

Ownership and Control in Mexico's Community Forestry Sector

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I. Introduction

In this study, we analyze the implications of ownership versus control in Mexican forestry, where most raw material is held as common property. New forestry laws since the eighties have enlarged the scope of communal ownership rights to forest resources so that communities, as represented by a local governance system, have a wider set of options in exploiting their commercial timber potential. We model and then empirically test their choice of vertical integration—their involvement along the production chain from selling stumpage rights to private logging companies, who extract and sell the timber, to the sale of roundwood, or logs, lumber, and secondary wood products. In this context, vertical integration represents a nexus of challenges faced by agrarian communities—the ability to marshal organizational capacity within a collective decision-making arena, make long-term investments, and exercise control over the allocation and use of a common property resource. Where transaction costs are present, we suggest, ownership assures a greater flow of benefits from production.

With trends in promulgating devolutionary policies, on the one hand, and privatization, on the other, understanding how local resource management institutions function in the economy is critically important. A large body of literature associates local participation in natural resource management with

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a wide range of economic benefits, such as job creation, public goods investments (Kusel and Fortmann 1991), poverty alleviation (Jodha 1992), risk diversification (Wilson and Thompson 1993; Nugent and Sanchez 1998), and reduced rates of deforestation (Duran, Mas, and Velasquez 2005). Oliver and Shapiro (1997) identify asset wealth as key to overcoming poverty and inequality. From a political perspective, the articulation of local and supralocal institutions in decentralization efforts remains unclear (Sellers and Lidstrom 2007). For economists, there are few studies of how local participation is integrated into the broader market setting (McKean 1997; Taylor and Zabin 2000).

The Mexican government's role in communal forest ownership brings these issues into relief. The 1917 Mexican Constitution legislated common property into existence, with the consequence that approximately 80% of Mexico's forests are held by formally recognized agrarian communities (World Bank 1995).¹ The Agrarian Reform of 1992 sought to modernize the countryside by introducing titling programs to create individual property rights in agrarian communities. Forestlands, however, are not subject to this program and must be left intact. Yet, even in agricultural lands cultivated by individuals, the privatization process has fallen short of expectations. Reasons include identity with the land within a history of agrarian struggle, a source of nonfarming income and savings, a source of political capital for community officials, real estate for which the *ejido* does not pay property taxes, and a source of community-level political power (Goldring 1998; Wilhusen 2003). In addition, forests may have advantages as common property, such as economies of scale in production and ecosystem services and a low value of alternative uses. A dichotomy exists in Mexico's economy between the private sector and the social sector, as the agrarian communities and its membership are called, where different laws and culture apply. As Mexico develops its economy, how the community form becomes integrated into the market at local, state, national, and international levels remains to be seen.

In this article, we examine the question of what explains the current pattern of communities' market integration in the Mexican forestry sector. We interpret market integration as vertical evolution into the market sector for forest products. A critical point is that degrees of vertical integration correspond to an underlying pattern of ownership and control over resources that permits the allocation of noncontractible benefits. We modify and extend an incomplete

¹ The term "agrarian communities" refers to the *comunidades* and *ejidos* incorporated under Article 27 of the Mexican Constitution, which have been given title as a group to land reappropriated from large landholders. Articles of incorporation include rules on membership, governance, and land rights.

contracts model (Grossman and Hart 1986; Hart 1995) to characterize vertical integration as a choice among the upstream (often quite literally) communities with raw material and the downstream processors and buyers. Ownership includes the residual rights of control that come into play when contracts are incomplete. The disincentives of moral hazard when investments are nonverifiable or nonenforceable and where unforeseen contingencies require contract renegotiation are balanced against the virtues of specialization and varied expertise across community and market participants. Proposition 1 specifies ownership benefits for the community sector in contrast to the private sector, while proposition 2 shows how increases in the size of the resource base may increase the importance of management and ownership control.

Hypotheses are structured around conditions under which contract incompleteness affects decision making, such as specificity of investments; uncertainty and complexity in managing inputs and outputs; and the ability of residents within the community to conduct, manage, and organize each step of the production process. The results are consistent with the proposition that communities integrate to control resource management and the payoff distribution. Our empirical results reveal that communities' skills, forest size, and organizational capabilities are significant.

Data collected for this study include both original survey and secondary data. Section II describes the organization and contracting environment for wood production among the social and private sectors in Mexico. Against this backdrop, a theoretical framework isolates under what conditions individual community members will collectively produce wood products using common property forests. Section III presents survey methodology and contracting details among the communities, private firms, and professional foresters in Oaxaca, Mexico. Empirical measures suggested by the model and propositions quantify a set of characteristics that increase community incentives to maintain residual control rights through ownership title over production equipment. An econometric analysis in Section IV is designed as logit regressions to predict vertical integration across a sample of communities owning forest resources. Section V, the conclusion, outlines implications of the results and areas for future research.

II. Mexico's Social Forestry Sector

A. Organization and Contracting

Despite its claim to land under agrarian law, Mexico's community sector has only recently had the opportunity to commercialize its forests in a liberalized market setting. Presidential decrees starting in the forties concessioned large tracts of communal forest land to semipublic, semiprivate companies (henceforth, parastatal), thereby restricting communities to selling only to the parastatal to

which their forests were concessioned. Intense and sometimes violent opposition to the federal lease program grew over the years, culminating in the nonrenewal of the leases in 1982 in Oaxaca and the 1986 Forest Law, which recognizes the communities' right to commercialize their own resource (Kearney 1972; Moros and Solano 1995; Weaver 2000). The majority of communities commercializing their forests today sell "stumpage," that is, their buyer harvests and extracts the timber. A substantial number of other communities have integrated downstream along the production chain into extraction and milling. This section briefly reviews these new relationships, since they are relevant to industrial organization patterns in the community sector, and then previews the model developed in the next section.

In production services, ownership and control are rarely synonymous. While a recognized property right allows the owner to have a final say in how resources are allocated, the owner can delegate control to managers who direct the day-to-day decisions for using the resource. Our concern here is the degree of control over tangible and intangible benefits that switches from outside private contractor to the community members as the community acquires more productive assets. At the community level, forestry operations are coordinated through a traditional governance structure codified in the Mexican constitution. The two offices of commissariat of communal property (*comisariado de bienes comunales*; CBC) and chief vigilance office (*jefe de vigilancia*; JV) are part of a structure of rotating civic responsibility, called *cargos*, and they are most critical to forestry operations. The general assembly (GA), consisting of registered members of the community, is the ultimate decision-making body in the community, and it elects officers every 3 years. The CBC attends to land-use responsibilities, while the JV monitors common property and oversees the CBC. Where forestry occurs, the CBC is the point person for coordinating contracts with buyers. As communities become more integrated, the GA or CBC may appoint positions outside the *cargo* system, such as a logging foreman (*jefe de monte*; JM), sawmill manager (*jefe de patio*; JP), and documenters to measure volume extracted.² Therefore, in this case, ownership over productive assets translates into extensive managerial control where community integration entails a switch in management personnel from outside private contractors to local managers.³

A number of models exist to characterize buyer-seller relationships. Eswaran

² In some communities the a cargo official doubles as a forestry manager, such as the JV acting as the JM, during production periods. A scenario where sawmill communities contract outside companies for extraction services rarely occurs.

³ Wilhusen (2003) claims that, in Quintana Roo, the intangible benefits of vertical integration in forestry production included the ability to control economic activity and to gain political power.

and Kotwal (1985) present a principal agent model of double moral hazard in the presence of nonmarketed inputs to determine the occurrence of a fixed wage, fixed rent, or sharecropping arrangement in the agricultural sector. Grossman and Hart (1986) develop a transaction costs model to describe the relationship between an upstream supplier and a downstream buyer of goods and services. As in Eswaran and Kotwal (1985), nonverifiable investments are central to the model results. Grossman and Hart add the inability to write complete contracts, with the consequence that unforeseen contingencies lead to contract renegotiation after key investments have been made. Holmstrom and Milgrom (1991, 1994) consider a range of tasks to be carried out by an agent, where some tasks are measurable and other tasks are not. The observability of effort across multidimensional performance determines optimal compensation schemes, job design, and ownership of assets between the principal and the agent. We focus on the trade-offs implied by having the residual control rights to assets, or “what it means to own an asset” (Baker and Hubbard 2001, 189), which is the central feature of the Grossman-Hart framework. We adopt and extend the Grossman-Hart model to a context of a thin market for managers in which job design is limited to illustrate the effects of switching ownership over capital between upstream and downstream market actors.

