Ownership and Control in Mexico’s Community Forestry Sector *

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Abstract

Ownership and control are rarely synonymous. This paper examines the factors motivating Mexican agrarian communities with forests to participate and invest in timber production activities, an opportunity which has opened in the last twenty years due to changes in Mexican forestry policy. We propose that contractual difficulties with downstream production services and buyers lead community members to forward integrate into the wood production industry to enjoy greater benefits from production. An incomplete contracting model frames our analysis while original community-level data from Oaxaca, Mexico serves as the basis for empirical quantification. Using measures of specificity of investments, uncertainty, multiple uses of the forest, and managerial and labor expertise, it is found that communities with higher levels of human, social and resource capital endowments are more likely to integrate forward into timber processing activities. JEL Classification: D23, L22, O17, Q23.
1 Introduction

In this study, we analyze the implications of ownership versus control in the Mexican forestry sector 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 decisionmaking 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 a wide range of economic benefits such as job creation, public goods investments (Kusel and Fortmann 1991), poverty alleviation (Jodha 1992), risk diversification (Nugent and Sanchez 1998; Wilson and Thompson 1993) 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, forthcoming). For economists, there are few studies of how local participation is integrated into a broader market setting where other management options and factors influencing collective action are present (McKean 1997; Taylor and Zabin 2000).

The Mexican government’s active intervention in community ownership of forest resources highlights these issues. Mexico’s 1917 Constitution legislated common property into existence, with the consequence that approximately 80% of its forests are held by formally recognized agrarian communities (SARH 1994).\(^1\) The Agrarian Reform of 1992 sought to modernize the countryside by introducing titling programs to recognize individual property rights and facilitate land privatization in agrarian communities. Forest lands, 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 \textit{ejido} does not pay property taxes; and a source of community-level political power (Goldring 1998; Wilhusen 2003).\(^2\) In addition, forests may have advantages as common property, such as economies of scale in production and ecosystem services, and low value of

\(^1\)The term “agrarian communities” refers to the \textit{comunidades} and \textit{ejidos} incorporated under Article 27 of the Mexican constitution which have been given title as a group to land re-appropriated from large land holders. Articles of incorporation include rules on membership, governance and land rights, so that these are communities of law and not only communities of space.

\(^2\)In Quintana Roo, Wilhusen (2003) claims that intangible benefits of vertical integration in forestry production included the ability to control economic activity and gain political power.
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. How to allocate its resources to produce a desired level of social welfare is a challenge with which Mexico continues to struggle.

In this paper, 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 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 resident 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 an original survey as well as secondary data. Section 2 describes the organization and contracting environment for wood production among the community 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 3 presents contracting details among the communities, private firms and professional foresters in Oaxaca, Mexico. Because of Mexico’s legal and political framework for the agrarian sector, the relationship of management and ownership has implications for the level and distribution of surplus generated. 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 4 is designed as logit regressions to predict vertical integration across a sample of communities owning forest resources. The conclusion section outlines implications of the results and areas for future research.
2 Mexico’s social forestry sector

2.1 Organization and contracting

Despite their claim to land under agrarian law, Mexico’s community sector has only recently had the opportunity to commercialize their forests on an industrial scale. Starting in the 1940’s, the Mexican government leased communal forests to semi-public, semi-private (henceforth parastatal) pulp manufacturers for newspaper production (Klooster 2002). Friction eventually developed across Mexico over the federal lease program. Complaints were leveled against timber companies about the quality of harvesting practices, lack of local hiring, training or on-time payments (Kearney 1972; Moros and Solano 1995). Problems extended to the then government-provided forestry services. Communities complained that foresters marked and felled trees in ways that benefited the private lumber companies in the short term, imposed costs onto communities and neglected to provide communities with information on management and environmental laws (Weaver 2000, page 5). The final leases were terminated in 1982. The subsequent 1986 Forestry Law is a product of the “community forestry” movement which included bureaucratic reformers and recognizes agrarian communities’ right to produce and sell timber. Today, the largest majority of communities which commercialize forests are “stumpage” communities, that is, their contracts with outside harvesters allows the contractor to enter the forest and extract the trees. However, a substantial number have integrated downstream along the production chain.

In contracting for 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 that switches from outside private contractor to the community members as the community acquires more productive assets. In this case, ownership over productive assets translates into managerial control where community integration entails a switch in management personnel from outside private contractors to local managers. At the community level, forestry operations are coordinated through a traditional governance structure which is codified in the Mexican constitution. The two offices of Comisariado de Bienes Comunales (CBC) and the Jefe de Vigilancia (JV) are most critical to forestry operations. These officials are elected by the General Assembly (GA) consisting of registered members of the community. The CBC carries out land use management responsibilities, while the JV monitors common property and oversees the CBC. The GA elects these individuals as part of a structure of rotating civic responsibility, called cargos, under the Usos y Costumbres system. Where forestry occurs, the CBC and JV maintain ultimate responsibility for coordination with forestry guidelines and oversight. The positions are typically for a three-year term and are frequently unpaid for general civic duties but could be compensated for forestry duties. A scenario where sawmill communities contract outside companies for extraction services rarely occurs. As communities become more integrated, the GA or CBC may appoint a logging foreman (Jefe de Monte; JM), sawmill manager (Jefe de Patio; JP), documenters to measure volume extracted, and other managers as necessary. These positions lie outside of the formal cargo system,
though in some communities the cargo officials may double as a forestry manager, such as the JV acting as the JM, during production periods.

A number of models exist to characterize contracting relationships. Eswaran 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) (GH) develop a transaction costs model to describe the relationship between an upstream supplier and downstream buyer of goods and services. Like in Eswaran and Kotwal, nonverifiable investments are central to the model results. GH adds 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) and Holmstrom and Milgrom (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 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, page 189), which is the central feature of the GH framework. We adopt and extend the GH model to a context of a thin market for managers and where job design is limited to illustrate effects of switching ownership over capital between upstream and downstream market actors.

