equation 1, where a higher quality common forest offers the possibility to produce more fuelwood for a given application of E_f. Trees on farm (T) are assumed to be predetermined (like agricultural land). To account for differences in tree quality, tree age (T_A) is also included explicitly in the production function. First derivatives are all positive and second derivatives are all negative. This production function is presented in Equation 7.

Equation 7

$$f = f\{E_f, Q, T, T_A\}$$

The final production function is for animals. Animals are produced using household labor allocated for grazing (E_{gr}) and for fodder collection (E_{fo}). Complementing these labor inputs is forest quality (Q), number of on-farm trees (T) and tree age (T_A). These three last variables are in fact related to availability of fodder. Animals in this model do not provide a store of value or other inter-temporal functions. Their functions are to produce meat, dung and traction, and therefore can be conceptualized as merely a technology for converting labor and forests into these products. First derivatives are all positive and second derivatives are all negative. Equation 8 presents this function.

Equation 8

$$A = A\{E_{fo}, E_{gr}, Q, T, T_A\}$$

Production occurs subject to the time constraint given in Equation 9. All the labor uses are included in the constraint, and in addition households can work off-farm for wages (E_w). In this case hiring out of labor on a labor exchange basis is not considered. E_w includes only work for money. Leisure is not included in the constraint, because the labor-leisure margin is not of interest for this model. Furthermore, it is believed that leisure is not a significant use of time among adults (and even children) in many households . The time constraint is presented in Equation 9.

Equation 9

$$E_T = E_g + E_f + E_{fo} + E_{gr} + E_w + E_H$$

In the model there is no saving or borrowing, and therefore cash income must equal expenditures. Cash is earned from wage labor at rate w, from sales of raw grains at price P_g, and from the sale of biomass fuel at price P_F. Cash is expended on purchased grains, priced at P_g, biomass fuels priced at P_F, wage labor hired in at wage rate w_h, and the purchased non-food good (X), which comes at a per unit cost of P_X, including transactions costs, such as travel time. The budget constraint is presented in Equation 10.

Equation 10

$$wE_w + P_g g_s + P_F f_s = P_g G + P_F F + P_f f + w_h E_h + P_x X + P_c C$$

For purposes of the analysis, Equation 8 can be substituted into Equations 5 and 6. Equation 7 can be substituted into Equations 4 and 5. With these substitutions complete, Equations 4 and 5 can be substituted into Equation 3. The lagrangian representing a representative household's maximization problem is given in Equation 11. λ_1 and λ_2 are the lagrange multipliers on the time and budget constraints respectively.

Equation 11

$$L = ag_c[s\{f(E_f, Q, T, T_{A,}) + F\} - f_s, \{g(E_g, E_h, \langle A(E_{fo}, E_{gr}, Q, T, T_A)\rangle, C, L) - g_s\} + G, E_H] +$$
$$bm_c[s\{f(E_f, Q, T, T_{A,}) + F\} - f_s, \langle A(E_{fo}, E_{gr}, Q, T, T_A)\rangle, E_H] + cX - \lambda_1(E_g, E_f, E_{gr}, E_{fo}, E_w, E_H - E_T)$$
$$- \lambda_2(wE_w + P_g g_s + P_F f_s - P_g G - P_F F - w_h E_h - P_x X - P_c C)$$

The endogenous variables in the model are Eg, E_f, E_h, E_{fo}, E_{gr}, E_H, E_w, F, f_s, g_s, G, C and X. Maximizing the lagrangian with respect to these variables yields thirteen first order conditions. These are presented as Equation 12. Because of their importance for upcoming analyses, partial derivatives that are a function of the quality of the forest (Q), trees planted on farm (T) and the average age of trees planted on farm (T_A) are indicated below.

Equation 12

$$a.\frac{\partial L}{\partial E_g} = a\frac{\partial g_c}{\partial g}\frac{\partial g}{\partial E_g}(Q,T,T_A) - \lambda_1 = 0$$

$$b.\frac{\partial L}{\partial E_f} = as\frac{\partial g_c}{\partial f}\frac{\partial f}{\partial E_f}(Q,T,T_A) + bs\frac{\partial m_c}{\partial f}\frac{\partial f}{\partial Ef}(Q,T,T_A) - \lambda_1 = 0$$

$$c.\frac{\partial L}{\partial E_h} = a\frac{\partial g_c}{\partial g}\frac{\partial g}{\partial E_h}(Q,T,T_A) + \lambda_2 w_h = 0$$

$$d.\frac{\partial L}{\partial E_{fo}} = a\frac{\partial g_c}{\partial g}\frac{\partial g}{\partial A}\frac{\partial A}{\partial E_{fo}}(Q,T,T_A) + b\frac{\partial m_c}{\partial A}\frac{\partial A}{\partial E_{fo}}(Q,T,T_A) - \lambda_1 = 0$$

$$e.\frac{\partial L}{\partial E_{gr}} = a\frac{\partial g_c}{\partial g}\frac{\partial g}{\partial A}\frac{\partial A}{\partial E_{gr}}(Q) + b\frac{\partial m_c}{\partial A}\frac{\partial A}{\partial E_{gr}}(Q) - \lambda_1 = 0$$

$$f.\frac{\partial L}{\partial E_H} = a\frac{\partial g}{\partial E_H} - \lambda_1 = 0$$

$$g.\frac{\partial L}{\partial E_w} = -\lambda_1 - \lambda_2 w = 0$$

$$h.\frac{\partial L}{\partial F} = as\frac{\partial g_c}{\partial F} + bs\frac{\partial m_c}{\partial F} + \lambda_2 P_F = 0$$

$$i.\frac{\partial L}{\partial f_s} = a\frac{\partial g_c}{\partial f_s} + bs\frac{\partial m_c}{\partial f_s} - \lambda_2 P_F = 0$$

$$j.\frac{\partial L}{\partial g_s} = a\frac{\partial g_c}{\partial g_s} - \lambda_2 P_g = 0$$

$$k.\frac{\partial L}{\partial G} = a\frac{\partial g_c}{\partial G} + \lambda_2 P_g = 0$$

$$l.\frac{\partial L}{\partial C} = a\frac{\partial g_c}{\partial g}\frac{\partial g}{\partial C} + \lambda_2 P_C = 0$$

$$m.\frac{\partial L}{\partial X} = c + \lambda_2 P_X = 0$$

The results from these first order conditions are standard for household labor allocation models of this type. The general rule is that in equilibrium the ratios of the marginal products of various activities are equalized with the relevant price ratios. Because so many activities are devoted to home production, in many cases the price of on-farm activities is the opportunity cost wage that could have been earned off-farm.

