Contractual Hazards and Vertical Integration in Mexico's Community Forestry Sector *

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Abstract

This paper develops and empirically tests a model of asset ownership in the Mexican timber industry where the timber supply is owned in common by rural communities. A property rights approach based on the incomplete contract literature rationalizes a vertical integration decision at the community level. The basic argument is that uncertainties in production and forest resource management create contractual hazards between community suppliers of wood products and private buyers and that residual decision-making rights affect community development. The model conditions tendencies towards community-level control with measures of the local community productivity relative to private contractors. Original survey data from Mexico provides the basis for empirical testing. It is found that communities are more likely to integrate forward into timber processing activities with higher levels of human, social and resource capital endowments. JEL Classification: D23, L22, O17, Q23.

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1 Introduction

The dynamics of sustainable common property management are complex. Common property is a resource mutually owned by a group of individuals. Research has identified its role in production, income risk diversification, poverty alleviation, natural resource management and cultural heritage, where it is often managed through local, self-governing institutions (Jodha 1992, Ostrom 1990, Burger et al. 2001). Despite tendencies towards the "tragedy of the commons," (Hardin 1968), cooperative action over time has led to long-lasting common property management systems (Ostrom 1990). How common property management systems persist when markets offer alternative income-generating strategies, however, remains unclear. The need has been recognized to consider broader, external influences on locally-based common property resource institutions (McKean 1997, Taylor and Zabin 2000).

As market liberalization programs change economic opportunities, social and property rights institutions are undergoing adaptation or demise (Chen and Rozelle 1999, Ponte 2000, Alatorre Frenk 2000). A research challenge is to place common property within a larger market structure to understand when people turn to the market for acquiring goods and services versus reliance on local institutions, such as community-based or common property management systems. This paper takes a first step in answering this question with economic methodology focusing on the importance of ownership and control over resources. We develop and empirically test an incomplete contracts model of timber production based on a survey sample of agrarian communities in Mexico which commercially harvests timber from communally-held forest land. Our purpose is to explain when a community of stakeholders organizes for producing and selling wood products versus relying on market contracts with private firms which extract and process their raw material. Using the vertical integration scenario from contract theory, the paper assesses the marketable and nonmarketable benefits of resource ownership that determine contract choice.

The efficiency properties of separating ownership from management control have been extensively explored in agency theory and applied in studies of industrial organization (e.g. Jensen and Meckling (1976), Fama and Jensen (1983), Laffont and Tirole (1993), Aghion and Tirole (1994)), while transaction cost economics and, more recently, contract theory focus on why ownership matters. Coase (1937) and later

Williamson (1985) argue that transaction costs – the costs of negotiating, writing, enforcing and breaking contracts – determine the size of a firm and explain vertical and horizontal integration among firms. The property rights approach, as developed by Grossman and Hart (1986), Hart and Moore (1990), and Hart (1995), formalizes transaction cost analysis. Its central claim is that complete contracts are infinitely costly to write, leaving owners with residual control that gives value to the owners depending on the nature and extent of the noncontractible elements of the proposed trade. For example, Hart, Shleifer and Vishny (1997) and Baker and Hubbard (2000) use this analytical framework to predict management contracts in prison management and the trucking industry, respectively, where quality concerns exist. Properly assigning ownership rights to achieve second-best efficiency depends on the characteristics of required investments and production processes and the importance of noncontractible elements so that the most efficient ownership structure depends on the special circumstances (Hart 1995).

By comparison, rural populations frequently face transaction costs in production where there are limited labor markets, access to credit and public infrastructure (McIntire 1993, Morduch 1995). In these cases, control over property is likely to affect the benefits individuals receive from exchanges. It has been argued, for example, that locally-based management in forestry facilitates coordination of multiple objectives such as job creation, public goods investments and multiproduct production (Kusel and Fortmann 1991).

Mexico has probably the largest percentage of forest land held as common property in the world (Bray 1997). The last thirty years in Mexico has seen a shift from parastatal control of timber production through leasing to a recognition and emergence of community-level rights to manage and commercialize common property forest resources. This transition provides a unique opportunity to examine the adaptability of common property management where aspects of management is a choice by the local community, given the *status quo* position of communal forest land holdings. A community today which owns a forest and sells timber commercially can choose to integrate forward by extracting and processing the timber with its own capital equipment and labor, or it can contract with outside private harvesting firms and sell the timber at stumpage value. During the period 1997-1999, we conducted field surveys in 42 communities with commercial timber production in Oaxaca, a southern state with extensive pine-oak forests. Preliminary regressions show that frequency of trades in terms of harvesting continuously each year since 1986 does not explain nor is

correlated with level of integration in communities. Large forests, while positively correlated with higher community vertical integration, do not explain why hiring private firms to manage the harvest is less efficient than community management.

In this paper, we develop and empirically test a model of contracting between local forest communities in Mexico and private harvesting firms where the community's choice is to hire in the services of the contractor or invest in forward integration to internalize harvesting and processing. This decision is modeled as the outcome of Nash bargaining between outside private firms and local communities with communal forest land holdings. This approach reflects the hold-up problem described by Williamson (1985) and formalized by Grossman and Hart (1986). The silvicultural management and timber extraction and processing require investments in physical and human capital. If the community integrates, it avoids the problem of dividing gains to trade whenever the contract is renegotiated, encouraging community investments in both stages of production. However, the community may lack expertise, reducing the efficiency of internalization. The main argument is that community integration provides the community with greater control over production decisions that affect broader community goals, such as economic development and nontimber forestry production, and that greater control is traded off against comparative efficiency with the private sector.

Using the original survey and secondary data, empirical results from an ordered logit regression find that variations in communities' human capital specific to timber production, historical experiences which influence "social capital" and forest resource endowments explain asset ownership patterns. No one variable completely explains the choice of contracts but rather a combination of variables. Control variables are included to test for alternative explanations. Distance to the capitol city of Oaxaca, for example, can be correlated with a number of factors reflecting risk of specialization, transportation and information costs and access to services. However, it does not perform as well as other indicators and does not fully explain the allocation of property rights.

Few other studies have modeled ownership patterns and market interactions where common property institutions are a central social force. Nugent and Sanchez (1998) and Wilson and Thompson (1993) analyze common grazing lands in risk diversification strategies. Dayton-Johnson (2000a) uses a dataset of irrigation organizations (*unidades de riego*) from Mexico's Guanajuato state to clarify how wealth inequality, social

heterogeneity and ages of individuals in a *unidad* affect distributive rule choices, while Dayton-Johnson (2000b) links wealth inequality to changes in cooperative effort. These are some of few papers adding an empirical component to models of common property management. In contrast to this paper, members of the irrigation organizations coordinate individual exploitation of a common water reservoir, where cooperation is measured as levels of maintenance effort on the canal infrastructure. Eswaran and Kotwal (1985) provide a theoretical explanation and simulation of agricultural contract choice where the relative importance of nonmarketable inputs vary and landlords and tenants have different skills in production and opportunity incomes. Chen and Rozelle (1999) considers the evolution of township and village enterprises (TVEs) during China's market reforms over the last decade. In early TVEs, local leaders were in a position to control expenditures, jobs and local infrastructure development that provided growth for local communities, and these leaders predominated TVE management. However, as markets evolved, TVEs were more often structured through profit-sharing or fixed-payment contracts with managers who had relatively better internal management skills. In the present paper, the choice of contract is an equilibrium outcome given characteristics of community resources and individuals as a group. It adds to the existing literature but offers an incomplete contracts framework relating transaction costs to ownership and management structures. In this way, it represents a different perspective focusing on the noncontractible elements of community-based resource management, uncertainties in production and interaction of communities with the private sector to determine the importance of natural resource ownership and control at a community level.

This paper is organized as follows. The next section provides a historical and institutional background of Mexican community forestry and discusses the use of common property forest land for timber and nontimber benefits. Section 3 introduces an incomplete contracts model to depict a buyer-seller relationship between a local community that owns forest land and a harvesting manager who operates the harvesting equipment. Section 4 describes the survey approach, descriptive statistics, hypotheses, the ordered logit regression model and regression results. A discussion section and conclusion follow.

2 Field setting

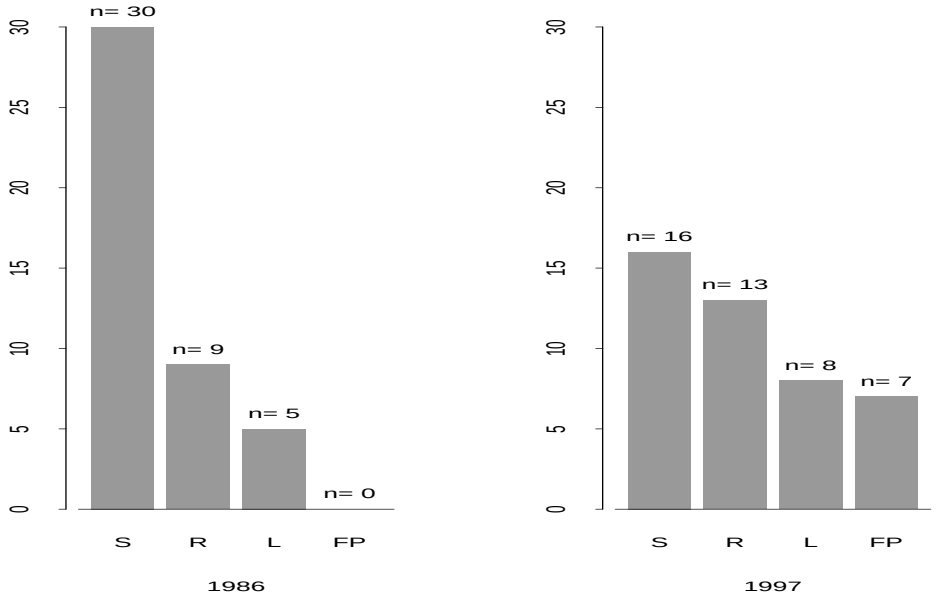
The high concentration of communally-owned and -managed forest industries in Mexico is unique. Agrarian communities account for about 80% of forest land in Mexico, which ranks tenth worldwide in forest cover (Wexler and Bray 1996). In the state of Oaxaca, 90% of forest land is common property (Stephen 1997). The term "agrarian communities" has a specific meaning in Mexican law, referring to the *comunidades* and *ejidos* incorporated under Article 27 of the Mexican constitution. This law establishes the rules for community membership, territorial boundaries and governance structure and classifies all community land as common property of members. Community members have usufructory rights over individual land plots and access to common property resources held by the community. To a large extent, the laws formalized *de facto* community relations which existed prior to Spanish colonialism. *Ejidos* differ from *comunidades* in that the latters' claim to land rests on precolonial territorial occupation. A newer form of community governance, the *colonias*, was established in the fifties but have similar organizational structures. Land rentals occur within the community population and sharecropping is common (DeWalt et al. 1994). The Agrarian Reform of 1992 (*Ley Agraria* 1992) allowed privatization of agrarian land but does not apply to forestland, partly because individual usufructory rights are not established. Therefore, the majority of agrarian community land remains communally-held and managed (Stephen 1997).