We now briefly describe the model. A trading relationship between intermediate buyers and sellers begins before and ends after each makes investments. Inherent in the overall production activities are uncertainties that preclude a complete, long-term contract, while nonverifiability, due to unobserved time and effort or quality levels, for example, of investments, increases the risk of opportunistic behavior. Furthermore, if investments are specific to the trade, they are worth less with alternative trading partners. Should the community and the service provider renegotiate once uncertainties are resolved, either the buyer or the seller can refuse to renegotiate. Within the bargaining framework used in this article, this means that, depending on relative bargaining power, one party can reduce the other’s gains to trade until those gains equal the default value, that is, the value that party receives from the investment outside of the proposed trade. Default values depend on which assets each party owns. In the case of a timber sale contract, for example, a community maintains access and control over the forest.⁴ This renegotiation maneuver, called “hold-up,” introduces a risk that lowers the marginal value of investments. Anything that threatens a breakdown of a contract, such as asymmetric information, also

⁴ This access has been contested over time, and we note that a property right does not necessarily equate with access rights (Ribot and Peluso 2003). However, the communities in this study have successfully exercised access rights based on ownership of the forest at various points in time by, e.g., blocking entry and refusing contract renewals (Moros and Solano 1995).

TABLE 1
ASSETS AND INVESTMENTS ACROSS PRODUCTION STAGES

Stages	Assets	Investments	Specificity between Buyer and Seller	Verifiability
Forest management	Forestland (F)	Safeguards against uncontrolled clearing, marketing, scheduling, silvicultural treatments	High	Low
Harvesting	Cranes, trucks, chainsaws, tractors (H)	Logging roads, management plan, sorting, placement of assets, marketing, job training in logging, scheduling	High	Low
Milling	Sawmill, auxiliary equipment, drying kiln (S)	Sawmill location, adjustments to saw, marketing, job training in milling, scheduling	High	Variable
Secondary production	Processing machinery (SP)	Specialized equipment for woodcutting, marketing for given products, job training in cutting, scheduling	Low-medium	Variable

creates conditions of hold-up risk. Efficiency depends on properly assigning ownership rights to increase investment incentives and maximize total social surplus given the conditions of production and contracting relationships (Hart 1995).

Table 1 describes basic assets and investments in wood production at the four production stages evident in Mexican community forestry: forest management, harvesting, milling, and secondary production. The last two columns qualify the degree of investment specificity and verifiability to further illuminate the contracting environment. The main asset at the first stage is the forest (F). For the forest landowner, management investments include reforestation, conservation practices, fire protection, and thinning. These are not specifically tailored for trade with any one potential downstream buyer, but from the perspective of an outside contractor making such investments, they become specific to the forest. A substantial range of quality in forestry management activities exists, but the ability to verify is low due to the long-term and unobservable nature of these activities.

For harvesting (H), the major capital assets are cranes to extract logs, transport trucks, and chainsaws. Ownership rights include the abilities to allocate the machinery among different uses, to set the pace of the harvest or work schedule, to take action in case of equipment failure, and to cut timber undetected. Loggers have considerable scope in using diligence to separate logs

from slash; to exercise care in topping, felling, and bucking trees; and to minimize stump heights. Variations in extraction efforts affect erosion, fire prevention, and the value of the product harvested, but these efforts are often difficult to monitor.⁵ Logging roads that connect the forest stand with transportation routes also represent large start-up and maintenance costs from year to year, and they become embodied in the community's physical infrastructure. The investments of effort at this stage tend to be specific and nonverifiable.

At the harvesting stage, the management plan is a considerable investment that is specific to the community's forest, and it can vary widely in quality. Professionally qualified foresters prepare the management plan required for harvest, which is submitted to the Ministry of Environment and Natural Resources (Secretaria de Medio Ambiente y Recursos Naturales; SEMARNAT) for approval. Plans consist of a forest inventory, a demarcation of harvest rotation areas, and a harvesting schedule over time. A management plan can be for as short as 1 year or as long as 20 or more years, and it can have varying degrees of detail regarding land use and inventory.

Capital equipment for milling (S) includes the sawmill, the maintenance equipment, and drying kilns. Asset specificity takes the form mainly of equipment location and type, as wood-processing machinery can be adjusted or modified to accommodate timber of different dimensions and quality (Globerman and Schwindt 1986). While millers try to mill the wood for pieces as wide, clear, and long as possible, there is little standardization. Client requests are made to order. Wood is graded with as many as five levels of quality, depending on knots and structural integrity, where third-party verifiability depends on the nature of the agreement.

The secondary products stage (SP) requires specialized equipment for making doors, furniture, pallets, tool handles, and other products. As at the milling stage, location can affect market access. The processing itself can vary in quality and complexity. Products may be customized according to quality, processing stage, or quantity.

Certain contractual hazards arise at all stages of production. Breach of contract, weak enforcement, equipment failures, and weather-related delays, all possible at each stage, limit the ability to find alternative trading partners as the season progresses, introducing temporal specificity. Job training or special employment arrangements (e.g., advance payments) between the outside contractor and the local residents represent specific investments. Further, the

⁵ For these reasons, Leffler and Rucker (1991) hypothesized and gave empirical evidence that nonindustrial private forest owners in North Carolina sell stumpage rights rather than hire loggers to extract the timber and subsequently sell roundwood to sawmills.

amount of effort provided by both parties has an element of nonverifiability and creates difficulties in enforcing contracts.

As regards current tenure and control patterns, the community by law always owns the forest (F), so capital asset ownership varies between community and outside private ownership over harvesting (H), sawmill (S), and secondary products (SP) equipment. For this analysis, the model for the integration decision could be presented thrice to cover the four production stages, but each iteration would yield similar results. In the timber extraction stage, the downstream operator owns or manages the capital to harvest. Moving along the chain of production, operators further downstream own or manage a sawmill or secondary processing equipment. To economize on space, we present the model once for the decision to integrate vertically from selling stumpage rights to own-harvesting.

B. The Model

The local community, C, owns forestland, $F = F(T, NT)$, where T is the timber stock and NT is the nontimber stock, and there is a downstream processor, P, whose identity is either a private outside firm that buys the community's product, in the case where the community is not integrated downstream, or a community manager who is employed by the community, in the case where the community is integrated into downstream activities. The stock of T , NT , and H represents both physical size and quality (e.g., hectares, biomass, equipment). There are two dates in the model. At date 1, the investments i_f and i_b are made, where i_f is a silvicultural investment in the forest management phase and i_b is an investment in the extraction or harvesting stage.

Community, C, and downstream processor, P, make investments independently, noncooperatively and simultaneously. Each observes the other's choice of investment, so they have symmetric information on investments and costs. In this model, i_f and i_b are also the costs of investing. The investments improve productivity, either enhancing efficiency or lowering the costs of production, while their degree of specificity increases the difference between a party's payoffs with trade and the payoffs without the trade, the default outcome. The functions B_c and B_p designate the benefit functions (including monetary and non-monetary values) when trade takes place between these two parties. The function $b_c(i_f; F, H)$ denotes the default benefit function for the community when it is forward integrated and $b_c(i_f; F)$ when it is nonintegrated, given the physical assets to which the community has access in the default outcomes. For notational simplicity, the arguments of F are dropped, that is, $F(T, NT) = F$. Similarly, $b_p(i_b; H)$ indicates the default benefit function for P under nonintegration. Specificity of investments implies that $B_c \geq b_c$ and $B_p \geq b_p$. The func-

tions B_c and B_p are assumed to be strictly concave, while the default payoffs are weakly concave.⁶

