Vertical Integration in Mexican Common Property Forests[1]

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Abstract

One of the missing links in common property research has been the interaction between common property resource users and the market. The present research fills that gap with a study of Mexico's agrarian communities which coordinate timber production within their commonly-owned forest land. The key research questions are whether a local community expands into downstream timber extraction and processing or contract with outside firms for production depending on uncertainties in production, and does the pattern of organization promote complementary investments in timber and nontimber production?

The property rights approach in contract theory and the common property literature form the basis of the analytic framework. A survey was administered to a random sample of 42 communities in Oaxaca, a state in southern Mexico with large expanses of pine-oak forests. The communities fall into four main categories indicating their level of ownership and control over the production process from standing timber to finished wood products --- communities which contract with private companies who pay the community to harvest standing timber, communities which harvest the timber themselves and sell roundwood, and communities which harvest the timber and transform it into lumber or other wood products. The level of vertical integration serves as the dependent variable in an ordered logit regression on theory and control variables. The model is extended to determine the impact of vertical integration on nontimber investments, empirically tested with instrumental variables regression methods. Empirical results provide evidence that communities opt to integrate forward when fixed costs of organization are lowered to control timber and nontimber production and possibly guide economic development within the community. In contrast to the transaction cost literature, outside firms are willing to make specific investments in return for access to timber resources. As predicted, vertical integration leads to greater investments in nontimber benefits. JEL Classification: D23, L22, L73, O13, Q23

Introduction

The goal of this research is to examine how multiple-use of forest ecosystems and risk diversification affect common property management in rural forest communities. Ownership rights are one means to address uncertainties when contracts cannot be written for all contingencies. Ecosystem management research has revealed the need for adaptive management plans that change as knowledge of the ecosystem changes. Local communities that recognize the continual need to update management plans may seek greater control over forest resources. From an economic perspective, common property plays a role in risk diversification strategies, especially in developing areas characterized by missing markets for labor and capital (Morduch (1995), Jodha (1992)). In addition, thin markets for development resources for infrastructure and public goods may simultaneously exist. Assured access to common property may be important for achieving socially optimal allocation of resources. Little research has explored how control and management over common property resources can be a response to uncertainties both in the market and the ecosystem (McKean (1997)).

Ownership and control to manage uncertainty has substantial support in the economics literature. In particular, transaction cost economics and the property rights approach focus on whether the allocation of property rights improves economic outcomes in uncertain and complex environments. Properly assigning ownership rights depending on the characteristics of the market, production technology, investments, or importance of hard-to-define qualities related to production brings investments closer to socially optimal levels.

The fieldwork sites for this research are Mexico's *comunidades* which have historically held forest land as common property since pre-Hispanic times. Due to changes in forestry law in 1986, these agrarian communities have evolved in the last ten years from selling stumpage to outside private firms to participating in the industrial forest sector of Mexico as producers of raw material and finished products. This transformation presents the possibility of a natural experiment. The modeling framework places communities vis a vis the market for forest products. Ownership of harvesting equipment and sawmills varies between local communities and private firms in industrial forestry. 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 the extraction and processing? Using a property rights framework, this paper proposes that communities with common property forest land integrate forward in the forest products sector to manage the forest as an ecosystem and lower economic risk. This approach sheds light on several key questions. How do uncertainties in timber production affect community organization when they have the opportunity to control production? Are the uncertainties of such a degree that the communities choose to integrate, or can they be managed through contractual relations in the open market with outside private firms? With the forest as a source of many nontimber uses, how are the nontimber benefits managed? Does the presence of nontimber benefits affect community control and ownership of timber operations? Better information on how management must be combined or separated for all uses of the forest can help to construct policy to support sound resource management and economic growth.