The shift from government to community control over timber production has been revolutionary. The Mexican government requires forest management plans for commercial timber harvest be submitted to the Ministry of Environment and Natural Resources and Fisheries (SEMARNAP)[1] for approval, a process which has been in place since the Forestry Law of 1926 and applied, with varying degrees of effectiveness, up to the present day (Klooster 2001). From the 1940's to 1982, the Mexican government leased communal forests to semi-public, semi-private (henceforth parastatal) pulp manufacturers for newspaper production, interpreting agrarian law as giving ownership rights over the land to the community, while the government maintained rights to the trees. Although communities had the right to negotiate and veto leasing, most communities arranged a contract with the parastatal. In Oaxaca, friction grew over the years between the parastatals

[1] This ministry is now called the Ministry of Environment and Natural Resources (SEMARNAT).

and communities, so that by the seventies, local, state and nongovernmental actors called for an end to the leasing system (Moros and Solano 1995). Labor strikes and protests criticized the parastatals' labor hiring and harvest practices. The movement was successful and leases were not renewed at the end of their term in 1982. The subsequent 1986 Forestry Law formally allowed communities to organize timber production units or contract with private firms directly in the market. Community-level timber production now occurs through various management forms, of which the most prominent are communities that sell standing timber at stumpage value to private companies, communities that extract and sell timber as logs, or roundwood, communities that have sawmills to process extracted timber into lumber or, finally, finished wood products, such as tool handles and house furnishings. Figure 1 illustrates the transition of communities over the last twenty years among the communities in the survey sample according to these end products sold by the community.

Figure 1: Profile of Community-Managed Forest Production by End Product Sold (N=44)



Community-organized timber production occurs within the overall community governance structure. Consistent with agrarian structure and customs, especially in Oaxaca where most agrarian communities

are the indigenous *comunidades*, commercial use of common property requires consent from community members. Members vote (one person-one vote) generally by consensus in the General Assembly (*Asamblea General*) on decisions such as contracts with private firms or plans to organize a community production enterprise or invest in downstream operations. Communities collect revenues from land taxes and state funding to municipalities under the law. Depending on local regulations, individuals may pay fees to gather large volumes, certain products or products intended for resale, such as truckloads of fuelwood or gravel. All or part of timber extraction revenues is allocated to community accounts.

The contact point for initiating activities on common property is the *Comisariado Ejidal* or *de Bienes Comunales*. As most of the communities in Oaxaca are indigenous, we will refer to this office as the *Comisariado de Bienes Comunales*, or CBC. The CBC consists of a president, secretary and treasurer, along with their *suplentes*, and fits within the larger organizational structure, which includes the president of the municipality, *Consejo de Vigilancia*, who monitors the CBC, and other offices, such as public health representatives and local police officers (Cancian 1992, Vidal Garcia Perez 2000). Holding office represents a civic responsibility as part of the *cargo* system to assure that everyone contributes to the community. Nominations to higher offices occur as one gains experience and merit fulfilling obligations in the lower offices. Elections to these posts are held every three years, although this can vary according to politics and circumstances. Increasing levels of vertical integration require more personnel and may include permanent employees in positions of secretaries, accountants or forestry technicians, while the managerial offices remain under the rotating *cargo* system. Communities that sell stumpage typically manage the timber transactions through the CBC, while more integrated communities form a production unit (*unidades comunales integrales*) incoporated under law and consisting of a general manager, logging foreman, sawmill manager and other positions depending on the community and scope of production activities. Since the forest land is seen as a community benefit, community members expect a return from common property activities, individual monetary rewards or otherwise. Fieldwork showed that CBCs use a variety of mechanisms to disburse funds locally, such as revenue dividends, loans to individuals and groups for entrepreneurial efforts, building or improving churches, schools, roads and electricity supply, and goods in kind (Antinori 2000).

We argue that the choice of whether to produce timber and downstream wood products or contract with

private harvesting companies that supply labor and capital involves transaction costs related to specificity of investments, as in other vertically integrated industries (Monteverde and Teece 1982, Joskow 1985) and entails consideration of the social and cultural aspects of community governance. Silvicultural treatments and extraction both require specific investments in physical and human capital. Logging roads that connect the forest stand with transportation routes represent large start-up and maintenance costs from year to year and become embodied in the community's physical infrastructure. Temporal specificity, where outside opportunities diminish over time, exist due to the window of opportunity during the dry season. Product specificity is less, as most sawmills can accommodate logs of varying sizes and quality. Sawmills and furniture manufacturers contracting with a community potentially have alternative supply sources through other communities and import markets. The forest management plan required for harvest must be prepared by professional foresters (*servicios tecnicos forestales*). Plans must meet minimum standards and consist at least of a forest inventory, demarcation of harvest rotation areas and harvesting schedule over time. Costs of this service vary according to size of forest and quality of the plan and is not inconsequential. In addition, silvicultural treatments are conducted during the entire year, such as cutting, thinning, treatment of diseases and reforestation. Knowledge of the region and community is beneficial in this process. The forester develops a plan in coordination with the CBC and CV who obtain its approval from the General Assembly. Building trust with the community is an important aspect of a forester being able to carry out his or her responsibilities successfully.

The management decisions in the course of production pose opportunities for the goals of community residents and an outside private firm to diverge. The multidimensional role of the Mexican agrarian common property system has been suggested as a reason why privatization with agrarian land in even urban *ejidos* has proceeded more slowly than expected (Goldring 1998). All contracts specify a volume which the firm will extract. Contracts may further specify that the firm build logging roads necessary for extraction, follow certain forest management guidelines, hire locally, or install public works, like electricity or public buildings improvements. Residual control rights for forest owners are access to and allocation of forest resources. For example, during the parastatal era, communities threatened to refuse renewal of the contract if the parastatal did not remove more cut timber instead of leaving it in the forest to rot or pose fire hazards. The conflict

included the community confiscating the firm's equipment and retaliatory local firings before being resolved (Moros and Solano 1995). The ability to coordinate among uses of the forest could become more challenging as the range of use expands. Residual control rights over harvest equipment include how to allocate the equipment over different uses such as timber and nontimber activities, action in case of equipment failure, scheduling and worker relations. Management decisions include how the business is conducted, whether it expands or is kept small, number and allocation of jobs in the short- and long-term and quality standards in timber extraction.

From interviews and survey data, managerial control maps to integration levels so that community integration usually entails a switch in management personnel from private to local managers. The logging foreman (*Jefe de Monte*), CBC and vigilance officers are always *comuneros* and paid by the community in non-stumpage groups. However, communities hire from outside for production work when people with technical skills are not available locally. Ownership and control also track increasing levels of vertical integration. All the sample sawmill communities own and operate the mechanical winch necessary for hauling logs across distances or from downslopes to the logging road, while slightly less than half of the roundwood communities and none of the stumpage communities own or operate the winches. Chainsaws tend to be individually owned by persons hired to operate them. Individual *comuneros* or contract companies offer trucking services for both integrated and non-integrated communities, but communities which produce roundwood and further processed goods usually own their own trucks.

3 Model of community forestry

A CBC representing a community with a commercial forest stand and a harvest manager are in a vertical production relationship. They negotiate a transfer of timber to the harvest manager who will then use the timber as input for other wood products. Assume that the CBC acts on behalf of the community members at large in all decisions made as managers of the community forestry enterprise. The General Assembly meetings could be thought of as the means by which the authorities and other community members coordinate their preferences. The local community, C, owns forest land, $F = F(T, NT)$, where T is the timber stock and NT

is the nontimber stock, and a harvesting manager, M, operates the harvesting equipment, H. The stock parameters T, NT and H represent physical size, such as hectares, biomass or equipment inventory, as well as the value which the community and manager places in the timber and nontimber stock for consumption, production, cultural and aesthetic use, and quality of the resource for commercial purposes. It is assumed that the parties are risk neutral and each has initial wealth large enough to purchase any asset which is efficient to own.

$B_c(\cdot)$ and $B_m(\cdot)$ are functions that represent the monetary value of production and trade of forest products if the two parties decide to trade. Since the model focuses on vertical integration relationships, the benefit function of the upstream community, $B_c(\cdot)$, can be negative to represent a cost of production which will be recouped through the sales price. The function $B_m(\cdot)$ includes revenues from selling timber products. The functions B_c and B_m include non-pecuniary private benefits which accrue to the owner of an asset such as the ability to make decisions over the allocation of the asset, feelings of pride of ownership, or ability to divert benefits to themselves.