At date 2, trade takes place and payoffs are realized. Assume ex post gains from trade strictly exist; that is,

$$B_c(i_f; F, H) + B_p(i_b; F, H) > b_c(i_f; \cdot) + b_p(i_b; \cdot) \geq 0, \quad (1)$$

where \cdot represents C's and P's assets in a no-trade scenario. Condition (1) implies that investments i_f and i_b are more productive in a trading relationship between the firm and the community, capturing the idea that the investments are specific to the other trading partner's human or physical capital and have less value outside the trade agreement. Such relationship specificity is assumed to hold in a marginal sense:

$$B'_c(i_f; F, H) > b'_c(i_f; F, H) \geq b'_c(i_f; F) \quad \forall 0 < i_f < \infty, \quad (2)$$

$$B'_p(i_b; F, H) > b'_p(i_b; F, H) \geq b'_p(i_b; H) \quad \forall 0 < i_b < \infty, \quad (3)$$

where the prime denotes the first derivative. Marginal productivity is strictly greatest when C and P trade, implying that (a) the investments, i_f and i_b , are partly specific to P's and C's human capital, respectively, and (b) they are both important to the trade because they increase marginal benefits (Hart 1995; Woodruff 2002). Outside of the trade, the marginal productivity of investments is nondecreasing depending on the degree of investment specificity to the physical capital assets. Nontimber resources are not traded between C and P, and cross-effects among timber stock, nontimber stock, and harvest equipment are assumed to be zero.⁷

The optimal contract is modeled as the outcome of Nash bargaining between local communities and downstream managers. At date 2, C and P negotiate to realize the ex post gains from trade, $(B_c + B_p) - (b_c + b_p)$. The transfer price, p , at which the two parties trade is a function of the respective bargaining powers, payoffs with trade, and reservation payoffs, and this price allocates the total surplus between the two players. The default price, \bar{p} , is what C can get on the spot market for its production. With Nash bargaining where the

⁶ $B'_c > 0$, $B''_c < 0$ for F, T, NT, H , and i_f ; $B'_p > 0$, $B''_p < 0$ for F, T, NT, H , and i_b . Also, $b'_c \geq 0$, $b''_c \leq 0$ for F, T, NT, H , and i_f ; $b'_p \geq 0$, $b''_p \leq 0$ for F, T, NT, H , and i_b .

⁷ $B'_c = B''_c = b''_c = b'_c = 0$ 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. This specification allows the model to highlight the basic effects of organizational issues. However, adding the complement and substitution effects would most likely strengthen the results and implications of the model, as they increase the complexity, and therefore the demand for coordinated management in production, to the extent that those nontimber products are valued.

symmetry axiom is assumed to hold, C and P split the gains from trade 50:50.⁸ The ex post payoffs, with the arguments suppressed for clarity, are

$$\pi_c = B_c + p = b_c(i_f; \cdot) + \bar{p} + \frac{1}{2}[(B_c + B_p) - (b_c(i_f; \cdot) + b_p(i_b; \cdot))], \quad (4)$$

$$\pi_p = B_p - p = b_p(i_b; \cdot) - \bar{p} + \frac{1}{2}[(B_c + B_p) - (b_c(i_f; \cdot) + b_p(i_b; \cdot))]. \quad (5)$$

1. The Unattainable First-Best Scenario

As a benchmark case, we show the social planner's problem when contracts are complete, B_c and B_p are contractible, and i_f and i_b are chosen cooperatively. In this open and integrated economy, the social planner maximizes net present value W where

$$W(i_f, i_b) = B_c(i_f; F, H) - i_f + B_p(i_b; F, H) - i_b. \quad (6)$$

The first-order conditions describe the investment levels i^* at which W is maximized:

$$i_f^* : W'_1(i_f^*, i_b^*) = B'_c(i_f^*; F, H) = 1, \quad (7)$$

$$i_b^* : W'_2(i_f^*, i_b^*) = B'_p(i_b^*; F, H) = 1. \quad (8)$$

2. Vertical Integration in Second-Best Scenarios

In contrast to the first-best case, investments i_j , $j = \{f, b\}$ and B_k , $k = \{c, p\}$, are no longer contractible, potentially leading to less than first-best outcomes. Since current agrarian law prevents sales of communal forestland, we consider two forms of organization, one of nonintegration, in which private harvesters provide production and planning services, and the other of forward integration by the community, in which community takes on these roles. Hence, the downstream manager P is characterized in two ways. Under nonintegration, P is an owner-operator of the extraction equipment, H. As such, P, under nonintegration, is an actor outside the community governance structure. With community forward integration, P is the set of decision makers, such as the logging foreman (JM) and the documenters appointed from within the community, who represent the community in the same way as the CBC and JV do upstream. For the sake of simplicity in the theoretical formulation, it is presumed that P has the same preferences regardless of whether the extraction activity is performed by an external firm or by internal representatives of the community.

⁸ This assumption of an equal split is not necessary for the results to hold (Hart 1995).

We apply parameterized weights to the investments i_f and i_b when the community makes these investments to capture the nonspecialized nature of communities relative to a specialized private firm. Specialized expertise would refer to managerial, marketing, administrative, and labor skills as a subset of the capabilities needed to run forestry operations. Parameters α_f and α_b range between zero and one for cases in which community investment is less than or just as productive as an outside private harvester's so that $i_f^c = \alpha_f i_f^p$ and $i_b^c = \alpha_b i_b^p$, where $0 < \alpha_f \leq 1$, $0 < \alpha_b \leq 1$ and the superscripts indicate who is making investments, a community member or a manager of an outside private firm. The parameter α measures how skilled community members collectively are relative to private firms, while a trade-off of higher transaction costs occurs for hiring in outside managers. The possibility that the community is more productive than the private firm in managing forestry operations is captured by observing community vertical integration. In the present context, local communities give up the benefits of control if they hire in production services but face the potential problem of having relatively less "in-house" specialized expertise in the field of timber production.⁹

3. Nonintegration: Stumpage Sales to Outside Contractor

In this case, the community owns the forest, and an outside private harvesting firm owns the harvesting equipment. In the community's default outcome, the community loses access to the specific human capital associated with the downstream P, and b_c is the value of the community's trade with another firm or the otherwise next-best alternative. P's default outcome b_p is the value of trade with another C or the otherwise next-best alternative, as P loses the benefits from any human capital-specific investment associated with C. We rewrite the ex post payoffs in equations (4) and (5) to depict this nonintegration scenario and include the costs of investing. With payoffs and investments under nonintegration superscripted by 0, each party's net payoffs realized through bargaining are as follows:

Community:

$$\pi_c^0 - i_f^0 = \bar{p} + \frac{1}{2}[B_c(\alpha_f i_f^0) + B_p(i_b^0) + b_c(\alpha_f i_f^0; F) - b_p(i_b^0; H)] - i_f^0. \quad (9)$$

⁹ Chen and Rozelle (1999) identified a trade-off of accessing specialized skills versus maintaining local control over common property as township and village enterprises (TVEs) evolved during China's market reforms. 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.

Outside harvester:

$$\pi_p^0 - i_b^0 = -\bar{p} + \frac{1}{2}[B_c(\alpha_f i_f^0) + B_p(i_b^0) + b_p(i_b^0; H) - b_c(\alpha_f i_f^0; F)] - i_b^0. \quad (10)$$

The first-order conditions with respect to i_j are now:

$$i_f^0 : \quad \alpha_f \frac{1}{2}[B_c' + b_c'(i_f^0; F)] = 1, \quad (11)$$

$$i_b^0 : \quad \frac{1}{2}[B_p' + b_p'(i_b^0; H)] = 1. \quad (12)$$

Investments are no longer chosen efficiently. The investments i_f and i_b are chosen noncooperatively, and bargaining costs lead to less-than-first-best investment levels i_j^* . That is, in choosing i_j , C and P place one-half the full weight on the default payoffs of b_c and b_p even though the no-trade option does not occur. Variables B_c and B_p 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 first-order condition further removes silvicultural investment levels away from first best.

4. Integration: Community Forestry Enterprises

In this first approximation of community governance versus market transactions, the community representatives are presumed to coordinate both upstream and downstream operations to distinguish the effects of changing control over assets and to recognize the difference in downstream decision makers in the nonintegration and integration scenarios. Thus, both B_c and B_p are community payoff functions, and investments are chosen cooperatively. However, the community, as represented by their officials and managers, may not have the specialized skills of an outside private company. The parameter α_b conditions the community's investments, i_f and i_b . With payoffs and investments under the community forward integration superscripted by 1, community payoffs from both upstream and downstream operations are

Integrated community:

$$\pi_c^1 + \pi_p^1 - i_f^1 - i_b^1 = B_c(\alpha_f i_f^1) + B_p(\alpha_b i_b^1) - i_f^1 - i_b^1. \quad (13)$$

The first-order conditions are

$$i_f^1 : \quad \alpha_f B_c' = 1, \quad (14)$$

$$i_b^1 : \alpha_b B_p' = 1. \quad (15)$$

Accordingly, the difference between community and outside private firm productivity due to community lack of specialization under integration potentially causes i_f and i_b to deviate from first best even when the investments are chosen cooperatively.