The first hypothesis tests the transaction cost prediction that the level of asset specificity, as measured by level of logging road infrastructure, discourages market transactions. The second hypothesis claims that as communities become more capable of managing timber operations on their own, as measured by initial "stock" of skills in the timber industry, the more the community members will support forward integration. The analysis tests if the incidence of markets in non-commercial timber goods raises the probability of forward integration by local communities. A fourth hypothesis explores the impact of historical parastatal leasing in Mexico on the fixed costs of organization. Finally, the argument is made that vertical integration leads to greater investments in nontimber benefits because of knowledge spillovers in timber and nontimber production. Ordered logit regression techniques test the model of vertical integration. Ordinary least squares and instrumental variables statistically assess the impact of vertical integration on nontimber investments. Results support the basic hypotheses that the presence of initial human capital stock, nontimber market activity and parastatal history raise the likelihood of community integration into the timber industry. In turn, vertical integration positively affects levels of new investments in nontimber forest benefits and services due to the complementarities between timber and nontimber production which communities are well-positioned to exploit.

The paper is organized as follows. The literature review in Section Two briefly discusses theory on collective action, contracts, transaction cost economics and political economy relevant to common property studies to lay the groundwork for the model. Section Three describes the fieldwork, including sample and survey design. The survey data is presented as part of the background of community forestry in Mexico, a sector that has received increasing attention from the development and environmental communities in recent years. Section Four proposes a modeling framework. The empirical section in Section Five describes the variables used for estimating vertical integration and nontimber investments. Section Six discusses results of the ordered logit regression of vertical integration and the instrumental variables method of regression for nontimber investments. The final Section concludes the paper.

Theory

Literature

The distinct branches of economics, political science, sociology and ecology inform the present research. The common thread lies in explaining the importance of access and control of resources and the corresponding management regimes. This section discusses the key concepts in each branch relevant to the present research.

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)). Complete, comprehensive contracts are infinitely costly to write. Buyers and sellers in a trade agreement subject themselves to the risk of opportunistic behavior by the other party under certain conditions. For example, if haggling ensues once the two parties have sunk investments, one side might bargain away the gains from trade from the other party, knowing that the person would get less value elsewhere. Each side foresees this possibility and invests at levels other than first-best. Vertical integration which brings the exchange "in-house" theoretically reduces this risk, otherwise known as hold-up risk. The central claim of property rights theory is that the inability to commit and not renegotiate a contract or the inability to specify a trade completely introduces inefficiencies such as the hold-up problem An appropriate allocation of property rights may ameliorate these inefficiencies (Hart and Moore (1999)).[2] Ownership gives the owner the residual rights of control, i.e. the right to make asset-related decisions not specified in the contract.[3] The question then becomes who should own which assets of production? The answer depends on the nature of the assets and each party's investment (Hart (1995), Grossman and Hart (1986).

In turn, the theory of the firm argues that vertical integration has positive effects on technological expansion in related areas due to interdependencies between different production activities, leading to greater expected value in research and development, technical innovation and investment (Armour and Teece (1980), Chen (1996), Cavanaugh (1998)). Knowledge gained in one area of production spills over in technologically related areas, and managers in different areas of production can coordinate their efforts and objectives (Armour and Teece (1980)).

Forests as common property contribute to food supply, income generation and income-risk diversification, employment, aesthetic value, soil and watershed quality, biodiversity, carbon sequestration and preservation of cultural heritage (Nugent and Sanchez (1998), Wilson (1993), Breckenridge (1992)). Common property research in the last twenty years has shown that long-standing rules or management systems among local populations can support these benefits (McCay and Acheson (1987)). Economic development which ignores the management systems operating within communities may lead to ecological and environmental damages (Jodha (1992)). Ostrom (1990) contrasts the presence of local management regimes with political theory which focuses on a central authority or privatization as the only means to manage common property. Political theory, she claims, does not explain why local stakeholders create management systems, monitor each other, and give credible commitments to cooperate with each other at future times, which recurrent interaction, trust relationships and reciprocity among groups of individuals partly explain (Seabright (1990), Wade (1994)).