We 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 which preclude a complete, long-term contract, while nonverifiability of investments, due to unobserved effort or quality levels, for example, 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 seller can refuse to renegotiate. Within the bargaining framework used in this paper, 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, i.e. 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.\footnote{This access, of course, 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, for example, blocking entry and refusing contract renewals (Moros and Solano 1995).} This renegotiation maneuver, called “hold-up” risk, reduces the marginal value of investments. Anything that threatens a breakdown of a contract, such as asymmetric information, also creates conditions of hold-up risk. Efficiency depends on properly assigning ownership rights to increase investment incentives and maximize total social surplus (Hart 1995).

Table 1 describes basic assets and investments in wood production at four production stages of 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, such investments are specific to the particular community’s forest. A substantial range of quality in forestry management activities exists but the ability to verify is low due to their long-term and unobservable nature.

For harvesting, major capital assets are cranes to extract logs, transport trucks, and chainsaws (H). Ownership rights include the ability to allocate the machinery among different uses, set the pace of the harvest or work schedule, actions in case of equipment failure and the ability to cut timber undetected. Loggers have considerable scope in using diligence to separate logs from slash, exercise care in topping, felling and bucking trees, and minimizing stump heights. Variations in extraction efforts affect erosion, fire prevention and value of product harvested, but these efforts are often difficult to monitor.\(^4\) Logging roads that connect the forest stand with transportation routes also represent large start-up and maintenance costs from year-to-year and become embodied in the community’s physical infrastructure. These investments of effort at this stage would tend to be specific and nonverifiable.

In the harvesting stage, the management plan is a considerable investment which is specific to the community’s forest and 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 (\textit{Secretaría de}

\(^4\)For these reasons, Leffler and Rucker (1991) hypothesized that all the non-industrial private forest (NIPF) owners in North Carolina sell stumpage rights rather than hire loggers to extract the timber and subsequently sell roundwood to sawmills. The stumpage contract transfers to the buyer ownership over the timber. With the rights to extract and sell the product, the buyer has a greater motivation to harvest in a way that benefits both NIPF and buyer.
Medio Ambiente y Recursos Naturales (SEMARNAT)) for approval. Plans must meet minimum standards and consist of a forest inventory, demarcation of harvest rotation areas and harvesting schedule over time. A management plan can be for as short as one year or as long as 20+ years and have varying degrees of detail regarding land use and inventory.

Capital equipment for milling (S) includes the sawmill, sawmill maintenance equipment such as the file for the saws, 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. Locating a sawmill next to or on community land would be a highly specific investment (Globerman and Schwindt 1986). Over the historical course of changes in forestry laws increasing the power of communities, private firms and parastatals that had machinery located near communities sold or abandoned their equipment to local communities or relocated their operations (survey data). Finally, for buyers of lumber, there is no standardization of lumber products. While millers try to mill the wood for pieces as wide, clear and long as possible, clients requests are made to order from the timber stock. Wood is graded with as many as five levels of quality, depending on knots and structural integrity, where third party verifiability as to contractual agreement depends on the nature of the agreement.

The secondary products stage (SP) requires equipment such as specialized mills and carpentry equipment for making doors, furniture, pallets, tool handles and other products. Like in the milling stage, location can affect market access and access to materials. The processing itself can vary in quality and complexity. There tends to
be some level of standardization in production, though products may be tailored to particular clients, like special orders for products of a given quality, processing stage or quantity.

Contractual hazards arise in all stages of production. Uncertainties include breach of contract, weak enforcement, equipment failures and weather-related delays. Temporal specificity, where outside opportunities diminish over time (Masten, Meehan Jr., and Snyder 1991), occurs at each stage because the onset of the rainy season poses a constraint to harvesting and management. Finding alternative trading partners mid-season imposes incremental costs. Any job training or employment agreements (e.g. advance payments policies) between outside contractor and local residents is a specific investment. Further, the amount of effort provided by both parties has an element of nonverifiability and creates difficulties in enforcing contracts. The planning and extraction phases have a greater degree of nonverifiable investments of effort, since logs delivered to a sawmill can be more clearly measured and classified, with the sawmill rejecting or repricing the logs if they do not meet the agreed standards.

By current Mexican law, the community 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 (H). Moving along the chain of production, operators further downstream own or
manage a sawmill (S) or secondary processing equipment (SP). To economize on space, we present the model once for the decision to integrate vertically from selling stumpage rights to own-harvesting.

2.2 Model

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 downstream processor, P, whose identity is either a private, outside firm who buys the community’s product in the case where the community is not integrated downstream, or a community manager employed by the community in the case where the community is integrated into downstream activities. Assume that the community officials and managers act on behalf of the community members at large where the General Assembly meetings are the means by which community members and their appointed officials coordinate their preferences. The stock of $T, NT$ and $H$ represent 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 $i_h$ are made, where $i_f$ is a silvicultural investment in the forest management phase and $i_h$ is an investment in the extraction or harvesting stage.

C and 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 $i_h$ are also the costs of investing. The investments improve productivity, either enhancing efficiency or lowering 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 nonmonetary 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, i.e. $F(T, NT) = F$. Similarly, $b_p(i_h; H)$ indicates the default benefit function for P under nonintegration. Specificity of investments imply that $B_c \geq b_c$ and $B_p \geq b_p$. The functions $B_c$ and $B_p$ are assumed to be strictly concave while the default payoffs are weakly concave.$^5$

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

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

where $\cdot$ represents C and P’s assets in a no-trade scenario. Condition (1) implies that 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 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:

$^5B'_c > 0, B''_c < 0$ for $F, T, NT, H$, and $i_f$, and $B'_p > 0, B''_p < 0$ for $F, T, NT, H$, and $i_h$. Also, $b'_c \geq 0, b''_c \leq 0$ for $F, T, NT, H$, and $i_f$, and $b'_p \geq 0, b''_p \leq 0$ for $F, T, NT, H$, and $i_h$.  