There are two dates in the model. At Date 1, the investments i_f and i_h are made, where i_f is a silvicultural investment in the forest or forest management process and i_h is an investment in the harvesting equipment or process. Assume the forest and the harvesting equipment already exist and are in place. The investments are to improve productivity, meaning that they enhance the efficiency or lower the costs of production, thereby increasing the value of *ex post* payoffs. It is assumed that the investments i_f and i_h involve temporal or human capital specific investments. For example, i_f could be adapting the management plan to accommodate the harvester's needs, or specific training to apply treatments that aid the harvester. Examples of i_h are improving the timber harvesting practices for this community's forest, learning about the forest to plan a harvest or consulting the management plan. It can also include constructing a road if human capital specific investments become embodied in the investing party so that the investment is specific to trading with the community. Neither the harvesting manager nor the forest community can acquire the human capital investments of the other party, only physical assets, F and H. Since Mexican laws currently prevent sales of communal forest land, only nonintegration and forward integration by the community are considered here.

The investments are made independently, noncooperatively and simultaneously by C and M. Each observes the other's choice of investment after it has been made, so they have symmetric information on investments and costs. B_c and B_m are functions of i_f and i_h, respectively, so that $B_c(\cdot) = B_c(i_f)$ and $B_m(\cdot) = B_m(i_h)$. The function $B_c(i_f)$ captures the costs and benefits of trade where i_f can be thought of as reducing costs of trade. Both investments i_f and i_h affect the final payoffs to C and M through bargaining. Finally, it is assumed that i_f and i_h are the costs as well as the levels of investing.

Consistent with the contract literature (Grossman and Hart 1986, Chung 1991, Hart 1995, Hanson 1995, Segal 1999, Holmstrom and Milgrom 1991, Baker and Hubbard 2000), production quantity is not modeled. It is assumed that that the quantity produced does not affect the transaction costs of the contracting relationship. The investments i_f and i_h improve the quality, efficiency or productivity of the trade relationship and do not contribute to production volume. Harvest level is decided prior to Date 1, and the characteristics of F and H (e.g. size, volume, capacity, quality) are exogenous.

Uncertainties preclude a complete long-term contract, i.e. it is too costly to specify all possible uses of the assets in a Date 1 contract. Say at some point during the contract period, C and M must renegotiate, say, a labor allocation, location choice, or a difficulty in road construction. *Ex post* bargaining creates potential sources of inefficiency. If investments are specific, C or M can hold-up the other and capture part or all of the gains to trade according to their bargaining power so that they receive a fraction of the marginal value of their investment. Trade at Date 2 takes place and payoffs are realized.

The transfer price, p, at which the two parties trade is a function of their bargaining power, payoffs with trade and reservation payoffs and allocates the total surplus between the two players. The default price, $\bar{p}$, is the price that C can get on the spot market if renegotiation between C and M fail and C finds another harvest manager. Denote the community's and harvest manager's reservation payoffs as the functions $b_c(\cdot)$ and $b_m(\cdot)$, respectively. In a default situation, C and M no longer have access to each other's assets, but to the assets which they own individually. The function $b_c(i_f; F, H)$ indicates the general default benefit function for the community when it is forward integrated, $b_c(i_f; F)$ under nonintegration. Similarly, let $b_m(i_h; H)$ indicate the default benefit function for the harvest manager under nonintegration. Under integration, however, the manager is a member of the community, so that the manager cannot be fired. This default position contrasts

with the nonintegration scenario, where the manager is a private harvester who is fired and seeks alternative trading partners if bargaining breaks down. This model adaptation is consistent with the observation that no communities in the sample hired managers from outside the community when they integrated forward. With this switching of managers, the community manager under integration maintains access to the assets F and H even if bargaining breaks down. Therefore, $b_m(i_h; F, H)$ is the community harvesting manager's default benefit function in the integration scenario. Before fully defining the default benefits of a manager in this position, a few more assumptions are in order.

When the two parties trade, $B_c(\cdot) = B_c(i_f; F(T, NT), H)$ and $B_m(\cdot) = B_m(i_h; F(T, NT), H)$. The *ex post* surplus with trade is $B_c(\cdot) + B_m(\cdot)$. Without trade, the *ex post* surplus is $b_c(\cdot) + b_m(\cdot)$. For simplicity of notation, the arguments to F are dropped so that $F = F(T, NT)$. Assume *ex post* gains from trade strictly exist, meaning:

$$B_c(i_f; F, H) + B_m(i_h; F, H) > b_c(i_f; \cdot) + b_m(i_h; \cdot) \geq 0 \tag{1}$$

where $\cdot$ represents C and M's assets in a no-trade scenario. Under condition (1), investments i_f and i_h are more productive in a trading relationship between the firm and the community, capturing the idea that the investments are human capital specific and have less value outside the trade agreement.

It is further assumed that relationship-specificity holds in a marginal sense. The marginal productivity of investments is strictly greatest when C and M trade because the human capital investments i_f and i_h are partly specific to the trade relationship but not to the physical assets. If C and M do not trade, the marginal productivity of investments increases the more assets C or M controls, but not as much as when the two parties trade. The weak inequalities allow for those cases:

$$B_c'(i_f; F, H) > b_c'(i_f; F) \quad \forall \quad 0 < i_f < \infty \tag{2}$$

$$B_m'(i_h; F, H) > b_m'(i_h; H) \quad \forall \quad 0 < i_h < \infty \tag{3}$$

This relationship shows that a person's investment produces more the more assets the person has to work with. The functions B_c and B_m are assumed to be strictly concave: $B_c'(\cdot) > 0, B_c''(\cdot) < 0$ for F, T, NT, H, and i_f, and $B_m'(\cdot) > 0, B_m''(\cdot) < 0$ for F, T, NT, H, and i_h. The default benefit functions $b_{C,M}$ are weakly concave: $b_c'(\cdot) \geq 0, b_c''(\cdot) \leq 0$ for F, T, NT, H, and i_f, and $b_m'(\cdot) \geq 0, b_m''(\cdot) \leq 0$ for F, T, NT, H, and i_h. Nontimber resources are not traded between C and M, reflecting the fact that local communities typically trade only timber with harvesting and sawmill firms. Further, cross-effects among timber stock, nontimber stock and harvest equipment are zero ($B_c''(\cdot) = B_m''(\cdot) = b_c''(\cdot) = b_m''(\cdot) = 0$ taken with respect to T, NT or H and any other asset T, NT or H), so that only direct effects of assets on the contracting decision are considered.

Since the exact nature of the product is not completely describable until at Date 2, the community and the harvest manager negotiate at Date 2 to realize the *ex post* gains from trade, $(B_c + B_m) - (b_c + b_m)$. Either can hold-out for better terms of trade or refuse to trade otherwise. Assume Nash bargaining occurs and the trade surplus is split 50:50. This assumption of an equal split is not necessary for the results to hold (Hart 1995). The *ex post* payoffs with the arguments suppressed for clarity are:

$$\pi_c = B_c + p = b_c + \bar{p} + \frac{1}{2}[(B_c + B_m) - (b_c + b_m)] \tag{4}$$

$$\pi_m = B_m - p = b_m - \bar{p} + \frac{1}{2}[(B_c + B_m) - (b_c + b_m)] \tag{5}$$

An argument to be explored is that communities have higher costs of organization, insurance against risk and investment in industrial forestry than specialized private firms in the marketplace. Because of the bias towards hiring internally, communities are thought of as having a fixed labor endowment, unlike a private firm which hires from the open market. Weights indicating the relative efficiency of community investments compared to outside private firms are applied to the investments i_f and i_h when the community makes those investments. Investments made by the community in forest management, $i_f^c = \alpha_f i_f^m$, and that $i_h^c = \alpha_h i_h^m$, where $0 < \alpha_f \leq 1$, $0 < \alpha_h \leq 0$ and the superscripts indicate who is making investments, a community member or a manager of an outside private firm. Parameters α_f and α_h range between zero and one for cases where community investment is less than or just as efficient than an outside private harvester. More

job skills, for example, in forestry management and production could lower costs of training and expertise and contribute to the stock of knowledge specific to a forest. This will be represented by a increase in the parameter values, α_f and α_h.

First best case

In an open and integrated economy, the social planner solves the problem of maximizing social welfare by choosing investments cooperatively without regard to relative efficiencies, since there are no restrictions on who makes each investment. Therefore, the social planner maximizes Date 1 net present value W where:

$$W(i_f, i_h) = B_c(i_f; F, H) - i_f + B_m(i_h; F, H) - i_h$$

In the social planner's problem, B_c and B_m are contractible and i_f, i_h are chosen cooperatively. In the first-best scenario, the maximum is attained at i^*. The first-order conditions (FOC) are:

$$i_f^*: \quad W_1'(i_f, i_h) = B_c'(i_f; F, H) = 1$$

$$i_h^*: \quad W_2'(i_f, i_h) = B_m'(i_h; F, H) = 1$$

Second-best cases

In contrast to the first best case, i and B are no longer contractible. Since forest land is always held as common property by the community, we consider only two cases, that of forward integration by the community and nonintegration where private harvesters provide production and planning services.