The emerging science of ecosystem management has drawn attention to community-based management as a policy option. Ecosystem management has as its dominant themes the connectiveness of genes, species, population, ecosystems and landscapes, the embeddedness of humans in ecosystems, and management as a learning process (Grumbine (1994)). Ecologists call for incorporating adaptability into the management process to keep open future options as information is gathered and hypotheses are tested (Swanson and Franklin (1991)). The literature notes the fundamental incompatibility of political or property boundaries that do not coincide with ecosystem boundaries (Grumbine (1994)). Given ecosystem management objectives, separate owners and managers may have difficulty coordinating different production activities. If locally managed common property regimes have an advantage in addressing ecosystems as a whole, then they are potentially viable management solutions (Fairfax et al. (1999), Duane (1997)).

The Setting: Mexican Common Property Forestry

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 dramatic. The national government exercised control of timber production in the 1940's and 1950's by issuing leases to parastatal firms. 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. 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 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.

The research targeted forestry communities in Oaxaca where commercial harvesting occurs. The figure below depicts the stages of the forestry production according to product. “Stumpage” sellers are those that contract with private firms to harvest the forest. These communities are paid by the volume extracted. “Roundwood” sellers harvest and sell round logs. Those that harvest and process the timber in a sawmill are “Lumber” sellers which sell lumber and sometimes logs. Finally, those that have a sawmill but also produce more finished products, such as furniture and tools handles, are grouped as “Finished Products” communities.

Figure 1. Stages of Timber Extraction and Processing

Stumpage ⟶ Roundwood ⟶ Lumber ⟶ Finished Products

Hypotheses

Timber harvesting requires both asset- and relationship-specific investments. Logging roads in particular become specific to the community's forest and infrequently access other forests. The private harvester could be subject to hold-up if, for example, a disagreement arises once the harvester constructs the roads. From a transaction cost perspective, the more specific are investments, the less exchanges are carried out in the market. Increased initial road stock is viewed as a substitute for asset specific investments and would lower the need for new specific investments.

An alternative explanation in line with transaction cost theory predicts less market transactions and more integration when capital investments are sunk and immobile.   Consider the option value of fixed capital. The 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 roads in time costs the community valuable time if the rainy season is approaching and it misses the opportunity to the harvest. In this case, the community's threat point, the value it gets from trading in the open market, becomes much lower than a community without this capital. As a community's threat point decreases, its risk of holdup rises. Therefore, initial physical capital stock both favors and disfavors community integration.

> *Hypothesis 1:* As the extent of initial stock of logging road infrastructure increases, the more likely is market transaction with outside private firms.

Communities seek control over forestland to provide jobs, increase job skills, increase profits through value-added activities, and have a source of funds for social services (Moros (1995), Kusel and Fortmann (1991)). Timber production can fit into a larger economic strategy for the community but yet be "noncontractible" in the sense that the local population continually adapts their economic development strategies to new situations. Community members want to be involved in labor, management and investment decisions. Profit streams are hard to verify and monitor. The numerous management decisions pose continuing opportunities where the goals of the community residents and an outside private firm diverge, leading to residual losses for the community when it contracts with an outside firm.   Economic development in this sense becomes complementary with ownership and control over timber production.

Assuming labor is mobile, it is proposed that communities will integrate when a stock of human capital is established to avoid risks of bargaining. Community members prefer to hire from their own community because they consider the purpose of the common property resource as generating community benefits.   According to several informants, outside hiring diminishes the forest's impact on community welfare.   Therefore, expertise within the community is important. However, as a mobile labor force, other opportunities exist, such as migration. Local competence also does not preclude a community from hiring an outside harvester and contracting with the harvester to hire locally. It is proposed that once acquiring a level of competence, communities choose ownership of the production process to maintain control over forest asset as unforeseen contingencies arise and owners must make residual decisions not specified in contract agreements.

> *Hypothesis 2:* 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.

