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VERTICAL INTEGRATION IN MEXICAN COMMUNITY FORESTRY

by

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Abstract

While research has revealed the role of common property in risk diversification, poverty alleviation and resource management, few studies identify how common property management systems fill that role uniquely where market mechanisms or private property rights fail. To address that gap, the present research develops a consistent framework for analyzing local level production where community organizations have vertically integrated into the wood products industry, using common property forest as a source of raw material. Based on an incomplete contracting approach, it is argued that vertical integration allows local stakeholders to guide development within their community, provided that marginal productivity attains a certain level. Empirical results using a survey of 44 community governance regimes in Oaxaca, Mexico, show that communities are more likely to integrate forward into timber processing activities when they achieve initial levels of human and and social capital and increase labor productivity through higher forest land endowments. The model is extended to demonstrate that economies of scope arise between community-level timber production and nontimber benefits. JEL Classification: D23, L22, L73, O13, Q23

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1 Introduction

Research in the last 20 years has recognized common property's role in production, risk diversification, poverty alleviation, natural resource management systems and cultural heritage (McCay and Acheson 1987, Ostrom 1990). Common property resources – resources such as forests, fisheries and grazing pastures which are owned by a defined group of persons – have been especially important where persons face considerable transaction costs and imperfect access to credit, labor markets and land (Jodha 1992, Nugent and Sanchez 1998). Despite a rich case study literature, however, current research lacks a systematic focus on how local community institutions that manage the common property resource respond to market mechanisms and contracting opportunities that possibly lower transaction costs or fill in missing markets. Considering that economic policies can fundamentally change relationships between local populations and common property, it is important to analyze the extent to which markets substitute for property rights institutions in providing economic and social benefits.

This paper uses an original data set from Oaxaca, Mexico to determine the nature of transaction costs and economic benefits of timber production in local community forests. Almost 90% of forests in Oaxaca are held as common property. From the 1940's to 1982, the Mexican government leased communal forests to semi-public, semi-private pulp manufacturers. After years of conflict, new forestry laws in 1986 formally recognized communities' legal right to exploit their own timber resources. A community today which owns a forest and sells timber commercially can choose to integrate forward by extracting and processing the timber with its own capital equipment and labor, or it can contract with outside private harvesting firms and sell the timber at stumpage value. Each additional step in the chain of production requires substantial coordination of time and financial resources at the collective level. The transition from communities being unable to commercialize their timber resources to a political environment in which they could provides a unique opportunity to test theories of property rights and transaction costs.

The theoretical model based on the incomplete contracts literature (Grossman and Hart 1986, Hart and Moore 1990, Hart 1995) offers an analytical framework for vertical integration in the wood products production in Oaxaca. The model reflects the choices facing communities with forest resources today. The central question is the "sell-or-make" decision: when does a local community invest as a group in downstream harvesting operations and when does it contract with outside firms for extraction and processing? Silvicultural management and extraction require specific investments in physical and human capital, introducing the possibility of opportunistic behavior if the community subcontracts outside services. If the community integrates, it avoids bargaining costs with subcontractors. Given the multitude of management decisions made during the course of timber harvests and difficulty of observing, verifying and enforcing contract commitments, these costs could be substantial. It is argued that in areas where markets for labor, capital and public goods are scarce, controlling production is particularly important in providing development opportunities in the local community. The community may lack expertise, reducing efficiency if members integrate into timber production as a group. Thus, communities balance comparative advantage in skills and resources in decisions to control production activities. Propositions and hypotheses are developed for when 1) parties to a contract have different abilities associated with timber operations, 2) labor/capital complementarities exist and 3) nontimber benefits are important. An empirical analysis using ordered logit regression techniques tests the predictions of vertical integration and provides results consistent with the theoretical model. Variables to compare alternative interpretations are included in the analysis.

Further, this paper argues that communities capitalize on economies of scope once they have integrated forward. Using data on investments in nontimber activities, ordinary least squares and instrumental variables regressions statistically assess the impact of vertical integration on nontimber investments. It is shown that vertically integrated communities are more likely to invest in nontimber benefits due to scope economies between timber and nontimber production.

There are several contributions to this research. First, no one to the author's knowledge has presented natural resources management problems in an incomplete contracting framework despite this framework's direct applicability to natural resource issues, where property rights has been targeted as key to sound environmental policy. The approach is distinctly different, though not a replacement for, models of the "commons problem." Rather than solve a free-riding problem, this paper takes a property rights approach to explain vertical integration in communities where vertical integration requires coordination and support at the community level. Implications for common property research lie in understanding the nature of transaction costs within community-level timber production. The model of contract choice and nontimber products diversification sheds light on this issue. Second, as a contribution to the economics literature, very few applications of the incomplete contracting approach exist.[1] Third, this research gives a more detailed look at community forestry with original data, whereas many studies of community-based management give a broad view of the issue. Privatization has often been seen as the only means to achieve economic progress. The results of this paper suggest the extent to which different forms of resource control further environmental and development goals.

The paper is organized as follows. The next section reviews the property rights literature. Section 3 presents background information critical to an understanding of community forestry in Mexico and its relation to property rights theory. With this background understanding, a model in the following section presents propositions based on the incomplete contracts literature, with related hypotheses in section 5. Section 6 discusses the empirical approach, econometric models and econometric results. The final section draws conclusions from the analysis.

2 Literature

Under a system of perfect and complete markets, ownership rights should not matter, and investment outcomes should be the same across ownership patterns. Transaction cost economics offers theories as to why this claim would not hold (Coase 1937, Williamson 1985). According to the "hold-up problem," for example, buyers and sellers in a trade agreement subject themselves to the risk of opportunistic behavior by the other party when one or both parties make trade-specific investments. Specificity means that the investment has more value in a trade with that party than in the open market. Once a specific investment is made, the other party can haggle for better terms, knowing that the person would get less value elsewhere. Each side foresees this possibility and invests at levels other than first-best. Since investments are nonverifiable, representing effort or quality levels, they are unenforceable by a third party. The transaction costs approach recommends vertical integration to reduce these haggling costs (Williamson 1985).

[1] See Hanson (1995) as one example.

Unlike transaction costs analysis, however, the property rights approach based on incomplete contracting claims that hold-up disincentives do not necessarily change with integration if the managers stay the same.[2] Therefore, who should own the asset to maximize social surplus depends on additional parameters of the model, such as how essential or elastic are a buyer's investment compared to the seller's (Hart 1995) or social objectives (Grossman and Hart 1986).

The multiproduct nature of the forest raises the question of the impact of community forestry on nontimber benefits of the forest. Studies have shown that diversification occurs due to economies of scope between production activities, leading to greater value in research and development (see, for example Teece (1980) and Armour and Teece (1980)). While economies of scope may exist, vertical integration or diversification is not necessarily the logical organizational result, as argued by Panzar and Willig (1981). A market contract can realize production of two goods by two separate firms. Rather, economies of scope realized by vertical integration would hold of there is a common input that cannot be traded across the market such as technological knowhow or a specialized, indivisible physical asset. If trading is difficult and intrafirm governance is better, then Panzar and Willig's organizational result will hold. Further, if contracts are continually updated, requiring continuous exchange of proprietary knowhow, the nonstandard nature of the transaction makes reliance on the market "hazardous" (Teece 1980).

3 Application to a Timber Industry with Communal Forest Land

The data for this research comes from the southern Mexican state of Oaxaca where 90% of forest land is common property. The term "community" in this paper refers to the agrarian communities created by the Mexican Constitution of 1917. Each community has well-defined membership, boundaries and governance structure. Despite the 1992 Agrarian Reform which allowed community land to be privatized under certain conditions, the majority of the land is held in common in these communities.

Timber production in Oaxaca is not new but the shift from government to community control has been

[2]Such arguments take issue with the principal-agent and mechanism design frameworks by explicitly recognizing that complete contracts are almost impossible to write (Hart 1995). Maskin and Tirole (1999) claim that complete contracts can be written despite unforeseen contingencies with joint ownership but with a clause that permits the buyer an option to sell her share of the assets to the seller. However, the complexity of such contracts could limit their use (Hart and Moore 1999).

dramatic. The national government exercised control of timber production in the 1940's and 1950's by issuing leases to parastatal firms. It interpreted agrarian law as giving ownership rights over the land to the community but government maintaining rights to the trees. Although communities had the right to negotiate and veto logging, most communities arranged a logging agreement with the parastatal firms. In 1982, the government leases expired and, after much political protest, were not renewed (Moros and Solano 1995). These changes culminated in the 1986 Forestry Law in which communities are formally allowed to organize production units or may contract with private firms directly in the market. Today, the high concentration of communally-owned and -managed forest industries in Mexico is found nowhere else in the world.

The forest industry in Mexico has characteristics which lend themselves to the analytical tools of contract theory. While a contract can assign certain flows of benefits and separate rights from ownership, other benefits which may be critical to community members are harder to specify and left as residual ownership rights. Timber production can fit into a larger development strategy. Residual control rights related to timber production cover rights to decide how the business is conducted, whether it expands or is kept small, number and allocation of jobs in the short and long term and actions which affect the physical stock of the timber resource. For example, before 1982, community residents complained that the parastatal did not hire locally. After intense conflict, the firm began to hire and train locally. Since quality of training is a nonverifiable investment, it may be asked at what level and cost the firm provided such training. Another example is the attempt by a community to get permission from the parastatal to establish its own carpentry workshop using oak from communal forests. Only after repeated negotiations was the community successful. In survey interviews, community authorities claimed that despite promises of building schools and other public services, the parastatal firm never followed through. Considering the forest as an ecosystem, ecological linkages could exist as well. Several interviewees noted that outside firms did not cut with the same level of quality control to prevent damage to other timber trees and the surrounding area as when the community supervised and controlled harvesting activity. In an example indicative of the range of harvesting practice quality, the communities threatened to refuse renewal of the contract with one parastatal if it did not remove more of the cut timber, instead of leaving it in the forest. The conflict included the community confiscating the firm's equipment and retaliatory local firings before the conflict was resolved (Moros and Solano 1995).