Nonintegration of forest management and harvesting stages

In this case, the community owns the forest, and an outside private harvesting firm owns the harvesting equipment. In this case, the net payoffs realized through bargaining are:

$$\begin{aligned}
\text{Community, C:} \quad \pi_c - i_f = \bar{p} + \frac{1}{2}\Big[B_c(\alpha_f i_f) + B_m(i_h)) + \\
(b_c(\alpha_f i_f; F) - b_m(i_h; H))\Big] - i_f \\
\text{Outside harvester, M:} \quad \pi_m - i_h = -\bar{p} + \frac{1}{2}\Big[B_c(\alpha_f i_f) + B_m(i_h)) + \\
(b_m(i_h; H) - b_c(\alpha_f i_f; F))\Big] - i_h
\end{aligned}$$

Investments i_j, where $j = F, H$, are no longer chosen efficiently. To see the inefficiency, note that the first order condition (FOC) with respect to i_j is:

$$i_f: \quad \alpha_f \frac{1}{2}[B_c' + b_c'] = 1 \tag{6}$$

$$i_h: \quad \frac{1}{2}[B_m' + b_m'] = 1 \tag{7}$$

That is, in choosing i_j, C and M place one-half the full weight on the default payoffs of b_c and b_m even though the no-trade option does not occur. B_c and B_m are the Pareto optimal outcomes with trade, but the *ex post* distribution of trade surplus has led to suboptimal *ex ante* investments. The comparative efficiency weight α_f in the FOC further removes silvicultural investment levels away from first best.

Integration of forest management and harvesting stages

In this first approximation of a modeling approach, assume that if the community is integrated, the community members make the investments in the forest management stage as in the nonintegrated scenario. However, the manager making investments in the harvesting stage at Date 1 is a member of the community and may not have the specialized skills of an outside private company. Further, if this member-manager does not agree with the community during the contract period, he still has access, as a member of the community, to the assets F and H in a default situation. Likewise, the community still has access to his human capital

specific investments. One can assume a fixed cost, c, that the manager (and perhaps the community) must pay for negotiating differences with the community authorities.[2] The costs could be large or small, positive or even negative. The point is to capture, however crudely, the generalized skill levels of *comunero* managers as opposed to the specialized skills of a private harvesting company. A further assumption is that the managers in each scenario have the same preference structure so that the functions differ only with respect to the weight α_h.

Therefore, if the community integrated forward, its payoffs are:

$$\begin{aligned}\pi_c - i_f = \bar{p} + \frac{1}{2}\Big[&\big(B_c(\alpha_f i_f) + B_m(\alpha_h i_h)\big) + \\ &\big(B_c(\alpha_f i_f; F, H) - B_m(\alpha_h i_h; F, H)\big)\Big] - i_f \\ = \bar{p} + B_c(\alpha_f i_f) - i_f\end{aligned}$$

The community harvest manager's payoffs are:

$$\begin{aligned}\pi_m - i_h - c = -\bar{p} + \frac{1}{2}\Big[&\big(B_c(\alpha_f i_f) + B_m(\alpha_h i_h)\big) + \\ &\big(B_m(\alpha_h i_h; F, H) - B_c(\alpha_f i_f; F, H)\big)\Big] - i_h - c \\ = -\bar{p} + B_m(\alpha i_h) - i_h - c\end{aligned}$$

The FOCs are:

$$i_f: \quad \alpha_f B_c' = 1 \tag{8}$$

$$i_h: \quad \alpha_h B_m' = 1 \tag{9}$$

It is immediately obvious that if community members are not as efficient at investing as a privately

[2]This cost is similar to division costs (d) in Lueck's model of contracting over common property (Lueck 1994).

operated firm, then the first-best solution is not obtainable. This statement is formalized in Proposition 1.

Proposition 1. *If community labor is less efficient than the harvesting firm's in silvicultural and extraction investments ($0 < \alpha_f < 1$ and $0 < \alpha_h < 1$), then the investment under nonintegration and integration by the community are less than investment under the first-best scenario (i_f^* and i_h^*).*

Proofs in Appendix.

In other words, where skills are exogenously given and local skills are less efficient than outside firms', then investment levels are less than the first-best Pareto optimal outcome under integration by the community. Bargaining costs with nonintegration also lead to less than first-best investment levels. The parameter α measures how less efficient community members collectively are than private firms, but a trade-off of higher transaction costs occurs for hiring-in outside managers.

The solution method first observes the optimal level of investments, i_f and i_h, in each ownership scenario and compares the "size of the pie" under each scenario, given the exogenous characteristics of the problem. Say there are two possible ownership options as outlined above. The problem becomes $\max\{V_0, V_1\}$, where V_0 is the total social surplus of nonintegration and V_1 is total social surplus from forward integration by the community, so that:

$$V^0 = B_c(\alpha_f i_f; F, H) - i_f + B_m(i_h; F, H) - i_h$$

$$V^1 = B_c(\alpha_f i_f; F, H) - i_f + B_m(\alpha_h i_h; F, H) - i_h - c$$

Given the value of each ownership structure, society "chooses" the ownership option with the greatest social surplus. By the assumption of wealth maximization, it is assumed that someone will propose a new ownership scenario if the prevailing one is not optimal.

The optimal allocation of harvest equipment becomes case specific and depend on parameter values. Proposition 2 considers the case where community members are just as efficient as private firms. In this case, integration by the community is socially preferable because integration avoids renegotiation costs.

Proposition 2. *If community labor is just as efficient as the outside firm's ($\alpha_f = 1$ and $\alpha_h = 1$), then forward integration by the community is more efficient than subcontracting.*

The next proposition considers characteristics of the forest asset, F, in terms of timber (T) and nontimber (NT) resources. In this proposition, increases in the timber resources, T, shift out the productivity of the investments, i_f. On the margin, more assets shift investment productivity outward to where integration becomes more efficient than nonintegration. This can be interpreted to indicate positive externalities of stock size, where organizations economize on supervision costs with larger forests, larger forests provide greater risk diversification opportunities and, therefore, are important to control, a labor force becomes more productive with greater stock levels, or managers may coordinate and allocate the stock among different uses more efficiently.

As with Conditions 2 and 3, assume that marginal productivity increases with stock increases. Say that the stock of timber in one community, T_1, is greater than the stock of timber in another community, T_2, so that $T_1 > T_2$ for $T_1 > 0$ and $T_2 > 0$. Then, holding all else equal:

$$\begin{aligned}
B_c'(i_f; F(T_1, NT), H) &> B_c'(i_f; F(T_2, NT), H), \\
b_c'(i_f; F(T_1, NT)) &> b_c'(i_f; F(T_2, NT)), \\
B_m'(i_h; F(T_1, NT), H) &> B_m'(i_h; F(T_2, NT), H), \\
b_m'(i_h; H) &= b_m'(i_h; H), \\
&\forall \quad 0 < i_f < \infty, \quad \forall \quad 0 < i_h < \infty
\end{aligned}$$

Both the benefit function with trade and the default option increase with timber stock increases. But the outside harvest manager under nonintegration loses access to the forest in a default situation, so default payoffs remain unchanged across variations in timber stock. Proposition 3 says that the disparity between the trade and no-trade payoffs for an outside manager grows with increases in timber stock, which discourages investments in the harvesting stage and raises the likelihood of community integration.

Proposition 3. *For any given α, NT, H, there exists a timber stock, T, large enough so that forward integration by the community is socially preferable to nonintegration.*

A similar relationship is assumed to hold for increases in the nontimber stock, NT with the other assets,

T and H, held equal. Increasing nontimber stock also may increase local labor productivity for the reasons given above, but interaction effects between timber and nontimber production raise monitoring issues.

The formalization of transaction cost theory and the hold-up problem as presented in Williamson (1985) raises theoretical and empirical distinctions from earlier transaction cost analysis. The property rights approach does not assume that integration reduces hold-up disincentives if the individual managers stay the same. Further, Whinston (2000) points out that transaction cost and property rights approaches to the same problem can lead to different property rights outcomes. With the more formalized property rights model, predictions vary depending on the type of specificity, i.e. people-specific or asset-specific, and who makes the investment, i.e. the upstream or downstream "buyer" or "seller".

Our model differs from the Grossman and Hart (1986) and Hart (1995) models in several ways. First, the efficiency parameters, α_f and α_h, are added to facilitate comparisons of human capital expertise across communities. However, it is implicit that there is a division of labor among the community members according to skills, that is, marginal costs are lower for one person than another in each job task. Second, the model breaks the asset F into two components T and NT to compare bargaining costs across different endowments of forest land. Third, while Grossman and Hart (1986) keep the same two managers in a production chain to illustrate implications different from earlier transaction cost literature, we allow a switching of managers between the private and community sectors across integration scenarios. The identity of managers switches from community to non-community member status between the integration and nonintegration scenarios. The community and manager under the integration scenario work out their differences at some fixed cost (c). This adaptation is appropriate to describe the *status quo* of the communities. The representative individual of the model can be seen as an "average" member of the community where the characteristics of the local resource and population determine the propensity for vertical integration using the common property resource. Finally, Baker and Hubbard (2000) show that the analysis applies to firms as well as individual owner-operators. We adapt the model analogously to local community organizations and private harvesting firms.

4 Model estimation and results

4.1 Survey Data

The unit of observation is communities or subgroups within the communities that are authorized to make decisions concerning common property. The criteria for including a community as part of the study population are that the community owns land for which it has a current management plan and permit that allows commercial harvests, and commercial production occurred in the community during at least one of the previous three harvest seasons, i.e. in 94/95, 95/96, or 96/97. To identify the population, permit files were obtained from SEMARNAP for the timber production cycles of 94/95, 95/96, and 96/97. Communities were categorized according to their known level of vertical integration, which was then verified to the extent possible prior to administering the survey. The total population of communities that met these criteria was 95. These 95 communities produced 80-95% of the commercial timber harvest in Oaxaca in 1994 which reached 430,060 cubic meters (SARH 1994). A random sample of 60 communities replicated the same proportion of each type as in the total population. The number of communities that processed timber into finished products was not known prior to the survey so that their number was initially included with communities that sell lumber. Corrections in classification were necessary during the course of fieldwork.[3] The final sample of 44 communities/subgroups is shown in Column 3 of Table 1. All roundwood communities sell their entire extracted volume as roundwood. Seven of the fifteen lumber and finished products communities direct 50% or more of their extracted volume to their sawmills, of which two communities, one lumber and one wood products, direct 100% to the sawmill. While it is possible that communities could own a sawmill yet contract outside companies for extraction services, this did not occur in the sample.