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

\[ B'_p(i_h; F, H) > b'_p(i_h; H) \quad \forall \quad 0 < i_h < \infty \] (3)

where the prime denotes the first derivative. Marginal productivity is strictly greatest when C and P trade, implying that 1) the investments, \( i_f \) and \( i_h \), are partly specific to P and C’s human capital, respectively, and 2) 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.\(^6\)

The optimal contract is modeled as the outcome of Nash bargaining between local communities and downstream managers. C and P negotiate at Date 2 to realize the \emph{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 their bargaining power, payoffs with trade and reservation payoffs and allocates the total surplus between the two players. The default price, \( p^\ast \), is what C can receive on the spot market for its production. With Nash bargaining where the symmetry axiom is assumed to hold, C and P split the

\[^6B''_c = B''_p = b''_c = b''_p = 0 \text{ taken with respect to } T, NT \text{ or } H \text{ and any other asset } T, NT \text{ or } H, \text{ so that only direct effects of assets on the contracting decision are considered. This specification allows the model to highlight the basic effects of organizational issues. However, adding the complement/substitution effects would most likely strengthen the results and implications of the model, as they increase the complexity and therefore demand for coordinated management in production, to the extent that those nontimber products are valued.}\]
gains from trade 50:50. The ex post payoffs with the arguments suppressed for clarity are:

\[
\pi_c = B_c + p = b_c(i_f; \cdot) + \bar{p} + \frac{1}{2}[(B_c + B_p) - (b_c(i_f; \cdot) + b_p(i_h; \cdot))] \\
\pi_p = B_p - p = b_p(i_h; \cdot) - \bar{p} + \frac{1}{2}[(B_c + B_p) - (b_c(i_f; \cdot) + b_p(i_h; \cdot))]
\]

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 \(i_h\) are chosen cooperatively. In this open and integrated economy, the social planner maximizes net present value \(W\) where:

\[
W(i_f, i_h) = B_c(i_f; F, H) - i_f + B_p(i_h; F, H) - i_h
\]

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

\[
i_f^*: \quad W'_1(i_f^*, i_h^*) = B'_c(i_f^*; F, H) = 1 \\
i_h^*: \quad W'_2(i_f^*, i_h^*) = B'_p(i_h^*; F, H) = 1
\]

This assumption of an equal split is not necessary for the results to hold (Hart 1995).
Vertical integration in second-best scenarios

In contrast to the first best case, investments $i_j, j = \{f, h\}$, 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 forest land, we consider the two cases of nonintegration where private harvesters provide production and planning services and forward integration by the community where the 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 decisionmakers such as the logging foreman (JM) and documenters appointed from within the community who represent the community in the same way as the CBC and JV upstream. For 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 internal representatives of the community.

We apply parameterized weights to the investments $i_f$ and $i_h$ when the community makes these investments to capture the non-specialized 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 $\alpha_f$ and $\alpha_h$ range between zero and one for cases where community investment is less than or just as productive than an outside private harvester’s so that $i^*_f = \alpha_f i^*_f$ and $i^*_h = \alpha_h i^*_h$, where $0 < \alpha_f \leq 1, 0 < \alpha_h \leq 1$ and the superscripts indicate who is making investments, a
community member or a manager of an outside private firm. The parameter \( \alpha \) measures how skilled are community members collectively 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.\(^8\)

(1) **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 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. Each party’s net payoffs realized through bargaining are, where payoffs and investments under nonintegration are superscripted by “0”:

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\(^8\)Chen and Rozelle (1999) identified a tradeoff 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.
Community: \[ \pi^0_c - i^0_f = \tilde{p} + \frac{1}{2} \left[ B_c(\alpha_f i^0_f) + B_p(i^0_h) + (b_c(\alpha_f i^0_f; F) - b_p(i^0_h; H)) \right] - i^0_f \] (9)

Outside harvester: \[ \pi^0_p - i^0_h = -\tilde{p} + \frac{1}{2} \left[ B_c(\alpha_f i^0_f) + B_p(i^0_h) + (b_p(i^0_h; H) - b_c(\alpha_f i^0_f; F)) \right] - i^0_h \] (10)

The first order conditions with respect to \( i_j \) are now:

\[ i^0_f : \quad \alpha_f \frac{1}{2} \left[ B'_c + b'_c(i^0_f; F) \right] = 1 \] (11)

\[ i^0_h : \quad \frac{1}{2} \left[ B'_p + b'_p(i^0_h; H) \right] = 1 \] (12)

Investments are no longer chosen efficiently. The investments \( i_f \) and \( i_h \) 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. \( B_c \) 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 \( \alpha_f \) in the first order condition further removes silvicultural investment levels away from first best.
(2) 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 effects of changing control over assets and recognize the difference in downstream decisionmakers 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 $\alpha_h$ conditions the community’s investments, $i_f$ and $i_h$. With payoffs and investments under the community forward integration are superscripted by “1”, community payoffs from both upstream and downstream operations are:

Integrated community: $\pi^1_c + \pi^1_p - i^1_f - i^1_h = B_c(\alpha_f i^1_f) + B_p(\alpha_h i^1_h) - i^1_f - i^1_h$ (13)

The first order conditions are:

$i^1_f$: $\alpha_f B'_c = 1$ \hspace{1cm} (14)

$i^1_h$: $\alpha_h B'_p = 1$ \hspace{1cm} (15)

Accordingly, the difference between community and outside private firm productivity due to community lack of specialization under integration potentially causes $i_f$ and $i_h$ 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 nonintegration is 

$$V^0 = \pi^0_c + \pi^0_p - i^0_f - i^0_h$$

while the total social surplus under integration is 

$$V^1 = \pi^1_c + \pi^1_p - i^1_f - i^1_h.$$ 

If $V^0 > V^1$, then nonintegration is chosen while if $V^0 < V^1$, then community forward integration is selected.\(^9\)

The optimal ownership allocation depends on 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 $\alpha_h = 1$), then forward integration by the community is more efficient than subcontracting.