These examples illustrate that different objectives between two parties to a contract opens the possibility of renegotiation as the production cycle evolves and that asset ownership gives the owner bargaining power.

This paper argues that control by the local community over forestry operations is important for two reasons. First is because of the complexity of directing resources in the local economy when the common property resource acts as a buffer to shocks and a public reserve of goods and services. Second, viewing the forest as an ecosystem, timber production has a potential impact on nontimber benefits such as soil maintenance, water quality and food sources. However, outside firms may have greater access to capital and expertise. Firms contracting with local communities built infrastructure in the communities such as logging road networks and roads that brought the community into easier communication with surrounding populations. Today, communities differ in their forestry infrastructure and skills to manage timber extraction and processing and forestry management.

Once vertically integrated, what is the impact of community forestry on nontimber benefits? As profits increase, diversification could help to maintain a higher return on investment in the forest stock. This can result if the community members seek to maximize the productive capacity of the local population and the forest. With a fixed forest size, diversification could increase returns from forest production activity. Patrolling, developing the management plan, coordination of the harvest and overall management can affect different aspects of forest exploitation and offer scope economies.

4 Bargaining Model of the Vertical Integration Decision

The bargaining model in this paper is an adaptation of that presented by Grossman and Hart (1986) and Hart (1995). It depicts a buyer-seller relationship between a local community, C, that owns forest land, $F = F(T, NT)$, where T is the timber stock and NT is the nontimber stock, and a harvesting manager, M, operates the harvesting equipment, H. The production of the assets is not modeled. The stock parameters T, NT and H represent physical size, such as hectares, biomass or equipment inventory, as well as the value which the community and manager places in the timber and nontimber stock for consumption, production, cultural and aesthetic use, and quality of the resource for commercial purposes. The owner of an asset has the residual control rights over the asset. The parties are risk neutral and each has initial wealth large enough to purchase any asset which is efficient to own. The community and the harvest manager are in a vertical production relationship. They negotiate a transfer of timber to the harvest manager who will then use the timber as an input for other wood products.

$B_C(\cdot)$ and $B_M(\cdot)$ are functions that represent the monetary value of production and trade of forest products if the two parties decide to trade. Since the model focuses on vertical integration relationships, the benefit function of the upstream community, $B_C(\cdot)$, can be negative to represent a cost of production which will be recouped through the sales price. Assume that the community forest authorities – the *Comisariado, Consejo de Vigilancia* and the General Manager (if the post exists) – act on behalf of the community members at large in all decisions made as managers of the community forestry enterprise. The General Assembly meetings could be thought of as the means by which the authorities and other community members coordinate their preferences. Future research would model this bargaining process in the community with an n–person bargaining game. The function $B_M(\cdot)$ includes revenues from selling timber products. The functions B_C, B_M include non-pecuniary private benefits which accrue to the owner of an asset such as the ability to make decisions over the allocation of the asset, feelings of pride of ownership, or ability to divert benefits to themselves.

There are two dates in the model. At Date 1, the investments i_F and i_H are made, where i_F is a silvicultural investment in the forest or forest management process and i_H is an investment in the harvesting equipment or process. Assume the forest and the harvesting equipment already exist and are in place. The investments are to improve productivity, meaning that they enhance the efficiency or lower the costs of production, thereby increasing the value of *ex post* payoffs. It is assumed that the investments i_F and i_H involve temporal or human capital specific investments. For example, i_F could be adapting the management plan to accommodate the harvester's needs, or specific training to apply treatments that aid the harvester. Examples of i_H are improving the timber harvesting practices for this community's forest, learning about the forest to plan a harvest or consulting the management plan. It can also include constructing a road if human capital specific investments become embodied in the investing party so that the investment is specific to trading with the community. The investments are made independently, noncooperatively and simultaneously by C and M. Each observes the other's choice of investment after it has been made, so they have symmetric information on investments and costs. B_C and B_M are functions of i_F and i_H, respectively, so that $B_C(\cdot) = B_C(i_F)$ and $B_M(\cdot) = B_M(i_H)$. The function $B_C(i_F)$ captures the costs and benefits of trade where i_F can be thought of as reducing costs of trade. Both investments i_F and i_H affect the final payoffs to C and M through bargaining. Finally, it is assumed that i_F and i_H are the costs as well as the levels of investing.

There is uncertainty at this point as to the exact nature of the product, since a harvest season is long enough where events could change the volume and form of the good traded. The uncertainty makes a long-term contract impossible to write, i.e. it is too costly to specify uses of the assets in a Date 1 contract. The uncertainty is removed at Date 2 when the C and M must renegotiate before trading to resolve unforeseen events and realize *ex post* gains from trade. This is the potential source of hold-up because if investments are specific, C or M can hold out for better terms or refuse to trade. As an example from the field, one community could not finish their harvest season because the contractor's equipment broke down beyond repair, and the community could not find another contractor before the rainy season ended the harvest season. In another example where the community "held-up" the firm, the community found another buyer willing to pay a higher price, forcing the current harvester to match the higher price.

The transfer price, p, at which the two parties trade is a function of their bargaining power, benefits and reservation payoffs. They negotiate the transfer price in the second period for the timber produced. The price allocates the total surplus between the two players.

The two "firms," the community enterprise and the harvesting company, receive benefits depending on which assets they own, which differs under each ownership scenario. Neither the harvesting entity nor the forest community can acquire the human capital investments of the other party, only physical assets, F and H. Since Mexican laws currently prevent sales of communal forest land, only nonintegration and forward integration by the community are considered here.

Now, notation is introduced to express the default payoffs. In a default situation, bargaining breaks down and the two parties search for other trading partners. The reservation payoff if the two "firms" do not trade at Date 2 are the functions $b_C(\cdot)$ and $b_M(\cdot)$. C and M no longer have access to each other's physical assets, only to the assets which they own individually. The function $b_C(i_F; F, H)$ indicates the general default benefit function for the community when it is forward integrated, $b_C(i_F; F)$ under nonintegration. Similarly, let $b_M(i_H; H)$ indicate the default benefit function for the harvest manager under nonintegration. Under integration, however, the manager is a member of the community so that the manager cannot be fired. This default position contrasts with nonintegration, where the manager is a private harvester who is fired and seeks alternative trading partners if bargaining breaks down. Such a modification to the typical incomplete contracts story is consistent with the observation that no communities in the sample hired managers from outside the community when they integrated forward. With this switching of managers, the community manager under integration maintains access to the assets F and H even if bargaining breaks down. Therefore, $b_M(i_H; F, H)$ is the community harvesting manager's default benefit function in the integration scenario. Before fully defining the default benefits of a manager in this position, a few more assumptions are necessary.

The default price, $\bar{p}$, is the price that C can get on the spot market if renegotiation between C and M fail and C finds another harvest manager to harvest. When the two parties trade, they have access to each other's human capital specific investments and physical assets, so $B_C(\cdot) = B_C(i_F; F(T, NT), H)$ and $B_M(\cdot) = B_M(i_H; F(T, NT), H)$. The *ex post* surplus with trade is $B_C(\cdot) + B_M(\cdot)$. Without trade, the *ex post* surplus is $b_C(\cdot) + b_M(\cdot)$. Assume that *ex post* gains from trade strictly exist so that the following holds:

$$B_C(i_F; F, H) + B_M(i_H; F, H) > b_C(i_F; \cdot) + b_M(i_H; \cdot) \geq 0 \tag{1}$$

where the $\cdot$ represents the assets owned in each integration scenario. Therefore, the investments i_F and i_H are more productive in a trading relationship between the firm and the community. This captures the idea that the investments are human capital specific and have less value outside the trade agreement.

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

$$B'_C(i_F; F, H) > b'_C(i_F; F) \quad \forall \quad 0 < i_F < \infty \tag{2}$$

$$B'_M(i_H; F, H) > b'_M(i_H; H) \quad \forall \quad 0 < i_H < \infty \tag{3}$$

This relationship shows that a person's investment produces more the more assets the person has to work with. The functions B_C and B_M are assumed to be strictly concave: $B'_C(\cdot) > 0, B''_C(\cdot) < 0$ for F, T, NT, H, and i_F, and $B'_M(\cdot) > 0, B''_M(\cdot) < 0$ for F, T, NT, H, and i_H. The default benefit functions $b_{C,M}$ are weakly concave: $b'_C(\cdot) \geq 0, b''_C(\cdot) \leq 0$ for F, T, NT, H, and i_F, and $b'_M(\cdot) \geq 0, b''_M(\cdot) \leq 0$ for F, T, NT, H, and i_H.

Since the exact nature of the product is not completely describable until at Date 2, the community and the harvest manager must negotiate at Date 2 to realize the *ex post* gains from trade, $(B_C + B_M) - (b_C + b_M)$. Either can hold-out for better terms of trade or refuse to trade otherwise. Assume the gains are realized through Nash bargaining and are split 50:50. This assumption of an equal split is not necessary for the results to hold (Hart 1995). Through bargaining, they reach the optimal outcome and trade because of the gains to be realized. The *ex post* payoffs with the arguments suppressed for clarity are:

$$\pi_C = B_C + p = b_C + \bar{p} + \frac{1}{2}[(B_C + B_M) - (b_C + b_M)] \tag{4}$$

$$\pi_M = B_M - p = b_M - \bar{p} + \frac{1}{2}[(B_C + B_M) - (b_C + b_M)] \tag{5}$$

The first terms on the right hand sides are the reservation payoffs.

The model does not solve for production level as in the optimal path of resource depletion but assumes that the community and harvest manager understand the future flows of benefits from these stocks. They are assumed able to perform backwards induction. The separability of the production and integration decision is consistent with contract theory and transaction cost approaches to the extent that quantity produced does not affect specificity of investments or contracting relationships. The characteristics of F and H stock levels are exogenous. Their size, volume, capacity, quality and other characteristics are given. The investments

i_F and i_H improve the quality, efficiency or productivity of the trade relationship and do not contribute to production levels. It is assumed in this model that harvest, price per unit, and location of the harvest are specified prior to Date 1. Therefore, the integration decision is independent of production.