We now present comparative static results, with a particular focus on the variables Σ, Q, T and T_A, because these are our environmental variables. Of special note is Q, because from Equation 1 we think that Q is a function of the community management variables Σ and I. Also of interest, however, are the predicted effects of wages and prices on our endogenous variables.

If we substitute Equation 12g into 12c and the outcome into 12a and rearrange, we get Equation 13.

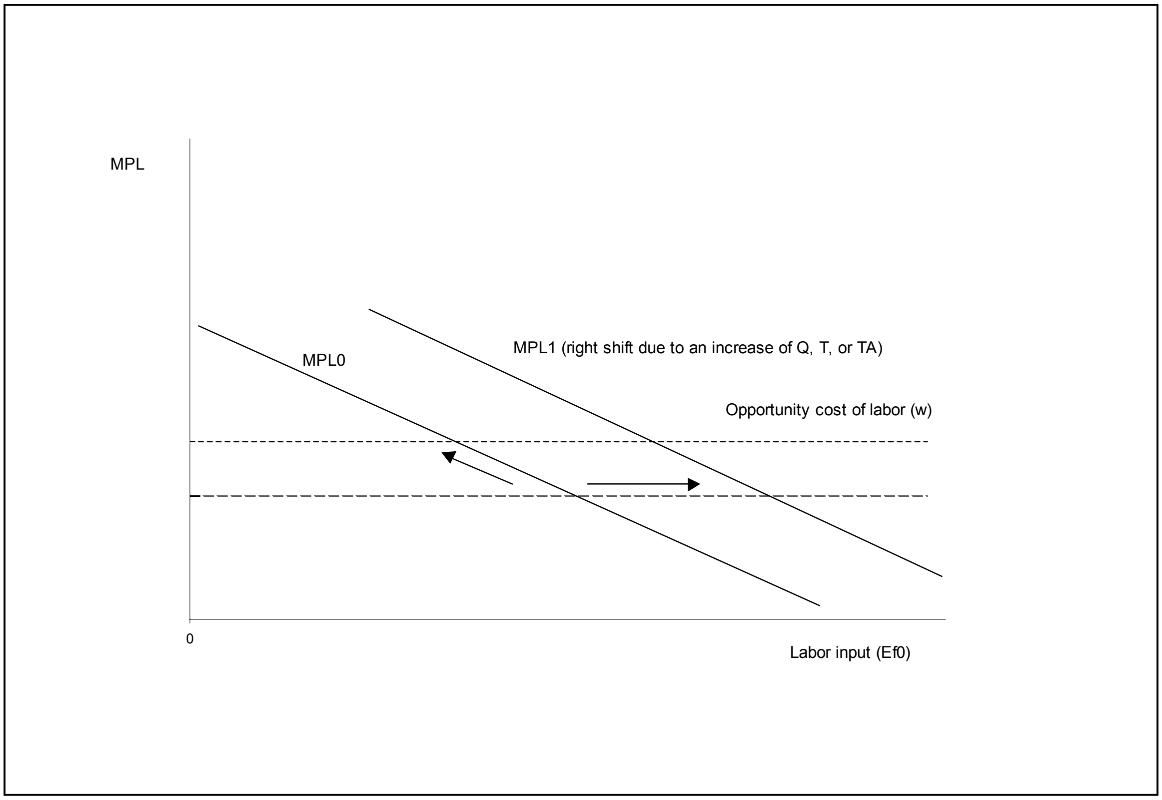
Equation 13

$$\frac{\partial g_c}{\partial g}\frac{\partial g}{\partial E_g}(Q,T,T_A) = -\frac{\partial g_c}{\partial g}\frac{\partial g}{\partial E_h}(Q,T,T_A) * \frac{w}{w_h}$$

Both terms are marginal products of labor, with the right-hand side being the marginal product of hired-in agricultural labor, scaled by the ratio of the two wages, and the left side being the marginal product of household labor. Because Q, T and T_A are exogenous, we can view them as parameters. Evaluating Equation 13 at the optimal labor values, we can use the envelope theorem to assess the effects of Q, T and T_A on the endogenous variables by differentiating Equation 13 with respect to Q, T and T_A. Because animals complement agricultural labor in Equation 6, and because all three exogenous variables increase A, we can conclude that higher levels of the exogenous variables should shift the marginal product of hired in labor. Because the sign of the partial derivative is positive, this means that an increase in Q should also increase the marginal product of household labor.

In interpreting these results, we note that the exogenous variables shift the marginal product curve to the right. With each unit of agricultural labor more productive, for a given opportunity cost wage, the exogenous variables increase E_g in equilibrium. This relationship is shown in Figure 1. This is to be contrasted with a movement along a given marginal product curve, which (given the assumption of diminishing returns) suggests a reduction in E_g.

Figure 1. Marginal product labor. A shift in MPL to the right and higher equilibrium hiring for a given opportunity cost wage



Differentiating Equation 13 with respect to w, also indicates a positive effect on the marginal product of household labor. The wage rate is not a production parameter like Q, T and T_A and so in this case the increased marginal product suggests a movement ALONG a function such as MPL_{Q0}, not a shift in the curve. Increases in opportunity cost wages therefore reduce household labor supply to agriculture. Increases in w_h, of course, have the opposite effect, increasing labor supply as hiring-in falls.

If we substitute Equation 12e into 12d and rearrange, we get Equation 14

Equation 14

$$MP_{g+m,Efo} = a\frac{\partial g_c}{\partial g}\frac{\partial g}{\partial A}\frac{\partial A}{\partial E_{fo}}(Q,T,T_A) + \frac{b}{a}\frac{\partial m_c}{\partial A}\frac{\partial A}{\partial E_{fo}}(Q,T,T_A) = \frac{\partial g_c}{\partial g}\frac{\partial g}{\partial A}\frac{\partial A}{\partial E_{gr}}(Q) + \frac{b}{a}\frac{\partial m_c}{\partial A}\frac{\partial A}{\partial E_{gr}}(Q) = 0$$

Once again, all terms in the equation are marginal products of labor. In this case, we are not interested in any margin of substitution between using resources for grain production versus meat production, and we have therefore combined the marginal products of grain and meat production (due to increased fodder collection) into a marginal product that we define as $MP_{g+m,Efo.}$ This definition is appropriate, because in this model animals produce joint goods, meat and agricultural capital and there is really no conflict between those two uses.

We can again use the envelope theorem to evaluate the effects of Q, T and T_A on $MP_{g+m,Efo}$ and E_{fo} by differentiating Equation 14 with respect to Q, T and T_A. We first differentiate with respect to Q. Better forests shift each of the marginal products on the right-hand side upward. $MP_{g+m,Efo}$ will therefore also unambiguously increase in a manner similar to that found in comparative statics for Equation 13.