The next hypothesis addresses the forest as an ecosystem which produces both timber and nontimber goods. Uncertainties in nontimber production and the difficulty of monitoring harvest management practices can make complete contracting infeasible. Collecting non-commercial timber forest products increases the awareness of the value of the forest and increases the importance of risk of damage to non-commercial timber products caused by the timber industry.

As the importance of nontimber production to the community members increases, the potential disparity between payoffs from integration and nonintegration grows so that integration becomes more attractive to a community population. 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 would suggest that the two processes are not separable.

> *Hypothesis 3:* As the value of nontimber sales increases, the more community ownership of the forest and harvesting equipment is observed, all else equal.

The parastatal experience may have lowered the fixed costs of community organization by encouraging cohesiveness among community members. This research maintains that communities' political resistance to parastatal leasing created solidarity within the community and among communities that facilitated collective organization, and that exposure to long-term industrial forestry changed the relationship between people and forests from subsistence use to large-scale market production. Once fixed costs of organization decrease, local populations integrate into forestry operations to avoid bargaining costs in market transactions.

> *Hypothesis 4:* Past history of parastatal leasing and harvesting increases the probability of community integration due to the reduced cost of organization and the possibility of opportunistic behavior in the marketplace.

Investments in forest resources and management can be such that community integration leads to greater synergy between timber and nontimber investment goals. 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. Nontimber and timber investments can be complementary on a broader scale given the inadequate knowledge of an ecosystem's true value. As knowledge about forest ecology evolves, management plans can change to further enhance forest resource benefits (Romm (1994), Getz et al. (1999)).

Unlike the previous hypotheses, this proposition examines the relationship between two possibly endogenous variables, vertical integration and investment in nontimber benefits. Instrumental variables techniques will explore the consistency of results. Exogeneity of vertical integration in the regression for these complementarities is claimed based on chronological order of events and statistical relationships. The measures of nontimber investments refer mostly to recent investments, which first occurred in the last three to five years, while most integration decisions were taken between 1978 and 1994. Only two observations have adapted their communal governance board to the timber industry since 1994, and the nontimber benefits mentioned by these communities is a general moratorium law on hunting deer applicable since 1996 in Mexico.

Hypothesis 5: Greater vertical integration leads to larger investments in producing nontimber forest products and services.

Empirical Approach

The population is the set of decision-making units which control common property in Oaxaca. This number includes communities or subgroups within the communities that are authorized to make decisions concerning common property. Subgroups refer to separate work groups formed by members of a single community that each organize production apart from the other group but still within the overall community governance structure. The number of subgroups was not known before the sampling process. 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 three harvest seasons 94/95, 95/96, or 96/97. To identify the population, we obtained the permit files 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 is 95. These 95 communities produce 80-95% of the commercial timber harvest in Oaxaca. 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 replicates the same typology as in the 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. Seventeen communities which sell stumpage, 26 communities that sell roundwood, and 17 communities which sell lumber and/or finished wood products were chosen at random, as shown in column two. Financial constraints limited the survey size to 44. In addition, corrections in classification were necessary during the course of fieldwork. Seven of communities targeted as roundwood or lumber sellers turned out to be stumpage sellers. The fourth column breaks the sample down by communities only while the fifth column accounts for the two additional work groups. The final sample of forty-four is detailed in column six.

Table 1. Population and Sample

Type	*Population*	*Selected Stratified Sample*	*Sample, communities only*	*Sample, with work groups*	*Final Sample*
Stumpage	27 (28%)	17 (28%)	15 (36%)	16 (36%)	16 (36%)
Roundwood	42 (44%)	26 (43%)	12 (28%)	13 (30%)	13 (30%)
Lumber	26 (27%)	17 (28%)	15 (36%)	15 (34%)	8 (18%)
Finished Products	?	?	?	?	7 (16%)
Total	95 (100%)	60 (100%)	42 (100%)	44 (100%)	44 (100%)

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.

Vertical Integration

The empirical analysis estimates a choice model of vertical integration across sample communities using the ordered logit model. A set of numbers of one to four ranks each observation in increasing magnitude according to the end product which it sells, namely stumpage, roundwood, lumber or wood products. The actual numerical values do not matter in the ordered logit model as long as they represent a natural ordering.