An argument to be explored is that communities have high costs of organization, are less able to insure against risk, and are less technically effective at timber and wood products industrialization. Because of the bias towards hiring internally, communities are thought of as having a fixed labor endowment, unlike a private firm which hires from the open market. From interviews and survey data, communities hire from outside, especially when people with the available skills are not to be found in the community. But most communities hire for manual work, while the managerial work in harvesting is by community members. Weights indicating the relative efficiency of community investments compared to outside private firms are applied to the investments i_F and i_H when the community makes those investments. Investments made by the community in forest management, $i_F^c = \alpha_F i_F^m$, and that $i_H^c = \alpha_H i_H^m$, where $0 < \alpha_F \leq 1$, $0 < \alpha_H \leq 0$ and the superscripts indicate who is making the investments, a community member or a manager of an outside private firm. Parameters α_F and α_H range between zero and one for cases where community investment is less than or just as efficient than an outside private harvester. More job skills, for example, in forestry management and production could lower costs of training and expertise and contribute to the stock of knowledge specific to a forest. This will be represented by a increase in the parameter values, α_F and α_H.

First best case

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

$$W(i_F, i_H) = B_C(i_F; F, H) - i_F + B_M(i_H; F, H) - i_H$$

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

$$i_F^*: \quad W_1'(i_F, i_H) = B_C'(i_F; F, H) = 1$$

$$i_H^*: \quad W_2'(i_F, i_H) = B_M'(i_H; F, H) = 1$$

Second-best cases

In contrast to the first best case, i and B are no longer contractible. Let us examine each case separately.

Nonintegration of forest management and harvesting stages

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

$$\text{Community, C:} \quad \pi_C - i_F = \bar{p} + \frac{1}{2}\Big[B_C(\alpha_F i_F) + B_M(i_H)) + (b_C(\alpha_F i_F; F) - b_M(i_H; H))\Big] - i_F$$

$$\text{Outside harvester, M:} \quad \pi_M - i_H = -\bar{p} + \frac{1}{2}\Big[B_C(\alpha_F i_F) + B_M(i_H)) + (b_M(i_H; H) - b_C(\alpha_F i_F; F))\Big] - i_H$$

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

$$i_F: \quad \alpha_F \frac{1}{2}[B_C' + b_C'] = 1 \tag{6}$$

$$i_H: \quad \frac{1}{2}[B_M' + b_M'] = 1 \tag{7}$$

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

Integration of forest management and harvesting stages

In this first approximation of a modeling approach, assume that if the community is integrated, the community members make the investments in the forest management stage as in the nonintegrated scenario. However, the manager making investments in the harvesting stage at Date 1 is a member of the community and may not have the specialized skills of an outside private company. Further, if this member-manager does not agree with the community during the contract period, he still has access, as a member of the community, to the assets F and H in a default situation. Likewise, the community still has access to his human capital specific investments. One can assume a fixed cost, c, that the manager (and perhaps the community) must pay for negotiating differences with the community authorities.[3] The costs could be large or small, positive or even negative. The point is to capture, however crudely, the generalized skill levels of *comunero* managers as opposed to the specialized skills of a private harvesting company. A further assumption is that the managers in each scenario have the same preference structure so that the functions differ only with respect to the weight α_H.

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

$$\begin{aligned}\pi_C - i_F &= \bar{p} + \frac{1}{2}\Big[\big(B_C(\alpha_F i_F) + B_M(\alpha_H i_H)\big) + \\ &\qquad \big(B_C(\alpha_F i_F; F, H) - B_M(\alpha_H i_H; F, H)\big)\Big] - i_F \\ &= \bar{p} + B_C(\alpha_F i_F) - i_F\end{aligned}$$

The community harvest manager's payoffs are:

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

$$\pi_M - i_H - c = -\bar{p} + \frac{1}{2}\Big[\big(B_C(\alpha_F i_F) + B_M(\alpha_H i_H)\big) + \big(B_M(\alpha_H i_H; F, H) - B_C(\alpha_F i_F; F, H)\big)\Big] - i_H - c$$

$$= -\bar{p} + B_M(\alpha i_H) - i_H - c$$

The FOCs are:

$$i_F: \quad \alpha_F B'_C = 1 \tag{8}$$

$$i_H: \quad \alpha_H B'_M = 1 \tag{9}$$

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

Proofs in Appendix

Proposition 1 says that where skills are exogenously given and local skills are less efficient than outside firms', then investment levels are less than the first-best Pareto optimal outcome under integration by the community. Bargaining costs with nonintegration also lead to less than first-best investment levels. The parameter α measures how less efficient community members collectively are than private firms, but a trade-off of higher transaction costs occurs for hiring-in outside managers.

Which case is best?

If neither integration nor nonintegration is Pareto efficient, the problem is to choose the property allocation yielding the highest social welfare. The solution method first observes the optimal level of investments, i_F and i_H, in each ownership scenario and compares the "size of the pie" under each scenario, given the exogenous characteristics of the problem. Say there are two possible ownership options as outlined above.

The problem becomes $\max\{V_0, V_1\}$, where V_0 is the total social surplus of nonintegration and V_1 is total social surplus from forward integration by the community, so that:

$$V^0 = B_C(\alpha_F i_F; F, H) - i_F + B_M(i_H; F, H) - i_H$$

$$V^1 = B_C(\alpha_F i_F; F, H) - i_F + B_M(\alpha_H i_H; F, H) - i_H - c$$

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

Proposition 1 claimed that if community members are not as efficient at investing as a privately operated firm, then the first-best solution is not obtainable. The next proposition considers the case where community members are just as efficient. In this case, integration by the community is socially preferable. As community members have greater initial stock of skills, the more efficient are their investments. Integration then avoids renegotiation costs.

Proposition 2. *If $\alpha_F = 1$ and $\alpha_H = 1$, forward integration by the community is more efficient than 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 resources, T, shift out the productivity of the investments, i_F. Complementarities between the community labor force and the stock levels may exist so that the community labor force becomes more productive with greater stock levels. Community members may be able to allocate the stock among different uses more efficiently, for example. The fact that timber production occurs in large forests is not surprising. However, the allocation of property rights remains to be explained. A simple interpretation of scale economies begs the question of why multiple firms or larger private firms do not enter to harvest. In reality, the forest is specific to a community and size is exogenously given, whereas private firms may not be large enough to provide the services, and additional investment to meet production requirements would be too specific to the community.

Similar to conditions 2 and 3, assume that the same pattern of marginal products holds as the stock increases in value. Say that the stock of timber in one community, T_1, is greater than the stock of timber in another community, T_2, so that $T_1 > T_2$ for $T_1 > 0$ and $T_2 > 0$. Then, holding all else equal, assume:

$$\begin{aligned}
B'_C(i_F; F(T_1, NT), H) &> B'_C(i_F; F(T_2, NT), H), \\
b'_C(i_F; F(T_1, NT)) &> b'_C(i_F; F(T_2, NT)), \\
B'_M(i_H; F(T_1, NT), H) &> B'_M(i_H; F(T_2, NT), H), \\
b'_M(i_H; H) &= b'_M(i_H; H), \\
& \qquad \forall \;\; 0 < i_F < \infty, \;\; \forall \;\; 0 < i_H < \infty
\end{aligned}$$

Both the benefit function under trade and the default option increase with increases in the timber stock. But, of course, the outside harvest manager, in the case of nonintegration, loses access to the forest in a default situation, so default payoffs remain the same for an outside harvest manager. The disparity between the default and trade utilities for an outside manager grows with increases in timber stock, which discourages his investments in the harvesting stage.

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

A similar relationship is assumed to hold for increases in the nontimber stock, NT with the other assets, T and H, held equal. Increasing nontimber stock also may increase local labor productivity for the reasons given above, but interaction effects between timber and nontimber production raise monitoring issues. Depending on the community's perception, more nontimber resources may require greater coordination of timber harvests. The separation of timber and nontimber production may be difficult to define, in terms of monitoring and quality control, therefore becoming a noncontractible element of the production process. Nontimber and timber investments can be complementary on a broader scale given the inadequate knowledge we have of an ecosystem's true value. As knowledge about forest ecology evolves, a change in management plans may be appropriate to enhance the flow of resource benefits. Also, with larger nontimber stock levels, the more likely are community members to harvest nontimber resources. Uncertainties in providing these nontimber products are more important to control.

Nontimber resources are not traded in the model. The model assumes that timber sales do not include nontimber sales, as is usually the case in the community forestry sector. This model assumes that timber and harvest equipment remain the same as nontimber values increase so that only direct effects of nontimber stock size on contracting decision are considered. Allowing nontimber trades in the model would introduce further layers of complexity and is left to future research.

Finally, investments in nontimber benefits can be an *outcome* of vertical integration. Joint production of timber and nontimber products can exhibit economies of scope. Examples include coordinating management plans, exploiting the knowledge gained from the forest resource as a whole, and better incentives to harvest according to practices that minimize damage to the ecosystem and its ability to produce market and non-market goods. The harvest of timber and nontimber products is coordinated in some communities, wherein the harvest management plan accounts for the presence of nontimber products (flora, fauna, mushrooms, area of high biodiversity) in delineating commercial forest stands. Planning for timber and nontimber production can occur simultaneously and with better knowledge of the other production activity. Further, as timber production brings community members into the forest, their knowledge of the location and biological habits of nontimber goods increases, creating a complementarity between timber and nontimber efforts. The know-how for nontimber production is unlikely to be static, but requires updating as the forest ecosystem experiences shocks or changes temporally and spatially. Vertical integration may provide the local community with the capital to enhance nontimber benefits.

Therefore, from the above propositions, a corollary follows:

Corollary *Investment in the forest, i_F, is greater under community integration than nonintegration.*

The model differs from other property rights models in three ways. First, the identity of managers switches from community to non-community member status between the integration and nonintegration scenarios. The community and manager under the integration scenario work out their differences at some fixed cost (c). This adaptation is appropriate to describe the status quo of the communities. Second, the efficiency parameters, α_F and α_H, are added. This facilitates comparisons of human capital expertise across communities. However, it is implicit that there is a division of labor among the community members according to skills, that is, the marginal costs are lower for one person than another in each job task. Third, the model breaks the asset F into two components T and NT to compare bargaining and organization costs across different endowments of forest land.