**Proof of Proposition 1:** If $\alpha_f$ and $\alpha_h = 1$ 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 $i_h = i^*_h$ under integration. By equations (2) and (3), $i_f$ and $i_h$ under integration are greater than $i_f$ and $i_h$ 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 the timber resource, $T$, 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

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\(^9\)Strictly speaking, the social planner would choose over all integration levels available, including integration into milling and secondary processing.
with value of the forest asset, such as size and quality, which relate to transaction costs or contractual hazards and which community vertical integration can capture. These costs, for example, are supervision costs, risk diversification opportunities, and a broader range of forest uses to be coordinated by the community. If 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) and holding all else equal that the marginal benefits of each unit of investments, \( i_j \), is larger in the community with \( T_1 \) than in the community with \( T_2 \). Specifically,

\[
B'_c(i_f; F(T_1, NT), H) > B'_c(i_f; F(T_2, NT), H),
\]

\[
b'_c(i_f; F(T_1, NT)) > b'_c(i_f; F(T_2, NT)),
\]

\[
B'_p(i_h; F(T_1, NT), H) > B'_p(i_h; F(T_2, NT), H),
\]

\[
b'_p(i_h; H) = b'_p(i_h; H),
\]

\[\forall \ 0 < i_f < \infty, \ \forall \ 0 < i_h < \infty\]

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 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 overcomes any community shortcomings in skills or expertise.

**Proposition 2.** For any given $\alpha, NT, H$, there exists a timber stock, $T$, large enough so that forward integration by the community is socially preferable to nonintegration.

*Proof of Proposition 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 $\alpha_f$ 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 $i_h$ 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, $B_p$, increases. Since the function $B_p$ is strictly concave, then by the property of real-numbers\(^{10}\) as $T$ increases, $T$ will reach a point where $\alpha B'_p(i_h) > \frac{1}{2}(B'_p(i_h) + b'_p(i_h; H))$ for any given $i_h$. So for the first order conditions to hold and by equations (2) and (3), $i_h$ under integration is greater than under 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 coordination efforts between timber and nontimber production raise contractual and organizational issues.

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\(^{10}\)If $x > 0$ and if $y$ is an arbitrary real number, there exists a positive integer $n$ such that $nx > y$ (Apostol 1967, page 26).
Our model differs from the Grossman and Hart (1986) model (GH) in a few critical respects. First, the efficiency parameters, $\alpha_f$ and $\alpha_h$, 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 GH 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.

3 Data Collection

3.1 Field methodology

Data for this project are based on field surveys conducted during 1997-1998 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 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 SEMARNAT 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 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 that their number was initially grouped with communities that sell lumber. Other corrections in classification were necessary during the course of fieldwork.\(^\text{11}\) Because two timber producing subgroups (work groups) existed in each of two communities, the final sample is 44, where the unit of observation is communities or subgroups within the communities that are authorized to make decisions concerning common property forests.

The survey has three parts. Part One focuses on the history of forestry activity in the community, labor and capital data, management structure, production, and contract and client characteristics. Part Two addresses questions of nontimber benefits of the forest, general community characteristics such as non-forest sources of income. Interviewers directed Parts One and Two to the community authorities responsible for forest administration. Part Three of the survey was conducted with the forester apart from the community and concerned management plan data, land use classifications, management practices and the forester’s relationship to the community.

\(^\text{11}\)For example, seven of communities targeted as roundwood or lumber sellers turned out to be stumpage sellers.
3.2 Organization and contracting: the data

Table 2 profiles the organization and contracting arrangements for wood production in the Oaxacan sample. A contrast emerges between stumpage and more vertically integrated groups. For example, in cases where the CBC or JV is paid, the buyer more often pays these cargo officials in the stumpage group as well as paying the JM and documenter even if they are members of the community. Communities have a bias towards hiring internally. The share of local hire includes logging and transportation for the lowest two integration categories plus milling for the processing communities. Again, a large change occurs between the stumpage and other groups. The highest percentage of community labor consist of loggers in the extraction phase. Most outside employment consists of privately contracted drivers who transport timber.

Chainsaws tend to be individually owned by persons hired to operate them (not shown). 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 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 the cranes.

The next section of the table characterizes investments and history of contracts. Downstream buyers invested in local public works (e.g. electricity, schools) at a decreasing rate to vertical integration, along with specific, production-related investments like 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 five years or less and the average duration of contracts across groups ranged from one to about four 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 are mostly similar or exactly the same as 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 five-year period before the survey. Reasons included inability to maintain the schedule for whatever reasons, weather delays, other forest conditions, new offers, and labor issues. Stumpage contracts were not changed due to tree damage since the outside private harvester can 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 five years prior to the survey occurred in all

\[12\] Where the total communities using these two sources of payment do not sum to sample totals in the table, other sources of payment were used, like government funds.

28
communities, although the stumpage group reported a slightly higher average than other groups. For example, a private harvester who promised to employ and train people from the local community did not fulfill these obligations. Another stumpage community did not finish their harvest season because the contractor’s equipment failed, and the community could not find another contractor before the rainy season. In yet another stumpage community, the community found an alternative buyer willing to pay a higher price mid-season, forcing the original harvester to match the higher price. While no statistically significant differences exist among mean number of contract failures across communities, Bartlett’s test (Bartlett 1937) rejects the assumption that the variances are homogeneous.

3.3 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 ($\alpha$) and characteristics of the assets $T$, $NT$, and $H$ which relate to their size, quality and specificity. We then test hypotheses of the likelihood of community-based or service-based timber production as these measures change in value. 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, $\alpha$. The first is the level of skills related to forestry operations. Mechanical skills in the community raises specificity and importance of control in the presence of transaction costs. Having more local residents with skills in production increases chances that local residents
will be hired but also introduces temporal specificity and lowers the default payoff should the contract break down.

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 integrated state hierarchies through the parastatal leasing system. State interventions have often mobilized civic involvement and increased local organizational capacity (see e.g. Larson (2004, Oyono (2004)). It is hypothesized that the political movement leading to the end of parastatal leasing reoriented community members towards a goal of forming their own timber operations, thereby lowering organizational costs and creating social capital within and among communities. In addition, exposure to long-term forestry management changed the relationship between people and forests from subsistence use to industrial-style production. 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 less 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 a greater community ability to monitor and enforce contracts, leading to less vertical integration provided little other contractual hazards existed (Williamson 1998; Baker and Hubbard 2001).