The survey had three parts. Part One focused on the history of forestry activity in the community, labor and capital data, management structure, production, and contract and client characteristics. Part Two addressed questions of nontimber benefits of the forest, general community characteristics such as non-forest sources of income. Parts One and Two were directed to the community authorities responsible for forest administration. Part Three of the survey was conducted apart from the community with the forester.

[3]Seven of communities targeted as roundwood or lumber sellers turned out to be stumpage sellers.

Table 1: Population and Sample

Type	Population	Selected Stratified Sample	Final Sample
Stumpage	27 (28%)	17 (28%)	16 (36%)
Roundwood	42 (44%)	26 (43%)	13 (30%)
Lumber (or finished)	26 (27%)	17 (28%)	8 (18%)
Finished products	–	–	7 (16%)
Total	95 (100%)	60 (100%)	44 (100%)

Survey questions explored causes and frequency of contract renegotiation to determine how uncertainty in production relates to institutional form. Table 2 shows the number of communities who renegotiated contracts at least once during the five-year period before the survey, by reason given. Data on lumber and finished wood products communities refer to their contracts to sell roundwood. Since the extraction process is similar across communities, we would expect causes for renegotiation to reflect the varying control rights in contracts across community type. Stumpage contracts were not changed due to tree damage because the private harvester is in charge of the extraction process and, therefore, condition of extracted timber. Management plans are frequently modified usually between seasons or at the beginning of a new contract relationship. Therefore, the stumpage group, which changes harvesters more often between seasons, reports the greatest frequency of modification. Harvesters who could not extract the total volume specified in the contract force modifications in harvest rotations between seasons or contractors.

Given that the model presented above explains contract choice in equilibrium, we would not expect to see large variations in the frequency with which trading partners breach their contracts. Table 3 reports summary statistics for the number of times in the five years prior to the survey that communities experienced contract breaches. While the stumpage and roundwood groups have higher averages, differences are not significant among groups according to Wald tests.

Bank credit has not played a major role in financing community forestry. From 1987 to 1993, about 15 communities received about 39,388,000 Mexican pesos from banks to fund investments or working capital in the state of Oaxaca (*FIRA* 1998). In 1997, the community sector received no new loans (*FIRA 1998)*. From survey data, most communities acquired chainsaws or truck services with community funds or, in the case of chainsaws, contracting with individual community members. Only three in the sample used bank

credit to acquire their first truck or crane. Credit was relatively more important for sawmill acquisition and installation.

Private firms or the parastatal companies were more frequent sources of outside capital to start extraction operations, both in direct lending and infrastructure investment. Former private contractors arranged with nine communities to acquire their first truck or crane. Three communities began sawmilling activities at the same time or before they began harvesting themselves because of equipment already in place by a parastatal. Further, a large percentage of communities' existing network of logging roads was constructed by either parastatal or private firms. Private harvesters laid about 82% and 40% of the existing logging network in stumpage and roundwood communities, respectively, while parastatals, who were more often in the sawmill communities, laid about 60% of the existing roads in these communities' forests. Preexisting infrastructure could present an advantage for communities considering forward integration.

Individual income in communities does not provide financing for timber operations. As summarized in Table 4, 1990 census data shows that while literacy rates and percent of households with water, electricity or drainage as proxies for income levels generally increase on average with more integration, these variables are not strongly correlated with vertical integration, except for drainage facilities. Nor are averages significantly different between adjacent groups according to Wald tests, except for percent of households with drainage facilities. Therefore, communities poor in terms of these well-being indicators have integrated forward. Employment provides a greater source of individual benefits as communities increase the number of processing stages. In the extraction phase of production, the rate of local hire, measured as the percentage of loggers

Table 2: Occurrence and Reason for Contract Renegotiation (Number of Responses)

	Stumpage (16)	Roundwood (13)	Lumber (8)	F. Products (7)
Contract changes due to damage Pearson $\chi^2_3 = 6.51$, $Pr = 0.09$	0	3	2	0
Contract changes due to price changes Pearson $\chi^2_3 = 3.69$, $Pr = 0.30$	4	1	1	3
Management plan modified in last five years Pearson $\chi^2_3 = 6.73$, $Pr = 0.08$	15	7	5	4

Source: Survey data

Table 3: Breaches of Contract in Five Years Prior to Survey

	Stumpage (15)	Roundwood (12)	Lumber (8)	F. Products (7)
Mean	1.13	1.08	0.75	0.86
s.d.	1.51	1.31	0.71	0.38
Min.	0	0	0	0
Max.	5	4	2	1

Source: Survey data

and vehicle operators hired from the community, increases along the chain of production controlled by communities.

4.2 Hypotheses testing

The econometric approach to testing the model identifies exogenous measures of the parameters α, T, NT, and H, and tests hypotheses of the likelihood of community-based or service-based timber production as these parameters change in value. We derived the relationship between vertical integration level as an endogenous decision (VI) and the exogenous parameters in Section 3:

$$VI = f(\alpha, T, NT, H) \tag{10}$$

The first interpretation of the α parameter is the level of mechanical skills for timber production. According to the first proposition, human capital stock related to forestry operations is expected to have a positive impact on levels of vertical integration, assuming that greater initial stock in human capital lowers the obstacles of starting timber operations within a community.

Existing physical capital's effect on the marginal productivity of investments has ambiguous effects. To the degree that physical infrastructure for timber production was in place as of 1986, physical logging infrastructure substitutes for relationship-specific physical investments, increasing the likelihood that outside harvesters contract with the community and consistent with a negative coefficient value for the initial stock of logging roads estimator. It is assumed this effect applies equally up the production chain. Sawmills also

Table 4: Summary Statistics

Variable by group	Mean	Standard Error	Number of observations
Percent households with electricity*			
Stumpage	82.91	6.64	14
Roundwood	92.82	1.59	12
Lumber	95.84	1.30	7
Finished wood products	94.02	4.19	6
Percent households with water*			
Stumpage	70.24	7.31	14
Roundwood	73.68	9.05	12
Lumber	80.43	12.44	7
Finished wood products	90.02	7.25	6
Percent households with drainage*			
Stumpage	8.52	6.39	14
Roundwood	15.10	7.02	12
Lumber	23.23	9.25	7
Finished wood products	63.88	12.27	6
Literacy rates of population over 15 years of age*			
Stumpage	76.79	4.53	14
Roundwood	77.53	2.70	12
Lumber	82.97	3.14	7
Finished wood products	83.83	5.06	6
Rate of local hire*			
Stumpage	.34	.06	15
Roundwood	.76	.05	11
Lumber	.86	.08	6
Finished wood products	.94	.04	7

*Five missing observations.

Source: Survey data for rate of local hire; *Instituto Nacional de Estadistica, Geografia e Informatica, Conteo 1990* for other variables.

benefit from more logging roads because the roads increase supply flows to the sawmills.

However, sunk costs, such as in-place physical capital stock, bring opportunity costs of capital and, therefore, threat points to zero for the trading party. Lower threat points reduce bargaining power, encouraging the party to integrate. As the threat point decreases, costs of holdup increase. Where fixed capital stock decreases the value of the community's default options, a community with this sunk capital is more likely to integrate than a community without this capital, resulting in a positive coefficient value of the estimate. In addition, fixed capital specific to the community could be interpreted as a substitute for required start-up capital and relaxation of a capital constraint. The strength of these opposing forces will be tested empirically.

Third, the α parameter measures a level of "social capital" that facilitates a group's ability to organize collectively. Social capital refers to the obligations, expectations, information channels, social norms and trust relationships that facilitate exchange among people (Putnam 1995). The economic development literature argues that social capital enhances growth, income and collective action to create public goods (Dayton-Johnson 2000c). The political movement leading to the end of parastatal leasing most likely solidified communities in a desire to form their own timber operations, thereby lowering organizational costs. It is maintained that communities' political resistance to parastatal leasing created social capital within and among communities, and that exposure to long-term forestry management changed the relationship between people and forests from subsistence use to industrial-style production. The hypothesis to be tested is that a history of parastatal leasing has positive effects on community-level downstream integration propensities.

Proposition 3 generates the hypothesis that a community is more likely to integrate vertically with greater forest stock, measured by forest stand size and commercial quality. Size and quality of the forest should not matter for industrial organization if transaction costs were zero. Therefore, a positive and significant sign on either the size or quality dimension indicates the presence of transaction costs.

Proposition 3 extends to non-commercial timber activity. To the degree that nontimber production is separable contractually from timber production, we should not observe any relationship between timber and nontimber production. However, in communities whose residents more frequently access and use of the forest for non-commercial timber benefits, the risk of damage by timber harvesting, noncontractibility and coordination of management decisions and nonverifiability of harvest practices may become more important.

A positive sign for the measure of nontimber marketization would suggest that the two processes are not separable and that transaction costs are significant.

A potential source of selection bias is the relationship between parastatal leasing, quality of the forest and distance to the capitol city of Oaxaca. Parastatals reportedly sought communities with commercial quality forests that were conveniently accessed from their pulp factories. One plant was located in Tuxtepec, on the northeast border with Veracruz. The parastatal paved a road linking Tuxtepec and Oaxaca city, with gravel side roads to villages with commercial quality forest stands. As shown in Table 5, however, the correlation between commercial quality of forest in 1940 and parastatal leasing is weak, and regressing parastatal leasing on initial human capital, physical capital, past timber marketization and forested hectares returns a nonsignificant coefficient for prior forest quality. Although distance is not correlated strongly with parastatal leasing, it has explanatory power in a regression of parastatal leasing on the other independent variables and distance. This suggests possible selection bias due to communication or marketing advantages of proximity to the capital even though parastatal headquarters were located elsewhere. Therefore, the effects of distance to the capitol are explored more fully in the econometric analysis.