Note that forest land is always held as common property by the community. Rather than predicting common property tenure systems, which are given, the model elucidates the role of common property in two ways. First, the representative individual of the model can be seen as an "average" member of the community. The characteristics of the community determine its propensity towards collective management of timber production and processing activities using the common property resource. Second, a connection with common property's role also lies in the nontimber parameter. Local populations typically access the forest for both domestic use and sales of non-commercial timber products. Individual owners may use their forest for both timber and nontimber purposes, but it is argued that multiple-use strategies are more prevalent where the resource is used by more than one person.

5 Hypotheses

The following hypotheses link the propositions in the theoretical section with the empirical analysis. The first two hypotheses present a way to measure the expertise parameter, α, in terms of physical, human and social capital. From Proposition 2, as the measure increases, the greater the expectation of vertical integration. Greater initial stock in human and social capital is expected to lower the obstacles of starting timber operations within a community and therefore encourage vertical integration to avoid costs of renegotiation.

The first interpretation of the α parameter is the level of human capital expertise relevant to timber operations. With a proxy which will be developed from the survey data, the human capital stock related to forestry operations is expected to have a positive sign in explaining higher levels of vertical integration, as opposed to a null hypothesis that says expertise should have zero explanatory power because an outside firm could always contract with the community to hire local labor in production.

Hypothesis 1. *As the extent of job or training experience in timber production increases among the local* *population, the greater is the likelihood of community integration into timber production.*

Next, it is maintained that communities' political resistance to parastatal leasing created social capital within and among communities, and that exposure to long-term industrial forestry changed the relationship between people and forests from subsistence use to large-scale market production. The hypothesis to be tested is that a history of parastatal leasing has positive explanatory power in explaining vertical integration, as opposed to a null hypothesis that parastatal leasing has no explanatory power because history should not matter.

Hypothesis 2. *Past history of parastatal leasing and harvesting increases the probability of community integration due to the reduced cost of organization in the face of opportunistic behavior in the marketplace.*

Since survey data shows that mechanical training was acquired through work with both private and parastatal firms, it is not implied that the parastatal presence changed training levels any more than a private firm's would. Therefore, a variable for both parastatal leasing and past mechanical training will be added independently to the regression.

The next three hypotheses are empirical applications of Proposition 3, which says that as timber and nontimber stock increases, the community is more likely to vertically integrate. The first hypothesis interprets stock as the number of forested hectares. Again, size of the forest should not matter if transaction costs were zero. Therefore, a positive and significant sign on forest stock indicates the presence of transaction costs.

Hypothesis 3. *As the size of the commercial forest increases, the more community ownership of the forest and harvesting equipment is observed, all else equal.*

The initial level of forest stock can be measured along a quality dimension. The next hypothesis interprets stock as including value of its commercial potential.

Hypothesis 4. *As the quality of the forest for commercial purposes increases, the more community ownership of the forest and harvesting equipment is observed, all else equal.*

The next hypothesis considers the implication of greater nontimber stock and nontimber interactions with timber harvesting. Uncertainties in nontimber production and the difficulty of monitoring harvest management practices can make complete contracting infeasible. In addition, greater non-commercial timber activity may increase the risk of damage to non-commercial timber products caused by timber harvesting. To the degree that nontimber production is separable from timber production, we should not observe any relationship between timber and nontimber production. A positive impact of nontimber marketization suggests that the two processes are not separable and that transaction costs are significant. Note that this hypothesis refers to exogenous nontimber production.

Hypothesis 5. *As the stock of nontimber resources increase, the more community ownership of the forest and harvesting equipment is observed, all else equal.*

The corollary demonstrates how scope economies between timber and nontimber production would increase nontimber investments in integrated communities. Testing this corollary requires comparing nontimber investments across communities with varying levels of integration. Since investment levels are not verifiable, we observe the existence of nontimber production activities across communities. Vertical integration is the independent variable in the next hypothesis.

Hypothesis 6. *Greater vertical integration leads to greater incidence of nontimber forest production.*

Unlike the previous hypotheses, Hypothesis 6 examines the relationship between two possibly endogenous variables, vertical integration and nontimber production. To verify results, additional econometric methods such as instrumental variables will be applied and the empirical analysis will focus on recent nontimber investments.

To the degree that existing infrastructure for timber production is a substitute for relationship-specific physical capital investments, existing infrastructure provides a counterfactual to the transaction cost/incomplete contracts interpretation. Transaction cost economics as put forth by Williamson (1985) predicts that whoever makes specific physical as well as human capital investments should own the asset. For example, once logging roads are built, they become specific to the community, discouraging investment by outside harvesters according to transaction cost economics. Existing initial stock of logging roads would reduce the need for new physical capital, increasing the likelihood that an outside harvester contracts with the community. The incomplete contracts approach argues that the need for specific investments in physical capital leads to joint ownership over the asset (Hart 1995). Since this is not possible given the institutional structure of Mexico's agrarian communities, the need for specific investments would also discourage outside firm investment. A negative coefficient value for initial stock of logging roads would be consistent with these theories. Specific physical capital investment may also be contractible. In this case, Williamson's transaction cost approach would predict a negative sign while an insignificant coefficient would be expected under the property rights approach.

Existing infrastructure also lowers capital start-up costs. If communities face substantial capital constraints, a positive regression coefficient argues against the transaction cost/incomplete contract interpretation.

However, another explanation within the transaction cost economic approach is consistent with a positive sign on initial stock of logging road infrastructure. The community may integrate to reduce its hold up risk, which increases with higher levels of sunk, immobile investments. A community with fixed capital stock has a very low or zero opportunity cost of capital because the investments are sunk. A harvester who claims he cannot finish the harvest on schedule costs the community valuable time. In this case, the community's threat point is lower than a community's without this capital. As the threat point decreases, risk of holdup becomes greater and community silvicultural investments incentives decrease. So initial capital stock simultaneously lowers an outside harvester's hold-up vulnerability and raises the community's vulnerability. These alternative empirical explanations will be tested in the next section.

6 Empirical Approach

Sampling and Survey Design

The population is the set of communities or subgroups within the communities that are authorized to make decisions concerning common property. The criteria for including a community as part of the study population are that the community owns land for which it has a current management plan and permit that allows commercial harvests, and commercial production occurred in the community during at least one of the last three harvest seasons, i.e. in 94/95, 95/96, or 96/97. To identify the population, permit

Table 1: Population and Sample

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

files were obtained from the Ministry of Environment, Natural Resources and Fisheries (SEMARNAP) for the timber production cycles of 94/95, 95/96, and 96/97. Communities were categorized according to their known level of vertical integration, which was then verified to the extent possible prior to administering the survey. The total population of communities with authorized timber production is 95 (see Table 1). These 95 communities produce 80-95% of the commercial timber harvest in Oaxaca (SARH 1994). Private harvesters, which number 40-50, hold mainly small parcels of land and make up most of the remaining production. A random sample of 60 communities replicated the same proportion of each type as in the total population. The number of communities that processed their timber into finished products, such as tool handles or house furnishings, was not known prior to the survey so that their number is included with communities that sell lumber. Identification of the finished products communities as well as corrections in classification were made during the course of fieldwork.[4] Forty-four of the sample observations were interviewed.

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

The empirical analysis tests the theoretical model in two basic regressions. The first regression tests Hypotheses 1 through 5 to predict vertical integration. The second tests Hypothesis 6, the impact of vertical

[4]Seven of communities originally identified as roundwood or lumber sellers turned out to be stumpage sellers.

integration on nontimber investments. The following two sections discuss the form of the regression models, variables in the regressions, results and tests of the regression results.

6.1 Vertical Integration

The first regression estimates a choice model of asset ownership across sample communities. The dependent variable is the level of vertical integration, defined as the end product which the observation unit sells, i.e. stumpage, roundwood, lumber or finished wood products. Based on the hypotheses developed in the theoretical chapter, the causal relationships with the expected sign is hypothesized to be as follows:

Vertical integration = f(initial training (+), parastatal leasing history (+), historical nontimber markets (+), forested hectares (+), initial quality of forest (+))

The variables for assessing alternative theories are: initial kilometers of logging roads; distance to the capital city; distance to the main client; coffee production and parcelization of the forest. Construction of each variable is as follows.

Vertical integration The dependent variable takes a value of one to four according to whether the decision-making unit is a stumpage, roundwood, lumber or finished products community. One outlier roundwood community was dropped from the sample so that the final vertical integration profile is 16 stumpage, 12 roundwood, eight lumber and seven finished products communities, for a sample size of 43 observations. All the roundwood communities sell their entire extracted volume as roundwood. Most of the lumber and finished products communities also sell a fraction of their extracted volume as roundwood, since their sawmills usually do not have the capacity to process the full harvest.

Initial human capital The initial human capital indicators represent either job experience prior to 1986 or prior to any extraction activities conducted by the community itself. Survey questions gathered data on experience in mechanical skills necessary in timber production and processing, specifically experience with chainsaws, handsaws, cranes, trucks for transporting logs and sawmilling. Creating the human capital measure required several steps. A dummy variable was first created for each task and recorded a value one if interviewees claimed anyone had received training in the community in the past. "In the past" means before 1986 for stumpage communities or before vertical integration into extraction activities for all other types of communities. The dummies were summed and divided by the number of tasks so that the resulting measure indicates a percentage of the possible activities in which the community population participated. Therefore, the job experience variables capture the range of skills community members acquired. The reasons for this are twofold. First, this avoids bias in recalling the number of persons hired, especially in formerly-concessioned communities who had negative experiences with parastatals. Second, the existence of people in the community with that skill should be sufficient to build a base of knowledge accessible to other community members. Training represents a base of knowledge about industrial forestry that can be passed on to others in the community. Survey data revealed that many people learned skills by observing other community members.