Third is physical infrastructure. Capital in place for production is a substitute for

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13 Other proxies for the group’s facility to organize collectively over a common property resource, such as heterogeneity of the local population across socioeconomic characteristics, are tested. The results are discussed in the empirical section.
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 be a strong aspect of timber
production. A lower default increases the costs of 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. Strength of each effect is
tested empirically. For the analysis, we assume that a credit constraint applies
equally across the sample, though we check the effect of dropping three communities
from the sample who used sawmill equipment already in place by parastatals and
were able to begin milling activities simultaneously with harvesting.\textsuperscript{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 which is valuable at the margin, thus
discouraging outside contracting. An alternative explanation is that size and
commercial value of 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 which larger, better quality forests can provide. Sawmills can

\textsuperscript{14}Bank credit has played a notoriously small role in financing forestry in the agrarian sector. From
1987 to 1993, about 15 communities in Oaxaca received approximately USD 4 million from banks to fund
investments or working capital (FIRA 1998). In 1997, the sector received no new loans (FIRA 1998) while
timber production increased that year.
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 this had no material effect on vertical integration. A total of ten communities in the sample with forest size below the sample median have integrated beyond the stumpage stage, and a total of eleven stumpage and roundwood communities have forests above the median value of forest hectares. Accordingly, economies of size alone cannot explain vertical integration.

Proposition 2 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 enjoy use of nontimber goods, the risk of damage by timber harvesting and 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 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 less alternative job opportunities, it may be assumed, lowering opportunity costs and increasing the importance to secure jobs.
Table 3 summarizes statistics for these variables. Detailed descriptions of the variables are in the Appendix. The mechanical skills index steadily increases with the vertical integration pattern. For nontimber marketization, the stumpage and wood products groups do not have a statistically significant difference in averages at the 5% level while the difference is significant between the roundwood and wood products groups at the 1% level, so that the stumpage and secondary wood products category are more alike than the roundwood and wood products groups.

The data reveal a marked break in parastatal history. Twenty percent and 33% of the stumpage and roundwood communities, respectively, versus > 80% of communities in each of the sawmill categories have been part of the parastatal leasing system. The average number of forested hectares by group rises about 2400 hectares between the stumpage and roundwood and the roundwood and lumber communities, with a large increase between the lumber and the wood product communities.

Harvesting technology and commercial tree species (pine) are similar across communities, so size of the forest should affect each community similarly. Although the average forest size increases with vertical integration, there is a relatively large variation within each group. The median value for the sample is 3700 so that a number of communities involved in extraction and processing have smaller sized forests. Correlation of logging roads with vertical integration is weak. There are two measures for distance in transportation hours to population centers, one for distance to the capital city of Oaxaca, which decreases with vertical integration levels, and distance to nearest population centers other than Oaxaca city (shown in table), which tends to increase with vertical integration.
4 Logit analysis

4.1 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 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.\(^\text{15}\) 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:

\[
y_i^* = \beta' x_i + \epsilon_i
\]

where \(y_i^*\) is an unobserved latent random variable, \(x_i\) is the vector of explanatory factors, \(\beta\) is a vector of parameters and \(\epsilon_i\) is the residual error. It is assumed \(y_i^*\) lies along a continuum and 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

\[\mu_{j-1} < y^* < \mu_j, \text{ where } j = 1, 2, 3, 4 \text{ and } -\infty = \mu_0 < \mu_1 < \mu_2 < \mu_3 < \mu_4 = +\infty\]

\(^{15}\)Ordered probit would also be appropriate. Application of the ordered probit model did not change the results of the estimations which follow.
the parameters, $\mu_i$, 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 one versus any other category, probability of being in category two versus any other category, etc.

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 being in category one, two, three or four. The cut points, or thresholds, act like intercepts and are allowed to vary. We test this assumption below.

4.2 Estimation results for organizational form

Our base model is the ordered logit estimation of vertical integration level as a function of the variables summarized in Table 3 (using distance variables alternately). 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 opposing effects of relaxed capital constraints and lower default values. Also, road density as an alternative measure provides no explanatory power.
Dropping from the regression the three communities which took over machinery from
the parastatal at the end of its lease did not affect results.

Mechanical training is positive and significant above the 10% level. 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. Educational attainment from the 1990 Census is also available to
measure general skill levels in the community. These measures are not ideal because
they post-date important policy changes that opened up community forestry options.
However, there may be some lag effect. Accordingly, to this base model, we
alternately added percent of cohort population who finished six years of primary
school, four years of a technical school, and one, two and three years of secondary
school. All had a positive and significant coefficients except for the secondary school
variables, which are nonsignificant. All variables lowered the significance of the
mechanical skills variable, suggesting a relationship between mechanical and general
skills in the community. Overall, the results indicate that with higher skills in the
community, the more productive are investments and the more important it is for
residents to secure jobs.

Our measure of nontimber activity 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 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 nontimber forest product collection for consumption which also resulted in nonsignificant results. Another possibility is that sustainable harvesting practices are generally desirable regardless of marketable non-commercial timber forest products.

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

Measures of heterogeneity to further test propensity for collective action include percentage of nonmember residents, literacy rates, importance of nonforest income sources, population size and density relative to the forest, whether forests are parcelized, percentage of population over 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 coefficient values. The importance of collective action indicators, it would appear, depend on the context and problem where the parastatal history dummy is most relevant to the current problem.

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 resulted in insignificant coefficients for both the base and 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 (of 500 people or more) 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.\(^{16}\)

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 cut points, is zero is rejected at the 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.