The independent variables for testing the vertical integration model include the theory variables and control variables. The theory variables are: initial levels of road infrastructure and human skill levels related to forestry, nontimber marketization activity, parastatal history and number of forested hectares. The control variable is quality of the forest prior to harvesting activities. The tables of summary statistics and the correlation matrix of these variables are available from the author.

Nontimber marketization: The survey data contains information on a variety of forest products sold by each observation unit for ten years or more. These include fuelwood, charcoal, wood for domestic use, mushrooms and an "other" category. Dummy variables were created to indicate whether the market had existed for more than ten years so that the market predated vertical integration for most of the sample. Fungi sales are omitted because of the particular circumstances in which this market arose. A new dummy variable takes the value one if there was any market in existence in the observation unit for more than ten years, zero otherwise.

Physical capital specificity: The number of kilometers of logging roads measures the level of asset specific stock available in the community and therefore the amount of additional capital investment needed to conduct timber extraction activities in the community. For stumpage communities, the measure is kilometers of logging roads as of ten years ago when the transition to community forestry began in earnest. For roundwood, lumber and roundwood 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.

Human capital specificity: Since logging has occurred in Oaxaca since the fifties, the survey collected data on the approximate number of persons who gained job experience and training in the forest products industry in the past and the range of those skills separated into technical and mechanical tasks. As for the physical capital measure, the indicators represent either job experience prior to 1986 or prior to any extraction activities conducted by the community itself. Mechanical training refers to experience with chainsaws, handsaws, cranes, trucks for transporting logs and sawmilling. Technical tasks include administration, documentation, silvicultural treatments and reforestation. A dummy variable was created for each task and records a value one if interviewees claimed that anyone had received that training in the community during the period specified in the past. With each category of mechanical and technical tasks, these dummies were summed and averaged to represent the scope for training in these activities. Training represents a base of knowledge about industrial forestry that can be passed on to others in the community, making the community more efficient in production. Aside from direct job training, many people have learned skills by observation from other community members.

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. Since other factors such as distance from the capital city, investment in the stock of physical infrastructure and human capital and quality for the forest could also explain a simultaneous occurrence of parastatal history and community vertical integration today, the econometric work analyzes the impact of these factors.

Forested hectares: The size of the forest stock as an independent variable allows for economies of scale. It is measured by the logarithmic scale of hectares of forested land in the community. As a theory variable, forested hectares represent the amount of assets owned. Property rights theory claims that the marginal productivity of investments increase as the investing party acquires more assets with which to work.

Distance: An indicator for hours of driving time from the community population to the capital city of Oaxaca and hours of driving time from the forest where logging occurs and the clients are the distance measures. Including a distance variable represents a measure of market integration and controls for parastatal history and advantages of lower risk of specialization (Morduch (1995)).

Quality of the forest: Control variables for quality for the forest for commercial ends tests whether vertical integration occurs for reasons other than contracting difficulties. Very little photographic or written data exists on Mexican forests in 1940, a date just prior to extensive intervention in Oaxacan forests. In addition, where data did exist, interpreting the data would be difficult. As an alternative measurement, three forestry engineers with extensive knowledge of Oaxacan forests and timber history ranked the their assessment of the historical quality of the forest in terms of soil and climate conditions and the presence of 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.

Investment in Nontimber Benefits

To establish an indicator for complementarities between timber and nontimber production and a potentially positive impact of vertical integration in timber production on nontimber benefits, interviewees responded to a series of questions that target areas of overlap between the two production processes. These overlaps can occur through the design of the management plan, supervision during harvesting and forest management in general, and the scope of the community enterprises activities. Data was collected concerning whether 1) the management plan delimits an area of conservation in the forested area, 2) the community enterprise pays foresters to carry out projects or training sessions on conservation, 3) the community forest enterprise 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 forestry enterprise participates in projects for the production of nontimber projects. The counts of responses by type are shown in Table 2. The chi-squared statistics are significant at the 5% level for all indicators except for protection of flora and fauna, which is significant at the 10% level. The reason for an insignificant chi-squared statistic on this variable is that the Mexican government recently introduced a law prohibiting deer hunting. While less than half the communities interviewed mentioned the moratorium, this law would affect all groups equally.