History of parastatal leasing A binary variable takes the value one if a parastatal held a lease or harvested regularly in the community by arrangement, zero otherwise. The parastatal historical experience could have affected present-day ownership patterns for several reasons. Collective action may have been a result of independent local movements, motivated state reformers and non-governmental organizations acting in communities (Fox 1996). Solidarity among communities who sought removal of the parastatals from their communities could have motivated organization in the community around common property forest land. Additionally, exposure to the timber industry as a long-term business changed local communities perception of the forest value. Historically, the forest has importance for cultural and subsistence reasons. Timber harvesting introduced larger scale industry for forest products. Other effects that may confound these influences are first the parastatals' investments in infrastructure and employment opportunities that developed job skills, and second, the possibility that parastatals originally chose higher quality forests. Parastatal history is expected to positively effect vertical integration tendencies because of the educational exposure to industrial forestry and unifying effect of the communities' political resistance to the leasing programs. Statistical tests for selection bias and multicollinearity are conducted to isolate these effects.

Initial physical capital The logarithmic scale for the number of kilometers of logging roads measures the level of asset-specific physical stock available in the community. A positive sign is consistent with the interpretation that lower start-up costs encourage community integration and raise community exposure to hold-up risk. A negative sign would indicate that outside harvesters find it easier to contract with the community because of lower specific investment needs. The survey recorded kilometers of logging roads 20 years ago and 10 years ago. For stumpage communities, the measure of initial physical capital is (logarithmic) kilometers of logging roads as of ten years ago, when the transition to community forestry began in earnest. For roundwood, lumber and finished product communities, the measure is either ten years ago, as with the stumpage communities, or twenty years ago if integration into extraction activities had already taken place by 1986.

Nontimber markets in past Hypothesis 5 claims that as nontimber stock increases, the propensity for communities to integrate forward increases. The proxy for the stock of nontimber benefits is the presence of markets in nontimber goods. Such a proxy assumes that markets are more likely to exist where more nontimber products are available. It can also be interpreted as a weight people place on nontimber benefits of the forest, assuming that people value these resources more when they harvest them for sale. The measure does not capture non-market benefits.

The survey supplies information on the range of forest products sold and number of years community members have sold each product. To avoid endogeneity, nontimber markets are considered only if the market has existed for more than ten years so that the market predates or is concurrent with the vertical integration decision. The mushroom export market began in the last eight years and so postdates much vertical integration.[5] The remaining non-commercial timber forest products are fuelwood, wood for domestic use and the "other" category. A dummy variable takes the value one if a market in these products existed for more than ten years, zero otherwise.

[5]Only two communities, a stumpage community and a lumber community, sold mushrooms in non-export markets. The former had been selling for 50 years while the latter only had sold for three years.

Quality of forest, 1940 A proxy for the quality of the forest is used to test Hypothesis 4. Because parastatal firms may have selected better quality forests, an indicator was needed of forest quality before the parastatal era. To prevent selection bias, the measure ranks quality of forest in 1940, since commercial logging in Oaxaca began in earnest in the mid-forties. Very little photographic or written data exists on Mexican forests in 1940. In addition, where they do exist, interpreting the data would be difficult. To create an indicator, three forestry engineers with extensive knowledge of Oaxacan forests and timber history ranked the quality of the forest in terms of soil and climate conditions that would be favorable to tree growth, and the presence of harvestable, commercial timber, including trees of large diameter. Commercial timber is mostly pine, but cedar, mahogany and common tropical species grow in more tropical zones. 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.

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

Distance Distance, here measured as the number of hours of driving time in a car from the village center to the capital city of Oaxaca, has an expected ambiguous effect. Greater distance could increase the propensity to integrate forward because local investments in the forest industry have less competition. Conversely, distance could decrease the propensity to integrate because of increased transportation costs and risks of specialization. A second distance measure represents the distance between the client served by the community and the community. The measure is number of hours required to drive a truck loaded with logs to the main client's yard.

Coffee As an alternative use of the forest, the production of coffee could conflict with efforts to develop a timber production industry where pine would be the commercial species. A binary variable takes a value one if community members have income from coffee production on a regular basis, zero otherwise.

Parcelization Several communities parcelized their forests at the time of founding. Since some community members held parcels while others did not, the incidence of conflict over managing the forest was slightly higher in communities with parcelized forest. To test whether parcelization decreases the probability of vertical integration due to increased internal conflicts, a binary variable takes the value one if the forest is parcelized, zero otherwise.

Summary Statistics

Summary statistics are shown in Table 2. Wald tests were applied to test whether significant differences exist among group averages.[6] Both pairwise comparisons and joint tests that all averages are equal were conducted. Initial road infrastructure jumps significantly (at the 10% level or above) between stumpage and roundwood groups on the one hand and each sawmill group on the other. The joint test statistics are also significant at the 5% level. Differences in initial mechanical training are significant at the 10% level or above between each group except the roundwood and lumber and the lumber and wood products groups, suggesting that mechanical training has the largest effect at the early stages of integration. Parastatal experience differs significantly between the sawmill groups and the other categories. Independent tests are significant at the 5% level between stumpage and sawmill communities and in the roundwood/lumber transition. The joint test that all averages are equal across groups is rejected at the 1% level. Independently, the difference in average forest hectares is significant between the stumpage group and each other category at a level of 6% or more. The joint test rejects the null at the 1% level mainly due to the difference in the stumpage group vis a vis the other groups. The Wald test rejects the null hypothesis at the 10% level that averages for past nontimber sales are equal across all groups. The only strong bivariate correlations are: forested hectares (base and squared) and initial physical infrastructure; and the base and squared terms for forested hectares. The forested hectares and initial physical infrastructure are retained for the base model despite their correlation since the aim of the empirical exercise is to control for these varying effects.

[6] Wald tests, correlation matrices and other summary statistics are available from the author.

Table 2: Summary Statistics, $n = 43$

Variable by group	Mean	Standard Error	Number of observations
Initial mechanical training			
Stumpage	0.20	.0506	16
Roundwood	0.48	.0842	12
Lumber	0.38	.0754	8
Finished wood products	0.57	.1037	7
Past nontimber marketization			
Stumpage	0.25	.1095	16
Roundwood	0.33	.1377	12
Lumber	0.50	.1789	8
Finished wood products	0.57	.1893	7
Parastatal existence			
Stumpage	0.19	.0987	16
Roundwood	0.33	.1377	12
Lumber	0.88	.1183	8
Finished wood products	0.86	.1338	7
Forested hectares, logarithmic			
Stumpage	7.42	.2318	16
Roundwood	8.09	.2868	12
Lumber	8.33	.4579	8
Finished wood products	8.90	.4236	7
Quality of forest in 1940			
Stumpage	3.61	.1433	16
Roundwood	4.06	.1448	12
Lumber	4.30	.1806	8
Finished wood products	4.57	.1644	7
Initial kilometers of logging roads, logarithmic			
Stumpage	2.25	.3372	16
Roundwood	2.43	.4483	12
Lumber	3.45	.3735	8
Finished wood products	3.69	.6320	7

Separating effects of the parastatal encounter Distance from the capital city and initial quality of the forest could explain why a parastatal chose a particular community, introducing selection bias. In addition, presence of a parastatal could explain the stock of physical infrastructure and human capital, contributing to multicollinearity in the model. Regressions of the independent variables on each other sought to identify selection bias. The negative correlation between distance from the capital city and the past parastatal leasing is weak ($\rho = -0.46$). Regressing parastatal leasing on distance from Oaxaca city and quality of the forest in 1940 demonstrates that distance has positive and significant explanatory power at the 5% level but that prior forest quality is not significant at the 28% level. The correlation between past quality of forest and parastatal existence is surprisingly weak ($\rho = 0.29$). Nor does past forest quality explain parastatal existence in a logit regression as a single explanatory variable. Therefore, initial quality of the forest can be eliminated as a confounding factor for any explanatory value that parastatal history has on the level of vertical integration of the communities today. It remains possible that the parastatal effect is strong because of its positive correlation to distance from the capital city of Oaxaca.

The possibility that the parastatal contributed to initial stock in human and physical capital was tested statistically. Separate ordinary least squares (OLS) regressions of initial logging road stock and mechanical training, with parastatal history as the single explanatory variable show that parastatal history has no explanatory power at more than the 10% level for logging roads or mechanical training.

Ordered Logit Model

The estimation technique is the ordered logit model developed by McKelvey and Zavoina (1975). In this case, the increasing levels of vertical integration from selling timber to selling finished wood products has a step-by-step characteristic. While it is possible that communities could own a sawmill and yet contract outside companies for the harvest stage, this has not occurred. Ordered logit is the appropriate model for choice options greater than two when the choices have an ordinal nature. In this case, the increasing levels of vertical integration from selling timber to selling finished wood products has a progressive characteristic. The multinomial logit would lose this information, making it an inferior choice of models.

The regression model is based on a linear probability model:

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

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

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

The ordered logit regression can be conducted with different techniques, such as the proportional odds version and the stereotype version (StataCorp 1997). The version used here is the proportional odds model (POM), which includes an assumption that the slope coefficients are equal across groups (McCullagh 1980). The result is that three cut points will be estimated but the coefficient parameters in β will be the same. This implicit assumption is tested below.

Regression Results

The regression results are displayed in Table 6. The first regression is the model with only the base term for forested hectares. The second regression adds the squared term but drops quality of the forest variable to determine the effects on past timber marketization, while the third regression is the full model.

In all three regressions, initial physical infrastructure is not significant. The lack of significance in the models could be due to opposing effects. More logging roads in place reduce the need for new specific investments by outside firms, encouraging subcontracting. Competing forces are that the initial infrastructure lowers start-up costs for the community or expose it to hold-up risk. The lack of significance could also indicate that contracts adequately address investments in roads so that the existing infrastructure characteristics do not affect ownership patterns.

Across all regressions, mechanical training is positive and significant above the 5% level, supporting the hypothesis that integration increases as human capital skills increase in the community. 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.

Past nontimber marketization does not have strong explanatory power in the first and third regression, but is positive and significant at the 5% level in the second regression where quality of the forest is dropped. The positive coefficient supports the hypothesis that nonseparability between timber and nontimber production encourages local communities to control production. Its weak explanatory power in the other two regressions may be because nontimber market activity substitutes for timber activity in the less integrated communities while it complements community forest investments or poses interaction costs in integrated communities. Its increased significance when quality of the forest is dropped indicates that these two variables are picking up a similar effect, perhaps related to available markets and value associated with higher quality forests. Although the measure for past forest quality refers to commercial timber, some quality factors, like soil and climate conditions, favorable to industrial forestry may overlap with conditions favorable to nontimber products.