To find which integration option will be chosen, a social planner selects the scenario with the highest social surplus. The total social surplus under non-integration is $V^0 = \pi_c^0 + \pi_p^0 - i_f^0 - i_b^0$, whereas the total social surplus under integration is $V^1 = \pi_c^1 + \pi_p^1 - i_f^1 - i_b^1$. If $V^0 > V^1$, then nonintegration is chosen. If $V^0 < V^1$, the community forward integration is chosen.¹⁰

The optimal ownership allocation depends on the values of the variables in the model. Proposition 1 isolates 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 1. If community labor is just as efficient as the outside firm's ($\alpha_f = 1$ and $\alpha_b = 1$), then forward integration by the community is more efficient than subcontracting.

Proof of proposition 1. If α_f and $\alpha_b = 1$, then B_c' and $B_p' = 1$ under forward integration by the community. By the concavity assumptions for B_k where $k = c, p$, then $i_f = i_f^*$ and $i_b = i_b^*$ under integration. By equations (2) and (3), i_f and i_b under integration are greater than i_f and i_b under nonintegration.

The next proposition considers characteristics of the forest asset, F , in terms of timber (T) and nontimber (NT) resources. In this proposition, increases in T shift out the productivity of the investments to where integration becomes more efficient than nonintegration. The shift represents greater labor productivity as capital assets increase. The shift also represents economies associated with the value of the forest asset, such as size and quality, that relate to transaction costs or contractual hazards and that community vertical integration can capture. These costs are, for example, supervision costs, risk diversification opportunities, and a broader range of forest uses to be coordinated by the community. If the stock of timber in one community, T_1 , is greater than the stock of timber in another community, T_2 , it follows from equations (2) and (3), holding all else equal, that the marginal benefits of each unit of investment, i_j , are larger in the community with T_1 than in the community with T_2 .

¹⁰ Strictly speaking, the social planner would choose over all integration levels available, including integration into milling and secondary processing.

Specifically,

$$\begin{aligned}
B'_c(i_f; F(T_1, NT), H) &> B'_c(i_f; F(T_2, NT), H), \\
b'_c(i_f; F(T_1, NT)) &> b'_c(i_f; F(T_2, NT)), \\
B'_p(i_b; F(T_1, NT), H) &> B'_p(i_b; F(T_2, NT), H), \\
b'_p(i_b; H) &= b'_p(i_b; H), \\
\forall 0 < i_f < \infty, \quad \forall 0 < i_b < \infty.
\end{aligned} \tag{16}$$

These results demonstrate that both the benefits from trade and the community's default outcome increase with timber stock increases. In a marginal sense, investments on both sides of the relationship become more valuable as the timber stock increases, except for the outside harvest manager's default outcome, which remains unchanged across variations in the community's timber stock since he loses access to the forest in a default outcome under nonintegration. Risks of contracting become greater, and the outside manager has less incentive to work with the community. Proposition 2 summarizes this effect where the marginal gains due to asset ownership overcome any community shortcomings in skills or expertise.

PROPOSITION 2. For any given α , NT , H , there exists a timber stock, T , large enough that forward integration by the community is socially preferable to nonintegration.

Proof of proposition 2. Comparing the first-order conditions 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 . By equations (2) and (3), i_f under integration is greater than i_f under nonintegration.

Comparing the first-order conditions for i_b 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_p , increases. Since the function B_p is strictly concave, by the property of real numbers,¹¹ as T increases, T will reach a point where $\alpha B'_p(i_b) > 1/2(B'_p(i_b) + b'_p(i_b; H))$ for any given i_b . So for the first-order conditions to hold and by equations (2) and (3), i_b under integration is greater than it is under nonintegration.

A similar relationship is assumed to hold for increases in the nontimber

¹¹ If $x > 0$ and if y is an arbitrary real number, there exists a positive integer n such that $nx > y$ (Apostol 1967, 26).

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 coordination efforts between timber and nontimber production raise contractual and organizational issues.

Our model differs from the Grossman and Hart (1986) model in a few critical respects. First, the efficiency parameters, α_f and α_b , are added to facilitate comparisons of human capital expertise across communities. 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 keep the same two managers in a production chain, we allow a switching of managers between the private and community sectors across integration scenarios. Implementation of our empirical analysis to Mexican community forestry requires each of these adaptations.

III. Data Collection

A. Field Methodology

The data for this project are based on field surveys conducted during the period 1997–98 in 42 communities with commercial timber production in Oaxaca. 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 that commercial production occurred in the community during at least one of the previous three harvest seasons, that is, in 1994–95, 1995–96, or 1996–97. To identify the population, permit files were obtained from the Secretaría de Medio Ambiente, Recursos Naturales, y Pesca (Secretariat of the Environment, Natural Resources, and Fisheries; SEMARNAP, changed to SEMARNAT in 2000) for the timber production cycles of 1994–95, 1995–96, and 1996–97. 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 numbered 95. These 95 communities produced 80%–95% of the commercial timber harvest in Oaxaca in 1994, which reached 430,060 cubic meters (SEMARNAP 1995). A random stratified sample was originally selected to replicate the same distribution by vertical integration level in the total population. The number of secondary products communities was not known prior to the survey, so this group was initially grouped with communities that sell lumber. Because two timber-producing subgroups (work groups) existed in each of two communities, the final sample size is 44, where the unit of observation is communities or

subgroups within the communities that are authorized to make decisions concerning common property forests. We administered the major portion of the survey in open meetings with the community authorities. The survey covered forestry history, organization, production, contracting, nontimber forest uses, and general community characteristics. We subsequently conducted a short survey separately with the responsible forester concerning management data and the forester's interaction with the community.

B. Organization and Contracting: The Data

Table 2 profiles timber organization and contracting in the Oaxacan sample, where the data illustrate contrasts in managerial control over vertical integration types. For example, in cases where the CBC or the JV is paid, the buyer more often pays these *cargo* officials in the stumpage group and also pays the JM and the documenter, even if they are members of the community. Communities have a bias toward hiring internally. The share of local hires includes logging and transportation for the lowest two integration categories plus milling for the processing communities. Again, a large change occurs between the stumpage group and the other groups. The highest percentage of community labor consists of loggers in the extraction phase. Most outside employment consists of independent truckers who transport timber.

Reviewing asset ownership, chainsaws tend to be individually owned (data not shown). Independent contractors, including local *comuneros*, often offer trucking services for both the integrated and the nonintegrated communities, but communities beyond the stumpage stage usually own at least one truck. All the sample sawmill communities own and operate the cranes (*grua*) for collecting and loading logs. Slightly less than half of the roundwood communities and none of the stumpage communities own or operate cranes.

The next set of data describes investments and contract history. Downstream buyers invested in local public projects (e.g., electricity and schools) at a decreasing rate to vertical integration, along with specific production-related investments, such as logging roads, sorting areas, and provisions to hire and train locally. Payment for the management plan and silvicultural services is also linked to organizational patterns. Buyers most often pay for the plan under stumpage contracts, while the more integrated communities usually finance their plans. For roundwood sales, in which about half the sawmill communities also participate, most communities had worked with the current buyer for 5 years or less, and the average duration of contracts across groups ranged from 1 to about 4 years.

The forester relationship is linked to the buyer relationship and vertical integration level. More integrated communities have worked with the current

forester for longer periods of time. Also, the number of years for which the community has been trading with its currently most important buyer is mostly similar or exactly the same as the number of years with their current forester, implying a correlation between these two organizational relationships.

Uncertainties in the production process are also present. Many communities renegotiated contracts at least once during the 5-year period before the survey. Reasons included weather delays, equipment failure, damaged trees, new offers, and labor issues. Stumpage contracts were not changed due to tree damage, since the outside private harvester could select which trees to cut. However, management plans are frequently modified between seasons or at the beginning of a new contract relationship. Harvesters who could not extract the total volume specified in the contract often force modifications in later harvest rotations. Breaches of contract in the 5 years prior to the survey occurred in all communities, although the stumpage group reported a slightly higher average than the other groups. While no statistically significant differences exist among the mean numbers of contract failures across communities, Bartlett's (1937) test rejects the assumption that the variances are homogeneous.