We can use the logic from Equations 13 and 14 to evaluate the effect of Q, T and T_A on fuelwood collection effort. Equation 15 presents the results of substituting Equation 12a into 12 b. We again define MP_{g+m} as the marginal product of labor in a particular use that affects both grain and meat production simultaneously.

Equation 15

$$MP_{g+m,Ef} = \frac{\partial g_c}{\partial f}\frac{\partial f}{\partial E_f} + \frac{\partial M_c}{\partial f}\frac{\partial f}{\partial E_f} = \frac{1}{s}\frac{\partial g_c}{\partial g}\frac{\partial g}{\partial E_g}(Q, T, T_A)$$

From Equation 13, we already know that derivatives of the right-hand side with respect to Q, T and T_A are positive. Using the envelope theorem, we therefore know that these variables increase $MP_{g+m,Ef}$. Because Q is a technical parameter, we also know that $MP_{g+m,Ef}$ rises because of a shift in the curve to the right. Increases in Q, T and T_A therefore increase E_f. Differentiating the right hand side with respect to the parameter s, we see that the derivative is negative. The prediction in this case is that an increase in s (for example due to the use of an improved stove) should reduce fuelwood collection time.

Comparative static results with regard to the various prices in the model were derived using Equations 12a - m. The findings are consistent with what one might expect, but are not central to our set of questions. Relevant selections from these results are summarized in Table 1.

Table 1. Price effects on household labor allocation

Price	Endogenous Variable	Relationship
w	E_g	Negative
w	E_f	Positive
w	E_{fo}	Negative
w_h	E_h	Negative
w_h	E_g	Positive
P_F	E_g	Positive
P_F	E_f	Positive
P_F	E_{fo}	Positive
P_c	E_{fo}	Positive
P_c	E_g	Positive
P_g	E_f	Positive
P_g	E_{fo}	Negative
P_g	E_h	Positive

IV. Data and Econometric Model

Data come from a survey of 378 households conducted by the Bolivian firm Encuestas and Estudios in 32 communities in the Bolivian Andes in May 2000. These communities were located in the provinces of Manco Kapac, Sud Yungas, Esteban Arze, Bolivar, Abaroa, Oropeza, Chayanta, and Tomas Frias, representing a broad range of ecological and historic contexts. Questions were asked to obtain information in five general areas: 1) household makeup and background; 2) forest management; 3) household consumption; 4) household production; 5) assets of the household.

With regard to forest management, data were collected to conform with what is understood to be the main principles of effective management:

1. Clear rules defining who can collect forest products;
2. Public participation;
3. Democracy;
4. Monitoring;
5. Effective sanctions;
6. Fairness;
7. Payments for forest products if appropriate.

The unit of analysis was the household. A decision maker in the house was chosen as the spokesperson for the family. Interviews took approximately one hour. Mean household size was 3.8 persons. The age distribution of households in the sample are given in Table 2 below.

Table 2. Age Distribution of Sample Households (n=378)

Males					**Females**				
Less 6	**6-15**	**16-35**	**36-65**	**+65**	**Less 6**	**6-15**	**16-35**	**36-65**	**+65**
8.64%	11.42%	14.76%	13.37%	4.67%	8.22%	10.03%	11.49%	13.86%	3.55%

Most households in the sample have lived in the communities in which they were interviewed for several generations. Indeed, 80% of households' families had lived in their communities for more than 50 years and 50% had lived there more than 100 years.

Most interviewees could speak Spanish (85%), but most also identified themselves as speaking Quechua, the main indigenous language in the region. A substantial minority (25%) spoke Aymara.

Table 3 below presents key descriptive statistics on perceptions of forest management and forest status.

Table 3. Descriptive statistics on perceptions of forest management and forest status

Question	Mean	Standard Deviation	N
During your lifetime has forest become much taller (=5), a bit taller (=4), the same (3), a bit shorter (2) or much shorter (1) Question P7A	3.1164	1.12233	378
Is the system of forest management clear and understandable (5 =completely clear; 1=no system exists) Question P7C	1.92857	1.4227	378
Are you allocated a fixed allotment of fuelwood per year? (yes=1) Question P8	0.087302	0.282651	378
Do other households have the same allotment of fuelwood as you? (yes=1) Question P10	0.495082	0.500797	305
Do you have to pay to collect fuelwood? (yes = 1) Question P13	0.031746	0.175556	378
Do you have a fixed allotment of animal fodder or grazing rights? (yes=1) Question P15	0.18254	0.386801	378
Do all other households have the same allotment of animal fodder or grazing rights? (yes=1) Question P17	0.536977	0.499434	311
How often do you need to get permission to collect fodder or graze? (1=every time I collect or graze; 4=no permission required) Question P19	3.8877	0.521092	374
Do you have to pay to collect animal fodder or graze? (yes=1) Question P20	0.029101	0.168311	378
For the remaining questions, 5=definitely, 1=definitely not			
Are you and others able to take the forest products you need, but not more? Question P22A	4.125	1.29525	376
Do you have an influence on policies for deciding houw much forest products people can take? Question P22C	1.37701	0.946055	374
Do you help decide who are the managers of the forest? Question P22D	1.17819	0.683249	376
Are the managers of the forest democratically chosen? Question P22F	1.39726	0.999172	365
Do village authorities carefully monitor who takes products from the forest? Question P22H	1.94102	1.45608	373
Do villagers generally watch who takes forest products? Question P22I	1.97067	1.44662	375
If you took more fuelwood from the forest than you were allowed to take would you be penalized? Question P23	1.51206	1.0385	373
If you took more animal fodder or grazing time from the forest than you were allowed to take would you be penalized? Question P25	1.51359	1.06202	368
Would other villagers be unhappy with you if you took more than your allotment of forest products? Question P27A	2.70106	1.70132	378
Would you be embarrassed or feel bad if you took more than your allotment of forest products? Question P27B	2.47355	1.61248	378
Could you lose some or all of your rights to collect forest	2.03183	1.48361	377

products if you were caught taking more than your allotment of forest products? Question P27C			

The picture that emerges from these data is one of very loose formal management, which at least some branches of the literature would suggest should lead to poor performance. In fact, despite the reputation of the region for complex, detailed local management systems, 64% of respondents said there was no system at all! Only 28% responded that their forest management systems were at least "somewhat clear."

Few respondents reported having fixed allotments for fuelwood (only 8%) or fodder/grazing (18%) and few people pay to cut fuelwood or collect fodder/graze. Approximately three-quarters of respondents thought they would "definitely not" be penalized if they took more forest products than they were allotted. In fact, virtually all respondents (95%) reported that they did not need any permission at all to collect forest products. Simply being a member of the community was sufficient to give them access.