The historical effect of parastatal leasing is positive and significant at the 5% level across all three regressions. Given these findings, the analysis points towards the social capital hypothesis, the claim that the historical experience of forests leased to parastatal firms bonded communities against a common enemy. The experience also led to a cultural shift regarding forestry, from one that accessed the forest for subsistence needs to long-term industrial operations.

The number of forested hectares has a significant (at the 5% level) and positive effect with only the base term in the model. Hart (1995) (p. 37) notes that on the margin, more assets, here represented as more stock in the same good and across goods, shifts a person's productivity outward to the point where integration becomes more efficient than nonintegration. Positive externalities of stock size could also be that community organizations economize on supervision costs with larger forests or that larger forests provide greater risk diversification opportunities and, therefore, are more important to control.

Another implication of larger forests is that it poses the opportunity to harvest over longer time horizons. With this in mind, local community members may foresee the need to renegotiate with outside private firms if they choose to subcontract production activities. Cumulative bargaining costs over time could rise to where forward integration is feasible.

Fixed costs of timber processing is yet another interpretation consistent with the data. Many of the stumpage communities have a shorter timber history and have not logged every year since beginning timber operations. A large jump in average forest size occurs between the lumber and finished products categories. About a third of the finished products communities buy additional timber from other communities, some on a regular basis, indicating a high demand for raw material. Integration beyond a certain point may require a discontinuous jump in minimum forest size required to maintain operations. One crane and a small fleet of trucks may be sufficient to cover timber operations from roundwood to lumber sales, but moving to finished products may require additional machinery. These "lumpy" investments can represent a discrete jump in production costs despite scale economies.

Adding the squared term reverses the sign of the base term. The squared term is positive, suggesting that additional hectares of forested land have increasingly larger positive effects on the propensity to integrate. However, the terms are not significant at the 10% level. Looking at the average number of hectares by group, there is an even rise of about 2400 hectares between the stumpage and roundwood and the roundwood and lumber communities. A large increase occurs between the lumber and the finished product communities after this gradual rise. The communities in the roundwood and lumber categories have approximately 5000 and 7500 average hectares of forest, respectively. Finished product communities have 11,000 forested hectares on average. The distinction in timber operations is also clear in the sawmill capacity. The sawmills of the lumber communities had capacities that ranged from 2.5 to 11 thousand board feet per day with an average of seven compared to a range of four to 20 thousand board feet per day with an average of ten for the finished wood products communities. Therefore, communities with forests in the five to seven thousand hectares range are candidates for vertical integration, although for smaller capacity sawmills.

Commercial quality of the forest in 1940 has a positive and significant effect in all three base models, so that commercial potential is clear indicator for the propensity to integrate. Initial quality has the effect of reducing the significance of the nontimber marketization variable. This is because quality of the forest is most likely associated with greater product value which leads to market opportunities, providing additional reasons to integrate vertically.

Tests

Likelihood ratio tests of the regressions in Table 6 against a model with only a constant reject the null hypothesis at a very significant ratio. Each of the χ^2 test statistics has significance at greater than the 1% level. For Regression (3), the χ^2 statistics for testing singly whether the coefficients are significantly different from zero are also significant at the 5% level for mechanical training, parastatal leasing, and quality of the forest. Past nontimber marketization is significant at the 11% level. The coefficients for forested hectares are not significantly different from zero at the 20% level. The hypothesis that the three cut points are equal to zero cannot be rejected at the 10% level, and all three cut points are significantly different from each other at the 1% level. Tested jointly, the hypothesis that all coefficients, including those of the cut points, are zero is rejected at the 1% level.

With the ordered logit regression model, marginal effects refer to changes in probability of being in each category as a variable changes by one unit. This change can be calculated by taking the partial derivative of the probabilities with respect to that independent variable. Table 7 displays the marginal effects calculated in this manner for the continuous variables. The marginal effects for forested hectares account for both base and squared terms in Regression (3) in Table 6. Past mechanical training and forest quality have limited ranges (zero to one for mechanical training and one to five for forest quality), but are also treated as continuous variables in calculating marginal effects. Marginal effects for binary variables are calculated with different methods (Greene 2000) and are shown in Table 8. The same calculations as above are done twice, once with the explanatory variable set to zero, then with the variable set to one, all else constant. The difference between the two probabilities is the marginal effect. All marginal effects are averages of the marginal effects for individual observations.

The two largest marginal effects are for mechanical training and parastatal experience. A unit change in either of these variables decreases a community's chance of selling stumpage by over 30 percentage points, and increases the chances of selling finished products by 20 percentage points or more. In addition, both variables show increasing positive tendencies for each progressive phase in the wood products transformation process, and each have their strongest effects at the two extremes of the spectrum included in this sample. Therefore, these variables have the most significant impacts on predicting level of integration. A χ^2 of mechanical training and vertical integration is significant at the 5% level. None of the stumpage communities had a score as high as the more integrated communities. However, four roundwood communities had scores as high as the lumber and finished products groups. Therefore, other factors explain why they have not integrated into sawmilling despite their range of mechanical skills.

The next strongest impact is that of initial forest quality, where higher initial quality increased the probability of vertical integration. Past nontimber product marketization encourages forward integration, albeit at lower rates. The negative percentage change on the probability of being a stumpage community, and the positive change in the sawmill categories suggest that this variable encourages diversification and investment in industrial forestry.

An increase in number of forested hectares tends towards further integration despite the low explanatory power in Regression (3). Accounting for the logarithmic scale, a one percent change in forested hectares decreases the chances of being a stumpage community by over 7%, whereas the chances of being a finished products community increases by 7%.

Consistent with the regression results, the marginal effects for logging roads are small. In addition, logging roads has a surprisingly perverse effect on forward integration, as it increases the chances of selling stumpage and decreases the chances of processing the raw material.

The small marginal effect and lack of explanatory power for the physical infrastructure indicator is some-what puzzling. In addition, a χ^2 test of initial physical capital and vertical integration is significant at only the 12% level, and its correlation with vertical integration is weak ($\rho = 0.37$). One finished products community had had no initial network of logging roads, while some of the stumpage and roundwood communities have just as much initial infrastructure as the sawmill communities. Therefore, the stumpage and roundwood communities choose not to fully integrate forward for other reasons. In adding independent variables one at a time, initial logging roads loses substantial significance when parastatal existence and forested hectares are added. However, the stumpage contract frequently calls for the private harvester to make investments in the community. Such investments may act as a "hostage." The firm makes specific investments that raise its risks of hold-up while the community risks breaches of contract as the firm extracts its timber. Mutual "hostage-taking" could be a form of protection against hold-up. However, the hostage-taking investment is in public goods and not industrial forestry development. If development were equated with investments in timber operations, having less roads would lead to more subcontracting. Yet the measure is insignificant. Consensus over public goods investments may be easier to reach than new timber investments which require more community-level commitment to timber production.

Whether mutual-hostage taking is an efficient or wise strategy can be considered in terms of trade. For example, the prices which the communities receive on average for roundwood, by increasing levels of vertical integration, are 148, 350, 438 and 448 pesos per cubic meter. The contractors with stumpage communities invest more physical capital in stumpage and roundwood communities, perhaps rationalizing lower payments. However, the range of prices among the stumpage group is the widest, with a minimum of 45 pesos per cubic meter to a maximum of 275 pesos per cubic meter. The roundwood and lumber groups each have one community receiving a low price for roundwood (less than 50 pesos per cubic meter) compared to the four stumpage communities receiving less than 100 pesos per cubic meter. Whether these communities are receiving a "fair deal" could be further explored.

McFadden et al. (1977), as cited by Maddala (1983) (p. 76), recommends a table comparing predicted versus observed choices as a goodness of fit measure for grouped data models. Table 3 displays the observed versus predicted choices in each category. The model correctly predicts stumpage, roundwood and finished wood products relatively more often than lumber status. The suggested overall prediction success index is:

$$\sigma = \sum_{i=1}^{4} \left[\frac{N_{ii}}{N_{..}} - (\frac{N_{.i}}{N_{..}})^2 \right]$$

which takes a maximum value of:

$$1 - \sum_{i=1}^{4} \left(\frac{N_{.i}}{N_{..}} \right)^2$$

where N_{ij} refers to the number of observations which choose alternative i but were predicted to chose alternative j, and $N_{..}$ refers to the number of correct predictions for alternative i. Taking the value of σ which is 0.39, and dividing by its maximum value which is 0.71, the index performs at 55% of its maximum value. A second measure is the number of correctly predicted observations divided by the sample size. This measure gives the model a 67% success rate (Maddala 1983).

Table 3: Prediction Table

	Predicted Choice				
	S.	R.W.	L.	F.W.P.	Observed Count
Observed Choice					
Stumpage	13	3	0	0	16
Roundwood	2	8	2	0	12
Lumber	0	3	3	2	8
Finished Products	0	1	1	5	7
Predicted Count	15	15	6	7	43

The proportional odds model assumption of equal slopes across groups is compared with the generalized ordered model that allows slope coefficients to vary and then tested. The comparison and tests provide information on the degree to which the POM assumption holds in this model. A likelihood ratio test for differences in the restricted and unrestricted models does not reject the null hypothesis that the slope coefficients are equal (χ^2_{14} = 17.75, Pr.=0.22). It is reasonable to assume that the slope coefficients are equal across categories.

Alternative Explanations Table 9 considers alternative explanations for the observed pattern of ownership. In the first regression, distance to the capital of Oaxaca is positive but not significant. Distance to the client is also positive but not significant. It does, however, reduce the significance of quality of forest in the past to the 10% level and drastically increases the coefficient value and significance level of forested hectares. It is interesting that the lumber communities have the closest proximity to clients on average. The more remote stumpage and roundwood communities may not fully integrate because of risks of specialization. The finished products communities may be able to compete in terms of economies of scale, reputation and quality to compensate for transportation disadvantages. Coffee production, while associated with smaller forests ($\rho = -0.53$) and greater distance from Oaxaca ($\rho = 0.51$), does not have explanatory power nor significantly alter the regression results. Finally, a regression including parcelization has an insignificant statistic. Neither does it significantly change parameter values of the model.