\(^{16}\)The distance-to-Oaxaca city variable is negative but insignificant and is dropped from the model (results not shown). A distance measure expressed as the minimum of distance to Oaxaca or distance to the nearest population center other than Oaxaca returns a positive but also insignificant coefficient.
4.3 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. Past forest quality and past mechanical training can take five or more possible values and are treated as a 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 mechanical training and parastatal experience 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.
A graphical depiction of marginal changes provides further insights. The bottom axes in Figures 1 and 2 record size of forest with a vertical line at 3700 hectares to mark the median size forest. Figure 1 shows 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 probabilities 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 mechanical skills substantially drops the probability of being a stumpage community (Figure 1a) and raises the probability of being in the most vertically integrated category (Figure 1b). The combination of skills and a level of forest size usually predict a vertically integrated community.

Figure 2 shows a similar pattern for the parastatal historical experience. 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 (Figure 2a). As we move to the probability of being a secondary products community, this experience has little impact on small size forest communities though a large distinguishing effect on large forest communities (Figure 2b). These figures reinforce the idea that size of forest is a predictor but 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 supports the main argument that communities seek benefits of residual control rights when they are able to do so but raises the concern
of whether these operations are economically feasible in the long run. 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 de-integration over time. However, only four communities of the 43 had de-integrated and none had had parastatal leasing. Two stumpage observations which previously had a sawmill actually represent two work groups in one community which had divided timber operations due to internal conflict.

Table 6 compares predicted versus observed choices for each category for the base model (Column (1)). The model correctly predicts stumpage, roundwood and secondary wood products relatively more often than lumber status.\footnote{This is due to ambiguous effects in calculating the in-between categories and is common to all ordered logit models.} 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:

\[
S_1 = \frac{1}{N_{\cdot\cdot}} \left( \sum_{i=1}^{4} N_{ii} \right)
\]

(18)

where \( N_{ii} \) refers to the number of correct predictions for alternative \( i \), and \( N_{\cdot\cdot} \) 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%.

### 4.4 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), Table 4 are similar to the ordered logit results in Column (1), except that initial mechanical training has a weaker statistical effect though still positive and significant at the 10% level. Parastatal historical experience, training 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 which outside contractors are not willing to undertake.

**Three levels of vertical integration** In Column (3), 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 experience, forest size and quality of forest remain positive explanatory variables while mechanical training as defined no longer differentiates the groups, suggesting a level of production expertise necessary to support more advanced operations beyond lumber.

**Stumpage versus roundwood** We have argued that parastatal experience built a social capital base that facilitated organizational capacity to make long range decisions regarding forestry. 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 parastatal leasing experience drops below conventional standards of significance, while forest quality and past mechanical training drop to 10% significance (See Column (4), Table 4). The results raise questions of whether organizational capacity is present and 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 available from authors). Therefore, we attribute the
positive influence of forest size in this case to scale economies in transaction costs.

5 Conclusion

The paper 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 arguments. Contrary to popular perception, forest size is not the only factor predicting vertical integration. Size and quality of forest play a role in prediction but in combination with other factors, and its marginal importance varies widely across communities. 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. Under certain levels of organizational ability, communities with small scale forests may also seek to vertically integrate. An increase in both general skills and skills particular to forestry, while they may increase options for local residents, make community integration more productive and raise the vertical integration probability where transaction costs are present. The positive and significant value of job expertise indicates that specialization to some degree is important and not generally available. 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 changes in institutional structure to enhance internal community managerial productivity and reduce contractual hazards at various stages of production. For example, forestry councils consisting of former *Comisariado de Bienes Comunales* who can advise current *Comisariados* on forestry management are emerging. Another managerial model promotes use of a general manager, which we encountered in a few communities, whose position is outside the *cargo* system, thereby lasting longer than three years and allowing more focused expertise on forestry management. Other communities have begun to re-organize themselves into sub-community level work groups, to avoid community-level mismanagement as well as direct more monetary benefits to individual members. Some forestry associations post information on market prices and serve as contract witnesses. Future research could expand on our depiction of the community versus outside private firm to further specify the collective decisionmaking process. Measures of managerial efficiency, such as the level of accountability and monitoring rules which permit the effective separation of ownership and control, could be also collected. Such extensions could be used to clarify the distributional effects of various organizational choices.

Mexico’s experience with common property and agrarian reform leaves unclear how agrarian communities will evolve. Where forestry activities exist in agrarian communities, it involves local members and residents at various levels of social, economic and political participation. 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 clarify new configurations of production organization and their impact should ownership and control over these resources change.
Appendix: Definition of Variables

**Mechanical skills**  A dummy variable was created for each of four tasks and recorded a value one if interviewees claimed anyone from the community had been employed or trained in that task either before 1986 for stumpage communities or before the year the community had integrated forward for roundwood, lumber and secondary products communities. The tasks were: chainsaw or handsaw operation, crane operation, transporting logs or millwork. 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. Historically, mechanical skills were not attained in anticipation of taking over forestry operations. As noted in the text, points of conflict between communities and outside private operators, including the parastatals, were lack of local hiring and training and defaults on wage payments.

**Nontimber marketization**  A dummy variable takes the value one if a market for fuelwood, wood for domestic use or an “other” category existed for more than ten years, zero otherwise.

**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 forestry engineers with extensive knowledge of Oaxacan forests and timber history ranked the quality of the forest which they recall or believe 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
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.