C. Measures for Empirical Analysis

In this section, we translate the factors of the theoretical model into measures for empirical estimation. We first identify exogenous measures for the relative effectiveness of community versus outside contractor (α) and characteristics of the assets T , NT , and H that relate to their size, quality, and specificity. We present proxies for each of the variables and note how they influence the theoretical predictions of the model.

A number of forces influence the relative effectiveness measure α . The first is the availability of local residents who at the time of market liberalization had familiarity with forestry work. Such availability increases the importance of control with incomplete contracts, since it increases the chance that local residents can engage in production activities but creates temporal specificity and lowers the default payoff should the contract break down. Our measure focuses on the initial expertise available across a range of mechanical skills necessary to build a local workforce in forestry.

A second influence is the group's ability to coordinate preferences and organize collectively. We create a measure for this capacity based on the opposition of local civic organizations to the integrated state hierarchies represented by the parastatal leasing system. State interventions have often mobilized civic involvement and increased local organizational capacity.¹² It is hypoth-

¹² See, e.g., Larson (2004) and Oyono (2004).

TABLE 2
ORGANIZATION AND CONTRACT CHARACTERISTICS

	Stumpage	Roundwood	Sawnwood	Secondary Products
No. observations	16	13	8	7
Management:				
Who pays CBC, if paid (community/buyer)	5/2	6/0	6/0	6/0
Who pays JV, if paid (community/buyer)	4/3	6/0	5/0	6/0
Who pays JM (community/buyer)*	2/11	10/0	7/0	6/0
Who pays documenter (community/buyer)*	3/13	9/0	6/0	5/0
Share of local hire/standard deviation	.34/.25	.76/.17	.89/.14	.92/.15
Community ownership: [†]				
% owning trucks	6	62	75	100
% owning cranes	0	46	88	100
Investments:				
Buyer, public works	7	4	1	0
Buyer, specific investments	9	6	0	0
Who paid for plan (community/buyer)*	5/11	11/1	7/0	7/0
Who paid for forest services (community/buyer)*	5/13	11/1	7/0	7/0
Contract relationship:				
Years with current stumpage/roundwood buyer:				
1	5	0	1	0
2-5	9	9	2	2
6-10	1	2	1	1
>10	1	0	0	3
Years of contract (mean/standard deviation)	3.67/.89	3.33/.81	2/1.41	1/0

Forestry services:					
Years forester has been working with community:					
1	5	0	0	0	0
2-5	9	12	2	2	2
6-10	2	1	5	5	5
11-20	0	0	1	0	0
Forester status:					
Private consultancy	.94	.69	.38	.43	.43
Community staff	0	0	0	.29	.29
Community association	0	.15	.63	.43	.43
No. of technical persons other than STF	1.40	1.10	.63	3.14	3.14
Contract uncertainty:					
Contract changes due to damage	0	3	2	0	0
Price changes	4	1	1	3	3
Plan modified in past 5 years	15	7	5	4	4
Breach of contract in past 5 years (mean/standard deviation)	1.13/1.51	1.08/1.31	.75/.71	.86/.38	.86/.38

Note. CBC = comisariat of communal property (comisariado de bienes comunales); JV = chief vigilance office (jefe de vigilancia); JM = logging foreman (jefe de monte); STF = technical forest service providers (servicios técnicos forestales).

* Data on lumber and finished wood products communities refer to their contracts to sell roundwood.

† Where the total communities using these two sources of payment do not reach sample totals, other sources of payment were used, such as government funds.

esized that the political movement leading to the end of parastatal leasing reoriented community members toward a goal of forming their own timber operations, thereby lowering organizational costs and creating social capital within and among communities.¹³ In addition, exposure to long-term forestry management changed the relationship between people and forests from subsistence use to industrial-style production (Vidal Garcia Pérez 2000). Communities with such experience may also place greater value on the ability to guide development through forestry activity. The positive effect of this influence is also consistent with the parastatal having selected communities with fewer internal conflicts, also suggesting that this variable proxies for a social capital effect. This variable can distinguish from alternative explanations contrary to the predictions of proposition 1. For example, a negative sign would be related to greater community ability to monitor and enforce contracts, leading to less vertical integration provided that few other contractual hazards existed (Williamson 1998; Baker and Hubbard 2001).

A third influence is physical infrastructure. Capital in place for production is a substitute for required start-up capital and a relaxation of a capital constraint, increasing the likelihood of community integration. In addition, sunk costs, such as in-place physical capital stock, bring opportunity costs of capital and, therefore, default values to zero for the trading party, say, should temporal specificity exist. A lower default increases hold-up risk, thus encouraging that party to integrate. However, opposing forces discourage integration. Where existing physical infrastructure reduces the need for relationship-specific investments, outside harvesters are more likely to contract with the community. For the analysis, we assume that a credit constraint applies equally across the sample, though we check the effect of dropping from the sample three communities who used sawmill equipment already in place by parastatals and who were able to begin milling activities simultaneously with harvesting.¹⁴

Proposition 2 generates the hypothesis that a community is more likely to integrate vertically with greater forest stock, measured by forest stand size and commercial quality. A positive sign is consistent with our proposition that larger and higher-quality forests require unobservable specific investment in coordination, scheduling, infrastructure, and planning that is valuable at the margin, thus discouraging outside contracting. An alternative explanation is

¹³ Other proxies for the group's facility to organize collectively over a common property resource, such as the heterogeneity of the local population across socioeconomic characteristics, are tested in the empirical section.

¹⁴ Bank credit has played a small role in financing forestry in the social sector. From 1987 to 1993, 15 Oaxacan communities received US\$4 million for investments or working capital, and in 1997, the sector received no new loans (FIRA 1998).

that the size and the commercial value of a forest provides a production cost advantage resulting from economies of scale. This is most relevant for sawmill operations, which need a steady supply of timber that larger, better-quality forests can provide. Sawmills can purchase roundwood on the open market, capturing any potential for scale economies even with small owned forests. Fifty percent of the sawmill communities buy additional timber from other communities, some on a regular basis. We also evaluated the costs of maintaining expertise from year to year, and we found that this had no material effect on vertical integration. A total of 10 communities in the sample with a forest size below the sample median (3,700 hectares) have integrated beyond the stumpage stage, and a total of 11 stumpage and roundwood communities have forests above the median. Accordingly, economies of size alone cannot explain vertical integration.

Proposition 2 extends to noncommercial 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 enjoy use of nontimber goods, the risk of damage by timber harvesting and a lack of coordination of management decisions may become more important to control. A positive sign for the measure of nontimber forest production would suggest that the two processes are not separable and that transaction costs are significant.

We predict a positive sign for increasing hours of driving from urban centers for several reasons. First, more remote communities require more specific transport costs for an outside service. Second, it is more difficult for a community to gain information to monitor the outside contractor. Third, if a community is more remote, there are fewer alternative job opportunities, and this may be assumed to lower opportunity costs and increase the importance to secure jobs.

Table 3 summarizes statistics for these variables. Detailed descriptions of constructed variables are given in the appendix. The index for preacquired range of production know-how steadily increases with vertical integration. For past nontimber markets, the stumpage and secondary products groups do not have a statistically significant difference in averages whereas the difference is significant between the roundwood and secondary products groups (1% level), so the stumpage group is more akin to the secondary products group than the roundwood group in this respect.

