CHAPTER 11

JOINT FOREST MANAGEMENT: EXPERIENCE AND MODELING

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Abstract. The experience with Joint Forest Management (JFM) in different countries has varied considerably, succeeding in limiting deterioration of the forest in some cases but not in others. Inequality within the forest community has also had a tendency to increase. The purposes of this chapter are (1) to review relevant literature on JFM, (2) to develop a multi-purpose model that could be used to identify conditions that can influence the likelihood of success of JFM in improving the welfare of those living and working in forest communities as well as making forest use more sustainable, and (3) to highlight the role of forest externalities and institutional conditions in analyzing the effects of JFM, and (4) to suggest applications and extensions that could provide valid policy implications tailored to specific

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circumstances. Although highly simplified, the model is designed so as to be flexible enough to deal with a wide variety of settings in rural areas of developing countries and yet at the same time specific enough to provide some policy conclusions. Even the present highly simplified model demonstrates general conclusions about the efficacy of JFM cannot be drawn without very specific empirical knowledge concerning the behavioral and technological parameters in the model.

1. INTRODUCTION

Data from around the world is revealing that substantial portions of the world's forests are quite rapidly disappearing and deteriorating. Frequently, such resources are owned by state or national governments, but can be considered *de facto* common property resources. Many of these common property regimes, however, have deteriorated so as to become rather indistinguishable from open access. Naturally, this has resulted in declining welfare of those in the forest community dependent on these resources.[1] As knowledge of these circumstances has spread, often at the behest of NGOs, governments are increasingly including local user groups in the management process of these forest resources. This is what is called co-management or Joint Forest Management (JFM).

While the details of JFM vary considerably from place to place, a common characteristic is for local communities to receive somewhat greater property rights and influence over local natural resources than under the preceding regimes. Some evaluators have gone so far as to see JFM as a creative and potentially optimal arrangement combining the separate strengths inherent in property regimes of private ownership, direct state control, and communal property so as to help sustain this important natural resource base (Baland & Platteau, 1996).

Current programs range from large game wildlife management in Africa (Bulte & Horan, 2003), fisheries in Japan (Baland & Platteau, 1996; Kenneth, 1989), community woodlots in Ethiopia (Gebremedhin, Pender, & Tesfay, 2003), and forests in Mexico (Klooster, 2000; Munoz-Pina, de Janvry, & Sadoulet, 2002), India (Kumar, 2002; Richards, 2000), China (Hyde, Belcher & Xu, 2003) and Nepal (Agrawal & Ostrom, 2001; Edmonds, 2002), to the management of all village resources in Burkina Faso (Baland & Platteau, 1996). The U.S. government has also experimented with co-management among Arctic Alaskan communities with respect to select marine mammals and large game. In Canada also, there are some 15 different examples of co-management in which the role of the local user group varies widely (Rusnack, 1997).[2]

As a result, JFM is viewed by some as a mechanism that can be counted on to promote the quality of life for the rural poor and at the same time to reduce forest degradation. Nevertheless, the jury is still out on its overall success since the experience seems to have varied from place to place, allegedly depending on institutional and other characteristics (Baland & Platteau, 2001; Bardhan, 2002; Jaramillo & Kelly, 2000; Kumar, 2002; Platteau, 2001). While JFM may lead to efficiency gains relative to pure State management in certain contexts, it may not do so in all. At the same time, moreover, many studies have been less sanguine about its role in reducing poverty and inequality, indeed suggesting that elite groups within the forest communities may capture the bulk of the benefits, quite possibly immiserizing the poor (Klooster, 2000; Kumar, 2002).

While the literature has begun to provide interesting stylized facts based on individual case studies or surveys, the modeling of these circumstances and the ability to evaluate the potential benefits of different features of JFM is still in a relatively primitive stage. The objectives of this chapter are (1) to review the literature on JFM relevant to modeling and assessment, (2) to provide a simple general equilibrium model that captures the stylized facts derived from the existing literature, (3) to highlight the role of forest externalities and institutional conditions in analyzing the effects of JFM, and (4) to suggest applications and extensions of the model that could yield policy implications tailored to the very specific circumstances of individual JFM cases.

Although the model necessarily makes many simplifications, it is designed to capture four important environmental and institutional features highlighted in the literature on JFM, namely, (1) the heterogeneous character of, and inequality within, forest user groups, (2) the influence of such heterogeneity on the degree of dependence on forest resources, the sustainability of forest production and the degree of inequality between the user groups, (3) the effect of JFM on each of these relationships and considerations, and (4) the importance of the quality of the forest and the externalities thereof, and the possible effect of JFM on the effectiveness of regulatory control and property rights over forest land. Section 2 reviews the relevant literature. Section 3 outlines the model. Section 4 derives insights from the model, suggests applications and further extensions.

2. FINDINGS FROM THE LITERATURE

2.1 Specific Examples of JFM

In 1989 the Indian Central Government mandated that the individual state governments formally adopt JFM as the primary mechanism through which the State would manage state-owned forest resources. The policy was reportedly motivated by a desire to both reduce environmental degradation (which, according to Kumar (2002), the Central Government attributed largely to local communities using the forests as *de facto* open access property) and to reduce rural poverty. The states, however, were left with a great deal of flexibility with respect to the particular approach they would adopt. In the 26 of 28 states that have formally adopted JFM, the incentives offered by various State Forest Departments to local village forest communities have ranged from wage payments for protective labor services, to in-kind and revenue shares of the non-timber forest products collected, to revenue shares of timber sales, and to combinations of each (Kumar, 2002).

A similar form of JFM was recently adopted in Nepal, though with somewhat less direct government involvement. Due to increasing rates of forest clearance and growing environmental degradation, the Nepalese government began a process of transferring ownership and control of all forests to local communities or "Forest User Groups." The central government provides the user groups with both the framework and resources necessary to reduce resource extraction (Edmonds, 2002).

User-groups in Nepal receive a greater share of the return from successful management in land held as common village property than those in India.

JFM has also occurred in Mexico. As a result of land reform that followed the 1910 peasant-led revolution in Mexico, roughly 80% of Mexico's forests are currently held as *de jure* common property (Klooster, 2000). Yet, only after the legislative changes of the 1980's, did local communities begin to have some autonomy in collectively managing timber resources. Prior to that, the communities were forced to contract with approved logging companies that autonomously made the important production and other decisions. More recently, however, communities were allowed to form cooperatives to harvest and manage logging operations under specified criteria, a context akin to the Nepalese case given that communities both own and manage resources with considerable State oversight. As a result of these changes, several successful examples of JFM have emerged in Mexico.[3]

According to Liu and Edmunds (2003), since 1978 China, too, has undergone a variety of JFM-like reforms. Indeed, the form and pace of these reforms have varied widely over space as well as time. In general, they have involved the devolution of management and control from the central government to the regional and local level and with different degrees of property rights conferred to individuals and groups in forest areas. A special problem that has arisen in the Chinese case has been the credibility of announcements of reform policies inasmuch as the government has from time to time seen fit to reverse some of these partial property rights devolutions on the basis of insufficient new investment by the forest populations in afforestation.