Another element of the management seems to be lack of public participation. Few respondents thought they had influence on the forest management structures or that systems were in any way democratic. Yet despite the lack of formal controls and apparent alienation, a substantial minority thought that village officials and villagers themselves monitored forest extractions. The data also suggest that villagers may be more motivated by social pressures. Almost half of all respondents felt that other villagers would at least "probably" be unhappy or angry if one took too much fuelwood or fodder. Similar portions would be embarrassed if they took too much, and a substantial minority even thought they could lose some of their forest product privileges if they were caught overusing forests.

Perhaps as a response to the loose commons management, on-farm tree planting is very common in the region. Sixty-two percent of respondents report they or their ancestors have planted trees on their own lands. The average number of trees planted is 86 and the average age of planted trees is 13 years. More than 20% reported that the average age of planted trees was more than twenty years.

Households were asked to rank the benefits they received from trees from one to seven. Table 4 below shows that the most important benefit is shade and ambiance, but fuelwood is of similar importance. The large numbers of trees suggests that households rely extensively on their own trees for their fuelwood.

Table 4. Ranking of benefits from trees planted on farm (maximum ranking was 7.0)

Benefits from trees planted on farm	Ranking
Others	1.81
Animal bedding	1.91
Fodder	2.10
Fruits and nuts	3.18
Construction timber	3.22
Fuelwood	4.71
Shade and ambiance	4.73

Most households in the sample are relatively poor, consuming meat and eggs an average of only 2.3 times per week. There is in general some integration with markets, with only 27% of households having not gone to a store during the past week. This is despite a mean travel time of two hours to reach the store where households most often go.

Borrowing is difficult in these regions. There are few if any banks outside the main cities of the region, and only 16% of respondents saying they have access to credit from local money lenders.

The most important fuel respondents had used during the week before the survey took place was fuelwood, with thola (a local shrub) being the second most important biomass fuel. As shown in the table below, a substantial minority also has access to natural gas. Almost half of all respondents use *lorena* stoves. Virtually no biomass fuels are purchased by households in the sample (Table 5).

Table 5. Fuels used by household surveyed

Fuelwood	Thola	Dry Moses	Dung	Gas	Crop Resides	Kerosene	Electricity
51.3%	36.2%	2.4%	17.5%	42.9%	5.8%	11.9%	2.7%

The average household in the sample does not own a lot of land. Mean land holdings are 1.5 hectares per household, but as one might expect the standard deviation is large, at almost 3.5 hectares. Households also access common agricultural lands, but this does not in any way reverse the conclusion that the average household is rather land-poor. On average, households accessed only 0.64 hectares of common agricultural land. Table 6 below presents key data on agricultural production.

Table 6. Land holdings and harvest levels

	Potato	Quinua	Corn	Haba	Cebada
%of households that planted	69.6	18.0	52.4	42.9	45.8
Crops per year	1	1	1	1	1
Area (mean hectares)	3.20	0.644	2.2	0.60	2.40
Harvest (mean Kilos)	1071	92	562	297	631
% of output sold	16	5	24	5	8
% that use animal fertilizer	94	61	77	63	34
% that use chemical fertilizer	34	15	12	13	4
% that use pesticides	31	10	9	9	2

We see from the table that potato is by far the most important crop, both in terms of area, harvest and participation by households. This crop also seems to receive the lion's share of dung fertilizer, as well as chemical inputs.

Large animal holdings in the sample are relatively limited, with over half of households having no cows and 60% reporting no pigs. Fifty-five percent of households have at least one sheep, however, and many have substantially more.

Survey respondents were asked to recollect their labor allocations during the previous week in the six areas included in the analytical model (household labor, agriculture, fuelwood collection, grazing, fodder collection and wage labor). Although survey questions that focus on past activities are known to suffer biased answers, valid responses can be expected when the household has fairly regular work patterns (Juster and Stafford 1991), a situation that can be expected within a given season in the Bolivian Andes. Households on average worked a total of 144 hours during the previous week. The breakdown by activity is given in Table 7 below.

Table 7. Household labor allocations during previous week

	Mean Hours	Standard Deviation	Maximum Hours	Number of Cases
Household labor	32.984	22.1253	123	304
Agriculture	50.365	30.5489	147	329
Fuelwood collection	9.774	17.4268	175	329
Grazing	28.067	31.0882	252	329
Fodder collection	10.365	22.2327	252	326
Wage labor	5.310	14.4583	110	329

The breakdown of activities is, perhaps, not unexpected. Agriculture consumes the most time, with household labor second and grazing third. Perhaps surprising is the relatively small amount of time devoted to fuelwood collection. This could potentially be the result of collections on own lands at relatively low cost or it could reflect seasonal patterns of labor allocation. May, when the survey took place, is approximately one month after the end of the rainy season and perhaps stockpiling of fuelwood had not yet begun.

The descriptive statistics on forest management suggest that a majority of households experience very loose management. The question then is how do the outcomes for this majority compare with those for the minority that has what the literature considers solid management. The data were analyzed to test the model presented in the previous section with a focus on the effects of differing forest management practices. Because the model focuses on the allocation of household labor, it is the allocation of labor that is the primary focus of analysis.

It should be emphasized that we were unable to explicitly evaluate the effects of differing forest management systems on forest quality directly. We do not have good measures for forest quality, and therefore this important extension must be left for the future. Instead, we rely on the common property and other literatures and with reference to our analytical model simply *presume* that steps such as creating clear management rules, explicit limits on collections, including penalties, democratic control and perceived fairness in reality have had favorable effects on the forest.

The question to be answered in the next section is how do different management features impact households' labor allocation decisions. To answer this question, structural form labor supply functions were estimated. Reduced forms were not used, because so many products had limited interaction with markets. Prices therefore either did not exist in our sample or so few households bought or sold that including prices typically reduced the active sample size by more than 50%. For example, only 53 households had ANY household member who worked for wages during the previous week. It was therefore not possible to include the wage rate in the wage labor supply function.

Structural forms were estimated using two stage least squares (2SLS), with all labor categories being included as independent (but endogenous) variables in the regressions of the other labor supply variables. Another endogenous variable included was cattle holdings, because of the importance of dung fertilizer for agricultural production.

V. Results

In all initial models, all labor categories were included. We also included key household information that was likely to be of relevance (e.g. household size, land holdings, market interaction, etc.) for each equation. These variables were then tested out using standard F tests and dropped from equations.