6.2 Investment in Nontimber Benefits

Hypothesis 6 stated that vertical integration in communities leads to more investment in nontimber activities due to scope economies. Therefore, vertical integration would be an independent variable in the next regression to explain new nontimber investments across communities.

Community authorities were asked a series of questions that targeted potential investments to protect or promote nontimber products, endangered species, wildlife or the forest in general. Interviewees were asked whether 1) the management plan delimits an area of conservation in the managed forest area, 2) foresters are paid to carry out projects or training on conservation, 3) the community forestry organization pays patrols to monitor non-commercial timber products and services, 4) the community members participate in projects for the protection of flora and fauna, and 5) the community participates in projects for the production of nontimber projects. The indicators do not capture the knowledge gained in timber activities but research in areas of nontimber forest products for commercial and scientific ends. The measures of nontimber investments refer mostly to recent investments which occurred in 1992-7, while most integration decisions were taken between 1978 and 1994. Two sample communities that began timber production since 1994 mentioned only the general moratorium law on hunting deer applicable since 1995 in Mexico as the complementarity between timber and nontimber planning. This factor is given less weight in the econometric analysis that follows.

Logically speaking, while the ability to invest in nontimber activities makes vertical integration more attractive to a community, the community would probably not vertically integrate for these gains absent other motivating factors. The new nontimber activities included in the indicators require overhead, like roads, management plans, and technical assistance which communities would not be able to afford without timber income. Larger cash flow can be directed towards new but related investments. Diversification employs underutilized productive capacity of the local population which has fixed, nontransferable forest stock and a distribution of education and skills.

To substantiate these claims, econometric techniques are employed. A common method to correct for endogeneity includes the instrumental variables technique where alternative variables supposedly uncorrelated with the dependent variable but correlated with the independent variable in question proxy for the independent variable. Complementary nontimber investments are factored using the principal factor method and scored to create the dependent variable for investment in nontimber benefits. Factor loadings are shown in Table 4. Complementary nontimber investments has explanatory power at the 5% level when added to Regression (3) in Table 6 as an independent variable. If vertical integration is endogenous to the model, vertical integration would be correlated with the error term. This results in a bias in the coefficient estimates and an asymptotic bias as well.

In the regression model of complementary investments, the independent theory variable is vertical integration. The control variables are firm size and high ratings of biodiversity. The regression model to be estimated is:

Complementary investments in nontimber activities = f(vertical integration level (+), firm size (+), high biodiversity (+))

Firm Size Models of technical innovation, investment or applied research include a firm size variable, such as number of employees, total asset value or total sales revenue (Armour and Teece 1980, Cavanaugh 1998, Chen 1996). Each should theoretically be a substitute for the other. The number of persons employed by

Table 4: Factor Loadings: Nontimber Investments

Principal Factors, 3 factors retained, Observations=42				
Factor	Eigenvalue	Difference	Proportion	Cumulative
1	2.16302	2.04803	1.0778	1.0778
2	0.11499	0.09630	0.0573	1.1351
3	0.01870	0.09011	0.0093	1.1444
4	-0.07142	0.14705	-0.0356	1.1089
5	-0.21846	.	-0.1089	1.0000
Loadings				
Variable	1	2	3	Uniqueness
Conservation	0.79895	-0.19502	0.00960	0.32356
Programs	0.84234	0.05033	0.03367	0.28680
Patrols	0.61856	-0.06401	-0.08817	0.60551
Protection	0.43028	0.05595	0.08978	0.80367
Production	0.49741	0.25922	-0.04046	0.68375

the extraction and transformation processes is the measure for firm size. Firm size should positively affect investments in nontimber benefits because of greater possibilities for organizational and informational scope economies.

Biodiversity Higher levels of biodiversity within a forest are expected to expand the range of investment in nontimber benefits. Biological diversity is likely to increase the range of forest products harvested. The definition and understanding of biodiversity can vary widely. To reduce ambiguity, only the percentage of hectares categorized in the highest level of biodiversity is used as a proxy.

Summary Statistics

Summary statistics are listed in Table 5. For firm size, the stumpage communities have a distinctly smaller average number of workers. The average is significantly different than the averages in all three other categories at the 6% level or above. Smaller operations may be due to smaller forests found in the stumpage group. However, despite differences in number of forested hectares, firm size was not significantly different among the top three integrated community groups due to the large spread of firm sizes within each category. For the biodiversity measure, the lumber group stands out as the overall lowest average. In seven out of the eight lumber communities, the forester ranked zero hectares as high biodiversity areas. The two extreme groups, stumpage and finished wood products, have the highest average. The averages for the stumpage and finished wood products groups are significantly different from the lumber group at the 10% and 1% level, respectively, while the roundwood group has an average significantly different from the finished wood products group at the 10% level. The average scores for nontimber investments is a consistently increasing measure going from the stumpage to the finished products groups. All pairwise and joint average comparisons of this measure were significantly different at the 5% level, except for the pairwise comparison of stumpage and roundwood, and roundwood and lumber groups.

Table 5: Summary Statistics, $n = 43$

Variable by group	Mean	Standard Error	Number of observations
Size of labor force			
Stumpage	30.8125	3.793557	16
Roundwood	70.08333	20.19465	12
Lumber	73.125	18.52604	8
Finished wood products	111.1429	26.30804	7
High biodiversity (% forested ha)			
Stumpage	16.875	8.082542	16
Roundwood	13.07692	7.733206	13
Lumber	2.5	2.365572	8
Finished wood products	35.71429	12.90215	7
Nontimber investments			
Stumpage	-0.50	.1122	16
Roundwood	-0.17	.1912	11*
Lumber	0.19	.3232	8
Finished wood products	1.21	.3208	7

* One observation missing.

OLS Regression Results

The first column in Table 10. is the ordinary least squares (OLS) regression of nontimber investments. Vertical integration and biodiversity are positive and significant at the 5% levels, supporting the hypothesis of complementarities in production. Firm size has no explanatory value at the 10% level.

Instrumental Variables Regression Results

Regression (2) of Table 10 is the instrumental variables version, where the instruments are past mechanical training, history of parastatal leasing, forested hectares (logarithmic), past nontimber marketization, and quality of the forest in 1940. The instrumental variables (IV) approach returns coefficient estimates, signs, standard errors and a R^2 statistic similar to the OLS regression.

Tests

Several statistics indicate that vertical integration is exogenous to complementary nontimber investments, leading to consistent estimates. First, the t-statistic for vertical integration decreases only slightly in magnitude and remains significant at the 5% level. The statistic for the Hausman test (Greene 2000) (p.385) is 0.21 with 1 degree of freedom, meaning that the null hypothesis that the OLS and the IV estimators are both consistent cannot be rejected. Further, the correlation between vertical integration and the error terms is zero.

7 Conclusion

This study adapts contract theory to explain vertical integration in the Mexican industrial forestry sector where forests are common property and decision-makers are community members and outside private firms. The central question is why do Mexico's agrarian communities integrate into industrial forestry, when hiring-in private contractors should be a perfectly substitutable choice? Greater endowments of human and physical capital for timber production does not explain why communities rather than private firms should extract and process timber because the private firm could always hire local labor and contract to use local resources.

The empirical section introduces two models, one of vertical integration and one of investments in non-timber activities. For the model of vertical integration, empirical results are consistent with an incomplete contracts interpretation that communities integrate forward to avoid contractual hazards with outside private firms. Specifically:

- *Human capital expertise* Communities gained from having prior job experience. With a unit change in the measure for initial mechanical skills, communities are 42% less likely to sell stumpage and 22% more likely to sell finished products. This suggests in the past, the logging firms operating in Oaxaca prior to 1986 created a positive externality for the community by raising the level of skills. The firms did not necessarily gain from creating this externality, so this is a possible area for government programs.

- *Social capital* Historical events of leasing to parastatal firms lowered the costs of organization for two reasons – motivating the communities to form alliances between communities as well as among themselves against a perceived common enemy and exposing local populations to industrial forestry as a consistent, long-term economic venture. Today, the technical foresters are one source of building social cohesiveness around the idea of managing the forest, either for timber production or nontimber benefits. One may speculate whether training programs and appropriate outreach activities could lower communities' costs of organization.

- *Physical infrastructure* The evidence mildly supports the Williamsonian prediction that less required specific investments would facilitate subcontracting. The insignificant coefficient and low marginal effects on the physical capital endowment measure suggests that these physical investments are contractible and therefore not relevant to the analysis. Transaction costs are not necessarily lowered by existing capital infrastructure but by training in basic skills. However, whether communities are trading access to raw material for development funds should be explored further. Stumpage communities may be giving up "too much" for access to scarce funds.

- *Uncertainty of non-commercial timber benefits* The hypothesis that a history of non-commercial timber market activity raises the community's value of controlling access to the forest resource had mixed support. Non-commercial timber sales in the past has explanatory value at the 5% level in one model, suggesting causality. However, this effect drops in significance when forest quality is added to the model, possibly because commercial forest quality captures similar effects.

- *Labor-capital complementarities* Forest quality and size, both considered as stock variables, exhibit scale economies that favor community integration. But to explain why community integration rather than continual contracting between a community and a private harvesting firm is favored, it is argued that complementarities between the asset and community labor and management exist, perhaps through monitoring and supervision advantages. A policy question is why communities with smaller forests do not pool production activities with other communities more than is observed. Local decision-makers' preferences for autonomy and avoid bargaining costs, even from other agrarian communities, may be a reason.

- *Alternative explanations* The empirical analysis provided evidence that selection bias does not exist between the parastatal leasing history and distance to the capital city or quality of the forest. Integration occurs despite differences in distance and coffee production, which have no explanatory value as control variables for opportunity costs and comparative advantage. Neither did the parastatal contribute significantly to mechanical training. A tendency towards internal conflicts as proxied by parcelized forests does not explain vertical integration.