2.2 Outcomes and Institutional Features of Successful JFM

There is at least some empirical evidence supporting the hypothesis that forest resources are managed more efficiently and in a more sustainable way under JFM than under central management. In an excellent empirical study of such programs, Edmonds (2002) tests the robustness of relatively lower mean levels of resource extraction in Nepalese forests managed by "Forest User Groups" relative to areas managed purely by the central government. Using several different estimation techniques, he finds that the difference is indeed robust, supporting the view that Nepalese JFM is more efficient in managing and preserving forest resources than the central government. Consistent with Edmond's (2002) findings, Kumar (2002) finds similar evidence in India. Yet, Kumar argues that the distribution of benefits under JFM has at the same time been highly unequal (a rural elite capturing most of the economic benefits) and that much of the gain in lower resource extraction has come at the expense of the poorest.

In Mexico, Klooster (2000) reports that in seven of the eight cases, community managers have been successful in increasing forest area but also that, in contrast to the Indian case, the distribution of benefits among community members has been relatively equal. Notably, the "successful" communities in Klooster (2000) were primarily the indigenous, ethnically homogenous communities.

Consistent with these findings, Kant and Berry (1998), Kant (2000), and Kumar (2002) argue that with group homogeneity JFM may result in a more efficient outcome both in terms of the sustainability of natural resources and income distribution. The explanation offered is that shared institutions at the community level reduce the degree of moral hazard and adverse selection therein serving as an important element in the stability of JFM. Homogenous groups are more likely to share common goals and values with respect to subsistence harvest amounts, enforcement mechanisms, and the distribution of benefits. Heterogeneity, however, can undermine these mechanisms and shared norms (Baland & Platteau, 1997). But at the same time, as shown by Varughese and Ostrom (2001) with respect to the Nepalese case, heterogeneities, while making collective action more difficult, may not necessarily eliminate effective local collective action when user groups can create rules which account for such heterogeneities (see also Hackett, Schlager, & Walker (1994) for experimental evidence).

Clearly, heterogeneity can take different forms. The two dimensions most frequently identified as affecting JFM outcomes have been intra-community differences in social class/power and income. Kumar's (2002) study points to caste inequality and an unequal distribution of benefits. In India, the group with dominant power essentially ran the village forest committee so that the preferences of that group were reflected in the programs adopted, helping that group to extract a majority of the benefits. Similarly, Platteau (2001) uses an analytic model and descriptive observations to characterize the oft-observed problem of "elite capture," that is, the ability of the dominant group to capture the benefits from a common property arrangement. He argues that this is a significant problem that must be accounted for in setting up appropriate incentive and enforcement mechanisms. Groups may also be homogenous with respect to goals but heterogeneous in terms of income. Cardenas (2003) presents evidence (based on field experiments conducted in rural Colombia) of reduced cooperation when the heterogeneity is based on the unequal distribution of wealth. The impact of wealth inequality is also demonstrated in several chapters of Baland, Bardhan, and Bowles (2001).

A second element identified as important to the success of JFM is the user group's degree of dependence on the resource base (Cardenas, 2003; Kant, 2000; Kant & Berry, 1998). Groups highly dependent on non-timber forest products, for example, are likely to have strong incentives to cooperate with the government or some other entity in managing the forest to achieve and maintain an "optimal" harvest level.

Consistent with these aspects of a successful regime, the particular incentive mechanisms selected by the State can also be of critical importance to the success of JFM. That is, given that a particular forest area is held by the State, the central government must decide on the degree of new local ownership or management, and a particular means for rewarding time spent by community members in cooperation and the enforcement of JFM rules of protection. In the case of Nepal, select communities obtained ownership to village land and the government heavily subsidized enforcement costs (Bromley & Chapagain, 1984; Chakraborty 2001), while communities in village India do not, as a rule, receive common property rights over local forests. Instead, India's state governments have the flexibility to develop incentive schemes that would promote forest agreements between the state and local communities. Such arrangements include providing members of the forest community with a share of profits from harvested forest, direct wage payments for enforcement effort, and /or a share of forest biomass.

As argued by Richards (2000) and modeled by Kant (2000) and Kant and Berry (2001, 1998), optimal resource allocation strategies may differ significantly on a continuum from pure private ownership through State control to open access. Even within a given state or province, community incentives for cooperation may vary significantly according to the type of land tenure, institutions, income inequality and natural resource dependence. In the language of Kant and Berry (1998), a user group in region A may be more heterogeneous (in terms of income or class) than a corresponding group in B but because of greater reliance on the natural resource may have greater incentive to use the resource in a self-sustaining way. Since there are tradeoffs in these respects, the relative success of one group vis-à-vis another may hinge on the details of the incentive system chosen by the JFM. It has also been argued that group homogeneity and greater dependence on the local resource base contribute to greater use of cooperative JFM whereas heterogeneity and independence encourage private property arrangements (Kant & Berry, 1998).

It would certainly appear that the impetus for initiating JFM and early experience with it may have considerable influence on its long-term effectiveness. Given that past state ownership and management has often resulted in very considerable and non-sustainable encroachment and misuse of the forests, to be successful it is obviously important for any new regime like JFM to make clear that past violations of sustainable use will no longer be tolerated. Any strengthening of community norms sanctioning violations and of cooperation in the enforcement of these norms would seem rather certain to raise the probability of success.

Yet, in fact, on these and many other potentially important aspects, the literature is either silent or unclear about the likely effects of other conditions on JFM outcomes. For example, as Ostrom (1999) has noted, virtually no attention has been given as to what to do when the local institutional conditions are quite inimical to rule compliance. One reason for this is the absence of historical/political perspectives in these studies. A partial exception is Agrawal and Ostrom (2001) which noted that the village council-managed forest areas in the Kumaon region of India that developed endogenously in the 1920s and 1930s from local resistance to arbitrary management of these forests by the colonial government have been much more successful in establishing a transparent system of rules and decision making for forest use and sustainability than in the more state-initiated JFM experiments in India or Nepal.

Another partial exception is the work by experimentalists on rule compliance and cooperation in common resource management settings. Several common property experimental game studies have shown that communication tends to improve cooperation and efficiency relative to what can be accomplished by rule sanctioning alone (Ostrom, Walker, & Gardner, 1992; Ostrom, 1999; Cardenas, 2003). Moreover, when through communication local resource users can design and choose their own rules for efficient use and enforcement, Cardenas (2003) and Hackett, Schlager, and Walker (1994) have shown that they may be able to overcome the obstacles to cooperation created by heterogeneity within the group. When communication is not possible as in large groups and forest areas, voting institutions may be an alternative means for accomplishing efficient decision-making and management (Walker, Gardner, & Ostrom 2000) and greater interaction over time can similarly improve efficiency (Hoffman, McCabe, Shachat, & Smith, 1994; Palfrey & Rosenthal, 1994). Also, evenly enforced sanctioning institutions which reward individual appropriators for monitoring have been found to result in more efficient appropriation levels (Casari & Plott, 2003). These, in turn, may be more efficient than state-of-the-art schemes designed by international experts (Ostmann, 1998; Cardenas, Stranlund, & Willis, 2000).