These fundamental variables aside, it turned out that it was not really reasonable to have an initial master regression model that applied to all six labor categories. The data set we used has 39 variables that relate to forest management divided into the seven categories listed in the previous section. Many of these forest variables are highly collinear and other than to include one or more from each category, we do not really have a model to help us know which of these variables *a priori* should belong in a particular regression equation. We therefore were forced to try combinations of different forest management variables within each of the seven categories to see which variables affected the dependent variable being analyzed.

This practice also had implications for the set of instruments used. Forest management variables are taken as exogenous in all models, and therefore they must be included both in the list of regressors and the list of instruments. While a basic set of 30 instruments was used across all equations, at times it was necessary to make minor modifications to the set of instruments to accommodate new regressors.

Because data matrices of full rank are required for both the set of regressors and instruments, often the observations used for the analysis were in the range of 200-230 rather than 378, which makes up the full data set. Observations with missing data were dropped automatically to create full rank matrices. Particularly if variables related to on-farm tree planting (a very important set of variables) were included degrees of freedom dropped dramatically.

The basic set of instruments included the following variables:
Household size; 2)highest level of education of a household member; 3)dummy for Spanish speaker; 4) perceived change in forest height; 5) degree to which rules of inclusion are clear; 6) dummy for whether there are clear limits on fuelwood extractions; 7) dummy for whether there are clear limits on fodder collection and grazing; 8) how often it is necessary to get permission to graze; 9) dummy for whether household has to pay to collect fodder/graze; 10) department of the community; 11) degree to which availability of forest products is sufficient, but not excessive; 12)degree to which monitoring by village authorities is effective; 13) degree to which penalties would be levied for violations with respect to fuelwood; 14) degree to which penalties would be levied for violations with respect to fodder/grazing; 15) degree to which villagers would be unhappy over cheating; 16) degree to which respondent would feel embarrassed if s/he cheated; 17) dummy for *lorena* stove; 18) price of beef; 19) price of pork; 20) price of chicken; 21) price of potatoes; 22) price of quinua; 23) price of corn; 24) average monthly cash expenditures in market; 25) time in minutes to reach the market; 26) dummy for whether respondent can borrow from a money lender; 27) technology used to plow; 28) land area in square meters devoted to potatoes; 29) total agricultural land owned by the family; 30) total number of sheep held.

Table 8. Determinants of household labor allocated to grazing (hours/week). Without On-Farm Tree Planting

Independent Variables	Coefficient	Standard Error	t-ratio	P-value
Constant	45.19	15.377	2.9388	0.003295
Household labor	0.251707	0.159461	1.57849	0.114453
Fodder collection	0.754851	0.154937	4.87197	1.10E-06
Wage labor	-0.47231	0.286645	-1.64772	0.09941
Household size	2.48185	0.840727	2.95203	0.003157
System defining access to forest is clear (5=completely clear; 1= no system)	-4.44868	1.24328	-3.57819	0.000346
Fixed allotment of fodder/grazing (1=yes; 0=no)	-10.3386	4.78153	-2.16219	0.030603
Frequency of permission to graze/collect fodder (1=every time; 4= never)	-4.4611	3.37082	-1.32345	0.185687
Money has to be paid to collect fodder/graze (1=yes; 0=no)	20.4886	14.3121	1.43156	0.152271
Respondent and others in village can take forest products they need, but not more (5=definitely; 1=definitely not)	-1.66935	1.03028	-1.62029	0.10517
Area devoted to potato cultivation (square meters)	0.00074	0.000331	2.23491	0.025423
Average monthly cash expenditures at store (bolivianos)	-0.05232	0.013672	-3.8267	0.00013
Respondent can borrow (1=yes; 0=no)	-6.66472	4.70732	-1.41582	0.156828
Total number of sheep held	0.250924	0.06488	3.86751	0.00011
2SLS Regression	N=223	F(13,209)=14.93	Adjusted R^2=.45	

The results for total household labor devoted to grazing are given in the table above. The analysis suggests that grazing is complementary with fodder collection and household labor, but a substitute with off-farm labor. This result is similar to that found for Nepal by Bluffstone (1995). With regard to the forest management variables, clear rules regarding access to forest commons appear to reduce grazing effort. The same is true when fixed allotments of grazing/fodder are given, but grazing effort is declining in frequency with which permission to graze is required, but is not significant.

It should be noted that these results contradict the analytical model, where better management was presumed to have led to higher quality forests and therefore households would have already devoted more effort to forest-based activities. Higher quality forests due to better management was predicted to spur more effort in the future; the model therefore predicted that better management should lead to more effort than in areas where forests were more degraded due to poor management.

In general, however, the econometric analysis suggests quite the opposite, that tighter management reduces labor supply to forest dependent activities. This result is robust and recurs throughout this section. For this reason it is mentioned at the beginning of the discussion of results. It seems either that this type of labor supply effect either has not yet kicked in throughout the Bolivian Andes, the cross sectional econometric analysis does not allow us to detect those effects or the analytical model requires revision. We believe that the last two explanations are most relevant. It seems that the analytical model should be revised to have first order and second order effects of forest management structures and instruments on production functions. At present, only the second-order effect (better forests) is included. Probably panel data analysis techniques would also be required to detect second order effects.

Grazing effort is, however, positively correlated with whether money must be paid to graze. This coefficient estimate is not significant, however, because money payments for fodder/grazing and fixed allotments of grazing/fodder rights are highly collinear. If either variable is dropped, the remaining variable is significant at the 10% level. The degree to which households can take what they need, but not more, is negatively related to grazing effort. We interpret the sign of this coefficient to mean that perceptions of fairness reduce grazing. The final four variables are proxies for wealth and cash incomes/market integration. In general, wealthier households (more land and more sheep) spend more time grazing, while more market oriented households graze less. Sheep are also well suited to grazing technologies.

The table below presents an alternative model of grazing effort, which includes a measure of on-farm tree stock, the average age of trees planted on-farm. As was already mentioned, the inclusion of this variable reduces observations dramatically (in this case to 138). It is nevertheless interesting to consider this case, because average age of on-farm trees is negatively correlated with reduced grazing effort and is significant at the 1.0% level. Coefficients on forest management variables do not change drastically when average age of on farm trees is included, and most estimates remain highly significant. The only major change is that including on farm trees causes the off-farm wage labor variable to be almost completely unrelated to grazing effort and was therefore dropped from the equation.