- *Transition into timber extraction* Stumpage communities are qualitatively and quantitatively different that other categories of communities in that they do not represent where the integrated communities were 20 years ago. The explanatory variables in the empirical analysis had their largest marginal effect most often in the stumpage category, especially for the initial mechanical training and historical leasing variables, emphasizing the difference in this category's basic characteristics. Policies directed at forest management should take these differences into account. For timber production, policies such as more efficient partnerships with outside private firms, multiyear contracts that reduce hold-up risk and government intervention could be considered.

Results of the second empirical model also supports the argument that integrated communities diversify their uses of the forest in timber and nontimber production because they can benefit from economies of scope:

- *Economies of scope* Vertical integration positively and significantly explains recent investments in nontimber activities which include the protection, conservation and production of nontimber goods and services. The reasoning is that communities can exploit economies of scope between timber and nontimber production better than outside private firms. Synergies between the two production processes, possibly through monitoring, management plan and administrative overlaps as well as knowledge of the forest gained through integrating forward, provide the scope opportunities. Private firms were not observed to engage in nontimber production. If they did, they would compete with the scope economies available to communities, assuming that forests remain community property.

- *Exogeneity of vertical integration* For investments in nontimber production and ecosystem services, the main relationship is in the direction of vertical integration to nontimber investments. The instrumental variable regression results, Hausman tests and near-zero correlation of residuals with vertical integration, point towards the consistency of the ordinary least squares and instrumental variables estimators, meaning that vertical integration is exogenous to recent nontimber investments.

The positive impact of vertical integration on recent nontimber investment and production bodes well for adopting ecosystem management approaches in self-governing systems. Several government programs are focusing on nontimber benefits of forest resources. The impetus in this direction may make it more likely that communities will forward integrate contemplating not just the production of timber but also nontimber production. As programs diffuse information and finance projects concerning forest projects, we may begin to see greater use of the complementarities between timber and nontimber production by community forestry enterprises and innovative approaches to industrial community organization.

The contribution to common property theory is indirect. The analysis predicts and tests under what conditions individual community members will collectively produce wood products using common property forests, implying the creation of self-governance structures. The economic role of common property management is always affected by the social and cultural context in which it is embedded. For example, *comunidades* and *ejidos* emphasize the contribution of common forest land to community development. The incomplete contract approach offers a theory for assessing when and how asset ownership enhances efficiency. In thinking about property rights as a bundle of rights, we should consider which benefits are provided through market mechanisms and which are not. This distinction has implications for land reform policies that change the access to resources for local populations. For community forestry, this approach has potential to expand and transform the idea of property, from a commodity which is assumed to be tradeable in the marketplace to an asset whose use is constantly renegotiated over time.

The research extends the applicability of the theory of the firm literature to natural resource management. Unlike the theory of the firm, however, it accounts for the organizational and human capital constraints and historical realities surrounding asset ownership and use patterns.

This paper suggested numerous avenues for future research. One extension would be to allow forest land to be traded to facilitate comparisons in other parts of the world. However, it is unclear how land markets would change the results. The factors under which a community was shown to integrate forward with higher probability may also apply with land markets, i.e. stumpage communities face substantial fixed costs of integration and may choose to sell land whereas communities with other characteristics would hold the land and make investments.

The research leaves open the question of management performance. While parcelization which is associated with internal conflicts, it does not explain vertical integration as an independent variable in the empirical analysis. Local governance could be further explored in terms of why conflicts arise and how they are solved. Multi-person bargaining games could provide insights, although the broader community characteristics as identified in this paper should not be ignored. Performance indicators such as profitability, forest management effectiveness and integrity of the ecosystem could be developed. A recurring theme in discussions with community authorities is if community forestry is a third way, beyond private or public ownership. The evolution of many forestry communities, from receiving only a stumpage fee dictated to them, to productive organizations has been a spectacular transformation. Yet, community members themselves grapple with how to maintain competitiveness in the marketplace and maintain community structure. The answer may lie in novel approaches to management and interaction with community members. The forests in these communities are an important source of income and well-being, so assured access may remain a priority for the foreseeable future.

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A Proofs

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

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

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

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

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

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

Comparing the FOCs for i_H under nonintegration and integration, note that the default payoff under nonintegration for a harvest manager stays the same even as the timber stock increases, although the benefit function in the trade situation, $B_M(\cdot)$ increases. Since the function $B_M(\cdot)$ is strictly concave, then by the property of real-numbers [7] as T increases, T will reach a point where $\alpha B_M'(i_H) > \frac{1}{2}(B_M'(i_H) + b_M'(i_M; H))$ for any given i_M. So for the FOCs to hold and by conditions 2 and 3, i_M under integration is greater than under nonintegration. QED.

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

B Regression Results

Table 6: Ordered Logit Regressions: Vertical Integration

Independent Variable	(1)	(2)	(3)
Theory:			
Initial Roads	-0.33	0.12	-0.21
	(-0.98)	(-0.41)	(-0.62)
Initial Mechanical Training	3.82**	4.08**	4.05**
	(2.71)	(2.98)	(2.82)
Past Nontimber Marketization	1.89	1.65**	1.35
	(1.42)	(2.04)	(1.58)
Parastatal Existence	3.52**	3.06**	3.38**
	(3.86)	(3.71)	(3.73)
Forested Hectares (logarithmic)	0.91**	-6.56	-5.23
	(2.32)	(-1.45)	(-1.08)
Forested Hectares (logarithmic), squared		0.47	0.39
		(1.64)	(1.27)
1940 Forest Quality	2.01**		1.89**
	(2.59)		(2.41)
cut 1	16.52	-19.51	-7.32
Standard error	4.57	17.54	18.91
cut 2	19.33	-16.99	-4.5
Standard error	4.86	17.52	18.94
cut 3	21.54	-14.85	-2.13
Standard error	5.12	17.41	18.86
Number of Observations:	43	43	43
LR chi-squared	48.16	42.86	49.75
d.f	6	6	7
Prob. $> \chi^2$	0.00	0.00	0.00
Pseudo R-squared	0.42	0.37	0.43
Log Likelihood	-33.22	-35.86	-32.42

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

Table 7: Marginal Effects of One Unit Change

Independent Variable	$\frac{\partial P(y=1)}{\partial x}$	$\frac{\partial P(y=2)}{\partial x}$	$\frac{\partial P(y=3)}{\partial x}$	$\frac{\partial P(y=4)}{\partial x}$
Initial mechanical training	-0.42	0.04	0.17	0.22
Initial logging roads (logarithmic)	0.02	-0.00	-0.01	-0.01
Forested hectares (logarithmic)	-0.07	-0.04	0.04	0.07
Quality of forest, 1940	-0.20	0.02	0.08	0.10

NOTES: Marginal effects are calculated from Regression 3 in Table 6 for each observation, holding all else constant.

Table 8: Marginal Effects for Binary Variables (probabilities in percentage points)

Independent Variable				
Parastatal leasing =0	53	30	12	5
Parastatal leasing =1	15	31	29	26
Change	-38	1	17	20
Nontimber marketization=0	42	28	17	13
Nontimber marketization=1	29	28	22	22
Change	-13	0	5	8

NOTES: Marginal effects calculated from Regression 3 in Table 6 for each observation, then averaged.

Table 9: Alternative Theories: Vertical Integration

Independent Variable				
Theory:	(1)	(2)	(3)	(4)
Initial Roads	-0.25	-0.01	-0.26	-0.18
	(-0.70)	(-0.02)	(-0.72)	(-0.54)
Initial Mechanical Training	4.43**	5.50**	4.16**	4.04**
	(2.76)	(2.89)	(2.83)	(2.83)
Past Nontimber Marketization	1.53*	0.48	1.54	1.52
	(1.67)	(0.44)	(1.61)	(1.72)
Parastatal Existence	3.66**	2.81**	3.60**	3.06**
	(3.49)	(2.93)	(3.44)	(3.32)
Forested Hectares	-5.42	-22.80**	-5.00	-4.32
(logs)	(-1.11)	(-2.35)	(-1.03)	(-0.87)
Forested Hectares	0.41	1.47**	0.38	0.33
(logs, squared)	(1.31)	(2.46)	(1.25)	(1.07)
1940 Forest Quality	1.92**	1.65*	1.87**	2.10**
	(2.46)	(1.84)	(2.38)	(2.56)
Controls:				
Driving Hours from Oaxaca	0.08			
	(0.58)			
Transport Time to Client		0.001		
		(0.02)		
Coffee			0.50	
			(0.50)	
Parceled Forest				1.44
				(1.18)
cut 1	-6.97	-78.66	-5.53	-1.62
Standard error	19.11	38.81	19.25	19.86
cut 2	-4.14	-74.30	-2.71	1.21
Standard error	19.15	38.25	19.29	19.88
cut 3	-1.71	-71.75	-0.32	3.68
Standard error	19.07	38.03	19.22	19.81
Number of Observations:	43	35	43	43
LR chi-squared	50.07	48.48	49.97	51.26
Degrees of Freedom	8	8	8	8
Prob. > χ^2	0.00	0.00	0.00	0.00
Pseudo R-squared	0.44	0.52	0.45	0.45
Log Likelihood	-32.26	-22.50	-32.31	-31.66

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

Table 10: OLS and Instrumental Variables Regressions: Occurrence of Nontimber Investment

	OLS	IV
Independent Variable	(1)	(2)
Vertical integration	0.42**	0.46**
	(3.93)	(3.33)
Percent of forest with high biodiversity	0.01**	0.01**
	(2.03)	(1.97)
Firm size	0.003	0.003
	(1.54)	(1.28)
Constant	-1.20**	-1.27**
	(-5.22)	(-4.73)
Number of observations	42	42
R-squared	0.49	0.49
Adjusted R-squared	0.45	0.45

NOTES: Numbers in parentheses are z statistics. "**" denotes statistical significance at the 5% level and "*" at the 10% level. Instruments are: past mechanical training, history of parastatal leasing, forested hectares (logarithmic), past timber marketization and quality of the forest in 1940.