In addition, past presence of a parastatal is potentially correlated with physical infrastructure and human capital. Historical data from survey questions reveal that community members acquired mechanical training through both private and parastatal firms working in their forests. Separate ordinary least squares (OLS) regressions of initial logging road stock and mechanical training on prior forest quality, past timber marketization, forested hectares and parastatal history indicates that parastatal history has no explanatory power at the 10% level or better. Therefore, the main effect of past parastatal leasing is through lower organizational, or social capital, costs. Measures for parastatal leasing, 1940 forest quality, forested hectares, kilometers of logging roads and past mechanical training are retained as independent variables for the econometric analysis.[4]

Table 6 lists summary statistics for sample communities, by level of integration. All averages are increasing with levels of vertical integration except for parastatal history. Although averages for initial physical capital are increasing by group, one wood products community had few logging roads as of 1986 while several

[4]Definition of variables are in the appendix.

Table 5: Correlation Table ($n = 43$)

	1	2	3	4	5	6	7	8
1. Initial kilometers logging roads (log)	1.0000							
2. Initial mechanical training	0.5645	1.0000						
3. Past nontimber markets	-0.2516	0.0912	1.0000					
4. Parastatal leasing	0.2255	0.2577	-0.0068	1.0000				
5. Forested hectares (log)	0.6270	0.3460	-0.1374	0.1745	1.0000			
6. Forested hectares (log, sqd.)	0.6163	0.3407	-0.1241	0.1917	0.9976	1.0000		
7. Quality of forest, 1940	0.3307	0.3693	0.2532	0.2871	0.2929	0.3050	1.0000	
8. Distance from Oaxaca city	-0.0751	-0.2080	-0.2466	-0.4606	-0.2628	-0.2810	-0.3565	1.0000

stumpage communities had an extensive stock. A χ^2 test of initial physical capital and vertical integration is significant at only the 12% level, and its correlation with vertical integration is weak. While an upward trend appears for size of forest in hectares, numerous stumpage communities have forests as large as the roundwood or lumber groups, and several integrated communities have relatively small forests. Looking at the average number of hectares by group, there is a rise of about 2400 hectares between the stumpage and roundwood and the roundwood and lumber communities, then a large increase between the lumber and the wood product communities. The communities in the roundwood and lumber categories have approximately 5000 and 7500 average hectares of forest, respectively. Wood products communities have 11,000 forested hectares on average. The jump may indicate a threshold volume to make production of finished products feasible. About a third of the finished products communities buy additional timber from other communities, some on a regular basis, indicating a high demand for raw material consistent with the large increase in average forest size between lumber and finished products communities. The sawmills of the lumber communities had capacities that ranged from 2.5 to 11 thousand board feet per day with an average of seven compared to a range of four to 20 thousand board feet per day with an average of ten for the finished wood products communities. With the forest quality index, a more pronounced pattern emerges, although some communities with high quality forest are selling stumpage.

Wald test statistics indicate that group averages for initial road infrastructure jumps significantly (at the 10% level or above) between the stumpage group and each sawmill group. Otherwise, only roundwood and lumber groups have significant differences. Joint test statistics are significant at the 6% level. Differences in initial mechanical training group averages are significant at the 10% level or above between the stumpage and lumber groups and between each group versus the wood products category, suggesting that past timber employment is especially important in moving to a more advanced stage of processing. The joint test that all averages are equal is rejected at the 1% level. Frequency of parastatal leasing differs significantly between the sawmill groups and the other categories. Independent tests are significant at the 5% level between stumpage and sawmill communities and between roundwood and sawmill communities. The joint test that all averages are equal across groups is rejected at the 1% level. Independently, the difference in average forest hectares is significant between the stumpage group and each other category at a level of 6% or more and between

the roundwood and wood products groups at the 5% level. The joint test rejects the null at the 1% level mainly due to the difference in the stumpage group vis a vis the other groups. The Wald test rejects the null hypothesis at the 10% level that averages for past nontimber sales are equal across all groups, where the stumpage and wood products groups have a significant difference in averages at the 11% level while the difference is significant between the roundwood and wood products groups at the 1% level, suggesting a nonlinear pattern in past nontimber marketization. For quality of the forest in 1940, the stumpage group has a significantly different average (at the 5% level) from all other categories. The transition from roundwood to lumber categories does not have significant changes in average forest quality, however, but a significant gap (at the 5% level) exists between the roundwood and wood products group. The joint test rejects the null at the 1% level.

4.3 Ordered logit model

Equation 10 can be estimated with the ordered logit model developed by McKelvey and Zavoina (1975). Ordered logit is the appropriate model for choice options greater than two when the choices have an ordinal nature. In this case, the increasing levels of vertical integration from selling timber to selling finished wood products have a progressive characteristic. The multinomial logit would lose this information, making it an inferior choice of models.

The regression model is based on a linear probability model:

$$y_i^* = \beta' x_i + \epsilon_i$$

where y_i^* is an unobserved latent random variable, x_i is the vector of explanatory factors, β is a vector of parameters and ϵ_i is the residual error. It is assumed y_i^* lies along a continuum and indicates the propensity of the ith community to be least, middle, upper middle or most integrated into the production chain. In this study, the dependent variable takes the value 1, 2, 3, or 4 for level of integration. The dependent variable is thought to be such that $\mu_{j-1} < y^* < \mu_j$, where $j = 1, 2, 3, 4$ and $-\infty = \mu_0 < \mu_1 < \mu_2 < \mu_3 < \mu_4 = +\infty$ where the parameters, μ_i, are cut points to be estimated. The cut points divide the distribution of y^* into the

Table 6: Summary Statistics, $n = 43$

Variable by group	Mean	Standard Error	Number of observations
Initial mechanical training			
Stumpage	0.23	.0569	16
Roundwood	0.35	.0696	12
Lumber	0.41	.0622	8
Finished wood products	0.61	.0864	7
Past nontimber marketization			
Stumpage	0.25	.1095	16
Roundwood	0.33	.1377	12
Lumber	0.50	.1789	8
Finished wood products	0.57	.1893	7
Parastatal existence			
Stumpage	0.19	.0987	16
Roundwood	0.33	.1377	12
Lumber	0.88	.1183	8
Finished wood products	0.86	.1338	7
Forested hectares, logarithmic			
Stumpage	7.42	.2318	16
Roundwood	8.09	.2868	12
Lumber	8.33	.4579	8
Finished wood products	8.90	.4236	7
Quality of forest in 1940			
Stumpage	3.61	.1433	16
Roundwood	4.06	.1448	12
Lumber	4.30	.1806	8
Finished wood products	4.57	.1644	7
Initial kilometers of logging roads, logarithmic			
Stumpage	2.25	.3372	16
Roundwood	2.43	.4483	12
Lumber	3.45	.3735	8
Finished wood products	3.69	.6320	7

Source: Survey data

four categories, so that the response variable y is a discrete realization of y^* and is assumed to be generated in the following manner:

$$y = \begin{cases} 1 & \text{if} \quad y* \leq \mu_1, \\ 2 & \text{if } \mu_1 < y* \leq \mu_2, \\ 3 & \text{if } \mu_2 < y* \leq \mu_3, \\ 4 & \text{if } \mu_3 \leq y*. \end{cases}$$

Various techniques are available for estimating the ordered logit model. The version used here is the proportional odds model (POM) (McCullagh 1980) which assumes that the slope coefficients are equal across groups.

4.4 Regression results

The regression results are displayed in Table 7. Mechanical training is positive and significant above the 10% level, supporting the argument that integration increases with human capital skills. Mechanical training is the most basic and fundamental job skill for timber operations. As more people acquire mechanical ability, the more likely are community members to choose forward integration.

In all regressions, initial physical infrastructure is negative but not significant. The negative sign would argue for a Williamsonian prediction that more initial roads require less specific investment from outside harvesters, increasing the chance that a community will sell stumpage. However, competing forces of greater hold-up risk for the community and possibly contractible aspects of road investments contribute to its lack of significance.[5]

The historical effect of parastatal leasing is positive and significant at the 5% level in regression models in which it is included. Given these findings, the analysis lends support to the claim that the historical experience of forests leased to parastatal firms galvanized communities and led to a cultural shift in forestry,

[5]Initial logging roads has positive and significant explanatory power as a single regressor but loses significance at the 5% level when parastatal existence and forested hectares are added.

from subsistence use to long-term industrial operations.

The number of forested hectares (logarithmic) has a significant (at the 5% level) and positive effect in Regression (1), suggesting that complementarities between community labor and forest stock increase with forest stock size. Adding the squared term in Regression (2) reverses the sign of the base term with a small gain in the log-likelihood ratio. The squared term is positive, suggesting that additional hectares of forested land have increasingly larger positive effects on the propensity to integrate. However, neither term is significant at the 10% level.

Commercial quality of the forest in 1940 has a positive and significant effect in all models, so that commercial potential is a clear indicator for the propensity to integrate. However, past nontimber marketization has a positive sign but weak explanatory power, possibly due to multicollinearity with past forest quality. Past forest quality explains nontimber marketization in a regression of nontimber marketization on other explanatory variables. Although the measure for past forest quality refers to commercial timber, some quality factors, like soil and climate conditions, favorable to industrial forestry may overlap with conditions favorable to nontimber products.

For Regression (1), the null hypotheses that the three cut points are independently equal to zero and that they equal each other are rejected at the 1% significance level. Tested jointly, the hypothesis that all coefficients, including cut points, is zero is rejected at the 1% level.