Table 9. Determinants of household labor allocated to grazing (hours/week). On-Farm Tree Planting Included

Independent Variables	Coefficient	Standard Error	t-ratio	P-value
Constant	67.7099	11.9853	5.64943	1.61E-08
Household labor	0.263139	0.135538	1.94144	0.052204
Fodder collection	0.714413	0.195243	3.6591	0.000253
Household size	2.77123	1.08885	2.5451	0.010925
System defining access to forest is clear (5=completely clear; 1= no system)	-2.49466	1.36151	-1.83228	0.06691
Fixed allotment of fodder/grazing (1=yes; 0=no)	-13.46	5.03766	-2.67188	0.007543
Frequency of permission to graze/collect fodder (1=every time; 4= never)	-11.202	2.51135	-4.46053	8.18E-06
Money has to be paid to collect fodder/graze (1=yes; 0=no)	-21.9488	10.6728	-2.05651	0.039733
Respondent and others in village can take forest products they need, but not more (5=definitely; 1=definitely not)	-1.46961	1.40319	-1.04734	0.294944
Area devoted to potato cultivation (square meters)	0.000671	0.000453	1.48239	0.138236
Average monthly cash expenditures at store (bolivianos)	-0.0421	0.013112	-3.21053	0.001325
Respondent can borrow (1=yes; 0=no)	-12.8016	4.25896	-3.00581	0.002649
Average age of trees on-farm (years)	-0.32178	0.136951	-2.34961	0.018793
Total number of sheep held	0.434547	0.190629	2.27954	0.022635
2SLS Regression	N=138	F(13,124)=12.8	Adjusted R^2=.53	

Table 10. Determinants of Household Labor Allocated to Fodder Collection (hours/week).

Independent Variables	Coefficient Estimate	Standard Error	t-ratio	P-value
Constant	-50.2929	15.4839	-3.24807	0.001162
Total fuelwood collection effort (hours/week)	0.716856	0.25757	2.78316	0.005383
Total grazing effort (hours/week)	0.507583	0.133746	3.79513	1.48E-04
Household size	-1.81698	0.778861	-2.33287	0.019655
Degree to which system defining access to forest is clear (5=completely clear; 1= no system)	5.58774	1.19464	4.67735	2.91E-06
How often permission to graze/collect fodder is needed (1=every time; 4= never)	7.32667	3.19816	2.2909	0.021969
Whether money has to be paid to collect fodder/graze (1=yes; 0=no)	-16.0151	13.5318	-1.18352	0.236603
Likelihood that penalties would be levied for overgrazing/taking too much fodder (5=definitely; 1=Definitely not)	2.1827	1.47101	1.48381	0.13786
Likelihood to which villagers would be unhappy if too much forest products was taken (5=definitely; 1=Definitely not)	2.45861	1.23526	1.99036	0.046551
Likelihood that some or all of rights to collect forest products would be lost if household was caught cheating (5=definitely; 1=Definitely not)	-2.69784	1.50326	-1.79467	0.072707
Area devoted to potato cultivation (square meters)	-0.00075	0.000309	-2.43764	0.014783
Average monthly cash expenditures at store (bolivianos)	0.048522	0.01225	3.96089	7.47E-05
Has respondent or his/her ancestors planted trees on farm (1=yes; 0=no)	-3.84924	2.95277	-1.3036	0.192369
Total number of sheep held	-0.13609	0.055248	-2.4632	0.01377
2SLS Regression	N=233	F(13,219)=6.3	Adjusted R^2=.23	

The table above presents the preferred model of total fodder collection effort. It should be recalled that average household time on fodder collections was only 10 hours per week compared with 28 for grazing. It therefore seems that fodder collections (at least during May) is an activity that is secondary to grazing in importance. In this model, all else equal fuelwood collection and grazing appear to complement fodder collection effort. Larger households, however, appear to graze more, but spend less time cutting fodder. There are important differences with forest management variables as well. While clear rules regarding access to forest commons appear to reduce grazing effort, it seems that some substitution into fodder collection occurs. Whether this increased fodder collection effort occurs on-farm or off-farm we do not know, but it certainly is likely that on farm collections increase. Indeed, this was the result found by Cooke (2000) in a similar model of Nepal. Though in this model not significant, it is notable that all else equal, households that have planted trees spend less time on fodder collection; on-farm trees therefore appear to save households time as one would expect. Planting trees on-farm could be a reasonable response to a tightening of access to common lands.

With regard to other forest management variables, households that need to get permission less often appear to spend more time on fodder collections. This could again be interpreted as households substituting out of grazing on common lands and into fodder collections at least partially on-farm. Payments for fodder/grazing are negatively related to fodder collection effort, but the coefficient estimate is not significant. If households are likely to pay penalties for overgrazing or cutting too much fodder on common lands, they seem to increase their fodder collection effort. This result reinforces the interpretation that as management becomes tighter, the proportion of cut from own land increases.

This interpretation is further reinforced by the positive coefficient on the predicted degree of unhappiness of villagers when cheating occurs, but appears to be contradicted by the negative coefficient on the likelihood that some or all rights would be lost if the household was caught cheating. Agricultural land in potato production (the main subsistence crop) is negatively related to fodder collection effort, which is a result that is opposite that found for grazing effort. Average cash expenditures in stores (a proxy for market exposure and cash income) is positively related to fodder collection, while negatively related to grazing. Sheep held are a proxy for wealth, but they are also ill suited to stall feeding. The negative relation with fodder collection effort is therefore not surprising and offers another contrast with grazing effort, which has a positive relationship with sheep holdings.

Despite the apparent positive relationship between grazing and fodder collection effort, the regressions suggest that fodder collection occurs within a very different context than grazing. Fodder collections (possibly on-farm) seem to be an alternative to grazing commons when control over common lands is tightened in a variety of ways. In contrast to grazing, which seems to be associated with a higher degree of subsistence agriculture and less market integration, fodder collection increases in these variables.

Table 11. Determinants of Household Labor Allocated to Agriculture (hours/week).

Independent Variables	**Coefficient Estimate**	**Standard Error**	**t-ratio**	**P-value**
Constant	19.5165	8.46804	2.30472	0.021182
Household labor (hours/week)	0.209412	0.150143	1.39475	0.163091
Fuelwood Collection Effort (hours/week)	0.770067	0.262844	2.92974	3.39E-03
Household size	1.3253	0.863793	1.53428	0.124962
Degree to which system defining access to forest is clear (5=completely clear; 1= no system)	-3.84597	1.25263	-3.07032	2.14E-03
Whether money has to be paid to collect fodder/graze (1=yes; 0=no)	12.6886	5.46641	2.3212	0.020276
Technology of plowing	6.6898	2.24809	2.97576	0.002923
Area devoted to potato cultivation (square meters)	0.000444	0.000313	1.41725	0.156411
Has respondent or his/her ancestors planted trees on farm (1=yes; 0=no)	6.59124	3.68678	1.7878	0.073808
2SLS Regression	N=233	F(13,219)= 6.3	Adjusted R^2=.23	

The table above presents results for total household effort in agricultural production.[5] The story this model tells is perhaps less striking than those for grazing and fodder collection. Agricultural labor input is positively related to household labor and fuelwood collections. In this model it is unrelated to gazing and fodder collection effort, which is consistent with the results of the models of those variables. Larger households tend to have higher labor inputs to agriculture, as do those with more land devoted to potato production (but not total agricultural land holdings)[6] and more primitive plowing technologies.