**Logging road network** For stumpage communities, the measure of initial physical capital is (logarithmic) kilometers of logging roads as of ten years ago. For roundwood, lumber and finished product communities, the measure is either ten years ago, as with the stumpage communities, or twenty years ago if any integration had taken place prior to 1988.
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<tr>
<th>Stages</th>
<th>Assets</th>
<th>Investments</th>
<th>Specificity between buyer/seller</th>
<th>Verifiability</th>
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</thead>
<tbody>
<tr>
<td>Forest Management</td>
<td>Forestland (F)</td>
<td>Safeguards against uncontrolled clearing, marketing, scheduling, silvicultural treatments</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Harvesting</td>
<td>Cranes, trucks, chainsaws, tractors (H)</td>
<td>Logging roads, management plan, sorting, placement of assets, marketing, job training in logging, scheduling</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Milling</td>
<td>Sawmill, auxiliary equipment, drying kiln (S)</td>
<td>Sawmill location, adjustments to saw, marketing, job training in milling, scheduling</td>
<td>High</td>
<td>Variable</td>
</tr>
<tr>
<td>Secondary Production</td>
<td>Processing machinery (SP)</td>
<td>Specialized equipment for woodcutting, marketing for given products, job training in cutting, scheduling</td>
<td>Low to medium</td>
<td>Variable</td>
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Table 2: Organization and Contract Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Stumpwood</th>
<th>Roundwood</th>
<th>Sawnwood</th>
<th>Secondary Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of observations</td>
<td>16</td>
<td>13</td>
<td>8</td>
<td>7</td>
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<tr>
<td>Management:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Who pays CBC (if paid):</td>
<td>5/2</td>
<td>6/0</td>
<td>6/0</td>
<td>6/0</td>
</tr>
<tr>
<td>Who pays JV (if paid):</td>
<td>4/3</td>
<td>6/0</td>
<td>5/0</td>
<td>6/0</td>
</tr>
<tr>
<td>Who pays JM:</td>
<td>2/11</td>
<td>10/0</td>
<td>7/0</td>
<td>6/0</td>
</tr>
<tr>
<td>Who pays doc.:</td>
<td>3/13</td>
<td>9/0</td>
<td>6/0</td>
<td>5/0</td>
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<tr>
<td>Share of local hire/s.d.</td>
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<td>.76/.17</td>
<td>.89/.14</td>
<td>.92/.15</td>
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<td>Community Ownership:</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>% owning trucks</td>
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<td>62</td>
<td>75</td>
<td>100</td>
</tr>
<tr>
<td>% owning cranes</td>
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<td>88</td>
<td>100</td>
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<td>Investments:</td>
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<td>Buyer - public works (count)</td>
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<td>4</td>
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<td>Buyer - specific investments (count)</td>
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<td>6</td>
<td>0</td>
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<td>Who paid for plan:</td>
<td>5/11</td>
<td>11/1</td>
<td>7/0</td>
<td>7/0</td>
</tr>
<tr>
<td>Who pays forest services:</td>
<td>5/13</td>
<td>11/1</td>
<td>7/0</td>
<td>7/0</td>
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<tr>
<td>Contract Duration:</td>
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<td></td>
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<tr>
<td>Years with current roundwood buyer:</td>
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<td>1</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>0</td>
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<td>2-5</td>
<td>9</td>
<td>9</td>
<td>2</td>
<td>2</td>
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<td>6-10</td>
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<td>&gt;10</td>
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<td>0</td>
<td>3</td>
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<td>3.33/.81</td>
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<td>1/0</td>
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<td>Forestry services:</td>
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<td>Years forester working with community:</td>
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<td>12</td>
<td>5</td>
<td>2</td>
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<td>6-10</td>
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<td>5</td>
<td>5</td>
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<td>11-20</td>
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<td>0</td>
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<td>Forester status:</td>
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<td>Private consultancy</td>
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<td>.69</td>
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<td>.43</td>
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<td>Contract changes due to damage** (#obs)</td>
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<td>3</td>
<td>2</td>
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<tr>
<td>Price changes (#obs)</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Plan modified in last five years** (#obs)</td>
<td>15</td>
<td>7</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Breach of contract in last 5 years (mean/s.d.)</td>
<td>1.13/1.51</td>
<td>1.08/1.31</td>
<td>0.75/0.71</td>
<td>0.86/0.38</td>
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*Data on lumber and finished wood products communities refer to their contracts to sell roundwood.**χ² significant at 10% level.
<table>
<thead>
<tr>
<th>Variable by group</th>
<th>Mean</th>
<th>Standard Error</th>
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<tr>
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<td>0.0569</td>
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<td>0.0696</td>
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<td>0.0622</td>
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<td>Secondary wood products</td>
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<tr>
<td><strong>Past nontimber marketization</strong></td>
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<td></td>
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<td>Stumpage</td>
<td>0.25</td>
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<td>0.1377</td>
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<tr>
<td>Lumber</td>
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</tr>
<tr>
<td>Secondary wood products</td>
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<td>0.1893</td>
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<tr>
<td><strong>Parastatal existence</strong></td>
<td></td>
<td></td>
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<tr>
<td>Stumpage</td>
<td>0.19</td>
<td>0.0987</td>
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<tr>
<td>Roundwood</td>
<td>0.33</td>
<td>0.1377</td>
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<tr>
<td>Lumber</td>
<td>0.88</td>
<td>0.1183</td>
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<tr>
<td>Secondary wood products</td>
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<td><strong>Forested hectares</strong></td>
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<td>Lumber</td>
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<td>Secondary wood products</td>
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<td>2828</td>
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<tr>
<td><strong>Quality of forest in 1940 index</strong></td>
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<tr>
<td>Stumpage</td>
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<td>Secondary wood products</td>
<td>4.57</td>
<td>0.1644</td>
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<td><strong>Stock of logging roads, km.</strong></td>
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<td></td>
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<tr>
<td>Stumpage</td>
<td>22</td>
<td>7.41</td>
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<tr>
<td>Roundwood</td>
<td>31</td>
<td>12.11</td>
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<tr>
<td>Lumber</td>
<td>57</td>
<td>17.93</td>
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<tr>
<td>Secondary wood products</td>
<td>98</td>
<td>28.20</td>
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<tr>
<td><strong>Hours driving to capital</strong></td>
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<td>Stumpage</td>
<td>7.60</td>
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<tr>
<td>Lumber</td>
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<tr>
<td><strong>Hours driving to pop. center</strong></td>
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<tr>
<td>Stumpage</td>
<td>3.61</td>
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<td>Roundwood</td>
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<tr>
<td>Lumber</td>
<td>4.25</td>
<td>0.60</td>
</tr>
<tr>
<td>Secondary wood products</td>
<td>5.73</td>
<td>0.52</td>
</tr>
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</table>

Stumpage, n=16; Roundwood, n=12; Lumber, n=8; Secondary wood products, n=7
Source: Survey data.