Table 2. Nontimber Investment (% responses by type)

	Stumpage	*Roundwood*	*Lumber*	*Finished Products*
Delimit area of conservation χ^2_3 =13.90, Pr.=.003	12	18	50	86
Pay forester to conduct conservation programs χ^2_3 =14.62, Pr. = .002	6	27	38	86
Pay patrols to monitor nontimber products χ^2_3 =9.21, Pr. = .027	13	18	38	71
Projects for protection of flora and fauna χ^2_3 =6.33, Pr. = .097	19	45	50	71
Projects for production of nontimber goods χ^2_3 =11.55, Pr. = .009	0	9	0	43

These variables were factored together using the principal factor methods and scored to create the dependent variable for investment in nontimber benefits. The independent theory variables are vertical integration and firm size as defined below. The control variable is level of biodiversity.

Firm Size: Models of technical innovation, investment or applied research frequently include a variable for total assets, measured as number of employees, total assets, or total sales. Each should theoretically be a substitute for the other. Number of persons employed by the extraction and transformation processes acts as the measure for firm size in this case. The size of forestry operations should positively affect investments in nontimber benefits because of greater synergistic possibilities and greater investment productivity.

Biodiversity: Higher levels of biodiversity within a forest would theoretically expand the range of possibilities for investment in nontimber benefits. Professional foresters assessed the level of biodiversity within the community's forest by estimating the percentage of the forest in five categories of quality levels ranging from high to low. The definition and understanding of the nature of biodiversity can vary even though terms were offered, so that only the percentage of hectares categorized in the highest level of biodiversity is used as a proxy.

Results

Vertical Integration

The estimation technique is the ordered logit model developed by McKelvey and Zavoina (1975). and McCullagh (1980). 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. Ordered logit defines the *y*-variable as lying along a continuum, which is broken up into intervals by "cut points" to be estimated. The predicted value of *y* can be calculated to determine the probability that the observation lies within each interval, here representing whether a community sells stumpage, roundwood, lumber or finished products. The ordered logit model employed for estimation is based on McCullagh's proportional odds model. The proportional odds model fits a set of equations for the cumulative distribution probabilities and estimates the probability that a community is at each level of vertical integration, given the set of characteristics represented by the independent variables.

Summary statistics and tests for multicollinearity were run for each of the independent variables. Mechanical and technical training in the past are highly correlated positively. Regressions of the technical training on the set of independent variables resulted in positive and significant at the 5% level coefficients for mechanical training and parastatal history. Eliminating the technical training variable reduces the chance of spurious results. Parastatal existence and forested hectares positively explains initial road infrastructure at the 5% level, while parastatal existence positively explains mechanical training. However, the correlation coefficients between parastatal history and initial road stock and parastatal existence and mechanical training are low. Since the aim of the empirical exercise is to control for these varying effects, these variables are retained in the regression equation.

The regression results are displayed in Table 3. Regression (1) is the base model. Initial infrastructure is not significant. Regressions of vertical integration on initial road infrastructure as a single explanatory variable give positive and significant results. However, the lack of significance in the base model suggests that initial levels of specific investments in logging roads does not discourage outside harvesters from extracting timber from community forests nor encourage forward integration by local communities.

Mechanical training is positive and significant above the 5% level, supporting the hypothesis. Mechanical training is the most basic and fundamental job skill for logging operations, without which communities cannot manage timber operations. As more people acquire mechanical ability, the more likely are the community members to vote on investing in logging operations.