As discussed, we make an effort to explicitly model, albeit in an incomplete manner, the institutional features highlighted above. Heterogeneity is illustrated by differences between the two different forest groups in terms of both income and access on the one hand and the degree of dependence on the resource base on the other. Different levels of enforcement are also assumed in interactions between the Forest Department and the Forest Community.[4] Forest communities may also differ in the extent to which JFM arrangements allow members to extract more non-timber products from the forest and shares in the present value of increased forest biomass.

2.3. Literature on Cooperation not Specific to JFM

Aside from the literature focusing on JFM experiments, there is a very extensive literature of very considerable relevance to JFM issues and modeling both on the relations between deforestation and land tenure and on inter-group cooperation in maintaining common property in the face of the tragedy-of-the-commons threat. If the returns are higher on other uses of the land than for timber and non-timber products, community members will have little incentive to prevent deforestation and conversion of the land to other uses. This is more likely to be the case the more depleted the forest has become and the lower is its ability to generate non-timber products that can benefit the members of the community. Many studies of cooperation have also confirmed the relevance of group characteristics in distinguishing between successful and unsuccessful attempts at defending the integrity of a jointly owned and managed resource[5]. Yet, for the very heterogeneous Terai region of Nepal, Chakraborty (2001) has shown that, despite very unfavorable group characteristics, cooperation in maintaining common property rights without large-scale deforestation can still be possible. This occurred because, thanks to both a rather stable elite-group-based traditional system of authority and a sufficient reserve on remaining government lands for satisfying subsistence needs, the traditional elite was able to exercise sufficient leadership to establish rules and, with the help of the forest department, credibly commit to their enforcement.

3. MODEL AND SIMULATION FRAMEWORK

Next we proceed to explain and outline the model whose primary purpose is to identify the key behavioral linkages between two user subgroups (elite and non-elite) within the local Forest Community, and between them and the Forest Department, a Residual Non-forest Sector and the government, with and without

JFM. So as not to reach conclusions about differences between the pre-JFM and JFM cases merely by assumption, we have tried to keep the two cases as similar as possible. The most important difference is that in the pre-JFM case we assume that there is little or no dialogue between the forest department and members of the forest community over the use of protective labor and other decisions whereas under JFM there would be. We also assume that the forest community would share in some of the revenues of the forest department from timber sales in the JFM. While the forest department might well have rather different objectives under the two different arrangements, for simplicity we assume that the forest department is trying to maximize forest biomass subject to its budget constraint.

In the present version of the model, certain simplifying assumptions are made such as that some agents do not play a very substantial role. For example, government is assumed to be rather passive in the model with its resource allocations largely exogenous. Similarly, we have not introduced land as a factor of production in either the forest or non-forest sectors. Finally, the non-forest sector has been assumed to be rural-, rather than urban-, based, hence not requiring rural-urban migration and transport costs to access employment there. Yet, as explained below, these are all assumptions that can be subsequently relaxed so as to come to grips with issues beyond those considered in this chapter.

3.1 The Five Sectors

Although there are five sectors, including two different user groups and the government, Figure 11.1 illustrates only the linkages between three of these, namely, the Forest Department (FD), the Forest Community (FC) as a whole (instead of separately as two different groups), and the Residual Sector (R). As detailed in the analytical model that follows, the figure presents the basic flows of goods, services, incomes, and expenditures among these key groups.

Briefly, the FC provides protective labor, N_p^s, and labor to process the forest good, F^s / c, to the FD, and labor for production of the market good, N_r^s, to the R Sector in exchange for payments w_p, w_h and w_r, respectively. Labor income, in addition to a share of FD revenues flow out of the FC back to the R Sector in the form of payments for good X, $P_x X_c$, and to the FD in terms of penalties for excess gathering, and payments for the Forest good, $P_f F_c^d$. Income also flows into (out of) the FD (R Sector) through sales (purchases) of timber, $P_f F$. The government also provides transfers to the three sectors through taxes on R Sector profits and FD timber revenues. We assume that these government transfers to both the FC and R Sectors are non-cash, in-kind benefits that contribute directly to utility, whereas transfers from the government to the FD are in cash and so enter the FD's budget constraint. Both gathering by the FC, N_{df}, and sales by the FD, F^s, reduce the size of the forest and its positive environmental externalities enjoyed by all sectors. In contrast, biomass production under FD management increases the size and/or quality of the forest and hence potential satisfaction of demand for the forest good.

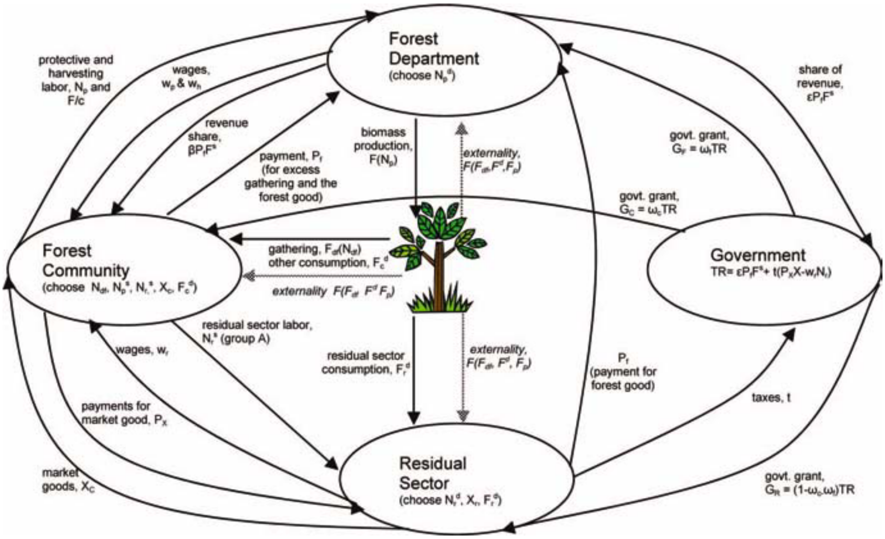

Figure 11.1 *A Circular Flow Diagram of Joint Forest Management*

3.2.1 The Forest Community (FC)

Utility for both FC groups is a function of goods collected from the forest, F_{df} (which can be thought of as fuel-wood, non-timber forest products, (NTFP's), or timber), consumption of the processed forest good, F_c^d, government grants, G_c (which are in-kind),[6] consumption of the market good produced in the residual sector, X_c, and an the positive externality effect, F_E. F_E, is a function of F_{df}, F^s, which includes the quantities of the Forest Good purchased by the FC and R sectors, and F_p, the increase in the forest due to protective labor supplied by the FC, where,

$$F_E = F_E(F_{df}, F_c^d + F_r^d, F_p),$$

$$F_{E1} < 0, F_{E11} < 0, F_{E2} < 0, F_{E22} < 0, F_{E3} > 0, F_{E32} < 0.$$

The Forest Community's utility can therefore be written as,

$$U_c = U_c(F_{df} + F_c, G_c, X_c, F_E(F_{df}, F_c^d + F_r^d, F_p)) \tag{1}$$

where X_c, F_c^d, F_p, and F_{df} are choice variables and F_r^d is demand for the processed forest good in the R sector, and U_c is increasing in all arguments.[7] F_{df} is simply a function of time allocated to removal of timber resources by the FC (which may be legal or illegal), N_{df},

$$F_{df} = F_{df}(N_{df}), \quad F_{df}^{'} > 0, F_{df}^{''} < 0, \tag{2}$$

Similarly, F_p is a function of time allocated to protective labor, N_p,

$$F_p = F_p(N_p), \quad F_p^{'} > 0, F_p^{''} < 0, \tag{3}$$

3.2.1.a Forest Community Group A Income Constraints

In order to measure the effects of group heterogeneity on co-management, we assume two different group types, an "elite" and "non-elite" group. The two groups are distinct in that, as detailed below, the elite group has greater income earning potential than the non-elites.