Other patterns are evident in parastatal history, capital, forest stock, and market access. Twenty percent and 33% of the stumpage and roundwood communities, respectively, versus greater than 80% of communities in each of the sawmill categories, have been part of the parastatal leasing system. Correlation of logging roads with vertical integration is weak. The average number of forested

TABLE 3
HUMAN AND PHYSICAL CAPITAL CHARACTERISTICS

Variable by Group	Mean	Standard Error
Initial mechanical expertise index:		
Stumpage	.23	.0569
Roundwood	.35	.0696
Lumber	.41	.0622
Secondary wood products	.61	.0864
Past nontimber markets:		
Stumpage	.25	.1095
Roundwood	.33	.1377
Lumber	.50	.1789
Secondary wood products	.57	.1893
Parastatal history:		
Stumpage	.19	.0987
Roundwood	.33	.1377
Lumber	.88	.1183
Secondary wood products	.86	.1338
Initial logging road stock (kilometers):		
Stumpage	22	7.41
Roundwood	31	12.11
Lumber	57	17.93
Secondary wood products	98	28.20
Forested hectares:		
Stumpage	2,403	483
Roundwood	4,922	1,205
Lumber	7,467	2,126
Secondary wood products	1,1047	2,828
Quality of forest index:		
Stumpage	3.61	.1433
Roundwood	4.06	.1448
Lumber	4.30	.1806
Secondary wood products	4.57	.1644
Hours driving to capital:		
Stumpage	7.60	1.03
Roundwood	4.79	.87
Lumber	3.71	.68
Secondary wood products	2.95	.67
Hours driving to population center:		
Stumpage	3.61	.37
Roundwood	4.21	.72
Lumber	4.25	.60
Secondary wood products	5.73	.52

Note. Stumpage, $n = 16$; roundwood, $n = 12$; lumber, $n = 8$; secondary wood products, $n = 7$.

hectares by group rises about 2,400 hectares between the stumpage and roundwood and the roundwood and lumber communities, with a marked increase between the lumber and secondary product communities and large variation within each group. Harvesting technology and commercial tree species (pine) are similar across communities, so size of the forest should affect each community similarly. The assessment of historical quality of forest also increases with vertical

integration. For access to markets, there are two measures for distance in transportation hours to population centers (of 500 people or more), one for distance to the capital city of Oaxaca, which decreases with vertical integration levels, and one for distance to nearest population centers other than Oaxaca city, which increases with vertical integration.

IV. Logit Analysis

A. Ordered Logit Model

The likelihood of vertical integration can be estimated with the ordered logit model developed by McKelvey and Zavoina (1975), where the dependent variable takes a value of from one to four according to whether the decision-making unit is a stumpage, roundwood, lumber, or secondary wood products community. Ordered logit is the appropriate model for choice options greater than two when the choices have an ordinal nature (Greene 2000).¹⁵ 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 neglect this progression, making it an inferior choice of models.

The regression model is based on a linear probability model:

$$y_i^* = \beta'x_i + \epsilon_i, \quad (17)$$

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 that y_i^* lies along a continuum and that it indicates the propensity of the i th community to be at any of the four levels of production. 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_j , are cut points, or thresholds, to be estimated. The thresholds divide the distribution of y^* into the four categories, so that the response variable y is a discrete realization of y^* . In the present case, the model generates four probabilities, interpreted to be the probability of being in category 1 versus any other category, the probability of being in category 2 versus any other category, and so forth.

Various methodologies 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. Therefore, the model delivers one set of slope coefficient for the four probabilities of

¹⁵ Ordered probit would also be appropriate. Application of the ordered probit model did not change the results of the estimations that follow.

being in category 1, 2, 3, or 4. The thresholds are allowed to vary. We test this assumption below.

B. Estimation Results for Organizational Form

Our base model is the ordered logit estimation of the vertical integration level as a function of the variables summarized in table 3 (using distance variables alternately).¹⁶ The results of the estimation are represented in column 1 of table 4. The econometric results of additional specifications in columns 2–4 are discussed in a later section. Column 1 shows the estimated coefficients for the ordered logit estimation of the four possible vertical integration levels. The negative sign for initial physical infrastructure is consistent with explaining the endowment of logging roads as substitutes for further specific investments. However, it is not statistically significant, possibly due to the opposing effects of relaxed capital constraints and lower default values. Road density (logging roads per forest hectare) as an alternative measure provides no explanatory power. Dropping from the regression the three communities that took over machinery from the parastatal at the end of its lease did not affect the results.

The index for the preacquired range of skills with forestry equipment contributes to a positive and significant impact (10% level). As the range of such skills broadens in the community, the more likely are community members to choose forward integration. Educational attainment from the 1990 Mexican Census is available to measure general skill levels in the community. These measures are not ideal, because they postdate important policy changes that opened up community forestry options. Assuming some lag effect, we alternately added percentage of cohort population who finished 6 years of primary school; 4 years of a technical school; and 1, 2, and 3 years of secondary school. All have positive and significant coefficients except for the secondary school variables, which are nonsignificant. All variables lowered the significance of the mechanical skills variable. Overall, the results indicate that, the higher the skills in the community, the more productive are investments and the more important it is for residents to secure jobs.

Our measure of prior nontimber markets has little explanatory value in this regression. There appears to be no benefit of asset control associated with a history of selling nontimber products. Possible explanations are either our choice of indicator or that monitoring and coordinating timber and nontimber

¹⁶ Possible multicollinearity effects among the independent variables were diagnosed using the condition index and variance-decomposition proportion analysis (Belsley, Kuh, and Welsch 1980). The analysis showed a low condition index (less than 30) and low variance-decomposition proportions among the variables, which is consistent with lack of degrading collinearity.

TABLE 4
EMPIRICAL RESULTS FOR OWNERSHIP PATTERNS

	Vertical Integration (Four Levels) (1)	Integrated into Harvesting (2)	Vertical Integration (Three Levels) (3)	Stumpage versus Roundwood (4)
Independent variables:				
Initial roads	-.40 (-1.09)	-1.25 (-1.59)	-.30 (-.73)	-1.62* (-1.77)
Initial mechanical expertise	3.80** (2.03)	7.44* (1.69)	3.25 (1.42)	7.91* (1.65)
Historical sale of nontimber forest products	.25 (.28)	-1.45 (-.98)	.52 (.54)	-2.06 (-1.19)
Parastatal history	3.07** (3.58)	4.02** (2.31)	3.54** (3.45)	2.87 (1.58)
Hectares of forestland (log)	1.06** (2.54)	1.93** (2.09)	1.16** (2.58)	2.37** (2.01)
Forest quality	2.08** (2.67)	3.40** (2.08)	2.36** (2.47)	2.94* (1.80)
Hours driving to population center	.50** (2.27)	.89** (2.02)	.47** (2.11)	1.00** (1.93)
Constant		-31.28** (-2.54)		-32.32** (-2.32)
Threshold 1	19.05 [4.98]		21.18 [6.10]	
Threshold 2	21.87 [5.32]		24.24 [6.56]	
Threshold 3	24.34 [5.66]			
No. observations	43	43	43	28
Likelihood ratio χ^2 -statistic	49.22	35.50	45.48	19.57
Degrees of freedom	7	7	7	7
$Pr > \chi^2$.00	.00	.000	.007
Pseudo- R^2	.43	.63	.48	.51
Log likelihood	-32.68	-10.63	-24.19	-9.34

Note. Numbers in parentheses are z-statistics. Numbers in brackets are standard errors.

* Statistically significant at the 10% level.

** Statistically significant at the 5% level.

activities can easily be separated. Sales of wood for fuelwood or domestic use, frequently using dry, dead, fallen, or secondary wood, may not conflict with timber production if done according to custom. To test other indicators, we created measures for historical nontimber forest product collection for consumption, which also resulted in nonsignificant results.

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, from subsistence use to long-term industrial operations. This experience created an organizational capacity within the community that allowed

community members and community leaders to support investments required to create and maintain vertically integrated operations.

Measures of heterogeneity employed to further test propensity for collective action include the percentage of nonmember residents, literacy rates, the importance of nonforest income sources, population size, density relative to the forest, whether forests are parcelized, percentage of population over age 18 (and by gender), percentage of women *comuneras*, and well-being indicators (1990 percentage of households with electricity, drainage, and running water). None had significant effects, though a larger sample size may reveal different results.

The number of forested hectares (logarithmic) has a significant (at the 5% level) and positive effect, suggesting that complementarities between community labor and forest stock increase with forest stock size. Adding a squared term for forest size results in insignificant coefficients for both the base and the squared forest size terms. 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, as expected.

Distance to population centers other than Oaxaca has a positive and significant influence on vertical integration. The sign on the distance measures goes in the opposite direction of a cost advantage argument. Communities further away from population centers rather than closer are more likely to integrate forward. The significance of the positive coefficient suggests that specificity of investments for remote communities is likely to motivate this result.¹⁷

For the estimation in column 1, the null hypotheses that the three threshold 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 thresholds, are zero is rejected (1% level). A likelihood ratio test that the coefficients are equal across categories to investigate the proportional odds specification does not reject the hypothesis of proportional odds. The POM assumption of equal slopes across groups is also tested by comparing results with the generalized 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.