Regression (3) adds a term for distance to Oaxaca to test alternative empirical explanations. The parameter estimates are similar in magnitude, sign and significance to the base model (1) with little change in model test statistics, indicating that it adds little additional explanatory power to the base model. Dropping parastatal leasing from the model in Regression (4) controls for multicollinearity with distance. If distance were the only advantage, then we should see distance as negative and significant, without substantially reducing the explanatory power of the model and other variables. In Regression (4), the distance variable is negative and significant at the 10% level while all other variables drop in magnitude and the forested hectares coefficient loses statistical significance. However, the drop in the log likelihood and R^2 statistics suggest this is an inferior choice of model specification.[6]

[6]In addition to distance to the capitol city, two other control factors were considered. As an alternative use of the forest,

Three communities which had substantial sources of credit from the parastatal to begin operations were dropped from the sample, bringing the sample size to forty in Regression (5). Dropping these three, however, changes neither the relative magnitudes nor significance of the coefficients. Finally, likelihood ratio tests of regression models in Table 7 reject the null hypothesis at a very significant ratio.

coffee production could conflict with efforts to develop a timber production industry. A binary variable with a value one if community members have income from coffee production on a regular basis, zero otherwise, while correlated with smaller forests (absolute value of correlation coefficient greater than 0.5) and greater distance from Oaxaca, does not have explanatory power nor significantly alter the regression results. Second, communities with parcelized forests experienced a slightly higher incidence of conflict over managing the forest. To test whether parcelization decreases the probability of vertical integration due to increased internal conflicts, a binary variable takes the value one if the forest is parcelized, zero otherwise. A regression including parcelization has an insignificant statistic which does not significantly change parameter values of the model.

Table 7: Ordered Logit Regressions: Vertical Integration

Independent Variable					
	(1)	(2)	(3)	(4)	(5)
Initial Roads	-0.43	-0.35	-0.41	-0.22	-0.45
	(-1.21)	(-0.97)	(-1.12)	(-0.67)	(-1.29)
Initial Mechanical Training	3.28*	3.69**	3.16*	2.94*	3.13*
	(1.83)	(2.00)	(1.74)	(1.75)	(1.75)
Past Nontimber Marketization	0.82	0.90	0.74	0.42	0.56
	(1.01)	(1.10)	(0.89)	(0.53)	(0.67)
Parastatal Existence	2.92**	2.74**	2.78**		2.78**
	(3.57)	(3.37)	(3.16)		(3.40)
Forested Hectares (logarithmic)	0.85**	-4.94	0.81**	0.60	0.82**
	(2.31)	(-1.06)	(2.11)	(1.63)	(2.24)
1940 Forest Quality	1.97**	1.86**	1.94	1.50**	1.87**
	(2.66)	(2.48)	(2.58)	(2.25)	(2.54)
Forested Hectares		0.37			
(logarithmic, squared)		(1.24)			
Driving Hours from Oaxaca			-0.05	-0.21*	
			(-0.38)	(-1.81)	
cut 1	15.09	-7.58	14.29	9.92	14.20
Standard error	4.14	18.47	4.58	3.96	4.13
cut 2	17.62	-5.02	16.83	11.84	16.68
Standard error	4.37	18.48	4.78	4.05	4.37
cut 3	19.75	-2.76	18.94	13.43	18.89
Standard error	4.62	18.41	5.02	4.18	4.61
Number of Observations:	43	43	43	43	40
LR chi-squared	43.41	44.94	43.56	31.47	32.85
d.f	6	7	7	6	7
Prob. $> \chi^2$	0.00	0.00	0.000	0.000	0.000
Pseudo R-squared	0.38	0.39	0.38	0.28	0.32
Log Likelihood	-35.58	-34.83	-35.51	-41.56	-34.77

NOTE: Numbers in parentheses are z statistics. "**" denotes statistical significance at the 5% level and "*" at the 10% level.

Table 8: Marginal Effects for Continuous Variables

Independent Variable	$\frac{\partial P(y=1)}{\partial x}$	$\frac{\partial P(y=2)}{\partial x}$	$\frac{\partial P(y=3)}{\partial x}$	$\frac{\partial P(y=4)}{\partial x}$
Initial logging roads (logarithmic)	0.05	-0.01	-0.02	-0.03
Forested hectares (logarithmic)	-0.10	0.01	0.04	0.06
Quality of forest, 1940	-0.23	0.02	0.08	0.13

NOTE: Marginal effects calculated from Regression 1 in Table 7 for each observation, then averaged holding all else constant.

Table 9: Marginal Effects for Binary Variables (Probabilities in Percentage Points)

Independent Variable	$P(y=1)$	$P(y=2)$	$P(y=3)$	$P(y=4)$
Initial mechanical training =0	49	30	15	7
Initial mechanical training =1	13	25	27	34
Change	-36	-5	12	27
Parastatal leasing =0	51	32	13	5
Parastatal leasing =1	14	30	30	25
Change	-37	-2	17	20
Nontimber marketization=0	40	28	17	14
Nontimber marketization=1	31	29	20	20
Change	-9	1	3	6

NOTE: Marginal effects calculated from Regression 1 in Table 7 for each observation, then averaged holding all else constant. Changes may not sum to one due to rounding errors.

With a discrete choice model, marginal effects refer to changes in probability of being in each category as a variable changes by one unit. For continuous variables, this change can be calculated by taking the partial derivative of the probabilities with respect to that independent variable. Results are in Table 8. Past forest quality has a limited range of one to five but is also treated as a continuous variable. Marginal effects for binary variables are calculated with different methods (Greene 2000) and are shown in Table 9. The same calculations as above are done twice, once with the explanatory variable set to zero, then with the variable set to one, all else constant. The difference between the two probabilities is the marginal effect. Mechanical training, which has a range of zero to one, is also treated as a binary variable.[7]

[7]Marginal effects of initial mechanical training were also calculated treating the variable as continuous, with practically identical results.

Mechanical training and parastatal experience have the most significant impacts on predicting level of integration. A unit change in either of these variables decreases a community's chance of selling stumpage by over 30 percentage points, and increases the chances of selling finished products by 20 percentage points or greater. Both variables show increasingly positive tendencies for each progressive phase in the wood products transformation process, and each have their strongest effects at the two extremes of vertical integration represented by the sample.

The next strongest positive effects are those of initial forest quality, past nontimber marketization and number of forested hectares. Note that accounting for the logarithmic scale, a one percent increase in forested hectares decreases the chances of being a stumpage community by 10%, whereas the chances of being a finished products community increases by 6%. Consistent with regression results, marginal effects for logging roads are small and have a perverse effect on forward integration, as more road stock increases the chances of selling stumpage and decreases the chances of processing raw material.

Table 10 compares predicted versus observed choices for each category for Regression (1). The model correctly predicts stumpage, roundwood and finished wood products relatively more often than lumber status, although the correct choice is predicted most often for all group. The stumpage and finished wood products categories have predicted probability distributions skewed towards their actual choices. Maddala (1983) suggests the following calculation as a goodness of fit measure for grouped data models:

$$S_1 = \frac{1}{N_{..}} \left(\sum_{i=1}^{4} N_{ii} \right)$$

where N_{ii} refers to the number of correct predictions for alternative i, and $N_{..}$ is the total number of observations. The measure is the number of correctly predicted observations divided by the sample size which gives the model a 61% success rate. For those communities "off the diagonal", let S_2 represent the number of times the actual choice was the second predicted choice and $S_1 + S_2$ an alternative goodness of fit measure (Maddala 1983). In this case, $S_2 = 33\%$, so that the goodness of fit measure equals 94%.

The POM assumption of equal slopes across groups is tested but comparing results with the generalized

Table 10: Prediction Table for First Choices

	Predicted First Choice				
	Stumpage	Roundwood	Lumber	Wood Products	Observed Count
Observed Choice					
Stumpage	12	4	0	0	16
Roundwood	4	6	1	1	12
Lumber	0	3	3	2	8
Wood Products	0	1	1	5	7
Predicted Count	16	14	5	8	43

Table 11: Prediction Table for Second Choices

	Predicted Second Choice				
	Stumpage	Roundwood	Lumber	Wood Products	Observed Count
Observed Choice					
Stumpage	4	0	0	0	4
Roundwood	0	5	1	0	6
Lumber	0	0	5	0	5
Wood Products	0	1	1	0	2
Predicted Count	4	6	7	0	17

ordered model that allows slope coefficients to vary. A likelihood ratio test for differences in the restricted and unrestricted models does not reject the null hypothesis that the slope coefficients are equal.

5 Discussion

The empirical results provide support for the theoretical model of Section 3. Rather than hiring subcontractors for extraction services, communities tend to integrate downstream as human capital skills, organizational skills and commercial forest quality and stock increase. This pattern is consistent with the interpretation that the local community with common property forest land seeks to control the noncontractible aspects of contract relationship, such as monitoring harvest quality and employment practices, through vertical integration and self-management.

The question of whether ownership and control over downstream production leads to local economic

development and higher levels of well-being indicators has supporting evidence but requires further research. Indicators of wealth in the community perform poorly as determinants of community vertical integration. Percentages of households with electricity or water and literacy rates are not correlated with level of integration or initial commercial quality of the forest resource. These indicators and the percentage of households with drainage are not correlated with size of the forest resource. Neither do the well-being indicators explain vertical integration or vice versa in regressions. Yet the communities that have harvested for longer periods of time tend to have higher levels of public infrastructure. In some cases, these public services have been constructed by harvesting firms. Regressions of percentage of households with electricity, drainage or water show that number of years harvesting positively and significantly explains these well-being indicators. This provides evidence that communities poor in general public infrastructure and literacy integrate forward, and harvest activity contributes to improving these developmental indicators.