For the elite group, we assume that consumption spending on market goods, $P_x X_{c,A}$ and the processed forest good, $P_f F_{c,A}^d$, is constrained by wage earnings from the R Sector, $w_r N_r^s$, plus income earned from the FD, specifically, the sum of labor payments for protective services $w_p N_{p,A}^d$, payments for timber harvesting $w_h \alpha F^s / c$

(where alpha, ($\alpha \le 1$) is an exogenously determined share of FD harvest employment going to elites) and a share of revenues from FD sales based in part on their contribution to protective labor services, $(N^s_{p,A}/(N^s_{p,A}+N^s_{p,B}))\beta P_f F^s$. The exogenously given parameter beta (where $\beta < 1$), is the share of FD revenues going to the Forest Community. The FC elite are also forced to pay fraction gamma (where $\gamma \le 1$) for the amount removed that is in excess of F_L, i.e., what is stipulated (by cooperative agreement or unilateral limit set by the government), and which can be thought of as a percentage of the biomass produced. The budget constraint is therefore,

$$\begin{aligned} & w_r N^s_r + w_p N^d_{p,A} + w_h \alpha \frac{F^s}{c} + \frac{N^s_{p,A}}{N^s_{p,A}+N^s_{p,B}} \beta P_f (F^d_{c,A} + F^d_{c,B} + F^d_r) \\ & = P_x X_{c,A} + P_f F^d_{c,A} + \gamma\eta(.)H(.) \end{aligned} \tag{4}$$

In the pre-JFM case, the FC does not receive a share of FD sales in this budget constraint.

The $\eta(.)$ term in equation (4) is a proxy for the effectiveness of enforcement of the agreement on maximum biomass removal. We assume that the probability of being caught for taking too much out of the forest increases with the magnitude of that removed above the allowable ceiling. Hence, $\eta(.)$ is a function of $(F_{df,A} + F_{df,B} - F_L)$ where $\frac{d\eta}{dF_{df}} > 0, \frac{d^2\eta}{dF_{df}{}^2} > 0$. We also assume that the penalty for excessive clearing, $H(F_{df,A} + F_{df,B} - F_L)$ is a function of the amount of this excess where $\frac{dH}{dF_{df}} > 0, \frac{d^2H}{dF_{df}{}^2} > 0$. If the rules against excess clearing are perfectly enforced, $\eta(.) = 1$, and the FC would pay for all harvesting beyond the agreed upon amount. On the other hand, if $\eta(.) = 0$, the FC would face no penalty for removal of timber. Similarly, a lower (higher) value of H is associated with a higher (lower) order of forest clearance than that specified by F_L. It is likely that enforcement would be greater under JFM than under pure state control because of greater incentives for local collective action under JFM.[8]

3.2.1.b Forest Community Group B Income Constraint

The "non-elite's" problem is identical to the elite's except that the non-elite: i.) do not supply labor to the residual sector and do not receive wages from the R sector; ii.) receive $\frac{N^s_{p,B}}{N^s_{p,A}+N^s_{p,B}} \beta P_f F^s$ as their share of sales of F; iii.) pay the share $(1-\gamma)$

as penalty; and iv.) provide the share $(1-\alpha)$ of harvest labor. As for the elite group, in the pre-JFM case, the non-elite group does not receive a share of FD sales.

3.2.1.c Labor Market Constraints of Both Sectors

Labor time supplied by both FC groups is constrained by total time. Time is allocated to protective service $N_{p,A}^{s}, N_{p,B}^{s}$, timber harvesting activities, $\frac{F^{s}}{c}$, collection of fuel-wood or non-timber forest products, N_{df}, and group A supplies labor to the R Sector, N_{r}^{s}. The labor market constraint is therefore,

$$N_{TOT} = N_{TOT,A} + N_{TOT,B} \tag{5}$$

where,

$$N_{TOT,A} = N_{p,A}^{s} + \alpha \frac{F^{s}}{c} + N_{r}^{s} + N_{df,A}$$

$$N_{TOT,B} = N_{p,B}^{s} + (1-\alpha) \frac{F^{s}}{c} + N_{df,B}$$

3.2.2 The Residual Sector (R)

The owners of capital and managers that constitute the households in the R Sector seek to maximize utility, which is a function of the consumption of the processed forest good, F_{r}^{d}, consumption of the market good, X_{r}, the government grant, G_{r}, and the "environmental purity externality." Utility in the R Sector can therefore be written as:

$$U_{r}(F_{r}^{d}, G_{r}, X_{r}{}^{d}, F_{E}(F_{df}, F_{r}^{d} + F_{c}^{d}, F_{p})) \tag{6}$$

where the choice variables are F_{r}^{d} and $X_{r}{}^{d}$; and, U_{r} is increasing in all arguments. Spending on the consumption good in the R Sector, $P_{x}X_{r}$, and the forest good, $P_{f}F_{r}^{d}$, is constrained by after-tax profits earned in the production of X, $(P_{x}X - w_{r}N_{r}^{d})(1-t)$. The budget constraint for the R Sector is therefore:

$$(1-t)(P_{x}X - w_{r}N_{r}^{d}) = P_{f}F_{r}^{d} + P_{x}X_{r}{}^{d} \tag{7}$$

where the production of X is simply a function of labor,

$$X = X(N_r^d), \quad \frac{dX}{dN_r^d} > 0, \frac{d^2X}{(dN_r^d)^2} < 0 \tag{8}$$

3.2.3 The Forest Department (FD)

The FD's costs of protective labor and timber removal services, $w_p N_p^d + w_h \frac{F^s}{c}$, are the same in both the pre-JFM and JFM cases. Similarly, its income includes transfers from the government, G_f and timber sales in both cases. Under JFM, however, total timber sales, $P_f F^s$, are shared with both the government (which gets the share ε) and the FC (which gets β), the share $(1-\varepsilon)(1-\beta)P_f F^s$ remaining with the FD. In the pre-JFM case the FD makes no transfers to the FC, so its share remains $(1-\varepsilon)P_f F^s$. In the JFM case, the FD budget constraint is:

$$G_f + (1-\varepsilon)(1-\beta)P_f F^s + \eta(.)H(.) = w_p N_p^d + w_h \frac{F^s}{c} + C \tag{9}$$

where N_p^d is the choice variable and C is a given fixed cost.