¹⁷ The alternative distance-to-Oaxaca city variable is negative but insignificant and is dropped from the model. Another distance measure expressed as the minimum of the distance to Oaxaca or the distance to the nearest population center other than Oaxaca returns a positive but also insignificant coefficient.

TABLE 5
MARGINAL EFFECTS

Continuous Variables	$\partial P(y = 1)/\partial x$	$\partial P(y = 2)/\partial x$	$\partial P(y = 3)/\partial x$	$\partial P(y = 4)/\partial x$
Initial logging roads (logarithmic)	.04	-.01	-.01	-.02
Initial mechanical training	-.42	.09	.13	.20
Forested hectares (logarithmic)	-.12	.03	.04	.06
Quality of forest, 1940	-.23	.05	.07	.11
Hours to population center	-.05	.01	.02	.03
Binary Variables	$P(y = 1)$	$P(y = 2)$	$P(y = 3)$	$P(y = 4)$
Parastatal leasing = 1	14	31	30	25
Parastatal leasing = 0	50	31	14	6
Change	-35	0	16	19
Nontimber marketization = 1	35	29	18	18
Nontimber marketization = 0	38	28	17	17
Change	-3	1	1	1

Note. Marginal effects calculated from regression 1 in table 4 for each observation, then averaged holding all else constant.

C. Marginal Effects on Probabilities

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. Historical forest quality and prior mechanical job experience can take five or more possible values and are treated as continuous variables. Marginal effects for binary variables are measured by calculating probabilities twice, once with the binary variable set to zero and once with the variable set to one, all else constant. The difference between the two probabilities is the marginal effect.

The largest marginal effects of the independent variables occurred for the stumpage category, where the prior mechanical expertise index and parastatal history have the biggest impact on predicting level of integration (table 5). A unit change in either of these variables decreases a community's chance of selling stumpage by over 30 percentage points and increases a community's probability of selling lumber or secondary wood products by 13 percentage points or more. 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 levels of vertical integration, which the ordered logit model typically estimates more precisely (Greene 2000). Increases in forest size or quality have their largest marginal impacts on reducing the probability of being a stumpage community, but there is no distinct positive effect in any one of the more integrated categories, suggesting that such forest characteristics cannot explain how far along the production chain a community organization will place itself.

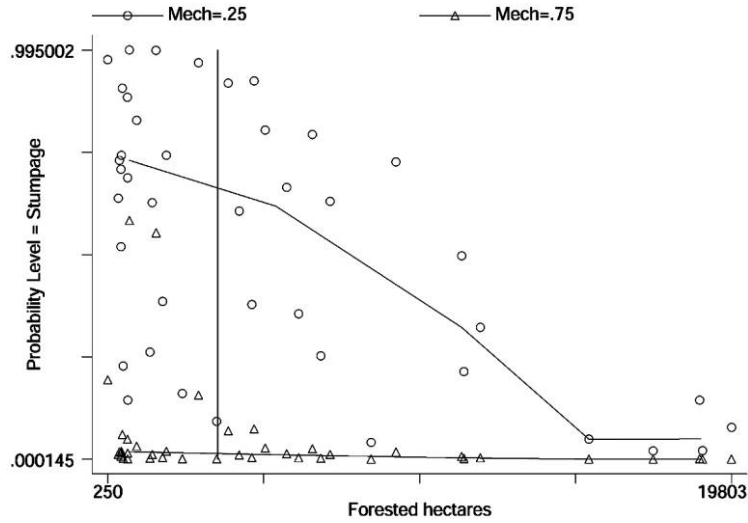


Figure 1. Effect of change in job skills index on predicted probabilities of being in a stumpage community

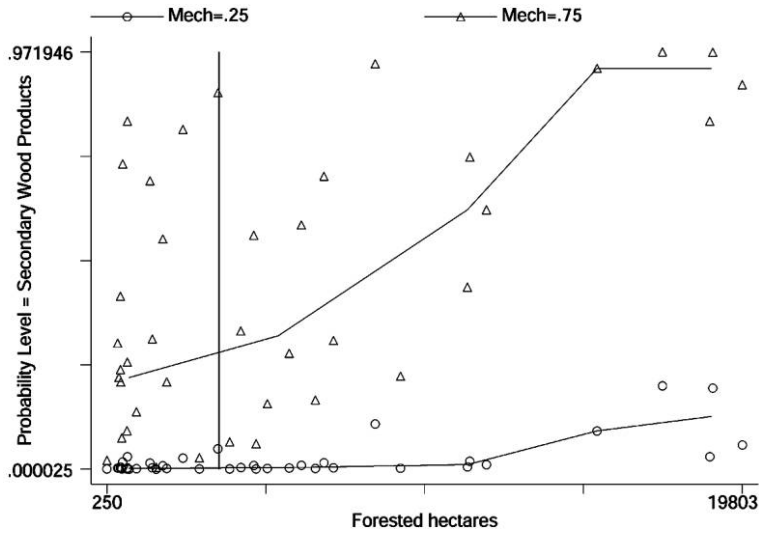


Figure 2. Effect of change in job skills index on predicted probabilities of being in the most vertically integrated category.

A graphical depiction of marginal changes provides further insights. The bottom axes in figures 1–4 record size of forest with a vertical line at 3,700 hectares to mark the median size forest. Figures 1 and 2 show the effect of a change in mechanical index for the probabilities of being either a stumpage or secondary products community. The curves connect the median bands for approximately each eight communities to show the trend in predicted prob-

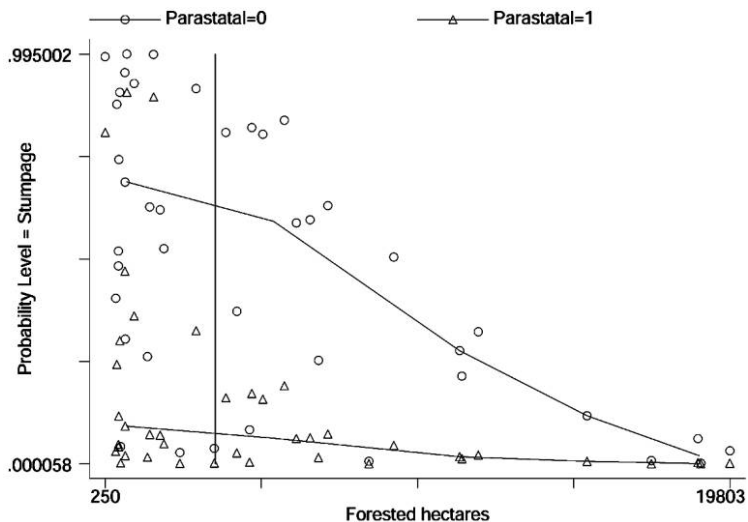


Figure 3. Effect of change in parastatal history on predicted probabilities of being in a stumpage community.

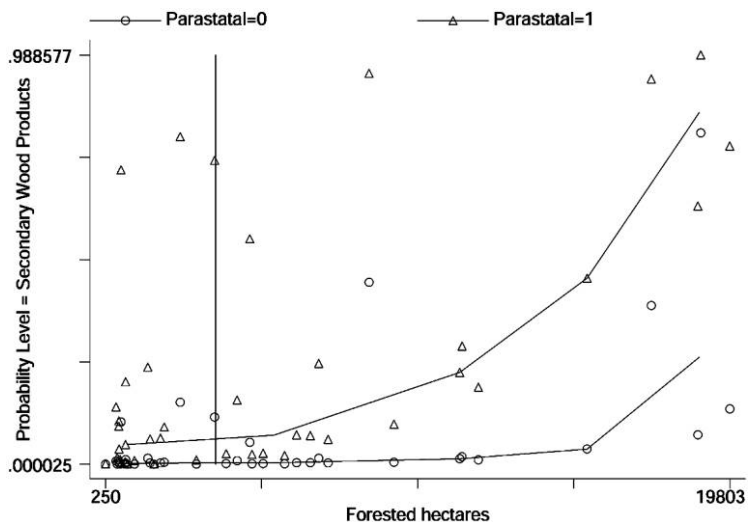


Figure 4. Effect of change in parastatal history on predicted probabilities of being in the most vertically integrated category.

abilities as we shift the mechanical skills index from 0.25 to 0.75, holding other values at their average. For smaller-sized forests left of the median size, an increase in the range of mechanical skills substantially drops the probability of being a stumpage community (fig. 1) and raises the probability of being in the most vertically integrated category (fig. 2). The combination of skills and a level of forest size usually predicts a vertically integrated community.