56
### Table 4: Empirical Results for Ownership Patterns

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>(1) Ologit</th>
<th>(2) Logit-H</th>
<th>(3) OlogitVI3</th>
<th>(4) Logit</th>
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<tbody>
<tr>
<td>Initial Roads</td>
<td>-0.40</td>
<td>-1.25</td>
<td>-0.30</td>
<td>-1.62*</td>
</tr>
<tr>
<td></td>
<td>(-1.09)</td>
<td>(-1.59)</td>
<td>(-0.73)</td>
<td>(-1.77)</td>
</tr>
<tr>
<td>Initial Mech. Training</td>
<td>3.80**</td>
<td>7.44*</td>
<td>3.25</td>
<td>7.91*</td>
</tr>
<tr>
<td></td>
<td>(2.03)</td>
<td>(1.69)</td>
<td>(1.42)</td>
<td>(1.65)</td>
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<tr>
<td>NTFP Market</td>
<td>0.25</td>
<td>-1.45</td>
<td>0.52</td>
<td>-2.06</td>
</tr>
<tr>
<td></td>
<td>(0.28)</td>
<td>(-0.98)</td>
<td>(0.54)</td>
<td>(-1.19)</td>
</tr>
<tr>
<td>Parastatal Existence</td>
<td>3.07**</td>
<td>4.02**</td>
<td>3.54**</td>
<td>2.87</td>
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<td></td>
<td>(3.58)</td>
<td>(2.31)</td>
<td>(3.45)</td>
<td>(1.58)</td>
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<tr>
<td>Forested Ha. (log)</td>
<td>1.06**</td>
<td>1.93**</td>
<td>1.16**</td>
<td>2.37**</td>
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<tr>
<td></td>
<td>(2.54)</td>
<td>(2.09)</td>
<td>(2.58)</td>
<td>(2.01)</td>
</tr>
<tr>
<td>Forest Quality</td>
<td>2.08**</td>
<td>3.40**</td>
<td>2.36**</td>
<td>2.94*</td>
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<tr>
<td></td>
<td>(2.67)</td>
<td>(2.08)</td>
<td>(2.47)</td>
<td>(1.80)</td>
</tr>
<tr>
<td>Hrs. to pop. center</td>
<td>0.50**</td>
<td>0.89**</td>
<td>0.47**</td>
<td>1.00**</td>
</tr>
<tr>
<td></td>
<td>(2.27)</td>
<td>(2.02)</td>
<td>(2.11)</td>
<td>(1.93)</td>
</tr>
<tr>
<td>Constant</td>
<td>–</td>
<td>-31.28**</td>
<td>–</td>
<td>-32.32**</td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>(-2.54)</td>
<td>–</td>
<td>(-2.32)</td>
</tr>
</tbody>
</table>

*threshold 1*:
- 19.05
- Standard error: 4.98

*threshold 2*:
- 21.18
- Standard error: 6.10

*threshold 3*:
- 24.34
- Standard error: 6.56

- No. Observations: 43
- LR chi-squared: 49.22
- d.f: 7
- Prob. > $\chi^2$: 0.00
- Pseudo-$R^2$: 0.43
- Log Likelihood: -32.68

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

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<thead>
<tr>
<th>Continuous Variables</th>
<th>$\frac{\partial P(y=1)}{\partial x}$</th>
<th>$\frac{\partial P(y=2)}{\partial x}$</th>
<th>$\frac{\partial P(y=3)}{\partial x}$</th>
<th>$\frac{\partial P(y=4)}{\partial x}$</th>
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</thead>
<tbody>
<tr>
<td>Initial logging roads (logarithmic)</td>
<td>0.04</td>
<td>-0.01</td>
<td>-0.01</td>
<td>-0.02</td>
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<tr>
<td>Initial mechanical training</td>
<td>-.42</td>
<td>.09</td>
<td>.13</td>
<td>.20</td>
</tr>
<tr>
<td>Forested hectares (logarithmic)</td>
<td>-0.12</td>
<td>0.03</td>
<td>0.04</td>
<td>0.06</td>
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<tr>
<td>Quality of forest, 1940</td>
<td>-0.23</td>
<td>0.05</td>
<td>0.07</td>
<td>0.11</td>
</tr>
<tr>
<td>Hrs. to pop. center</td>
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<td>.01</td>
<td>.02</td>
<td>.03</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Binary Variables</th>
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<th>$P(y = 4)$</th>
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<td>14</td>
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<td>Change</td>
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<td>19</td>
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<td>Nontimber marketization=1</td>
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<td>17</td>
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</tbody>
</table>

NOTE: Marginal effects calculated from Regression 1 in Table 4 for each observation, then averaged holding all else constant.
<table>
<thead>
<tr>
<th>Observed Choice</th>
<th>Stumpage</th>
<th>Roundwood</th>
<th>Lumber</th>
<th>Wood Products</th>
<th>Predicted Count</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Predicted First Choice:</strong></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stumpage</td>
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<td>3</td>
<td>0</td>
<td>12</td>
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<tr>
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<td>4</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Wood Products</td>
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<td>1</td>
<td>1</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td><strong>Predicted Count</strong></td>
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<td>11</td>
<td>7</td>
<td>7</td>
<td>43</td>
</tr>
</tbody>
</table>

<table>
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<th>Observed Choice</th>
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<th>Roundwood</th>
<th>Lumber</th>
<th>Wood Products</th>
<th>Predicted Count</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Predicted Second Choice:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Roundwood</td>
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<td>4</td>
<td>1</td>
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</tr>
<tr>
<td>Lumber</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Wood Products</td>
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<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
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<td>5</td>
<td>4</td>
<td>1</td>
<td>13</td>
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</tbody>
</table>
Figure 1: Effect of Change in Mechanical Index on Predicted Probabilities

Figure 2: Effect of Change in Parastatal History on Predicted Probabilities