In JFM, we assume that the FD seeks simply to maximize the end-period biomass defined as:

$$F_{TOT} = \overline{F} + F_p(N_p) - F^s - F_{df} \tag{10}$$

where F is the initial stock of forest, F_p is the production of new forest and F_S and F_{df} are the sales of the forest good by the FD and collection for own use of the good by the FC.

3.2.4 Government Grants

The Government grant received by each stakeholder is a fraction of its tax receipts from the R Sector, $t(P_x X - wN_r)$, plus its share of timber sales, $\varepsilon P_f F$. Thus, the total tax revenue collected by the Government is

$$t(P_x X - wN_r) + \varepsilon P_f F \tag{11}$$

The FC receives a share, ω_c, the FD ω_f, and the R Sector $(1-\omega_c-\omega_f)$.

3.3 Constrained Optimum by Sector

3.3.1.a The Forest Community: Group A

The elite group in the FC chooses $N_{df,A}, N_r^s, N_{p,A}^s, F_{c,A}^d$ to maximize utility as described in equation (1). After forming the Lagrangian, where λ_1 is the multiplier on the elite's labor time constraint and λ_2 is the multiplier on its budget constraint, the first order conditions are given in Table 11.1. In the pre-JFM period first order conditions are identical except that $\beta = 0$, implying that there is no income benefit from sales of the forest good and changing equations (19) and (20), as shown in Table 11.1.

As shown in the table, in choosing the quantities of *defacto* labor, protective labor, and demand for the forest good to maximize utility, the FC sets marginal benefits equal to marginal costs. In the case of *defacto* labor, $N_{df,A}$, the direct utility benefit is set equal to the negative externality effect on utility, the shadow price of time and money, and the penalty for over-extraction (see equation (16)). In contrast, marginal benefits for protective labor include a positive externality benefit, direct wage benefits, and a share of revenue from the forest department which are set equal to the shadow price of time (equation (19)). Because consumption of the forest good, $F_{c,A}^d$, is also modeled as reducing biomass, the first order condition is similar to the case of *defacto* labor. Marginal benefits realized in consuming more $F_{c,A}^d$ include a direct utility benefit and a greater share of forest department revenue which are set equal to the indirect utility loss and the price of F (equation (20)).

3.3.1.b The Forest Community: Group B

Similar to the elite, the non-elite (group B) choose $N_{df,B}, N_{p,B}^s, F_{c,B}^d, X_{c,B}$ (but not N_r^s) to maximize utility as described in equation (1). In this case, λ_3 is the multiplier on the time constraint and λ_4 is the multiplier on the income constraint. First order conditions in both cases are identical to group A's when accounting for differences in multipliers and differences with respect to the inequality parameters. Note that group B must pay the share $(1-\gamma)$ of the penalty incurred due to timber withdrawal not only by itself but also by the elite group A. In addition, group B's share of forest department revenue is determined by $\dfrac{N_{p,B}^s}{N_{p,A}^s + N_{p,B}^s}$ which changes appropriate elements of equations (19) and (20). As with group A, in the pre-JFM case $\beta = 0$, as the FD does not share revenue with the forest community.

3.3.2 The Residual Sector

The R Sector seeks to maximize utility as described in equation (6) subject to a budget constraint. Forming the Lagrangian, where λ_5 is the multiplier for the budget constraint, first order conditions are given in Table 11.1. None of the conditions for the R Sector differ between the pre- and post-JFM cases.

As shown in Table 11.1, in choosing the optimal level of F_r^d the FC sets the direct utility benefit equal to the price of consumption in addition to the indirect negative utility loss. And in choosing the optimal amount of labour, N_r^d, the marginal revenue product of labour is equal to the wage rate.

3.3.3 The Forest Department

The FD chooses N_p^d to maximize biomass (equation (10)) subject to their income constraint (equation (9)). Forming the Lagrangian and taking first order conditions, we present results in Table 11.1, where λ_6 is the multiplier for the budget constraint. Equation (24) indicates that the forest department maximizes biomass by acquiring protective labor to the point that the marginal product of protective labor is equal to the wage times the multiplier of the income constraint, an outcome that is also identical to that in the pre-JFM case.

3.4 Equilibrium Conditions

The model is closed with the following equilibrium conditions

$$N_r^d = N_r^s \text{ to determine } w_r \tag{12}$$

$$N_p^d = N_{p,A}^s + N_{p,B}^s \text{ to determine } w_p \tag{13}$$

$$X(N_r{}^d) = X^d{}_{c,A} + X^d{}_{c,B} + X^d{}_r \text{ to determine } P_x \tag{14}$$

$$F^s = F_r^d + F_{c,A}^d + F_{c,B}^d \text{ to determine } P_f \tag{15}$$

3.5 Pareto Optimality Conditions

Pareto optimality conditions are given in Table 11.2. We maintain the notation for the constraints described and in addition we use λ_7, λ_8, and λ_9 to reference the multipliers on the utility functions for forest community groups A and B, and the residual, respectively. For ease of reference a comprehensive list of variables used in the model along with definitions is given in Appendix 11.1.

Table 11.1. *First Order Conditions in the JFM Environment*[a]

A. Forest Community (Group A)

$$\frac{dL}{dN_{df,A}}: U^1_{c,A} F_{df,A}{}'(N_{df,A}) + U^4_{c,A} F^1_E F_{df,A}{}'(N_{df,A}) - \lambda_1 - \lambda_2 F_{df}{}'(N_{df,A})\gamma[\eta'(.)H(.) + H'(.)\eta(.)] = 0 \qquad (16)$$

$$\frac{dL}{dN^s_r}: -\lambda_1 + \lambda_2 w_r = 0 \qquad (17)$$

$$\frac{dL}{dX_{c,A}}: U^3_{c,A} - \lambda_2 P_x = 0 \qquad (18)$$

$$\frac{dL}{dN^s_{p,A}} \quad \underline{JFM\ case}: \; U^4_{c,A} F^3_E F_{p,A}{}'(N^s_{p,A}) - \lambda_1 + \lambda_2 (w_p + \beta P_f (F^d_{c,A} + F^d_{c,B} + F^d_r)(\frac{N^s_{p,B}}{(N^s_{p,A} + N^s_{p,B})^2})) = 0 \qquad (19)$$

$$\underline{pre\text{-}JFM\ case}: \; U^4_{c,A} F^3_E F_{p,A}{}'(N^s_{p,A}) - \lambda_1 + \lambda_2 w_p = 0 \qquad (19)'$$

$$\frac{dL}{dF^d_{c,A}} \quad \underline{JFM\ case}: \; U^1_{c,A} + U^4_{c,A} F^2_E - \lambda_2 P_f (1 - \beta \frac{N^s_{p,A}}{N^s_{p,A} + N^s_{p,B}}) = 0 \qquad (20)$$

Table 11.1 (cont.)

Table 11.1 (cont.)