TABLE 6
PREDICTION TABLE

	Stumpage	Roundwood	Lumber	Wood Products	Observed Count
Predicted first choice:					
Observed choice:					
Stumpage	14	4	0	0	16
Roundwood	2	7	3	0	12
Lumber	0	0	4	2	8
Wood products	0	1	1	5	7
Predicted count	16	11	7	7	43
Predicted second choice:					
Observed choice:					
Stumpage	2	0	0	0	2
Roundwood	0	4	1	0	5
Lumber	1	0	3	0	4
Wood products	0	1	0	1	2
Predicted count	3	5	4	1	13

Figures 3 and 4 show a similar pattern for the parastatal history. A change in this variable from zero to one drops the probability of being a stumpage dramatically for small forests and then becomes less of a motivating factor for very large forest communities (fig. 3). As we move to the probability of being a secondary products community, this experience has little impact on small-sized forest communities but a large distinguishing effect on large forest communities (fig. 4). These figures reinforce the idea that size of forest is a predictor but that other indicators have significant marginal impacts at both ends of the size ranges.

We interpret these results to mean that, within the smaller-forest set, the organizational impetus provided by a history of parastatal leasing encourages collective management. This raises the concern of whether, to the extent that the concessionaire experience causes people to place greater weight on control, the facility with which community members organize an enterprise may have overplayed its hand, pushing some communities to integrate forward when other modes of governance are optimal. If this were the case, we would expect to see deintegration over time. However, only four communities of the 43 had deintegrated, and none had had parastatal leasing. Two stumpage observations that previously had a sawmill actually represent two work groups in one community that had divided timber operations due to internal conflict.

Table 6 compares predicted versus observed choices for each category for the base model (col. 1). The model correctly predicts stumpage, roundwood, and secondary wood products relatively more often than lumber status. The stumpage and finished wood products categories have predicted probability

distributions skewed toward their actual choices. Maddala (1983) suggests the following calculation as a goodness of fit measure for grouped data models:

$$S_1 = \frac{1}{N_{..}} \left(\sum_{i=1}^4 N_{ii} \right), \quad (18)$$

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 70% 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, $S_2 = 23\%$, so that the goodness of fit measure equals 93%.

D. Robustness

Based on the empirical results presented in table 4, we investigate a number of robustness properties of our model. Specifically, we test the possibility that the forces of integration are different as a community integrates from a stumpage to a roundwood community versus a community moving from a roundwood to lumber operation.

Stumpage versus other more vertically integrated groups. Using a logit model with a binary dependent variable (stumpage = 0, more vertically integrated = 1), estimation results in column 2 of table 4 are similar to the ordered logit results in column 1, except that initial range of mechanical expertise has a weaker statistical effect, though it is still positive and significant (10% level). Parastatal history, range of expertise in basic skills, and forest size and quality encourage integration. Even at this stage, distance to urban centers is positive and significant, suggesting specificity in access costs that outside contractors are not willing to undertake.

Three levels of vertical integration. In column 3 of table 4, we collapsed the two most integrated categories into one group, so that we have a dependent categorical variable with three ordered levels of vertical integration: stumpage, roundwood, and further processed wood. Parastatal history, forest size, and quality of forest remain positive explanatory variables, whereas range of mechanical expertise no longer differentiates the groups, suggesting a level of production expertise necessary to support more advanced operations beyond lumber.

Stumpage versus roundwood. Another test examines the robustness of the parastatal experience variable to explain the step from stumpage to roundwood

sales, where capital investments are lower than advanced milling operations represented by the sawmill communities. Applying binomial logit econometric techniques to a subsample of only the stumpage and roundwood communities (roundwood = 1) indeed shows that the parastatal leasing dummy drops below conventional standards of significance, while forest quality and prior job experience drop to 10% significance (see col. 4 of table 4). The results raise questions of whether organizational capacity is present and of how to build it should these communities seek to integrate further downstream. Initial road infrastructure remains negative but becomes statistically significant at the 10% level, suggesting that lack of forestry infrastructure deters outside contractors. Number of forest hectares maintains a positive and significant influence. For the extraction phase, production scale economies are less a driving force above a certain level of forest size and quality represented in the sample. An estimated production function for extraction activities using land, labor, and capital showed constant returns to scale (details are available upon request). Therefore, we attribute the positive influence of forest size in this case to scale economies in transaction costs.

V. Conclusion

This article explores how a natural resource generates benefits for its community owners. Placing community-level management over forestry operations within a vertical integration scenario isolates the net benefits of ownership over production assets, controlling for productivity differences between the community managers and the private contractors. The propositions focus on conditions under which vertical integration permits greater control over important but hard-to-define aspects of production. Empirical evidence tends to support the hypotheses. Contrary to popular perception, forest size is not the only factor predicting vertical integration. Size and quality of the forest play a role in prediction but in combination with other factors, and their marginal importance varies widely across communities. With certain levels of organizational ability, communities with small-scale forests may also seek to vertically integrate. Our proxy for social capital to facilitate collective decisions over forest resources, parastatal leasing history, is an important predictor for both small and large forests, suggesting that communities seek the benefits of residual control rights when they are able to do so. Broadening both general and forestry-specific skills, while it increases opportunity costs for local residents, also makes community integration more productive. The statistical effect is to raise the vertical integration probability where transaction costs are present. Stock of logging roads tends to substitute for necessary specific investments and decreases the likelihood of community integration into extraction.

Given the results of this analysis, we anticipate institutional innovations to enhance internal community managerial productivity and to reduce contractual hazards at various stages of production. Future research could expand on our depiction of the community versus outside private firm to further specify the collective decision-making process among forestry actors and to clarify the distributional effects of variations. However, the ambiguities in Mexican law regarding forest resources should privatization policies progress further in the community forestry sector leaves at stake a large asset base currently governed by agrarian institutions. This work sheds light on how that asset base marshals resources for its current owners. Work remains to be done to clarify new configurations of production organization and their impact as ownership and control over these resources change.

Appendix

Variable Definitions

Initial stock of logging roads: For stumpage communities, the measure of initial physical capital is (logarithmic) kilometers of logging roads as of 10 years ago (1988 at time of survey). For roundwood, lumber, and finished product communities, the measure is either 10 years ago, as with the stumpage communities, or 20 years ago (1978) if forward integration activities had begun prior to 1988.

Preexisting nontimber markets: A dummy variable takes the value one if a market for fuelwood, wood for domestic use, or an “other” category existed for more than 10 years (prior to 1988), zero otherwise.

Index for range of preacquired mechanical skills: The index combines responses to whether any local residents had preacquired experience in four mechanical activities related to industrial forestry. Experience includes employment, training, or learning through observation in four basic mechanical skills: work with chainsaws or handsaws, logging trucks, cranes, and sawmills. “Preacquired” refers to prior to 1986 (for stumpage communities) or prior to the community’s initial forward integration (for other types).¹⁸ The four dummies are summed and divided by four, so that possible values are 0, 0.25, 0.50, 0.75, or 1.00.¹⁹

¹⁸ The majority of integrated communities began to harvest their own timber in 1986 or afterward, though a few began in the period 1982–85 soon after the concessions were canceled.

¹⁹ Of the $4 \times 43 = 172$ possible yes/no responses to be combined in this index, 50 are positive (= 1). Of the 50, 92% refer to on-the-job experience acquired working for the parastatal and 8% are acquired from other sources, e.g., work with private companies, observation, or training by a forester. In the context of Oaxaca’s forestry history, little or none of this expertise was acquired in anticipation of vertical integration. Companies, particularly the parastatals, had conflictual relationships with the communities, and it was not in their interest to position communities to integrate

Parastatal history: A binary variable takes the value one if a parastatal held a lease or harvested regularly in the community, zero otherwise.

Forest quality: Three foresters with extensive knowledge of Oaxacan forests and timber history ranked the quality of the forest that existed around 1940 in terms of soil and climate conditions that would be favorable to tree growth and the presence and quality of harvestable, commercial timber. The ranking is on a 1–5 scale (5 = excellent, 1 = very low). The three estimates are averaged and rounded to get a measure from 1 to 5.

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forward. Government programs tended to support the status quo in this period as well (Moros and Solano 1995; Vidal Garcia Pérez 2000; López-Arzola 2005).

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