With regard to the forest management variables, clear rules regarding access to forest commons seems to reduce agricultural labor, suggesting that at least in the short run tighter forest management could have agricultural productivity effects that are independent of those associated with reduced herd sizes. Households that pay for the right to collect fodder or graze animals, however, have higher agricultural labor inputs. No other variables were directly correlated with agricultural labor input.

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[5] These estimates were corrected for heteroskedasticity using the method of White (1980).
[6] Significant only at 15% level.

For fuelwood collection effort, there are again two models, one with average age of on-farm trees and one without that variable. Both are presented, because including average age of on-farm trees causes the loss of so many degrees of freedom. The next table presents results without including on-farm tree planting.

The results suggest that fuelwood collection effort is positively correlated with fodder collections and agricultural labor. Clear rules defining forest access reduce fuelwood collection effort, which is the expected result, though the coefficient estimate is only significant at the 15% level. Fixed allotments of fuelwood are positively correlated with fuelwood collection time, which is not the expected result. One possible explanation for this result is that significant cutting on-farm or from other sources is taking place which requires more effort per unit of fuelwood collected that common lands. Finally, the last two variables suggest that households that spend more time collecting fuelwood are similar to those that graze animals a lot. In both cases, increased market integration and incomes are negatively related with household effort.

Table 12. Determinants of Household Labor Allocated to Fuelwood Collection (hours/week). Model without Average Age of Trees On-Farm

Independent Variables	Coefficient Estimate	Standard Error	t-ratio	P-value
Constant	-0.61878	6.38072	-0.09698	0.922745
Total agricultural labor (hours/week)	0.190348	0.103702	1.83552	0.066429
Total fodder collection effort (hours/week)	0.431276	0.183187	2.35429	1.86E-02
Degree to which system defining access to forest is clear (5=completely clear; 1= no system)	-1.40584	0.992361	-1.41666	0.156582
Fixed allotment of fuelwood (1=yes; 0=no)	5.63868	2.03001	2.77765	5.48E-03
Average monthly cash expenditures at store (bolivianos)	-0.00988	0.00442	-2.23413	0.025474
Whether respondent can borrow (1=yes; 0=no)	-4.03887	1.67993	-2.40419	0.016208
2SLS Regression	N=287	F(6,280)=6.3	Adjusted R^2=.18	

The next table includes the effects of on-farm tree planting. We see that, though only significant at approximately the 23% level, households with older trees on-farm devote less labor to fuelwood collection, all else equal. This result suggests that households may save time by planting trees on-farm, and we know from descriptive statistics that respondents consider fuelwood production an important output of on-farm trees.

Fodder collection effort was again positively related with fuelwood collecting, but a difference in this model is that agricultural labor no longer was related to fuelwood collection effort and was dropped. Clear rules defining forest access are still associated with reduced fuelwood collection effort, but this time the estimate is significant at the 2% level. The variable "whether fixed limits on fuelwood collections exist" appeared to be totally unrelated with fuelwood collection effort and was dropped from the model. More directed and specific forest management variables appear, however, to be important. Households who paid for access to fuelwood devoted less labor to fuelwood collection, which is the expected result. The more frequently permission must be obtained, also the less effort tends to be devoted to fuelwood collection. Though these coefficient estimates were only significant at the 14% and 19% levels respectively, it should be noted that these variables are collinear. Dropping either variable makes the other one significant at the 5% level while increasing the magnitude of the coefficient. Integration with the market is again negatively related with fuelwood collection effort as in the previous model. A possible paradox is the coefficient on the likelihood villagers would be unhappy if too much forest products was taken. The estimated coefficient is negative, which is perhaps not what one would expect (more social pressures for conformity should result in less fuelwood collection effort all else equal). This result can perhaps be explained if social pressures tend to develop where reliance on fuelwood is highest. Investigating this question is, however, beyond the scope of this paper.

Table 13. Determinants of household labor allocated to Fuelwood Collection (hours/week). Model includes On Farm Tree Planting

Independent Variables	**Coefficient Estimate**	**Standard Error**	**t-ratio**	**P-value**
Constant	6.82589	4.25363	1.60472	0.108556
Fodder collection effort (hours/week)	0.196704	0.113424	1.73424	0.082875
Degree to which system defining access to forest is clear (5=completely clear; 1= no system)	-1.57182	0.690144	-2.27752	0.0228
Whether money has to be paid to collect fuelwood(1=yes; 0=no)	-2.87303	1.97003	-1.45837	0.144739
How often permission to collect fuelwood is needed (1=every time; 4= never)	0.975224	0.744547	1.30982	0.190
Likelihood to which villagers would be unhappy if too much forest products was taken (5=definitely; 1=Definitely not)	0.9178	0.674723	1.36026	0.173747

Average monthly cash expenditures at store (bolivianos)	-0.00585	0.003906	-1.49813	0.1341
Whether respondent can borrow (1=yes; 0=no)	-6.05834	1.33578	-4.53543	5.75E-06
Average age of trees on farm (years)	-0.06651	0.055185	-1.20516	0.228141
2SLS Regression	N=187	F(8,178)=3.73	Adjusted R^2=.11	

We have seen that in general better management (especially clear access rules) seems to reduce grazing and fuelwood collection effort. We would therefore expect that, all else equal, better management of common forests would result in labor shifting into non-forest dependent activities such as household labor. The results presented in the table below uniformly (but not always significantly) support this hypothesis. Work in the home is positively related with agricultural labor and grazing, and negatively related with fodder collection time. As expected, clear rules defining forest access increase work in the home, and this result is significant at the 3% level. Fixed allotments of fuelwood and fodder are also associated with increased work in the home. Although the coefficient estimates are significant only at the 18% and 13% levels, these variables are collinear. Dropping either variable makes the remaining one significant at the 5% level. Social pressures, as represented by a belief that villagers would be unhappy if cheating occurred, also are correlated with increased work in the home, though the coefficient estimate is significant only at the 23% level. *Lorena* stoves appear to save households time, which perhaps explains the widespread use in the sample. Higher cash incomes and wealth are associated with more work in the home, while sheep holdings are negatively associated with this set of activities.