<u>*pre-JFM case*</u> : $U^1_{c,A} + U^4_{c,A} F^2_E - \lambda_2 P_f = 0$ (20)’

B. Residual Sector

$$\frac{dL}{dF^d_r} : U^1_r + U^4_r F^2_e - \lambda_5 P_f = 0 \quad (21)$$

$$\frac{dL}{dN^d_r} : \lambda_5 (1-t)(P_x X'(N^d_r) - w_r) = 0 \quad (22)$$

$$\frac{dL}{dX_r} : U^3_r - \lambda_5 P_x = 0 \quad (23)$$

C. Forest Department

$$\frac{dL}{dN^d_p} : F_p'(N^d_p) - \lambda_6 w_p = 0 \quad (24)$$

Table 11.2. *Pareto Optimality Conditions in the JFM Environment*

A. Forest Community (Group A)

$$\frac{dZ}{dN_{df,A}}: -F_{df,A}{}'(N_{df,A}) - \lambda_1 - F_{df,A}{}'(N_{df,A})(\eta(.)\frac{dH}{dF_{df,A}} + H(.)\frac{d\eta}{dF_{df,A}})(\lambda_2\gamma + \lambda_4(1-\gamma))$$
$$+\lambda_6 F_{df,A}{}'(N_{df,A})(\eta(.)\frac{dH}{dF_{df,A}} + H(.)\frac{d\eta}{dF_{df,A}}) + \lambda_7 F_{df,A}{}'(N_{df,A})U_A^1 + F_E^1 F_{df,A}{}'(N_{df,A})(\lambda_7 U_A^4 + \lambda_8 U_B^4 + \lambda_9 U_r^4) = 0 \quad (25)$$

$$\frac{dZ}{dN_{r,A}^s}: -\lambda_1 + \lambda_2 w_r = 0 \quad (26)$$

$$\frac{dZ}{dX_{c,A}}: \lambda_7 U_A^3 - \lambda_2 P_x = 0 \quad (27)$$

$$\frac{dZ}{dN_{p,A}^s}: -\lambda_1 + \lambda_2 w_p - \beta P_f(F_{c,A}^d + F_{c,B}^d + F_r^d)\frac{N_{p,B}^s}{(N_{p,A}^s + N_{p,B}^s)^2}(\lambda_4 - \lambda_2)$$
$$+F_E^3 F_p{}'(N_{P,A}^S)(\lambda_7 U_A^4 + \lambda_8 U_B^4 + \lambda_9 U_r^4) = 0 \quad (28)$$

Table 11.2 (cont.)

Table 11.2 (cont.)

$$\frac{dZ}{dF^d_{c,A}}: -\lambda_2 P_f + \frac{P_f \beta}{N^s_{p,A} + N^s_{p,B}}(\lambda_2 N^s_{p,A} + \lambda_4 N^s_{p,B}) + \lambda_7 U^1_A + F^2_E(\lambda_7 U^4_A + \lambda_8 U^4_B + \lambda_9 U^4_r) = 0 \quad (29)$$

B. Forest Community (Group B)

$$\frac{dZ}{dN_{df,B}}: -F_{df,B}{}'(N_{df,B}) - \lambda_3 - F_{df,B}{}'(N_{df,B})(\eta(.)\frac{dH}{dF_{df,B}} + H(.)\frac{d\eta}{dF_{df,B}})(\lambda_4(1-\gamma) + \lambda_2\gamma)$$
$$+\lambda_6 F_{df,B}{}'(N_{df,B})(\eta(.)\frac{dH}{dF_{df,B}} + H(.)\frac{d\eta}{dF_{df,B}}) + \lambda_8 F_{df,B}{}'(N_{df,B})U^1_B + F^1_E F_{df,B}{}'(N_{df,A})(\lambda_7 U^4_A + \lambda_8 U^4_B + \lambda_9 U^4_r) = 0 \quad (30)$$

$$\frac{dZ}{dX_{c,B}}: \lambda_8 U^3_B - \lambda_4 P_x = 0 \quad (31)$$

$$\frac{dZ}{dN^s_{p,B}}: -\lambda_3 + \lambda_4 w_p - \beta P_f(F^d_{c,A} + F^d_{c,B} + F^d_r)\frac{N^s_{p,A}}{(N^s_{p,A} + N^s_{p,B})^2}(\lambda_2 - \lambda_4)$$
$$+F^3_E F_p{}'(N^S_{P,B})(\lambda_7 U^4_A + \lambda_8 U^4_B + \lambda_9 U^4_r) = 0 \quad (32)$$

Table 11.2 (cont.)

Table 11.2 (cont.)

$$\frac{dZ}{dF^d_{c,B}} : -\lambda_4 P_f + \frac{P_f \beta}{N^s_{p,A} + N^s_{p,B}} (\lambda_4 N^s_{p,B} + \lambda_2 N^s_{p,A}) + \lambda_8 U^1_B + F^2_E (\lambda_8 U^4_B + \lambda_7 U^4_A + \lambda_9 U^4_r) = 0 \quad (33)$$

C. Residual Sector

$$\frac{dZ}{dF^d_r} : \frac{\beta P_f}{(N^s_{p,A} + N^s_{p,B})} (\lambda_2 N^s_{p,A} + \lambda_4 N^s_{p,B}) - \lambda_5 P_f + \lambda_9 U^1_r + F^2_E (\lambda_7 U^4_A + \lambda_8 U^4_B + \lambda_9 U^4_r) = 0 \quad (34)$$

$$\frac{dZ}{dN^d_r} : \lambda_5 (1-t)[P_x X'(N^d_r) - w_r] = 0 \quad (35)$$

$$\frac{dZ}{dX^d_r} : -\lambda_5 P_x + \lambda_9 U^3_r = 0 \quad (36)$$

D. Forest Department

$$\frac{dZ}{dN^d_p} : F_p'(N^d_p) - \lambda_6 w_p = 0 \quad (37)$$

4. ANALYSIS AND SUGGESTIONS FOR SOME POSSIBLE SIMULATION EXPERIMENTS

Since the main purpose of the model was to examine the effects of JFM on various behavioral outcomes, the first question we put to the model is "Is the introduction of JFM sufficient to increase forest biomass and the welfare of the forest community?"

4.1 The Impact of JFM on Forest Biomass and FC Welfare: Simulation

Because of the model's several institutional parameters $\alpha, \beta, \gamma, \varepsilon, t$, and its behavioral and technological functions, each of which would have to be converted from the above general specifications to ones of appropriate functional forms with realistic parameter values, any definitive answer to the question must await the completion of these tasks, each of which is well beyond the objectives of this chapter.

Nevertheless, we can get a hint at the qualitative answer by comparing the relevant first order conditions of the JFM case with those of the pre-JFM case. For example, from equation (19) it can be seen that the sharing of revenues from timber sales with the elite of the FC would give such community members an additional benefit in supplying protective labor to the FD. The same would be true for the non-elite of the FC. In both cases also the incentive for illegal or unauthorized collecting from the forest (F_{df}) would fall. As a result, N_p^s would rise and both N_{df} and F_{df} would fall. From these effects, it would seem rather clear that biomass would increase with the introduction of JFM.