Nontimber marketization as represented by a history of selling non-commercial-timber products is positive and significant at the 5% level, supporting the hypothesis that nonseparability between timber and nontimber production encourage local communities to control production. It is possible that these markets were correlated with distance to major population centers, namely the capital city of Oaxaca. However, the correlation coefficient is weak, and regression of nontimber marketization on distance results in a negative coefficient which is nevertheless insignificant at the 10% level.

The historical effect of parastatal leasing is positive and significant at the 5% level. To check for confounding factors, a regression of parastatal leasing on distance and quality of the forest in 1940 demonstrated that distance has positive and significant explanatory power at the 5% level but that prior forest quality has no explanatory value. Neither is 1940 forest quality strongly correlated with parastatal leasing. The possibility that the parastatal contributed to initial stock in human and physical capital also was tested. However, regression of initial logging roads and initial mechanical training on parastatal leasing with the other independent variables showed that parastatal leasing has no explanatory power at a 10% level for any of these variables. Nor is parastatal history correlated strongly with initial road stock or mechanical training. Therefore, the remaining possible impact of parastatal leasing is through its relationship to distance from the capital city of Oaxaca, the educational exposure to industrial forestry or the unifying effect of the communities' political resistance to the leasing programs. Controlling for distance from the capital city of Oaxaca does not have significance, either added as a substitute or additional variable with parastatal leasing, as shown in regression (3). Given these findings, the analysis points toward the interpretation that the historical experience of having communal forests leased to parastatal firms politicized the local communities, motivating them to build social and political networks to resist the leasing system and open the way for production on their own. The experience also exposed the community population to industrial forestry, expanding how they perceive the potential benefits of the forest.

The number of forested hectares surprisingly does not have a significant impact on the propensity to vertically integrate. In all regressions, a nonlinear pattern emerges in which the base term is negative and the squared term has a positive impact, yet the pattern does not have explanatory value.

The control variable for quality of the forest in 1940 has a positive and significant effect when added to the base regression in (2). It 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. The measure of the quality of the forest therefore picks up part of nontimber marketization's effect.

Table 3. Ordered Logit: Vertical Integration

Coefficient values, *t*-statistics (in parentheses)

Numbers in ***bold italics*** are significant at 5%, numbers in **bold** at 10%

	(1)	(2)	(3)
Theory:			
Initial Roads	0.12	-0.21	-0.25
	(-.41)	(-.62)	(-.70)
Initial Mechanical Training	***4.08***	***4.05***	***4.43***
	(2.98)	(2.82)	(2.76)
Past Nontimber Marketization	***1.65***	1.35	**1.53**
	(2.04)	(1.58)	(1.67)
Parastatal Existence	***3.06***	***3.38***	***3.66***
	(3.71)	(3.73)	(3.49)
Forested Hectares (logarithmic)	-6.56	-5.23	-5.42

	(-1.45)	(-1.08)	(-1.11)
Forested Hectares (logarithmic), squared	0.47	0.39	0.41
	(1.64)	(1.27)	(1.31)
Controls:			
1940 Forest Quality		***1.89***	***1.92***
		(2.41)	(2.46)
Driving Hours from Oaxaca			0.08
			(0.58)
cut 1	-19.51	-7.32	-6.97
cut 2	-16.99	-4.5	-4.14
cut 3	-14.85	-2.13	-1.71
Number of Observations:	43	43	43
LR chi-squared	42.86	49.75	50.07
d.f	6	7	8
Prob. > chi-squared	0.0000	0.0000	0.0000
Pseudo R-squared	0.37	0.43	0.44
Log Likelihood	-35.86	-32.42	-32.26