Table 14. Determinants of Total Household Labor in the Home (hours/week).

Independent Variables	**Coefficient Estimates**	**Standard Errors**	**t-ratio**	**P-value**
Constant	-0.23369	8.83619	-0.02645	0.978901
Agricultural labor (hours/week)	0.219276	0.13738	1.59613	0.11046
Grazing effort (hours/week)	0.4594	0.138877	3.30796	9.40E-04
Fodder collection effort (hours/week)	-0.41475	0.176396	-2.35124	0.018711
Degree to which system defining access to forest is clear (5=completely clear; 1= no system)	2.89981	1.35331	2.14275	0.0321

Fixed allotment of fuelwood (1=yes; 0=no)	7.17728	5.33875	1.34438	0.178827
Fixed allotment of fodder/grazing rights (1=yes; 0=no)	6.22266	4.14371	1.50171	0.133171
Likelihood to which villagers would be unhappy if too much forest products was taken (5=definitely; 1=Definitely not)	1.13345	0.94233	1.20281	0.229
Has an improved (*lorena)* stove (1=yes; 0=no)	-6.28764	3.88918	-1.6167	0.105943
Average monthly cash expenditures at store (bolivianos)	0.025113	0.012008	2.09138	0.036494
Total agricultural land holdings (square meters)	6.25E-05	3.97E-05	1.57311	0.115694
Total sheep held	-0.08741	0.038102	-2.29402	0.0218
2SLS Regression	N=224	F(11,212)=3.63	Adjusted R^2=.12	

Finally, we come to off-farm wage labor. The analytical model suggests that the possibility to earn a wage off-farm is a major determinant of on-farm behavior. Unfortunately, so many observations were missing that it was not possible to include the wage rate in the analysis. Nevertheless, it is reasonably clear that off-farm opportunities interact with on-farm opportunities in important ways. Agricultural labor and wage labor are complements in this model. This is perhaps not surprising given the low level of wage labor observed. Grazing effort and wage labor appear to be substitutes, though this strong negative relation disappears when sheep holdings are not included. We interpret this result as meaning that adjusted for wealth levels, the relationship between grazing and wage labor is negative. Identification as a farmer was negatively (but not significantly) correlated with wage labor and the longer a family had lived in a community the more off-farm work was observed.

Two forest management variables remained in the equation after testing. Clear rules of forest access were associated with more off-farm work (significant at 22% level) as expected. Furthermore, the existence of penalties for overcutting fuelwood (significant at 10% level) also increased work off-farm. Beef and pork prices are related to off-farm work in opposite directions, perhaps reflecting the likelihood that with cow holdings low, beef tends to be purchased in the market. As beef prices rise, incentives for wage labor decline. Ability to borrow and on-farm tree planting were negatively related with wage labor, suggesting that borrowing may be tied to landholding and agricultural activities rather than wage labor (perhaps because of low wage rates) off farm. The negative relation with the existence of on-farm trees is a bit of a mystery. Our priors suggested a positive relation if households plant trees to reduce grazing time.

Table 15. Determinants of Household Labor Allocated to Off-Farm Work (hours/week).

Independent Variables	**Coefficient Estimates**	**Standard Errors**	**t-ratio**	**P-value**
Constant	-7.96618	7.42996	-1.07217	0.283644
Household agricultural labor (hours/week)	0.150875	0.089762	1.68084	0.092793
Grazing effort (hours/week)	-0.13167	0.063909	-2.06022	0.039378
Respondent identified him/herself as a farmer (1=farmer; 0=otherwise)	-5.7785	3.94079	-1.46633	0.142559
Length of time respondents' family lived in community (1= 2-5 years; 7=greater than 100 years)	0.972597	0.566343	1.71733	0.085919
Degree to which system defining access to forest is clear (5=completely clear; 1= no system)	0.993995	0.811542	1.22482	0.220642
Likelihood that penalties would be levied for taking too much fuelwood (5=definitely; 1=Definitely not)	2.69111	1.67293	1.60862	0.107699
Reported price of beef (bolivianos)	-0.0607	0.025325	-2.39675	0.016541
Reported price of pork (bolivianos)	0.079284	0.030072	2.63645	0.008378
Whether respondent can borrow (1=yes; 0=no)	-3.84962	1.81132	-2.12531	0.03356
Has respondent or his/her ancestors planted trees on farm (1=yes; 0=no)	-3.15153	1.96125	-1.60689	0.108078
Holdings of sheep	0.107602	0.033819	3.18174	0.001464

2SLS Regression	N=235	F(11,223)=3.3	Adjusted R^2=.10

VI. Conclusion

In conclusion, local management and institutions appear to affect rural households in important ways. Clarity of rules to access the commons and extract products appears to be a critical variable. Clear rules reduce the time allocated by the household to grazing and fuelwood collection activities. This reduction of time spent in forest-related activities may mean that the forest quality is higher, thus producing more goods per unit of time.

Households that perceived the existence of a fixed allotment of fodder/grazing and clear access rules were likely to spend about 14 hours less in grazing activities than households without clear rules. The magnitude of this estimate is large, given that the average household in the sample spent 28 hours per week in this activity. This result is consistent with what Edmonds (2000) found in Nepal following the creation of forest user groups. It is also consistent with the large literature on the effects of tenure security on resource use (see, e.g., Godoy and Kirby 2000 for a review of studies and some econometric analysis of household data from the Bolivian lowlands.) In fact, clarity of rules reduces uncertainty about who has access to the resource and how much they are allowed to extract.

The analysis also suggests that clarity of rules, together with required payments (or fixed allotments), is associated with higher investments in tree planting and a shift from using common forest to using on-farm trees, particularly for fodder collection. Although our data collection failed to identify the source of fodder (i.e., whether fodder was collected on-farm or off-farm), the analysis strongly suggests that increases in fodder collection partly occurred on private property.

The labor savings induced by better management of common forests also resulted in a shift of labor into non-forest dependent activities such as household labor and, to a smaller degree, wage labor. While the average household spent 33 hours/week on home labor, households that lived in areas with clear rules to use the commons and fixed allotments of commons' products had available about 16 hours/week more to do home work than households where rules were unclear. Furthermore, households that adopted improved stoves spent 6 hours per week less on domestic labor than household that burned fuels traditionally.

It would be quite interesting to test for the direct impact of local management and institutions on forest quality. Environmental variables such as rainfall, altitude, and temperature are being collected, but an approach where direct measurement of changes in resource quality are carried out (such as the one pursued by Foster et al. 1998) would provide valuable new insights into the environmental benefits and costs of local management of common resources.

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