But, at the same time, from the first order condition for the demand for the forest good by the elite $(F_{c,A}^d)$, given by equation (20), with $\beta > 0$ it can be seen that the relative cost of purchasing the forest good F would fall. The same would be true for the non-elite group B. Hence from this effect the demand for F by all sectors would rise, thereby having the opposite effect on forest biomass and the environment. Hence, it is clear that the answer to the question is ambiguous and would depend on the relative size of these two opposite effects that, in turn, would depend not only on the sharing parameter β but also on the various parameters of the utility and production functions.

One useful simulation exercise that could be conducted after functional forms and suitable parameter values were chosen, therefore, would be to see how the answer would vary with the choice of β. Similarly, it would be useful to see how the answer would depend on the parameters of the utility functions, such as differences in the strength of the taste for F (relative to X) and its sensitivity to both relative price and income changes.

Another set of simulation experiments might well investigate the effects of heterogeneity between the elite and non-elite groups. This could be done by varying the differences between the elite and non-elite groups with respect to (1) their relative preferences for the forest good relative to the residual sector good, (2) the magnitudes of their preference for the positive environmental externality and its sensitivity to F_{df} , (3) their shares in the penalty paid for excess clearing/collecting, (4) the distribution of FC revenues from timber sales, (5) the productivity of protective labor, (6) the penalty and probability of being detected for excess gathering, (7) government grant allocations and (8) the degree of access to employment in the R sector.

In this way, once suitable parameter values had been selected, simulation methods could be used to generate specific, testable hypotheses about how the effects of JFM would be expected to vary depending on environmental circumstances including the tastes and preferences of the different groups, institutional conditions concerning the values of $\alpha, \beta, \gamma, \varepsilon,$ and t , and the magnitudes of the environmental externalities. Then, with further data collection on the values of these parameters across actual and otherwise comparable JFM experiences, one could formally test the hypotheses. These could include subtler and more nuanced versions of those suggested in the literature survey given in Section 2 above. For example, one could test hypotheses concerning the extent to which greater dependence on the forest good by non-elite members of the FC would offset their disadvantages in terms of wealth and access to employment in the rural sector, with and without JFM.

4.2 A Comparison of Pareto Optimal Conditions to the Benchmark Case

Another objective of the model is to determine to what extent the typical features of JFM contribute to achieving outcomes that are closer to the Pareto-optimal solutions. Some progress toward the fulfillment of this objective can be accomplished by comparing the first-order conditions (FOC) in Table 11.1 with the Pareto optimality conditions (POC) in Table 11.2 for corresponding decision variables in the above formulation. For example, to what extent do the FOCs derived from the JFM case move the solutions of key variables like forest biomass and the total utility achieved by each group within the FC toward the POC solutions. For the forest community, it can readily be seen from equations (17) and (26) that the first order condition with respect to N_r^s in the JFM case is of the same form as that for Pareto optimality. Yet, for most of the other decision variables, this is not the case, even under JFM.

For example, from (16) it can be seen that the FOC under JFM includes neither all of the negative externality effects on utility nor all of the negative income effects of N_{df} relative to the corresponding POC equation (25). In the POC case, each group within the forest community accounts for negative utility impacts on all other sectors (recall $F_E^1 < 0$) in addition to the negative income effects on the other forest community group. Consequently, under JFM, the model's FOC predicts levels of N_{df} that are greater than the levels implied by the POCs.

Since $X_{c,A}$ only affects the forest community group A, the FOC for $X_{c,A}$ in the JFM case, equation (18) is of the same form as corresponding POC equation (27).

Furthermore we see that the predicted levels of protective labor under JFM are sub-optimal from equations (19) and (28). Relative to the POC, in (19) the elite group in the FC does not take into account the positive externality benefits accruing to the other sectors and neither does it account for the income benefits realized by the other forest community group with increased levels of N_p^s. Since in the pre-JFM framework, the FC does not receive a share of income from sales of the processed forest good $(\beta = 0)$, the levels of N_p^s which increase forest biomass and eventually income are likely to be even lower.

A final important difference for the FC is in the level of purchases of the processed forest good. From equations (20) and (29) in the JFM case the FC does not account for the negative externality effects on other sectors ($F_E^2 < 0$) as is required for the POC. Neither does it account for the positive income benefits realized by the other FC group (as the other group receives a share of FD revenues). But, since similar comparisons apply to the pre-JFM case, in this respect, JFM does not bring the solution closer to Pareto optimality in itself.

For the residual sector, from equation (21) in the JFM case and equation (34) in the Pareto optimal case we can see that in deciding F_r^d under JFM the residual sector does not take into account the negative externality effect from F_r^d. On the other hand F^s is increasing in F_r^d and consequently it has a positive effect on the income of the FC which gets a share of FD sales. But, this positive effect is not taken into account in the JFM case. At this level of generality, therefore, it cannot be ascertained whether F_r^d under JFM will be lower or higher than the Pareto optimal level. The FOCs for N_r^d and X_r are of the same form since N_r^d appears only in the budget constraint for the residual sector and X_r appears only in the utility function.

For the FD, we note from (24) and (37) that the choice of protective labor is at the Pareto optimum. In each case the FD sets the marginal benefits of protective labor equal to its costs and is not accounting for external benefits. In contrast, as already discussed, the external benefits of protective labor are taken into account by the FC in its' choice of protective labor.

4.3 Other Findings and Extensions with Respect to Inequality

In terms of inequality, there are three levels wherein inequality affects the equilibrium values of choice variables. First, suppose that $\gamma < 0.5$, which implies non-elites share a greater burden in paying penalties for illegal N_{df}. One could imagine such a scenario, for instance, in a case where elites possess greater authority in determining which community members would pay sanctions for illegal extraction. In such a case, based on (16), the levels of $N_{df,A}$ are likely to be higher but at the same time those of $N_{df,B}$ would be lower.

Second, and more importantly, as shown in (19) the greater the participation of non-elites in protective labor, the lower will be the benefits to elites. Assuming that wage differentials between the R sector and the FD are enough to compensate elites for relatively greater levels of $N_{p,B}$ (and consequently a lower share of FD revenues accruing to elites) elites would be no worse off. If, however, wage differentials from the residual sector to do not compensate elites for this difference, elites could increase their share of protective labor, reducing the share provided by non-elites and therefore indirectly increasing the amount of time non-elites spend on N_{df} . It is the assumptions (a) that non-elites cannot work in the residual sector and (b) that the distribution of forest department revenues would be based on the share of labor provided to the forest department that drive this result. In contrast, the effect of higher levels of $N_{p,B}$ in the Pareto optimal case are less negative for the elite group (see equations (28) and (32)) and depend on the relative weights of λ_2 and λ_4 .

Finally, as already discussed, the unequal share of revenues from the forest department also affects the equilibrium values of the demand for the forest good as shown in equation (20). Assuming greater levels of inequality, for instance with elites providing a greater share of protective labor, demand for the forest good by elites is higher relative to the case where elites provide a lower share of protective labor.