Nontimber investment

The first column in Table 4. is the ordinary least squares (OLS) regression of nontimber investments. Vertical integration and biodiversity are positive and significant at the 5% levels. Firm size as represented by number or workers has no explanatory value. Vertical integration could be endogenous to the model and therefore correlated with the error term. In a regression of vertical integration on nontimber investments, nontimber investments has positive explanatory power at the 5% level. To correct for this inconsistency, an instrumental variables (IV) version of the model was tested. Regression (2) is the results of applying the instrumental variables technique where the instruments are past mechanical training, history of parastatal leasing, forested hectares (logarithmic), past nontimber marketization, quality of the forest in 1940, labor and percent of forest rated as having high biodiversity levels. Coefficient estimates, signs, standard errors and R^2 statistic relatively similar to the OLS regression, supporting the hypothesis of exogeneity of vertical integration. The *t*-statistic for vertical integration decreases in magnitude but remains significant at the 5% level. The statistic for the Hausman specification test is 0.21 with 3 d.f.. Thus, the null hypothesis that the OLS and the IV estimators are both consistent cannot be rejected.

Table 4. Occurrence of Nontimber Investments
Coefficient values, *t*-statistics (in parentheses)
Numbers in ***bold italics*** are significant at 5%, numbers in **bold** at 10%

	(1)	(2)
Vertical integration	***0.42***	***0.46***
	(3.92)	(3.33)
Percent of forest with high biodiversity	***0.01***	***0.01***
	(2.03)	(1.97)
Labor	0.003	0.003
	(1.54)	(1.28)
Constant	***-1.2***	***-1.27***
	(-5.22)	(-4.73)
Number of observations	42	42
R-squared	0.49	0.49
Adjusted R-squared	0.45	0.45

Conclusion

This paper develops a theoretical framework to analyze how common property tenure systems affect collective production decisions of a local community. The question addressed is whether uncertainties related to timber production, local economic development and nontimber forest benefits influence a local community's propensity to integrate forward into timber production from the point of selling stumpage to further stages in the wood products production process.

Overall, the empirical findings support the predictions. The central question addressed is why do Mexico's agrarian communities integrate, when hiring-in private contractors should be a perfectly substitutable choice and other options are available? The interpretation offered is that, when able, communities choose to maintain control over the forest ecosystem and economic development in the community, both of which are difficult to define n contracting arrangements with outside private harvesting firms. The positive effect of human capital skills and parastatal leasing on forward integration suggests a complementarity between community workers and the forest resource. Once acquiring a base level of mechanical skills, communities tend to integrate forward into timber production and processing. The parastatal history may have also lowered the fixed costs of organization by motivating the communities to form alliances between communities as well as among themselves against a common enemy. While the ending of the concession era allowed communities to guide forestry to their own development goals, the parastatal era provided an impetus. Integration occurs despite differences in distance[4], which had no explanatory value as a control variable. Historical patterns of selling non-commercial timber was hypothesized to raise the community's concern over controlling access to the forest resource and therefore integration forward. Nontimber sales in the past has weak explanatory value. The variable for quality of the forest picks up the variation explained by past nontimber marketization since higher quality forest yield potentially more marketable products.

Contrary to transaction cost predictions, the level of logging road infrastructure did not affect the propensity to hire-in services or integrate. One of the interpretations is that other factors overwhelm the affect of asset specificity. In a trade of "access for development", communities and firms reach agreements to trade raw material for public goods investments, such as logging road networks. Outside private firms today may be partially filling the role the parastatal played before 1982.

The positive impact of vertical integration on recent nontimber investment and production suggests further that synergies between the two production processes exist, possibly through monitoring, management plan, and administrative overlaps as well as knowledge of the forest gained through integrating forward. This bodes well for adopting ecosystem management approaches in self-governing systems.

This research provides evidence that the desire to control production to manage economic and ecological uncertainties explains forward integration of forest communities studied. In turn, the degree to which nontimber production is nonseparable from timber production and complete contracts are infeasible leads to increased nontimber investment when communities integrate forward. The remaining questions are left to future research.

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[2] The hold-up problem is not essential to the theory. Anything that threatens a breakdown of a contract, such as asymmetric information, creates the same conditions as hold-up risk.

[3] 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)).

[4] Literacy rates for over-15-year-olds, as a proxy for opportunity costs and degree of market integration, also yielded insignificant results.