Stumpage contracts frequently call for the private harvester to make investments in the community, which may serve as a form of "hostage-taking" to reduce hold-up risk. However, the hostage-taking investment in stumpage contracts is often in public goods and not industrial forestry development beyond logging road infrastructure. If communities subcontracted to gain access to timber development funds, having less roads would lead to more subcontracting, yet the measure is insignificant. Further, timber sales revenue is not necessarily reinvested into timber production. From survey data, the stumpage types disburse most of their profits into the community as public goods rather than reinvest in the long-term timber operations. Consensus over public goods investments may be easier to reach than new timber investments which require more community-level commitment to timber production. The longer the time that stumpage communities have been harvesting, the higher their well-being indicators, suggesting that funds go towards public goods. OLS regressions of water and electricity coverage on distance, size of forest and years of harvesting, either by own or hired contractors, show that years of harvesting is positive and very significant, while distance from the capital city and number of forested hectares are insignificant.

6 Conclusion

This study adapts contract theory to explain vertical integration within the institutional setting of Mexico's community forestry sector where forests are common property and decision-makers are local common property officials and outside private firms. The central question is why some Mexican agrarian communities integrate forward into industrial forestry production and others do not. We argue that communities seek control over noncontractible economic development and ecosystem management decisions. Our model predicts the allocation of property rights when 1) parties to a contract have differential abilities, 2) labor/capital complementarities exist and 3) nontimber benefits are present and 4) specific physical investments have already been made. Causal forces explaining the marginal productivity of investments affect the ownership outcome. With labor productivity measures comparable to the specialized private sector and a given level of forest endowments, the interpretation of community integration offered is communities will integrate forward to avoid contractual hazards. Communities balance comparative advantages in skills and physical capital, which may be specific to the community, and contractual hazards.

There are five main results to our empirical analysis. First, communities gain from prior job experience. With a unit change in the measure for initial mechanical skills, communities are much less likely to sell stumpage and more likely to sell finished products. Second, sample communities are 37% less likely to be stumpage and 20% more likely to be a finished product community where the community had a history of parastatal leasing prior to 1986. Empirical analysis shows that the explanatory power is not related to infrastructure development or employment generated by the parastatal, nor does selection bias in distance to the capitol city or historical commercial forest quality fully account for the parastatals' effect on vertical integration patterns. Third, physical infrastructure, measured as the existing network of logging roads, is not significant, although the negative sign is consistent with lower transaction costs for outside harvesters. Many explanations of why physical infrastructure is insignificant are possible: physical investments are contractible, physical capital reduces capital constraints or sunk costs increase hold-up risk. Fourth, larger and better quality forests favor community integration. From the theoretical model, this occurs because a community's default option increases with greater forest resources. With the coincident lack of a forest land

market in Mexico, this situation discourages outside contractors. Fifth, the most significant marginal effects of the independent variables occurred for the stumpage category.

Our results extend the applicability of incomplete contract analysis to natural resource management. Unlike the contract literature, however, it accounts for the human and social capital and historical realities surrounding asset ownership patterns. The approach is distinctly different, though not a replacement for, models of the commons problem that explain individual motivation to form and maintain a commons (Sethi and Somanathan 1996). Implications for common property research lie in understanding the relationship of transaction costs, traditional common property systems, stakeholder well-being and productive services available in the marketplace. The analysis predicts under what conditions local stakeholders collectively control and manage entrepreneurial operations using common property resources, implying the creation of cooperative production mechanisms. In terms of contract theory, the model assesses how localized vertical integration, with common property as one factor of production, enhances economic efficiency within a particular social and cultural context.

The broader application of the research is the growing interest in devolution of natural resource management. The unique characteristics of the Mexican community forestry sector facilitates analysis of the role of property rights. Placing a community-level decision over management control within a vertical integration scenario and changing parameters of the model can identify economic rationale motivating community-level decisions. This research rests partly on the extent to which forest-related activities are separable in an ecological, social and economic sense so that adequate land management systems, either market or institutional, can be developed. Further research is needed to refine the relationships among timber, nontimber and non-forest production within the communities and the investment impacts on timber versus nontimber resources. This and other lines of research inquiry await attention.

Appendix A. Proofs

Proposition 1 If $0 < \alpha_F < 1$, then i_F under nonintegration and integration by the community is less than first-best i_F^*. Likewise, if $0 < \alpha_H < 1$, then i_H under nonintegration and integration by the community is less than first-best i_H^*.

Proof of Proposition 1: Suppose i_F and i_H satisfy 2 and 3. Then, $i_F^* > i_F$ and $i_H^* > i_H$ under nonintegration because B_C and B_M are strictly concave. Under integration by the community, $B'_C = \frac{1}{\alpha_F} > 1$ and $B'_M = \frac{1}{\alpha_H} > 1$. Therefore, $i_F^* > i_F$ and $i_H^* > i_H$, since B_C and B_M are strictly concave. QED.

Proposition 2 If $\alpha_F = 1$ and $\alpha_H = 1$, forward integration by the community is more efficient than nonintegration.

Proof of Proposition 2: If α_F and $\alpha_H = 1$ then B'_C and $B'_M = 1$ under forward integration by the community. By the concavity assumptions for B_k where $k = C, M$, then $i_F = i_F^*$ and $i_H = i_H^*$ under integration. By conditions 2 and 3, i_F and i_H under integration are greater than i_F and i_H under nonintegration. QED.

Proposition 3 For any given α, NT, H, there exists a timber stock, T, large enough so that forward integration by the community is socially preferable to nonintegration.

Proof of Proposition 3: Comparing the FOCs for i_F under nonintegration and forward integration by the community, the community's investment i_F is greater under forward integration for any given α_F because of the weight placed on the default payoff $b_C(\cdot)$. By 2 and 3, i_F under integration is greater than i_F under nonintegration.

Comparing the FOCs for i_H under nonintegration and integration, note that the default payoff under nonintegration for a harvest manager stays the same even as the timber stock increases, although the benefit function in the trade situation, $B_M(\cdot)$ increases. Since the function $B_M(\cdot)$ is strictly concave, then by the property of real-numbers [8] as T increases, T will reach a point where $\alpha B'_M(i_H) > \frac{1}{2}(B'_M(i_H) + b'_M(i_M; H))$ for any given i_M. So for the FOCs to hold and by conditions 2 and 3, i_M under integration is greater than under nonintegration. QED.

Appendix B. Definitions of Variables

Vertical integration Takes a value of one to four according to whether the decision-making unit is a stumpage, roundwood, lumber or finished products community. One roundwood community was dropped from the sample due to unreliable data, so that the final vertical integration profile is 16 stumpage, 12 roundwood, eight lumber and seven finished products communities, for a sample size of 43 observations.

Initial human capital Survey questions gathered data on experience with chainsaws, handsaws, cranes, trucks for transporting logs and sawmilling. A dummy variable was created for each task and recorded a value one if interviewees claimed anyone had received training in the community before the 1986 Forestry Law for stumpage communities or before vertical integration into extraction activities for all other types of communities. Skills were acquired as employees of outside firms, without any training program that anticipated the transition to community forestry. The dummies were summed and divided by the number of tasks so that the resulting measure captures the range of skills available in the community. This assumes that training represents a base of knowledge that can be passed on to others in the community. Survey data revealed that many people learned skills by observing or being trained by other community members.

History of parastatal leasing A binary variable takes the value one if a parastatal held a lease or harvested regularly in the community, zero otherwise.

[8] If $x > 0$ and if y is an arbitrary real number, there exists a positive integer n such that $nx > y$ (Apostol 1967) (p. 26).

Initial physical capital The logarithmic scale for the number of kilometers of logging roads. The survey recorded kilometers of logging roads 20 years ago and 10 years ago. For stumpage communities, the measure of initial physical capital is (logarithmic) kilometers of logging roads as of ten years ago, when the transition to community forestry began in earnest. For roundwood, lumber and finished product communities, the measure is either ten years ago, as with the stumpage communities, or twenty years ago if integration into extraction activities had already taken place by 1986.

Past nontimber markets The proxy for the stock of nontimber benefits is the presence of markets in nontimber goods. Such a proxy assumes that where more nontimber products are available, more markets for these goods exist. It can also be interpreted as a weight people place on nontimber benefits of the forest, assuming that people value these resources more when they harvest them for sale. The measure does not capture non-market benefits. The survey supplies information on the range of forest products sold and number of years community members have sold each product. To avoid endogeneity, nontimber markets are considered only if the market has existed for more than ten years so that the market predates or is concurrent with the vertical integration decision. The mushroom export market began in the last eight years and so postdates much vertical integration. The remaining non-commercial timber forest products are fuelwood, wood for domestic use and the "other" category. Generally, people collect dead or fallen wood for fuel needs so that fuelwood collection for resale complements rather than substitutes for commercial timber production, or is a functionally separate activity. A dummy variable takes the value one if a market in these products existed for more than ten years, zero otherwise.

Forested hectares The size of the forest is measured by hectares of forested land in the community. Technology was similar across communities for harvesting, so size of the forest should affect each community similarly in relation to economies of scale. The logarithmic scale of this variable is used in the regression.

Quality of forest, 1940 To prevent selection bias with parastatal leasing, the measure ranks quality of forest in 1940, since commercial logging in Oaxaca began in earnest in the mid-forties. Very little photographic or written data exists on Mexican forests in 1940. In addition, where they do exist, interpreting the data would be difficult. To create an indicator, three forestry engineers with extensive knowledge of Oaxacan forests and timber history ranked the quality of the forest in terms of soil and climate conditions that would be favorable to tree growth, and the presence of harvestable, commercial timber, including trees of large diameter. The range was a 1-5 scale, with 5 meaning "excellent," and 1 "very low." The three estimates were averaged together and rounded to get a measure from 1 to 5.

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