In summary, these results imply that in cases where the wage differential between the R sector and the FD is likely to be low (or even negative), elites will likely provide a greater share of protective labor. This will lead to greater levels of production of the processed forest good and at the same time greater levels of labor allocated to unauthorized collection of the forest good (N_{df}) by non-elites. If, however, γ is low enough, N_{df} by non-elites will be significantly reduced, but at the expense of their consumption. The model therefore predicts that inequality can potentially constrain efficient levels of N_{df} . If elites are able to constrain illegal extraction by non-elites (i.e. a low γ), then JFM results in greater gains in biomass. Yet, at the same time, if greater gains in biomass are realized under these conditions, such gains come at the expense of biomass consumption by the non-elites.

Useful conclusions for policy should also be derivable. If besides gaining a share in timber sales in JFM, which as noted above is a stimulus for greater supply of N_p and reduced supply of N_{df} , the forest community were asked to share in the fixed or other costs of planting new forest, to what extent would this policy offset or strengthen the aforementioned effects of JFM on forest biomass? Would there be some combination of cost sharing and revenue sharing (consistent with budget balancing by all agents) that would yield optimal results as in some of the sharecropping literature?

How much additional benefit in terms of the desired objectives of JFM would be achieved by introducing into the JFM case additional mechanisms to induce communication and collaboration between the two FC groups and between the FD and these groups? If the model could be used to identify conditions under which the non-elite Group B could be immiserized, it should be possible to identify policies such as tax policies and institutional rules that would reverse this and thereby prevent immiseratization.

4.4 Extensions

As noted above, the model in its present form is highly simplified. Several extensions of the model deserve high priority in future research. One of these is to introduce land into the model, specifically into the production functions of the F and R sectors and also its rental and purchase into the budget constraints of the relevant parties.

In view of the findings of Rozelle, Huang and Benziger (2003) and Zhang, Uusivuori, Kuuluvainen, and Kant (2003) concerning the strikingly different effects of relative price changes and property rights on natural forest stock and managed forests, it would also be important to disaggregate F into these two types and possibly also into various other tree types because of their differential utility for using sectors such as furniture, paper and home construction. By the same token, the model could then be usefully extended in the direction of having various additional forest-using sectors as well as forest-competing sectors like agriculture and urbanization. Likewise, with forest-competing sectors included, it might be desirable to introduce other inputs and outputs of both forestry and agriculture into the model. If so, it would then be possible to examine the effects of subsidies and taxes on these inputs and outputs. (Note for example, that numerous scholars such as Repetto and Gillis, 1988 and Binswanger, 1991 suggest that implicit subsidies to agriculture are a major contributor to deforestation).

Each one of these extensions would open the model up to new policy uses. With land included, one could examine how the differential assignment of property rights (i.e., modeled as decision-making power over land use) would affect outcomes. What kinds of property rights allocations – allocations to specific agents, or commonly to two or more agents – would be most beneficial? With competition from agriculture and more interdependencies between the different agents and markets, would the standard policy pronouncements concerning agricultural subsidies still hold? If so, would they be strengthened or weakened? Suppose that the optimal property rights allocations are infeasible, what second-best policies should be adopted? Instead of simply treating the environmental benefits of forest biomass as an externality, conceptually the model could be modified so as to make the environmental benefits marketable. If so, in what direction and to what extent would this affect the potential benefits of JFM? Finally, how might the answers to these questions vary by institutional circumstances? These are all questions that an appropriately extended model of this sort could address.

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APPENDIX 11.1. SYMBOLS AND DEFINITIONS*

Symbol	Definition
Utilities	
U_c	Utility of the forest community
U_r	Utility of the residual sector
Labor	
N_p	Protective labor
$\frac{F^S}{c}$	Labor to harvest process the forest good
N_r	Labor for production of the market good
N_{df}	Labor for defacto gathering of the forest good
Wage Rates	
w_P	Wage rate for protective labor
w_h	Wage rate for harvesting and processing of forest good
w_r	Wage rate for production of market good
Prices	
P_f	Price of the forest good
P_x	Price of the market good
Quantities	
X_c	Quantity of market good consumed by forest communities
X_r	Quantity of market good consumed by residual sector
F_c	Quantity of forest good consumed by the forest communities
F_r	Quantity of forest good consumed by the residual sector
F_L	Quantity of forest good approved for removal by forest communities and forest department
$\overline{F}$	Quantity of initial forest biomass
F^S	Quantity of forest good supplied
Parameters	
α	Share of FC A in forest department (FD) harvest employment
β	Share of FD revenues going to the forest community as a whole
γ	Fraction of the fine for excess removal paid by community A
t	Tax rate on profits of residual sector
ε	Share of forest department revenues going to the government

ω_c	Share of forest community in government revenue (grant)
ω_f	Share of forest department in government revenue (grant)
Functions	
η	Probability of getting caught for excess removal
H	Penalty for excess removal
F_E	Environmental externality
Government Grants	
G_c	Grant to the forest community
G_r	Grant to the residual sector
G_f	Grant to the forest department
Lagrange Multipliers	
λ_1	Shadow price of time for community A
λ_2	Shadow price of income for community A
λ_3	Shadow price of time for community B
λ_4	Shadow price of income for community B
λ_5	Shadow price of money for residual sector
λ_6	Shadow price of money for forest department
λ_7	Lagrange multiplier for utility of community A
λ_8	Lagrange multiplier for utility of community B
λ_9	Lagrange multiplier for utility of residual sector

* Superscripts 'd' and 's' indicate demand and supply respectively. Subscripts $U_{c,i}$ indicates utility of ith community (I = A, B), $X_{c,i}$ indicates consumption of market good by the ith community (I = A, B), and $F_{c,i}$ indicates consumption of the forest good by the ith community (I = A, B)

NOTES

[1] Sandalwood forests in the Indonesian province of Nusa Tengara Timur provides an interesting and rather telling example of how, in the absence of democracy, even decentralization of forest ownership and forest policy can result in destruction of the resource. See Marks (2002).
[2] See Kruse et al. (1998) for a comparison of Canadian and US caribou co-management programs.
[3] See Becker and Leon (1998), and Smith (2000) for South American examples.
[4] Under joint management, the Forest Community may be allowed to remove a certain percentage of biomass production without penalty. But, forest products removed beyond that specified amount are subject to fines. Both the fine and the percentage of removal allowed are flexible.
[5] Many of these are of the type identified by Olson (1962) and Ostrom (1990). For example, the ability of a group to have successful collective action in promoting the commons is higher the longer the members of the group have resided together in the same area, the more homogeneous they are in their backgrounds, the more they have different though not necessarily conflicting goals, the less unequal they are in their

income and wealth, the smaller the group, the better they can observe each other's actions, and the more they can trust each other.

[6] Apart from government in-kind transfers to the FC, some Indian state governments mandate certain percentages of profits earned by Village Forest Committees be allocated to community development projects (Kumar, 2002).

[7] The first two elements in the externality function, F_E , however, enter that function negatively.

[8] For instance, see Ostrom, Walker and Gardner (1992) and Hackett, Schlager and Walker (1994) who present experimental evidence consistent with this hypothesis for a similar commons situation.

[a] The numerical superscripts 1, 2 …in these expressions represent the first derivatives with respect to the first, or second or other arguments of the relevant function while 'indicates the first derivative when there is only one argument in the function.

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