Logging firms, nonindustrial private forests, and forest parcelization: evidence of firm specialization and its impact on sustainable timber supply

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Abstract: Increasing forest parcelization has raised concerns about tract-size economies and sustainable timber supply. We explored this issue by examining the logging sector and forest ownership in northern Wisconsin and Michigan's Upper Peninsula. Using 2004 survey data, we found that 48% of logging firms demonstrated a near exclusive reliance on nonindustrial private forests (NIPFs). NIPF-dependent firms derived 87.5% of their stumpage from this ownership, whereas nondependent firms exhibited a significantly more diversified stumpage supply distributed among public (42.6%), industrial–corporate (33.3%), and NIPF (24.0%) sources. Additionally, NIPF-dependent firms operated on significantly fewer, smaller, and less intensely harvested timber sales, and they were more likely to harvest small tracts profitably. There were no significant differences in the forest products harvested or overall firm profitability. We found statistical evidence that NIPF-dependent and nondependent firms organize themselves differently: NIPF dependency was negatively correlated with total number of employees, timberland area in the firm's wood basket, and firm location and positively correlated with owner age. Results suggest the impacts of parcelization on the logging sector are minimal. NIPF-dependent firms appear to have structured themselves to operate profitably; however, it is unclear how continued parcelization might influence these firms and the sector as a whole.

Résumé : L'augmentation du morcellement des forêts a soulevé des préoccupations concernant les économies reliées à la dimension des parterres de coupe et l'approvisionnement durable en matière ligneuse. Les auteurs explorent cet enjeu en examinant le secteur de l'exploitation et les tenures forestières au nord du Wisconsin et dans la Péninsule du Haut Michigan. En utilisant des données d'inventaire de 2004, ils ont trouvé que 48 % des entreprises d'exploitation dépendaient presque exclusivement des lots boisés non industriels (LBNI). Ces entreprises obtiennent 87,5 % de leur bois sur pied de ce type de propriétés alors que les entreprises qui n'en dépendent pas ont des sources d'approvisionnement significativement plus diversifiées comprenant des terres publiques (42,6 %), des terrains industriels ou corporatifs (33,3 %) et des LBNI (24,0 %). De plus, les entreprises qui dépendent des LBNI réalisaient significativement moins d'opérations, sur de plus petits territoires et de manière moins intensive. Elles avaient aussi plus de chances de récolter de manière rentable de petits parterres de coupe. Les produits récoltés et la rentabilité globale des entreprises ne présentent aucune différence significative. Des indices de nature statistique montrent que les firmes dépendantes et non dépendantes des LBNI s'organisent différemment : la dépendance aux LBNI est corrélée négativement avec le nombre total d'employés, les aires de coupe accessibles à l'entreprise, la localisation de la firme et positivement avec l'âge du propriétaire. Les résultats indiquent que l'impact du morcellement sur le secteur de l'exploitation est minimal. Les firmes dépendantes des LBNI semblent s'être structurées pour opérer de manière rentable. Cependant, on ne sait pas quelle influence le morcellement accru des territoires forestiers aura sur ces entreprises et le secteur dans son ensemble.

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Introduction

Loggers and logging firms employ a wide array of timber harvesting technologies, business skills, and marketing approaches toward providing an adequate timber supply for the wood- and paper-producing industries. In meeting this demand, they perform critical tasks that reshape the landscape mosaic and affect long-term resource sustainability. Whether the forest is owned by the public, shareholders, trustees, or private individuals, loggers and logging firms are the mechanism by which trees are harvested and begin their journey through the product chain. In this paper we consider the extent to which logging firms specialize and (or) depend on that landownership category with the most acres owned and

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timber volume harvested in the United States, namely nonindustrial private forests (NIPFs).

Our interest in the relationships between logging firms and NIPFs emerges from the growing knowledge of and, from some perspectives, concerns over changes wrought by parcelization of the forest resource (Rickenbach and Gobster 2003; Butler and Leatherberry 2004). The last decade or so has seen the number of forest owners increase dramatically, with a subsequent decrease in the average size of forest ownerships, and these trends pose both operational and social challenges to future sustainable timber supply. In purely operational-efficiency terms, decreases in tract size increase the costs of timber production via diminished timber harvest economies of scale (Row 1978; Cubbage 1983). In addition, studies indicate that decreasing tract size also results in decreased investment in and completion of forest management activities by NIPF owners (Straka et al. 1984; Romm et al. 1987). Beyond these well-documented tract size relationships are the related phenomena of exurbanization and land use conversion (i.e., development) that have accompanied parcelization in many regions of the country. These include negative effects on timber management and supply (Egan and Luloff 2000; Wear et al. 1999; Kline et al. 2004) and other resource-related services (e.g., LaPierre and Germain 2005).

Amid these land tenure and use changes, the logging sector itself is experiencing considerable change through the adoption of new harvesting technologies. Driven in large part by economies of scale that tend to favor highly productive and efficient harvest systems, the logging sector has become more mechanized and, as a result, more capital intensive. Such systems are safer and more worker friendly, but increasing mechanization and larger scale operations may be mismatched with the smaller tract sizes and lower timber volumes that characterize parcelized NIPFs (Greene et al. 1997). These conflicting trends could be offset, though, if logging firms specialize. Under such specialization some logging firms would adapt their business model and harvest system(s) to profitably harvest timber from small ownerships. Keefer et al. (2003) found that some firms were choosing not to adopt new technology and instead focus their operations on small NIPFs that were 8 ha or less in area. Rickenbach and Steele (2005) posit a similar response in Wisconsin, but that study does not adequately control for the diverse ownership patterns, markets, and timber types found throughout the state.

Historically, timber supply assessments have relied primarily on forest inventory data and market analyses, with relatively little consideration given to the harvesting and procurement behaviors of individual logging firms or the sector as a whole (Abt et al. 2000; LeDoux et al. 2001). These studies implicitly assume that trees will be harvested when mature and that loggers will be present to do the job. However, loggers do not solely work as employees or subcontractors of mills. In our region and many other parts of the United States, independent logging firms are the principal market agents that buy stumpage and market timber products to the primary wood-using sectors. In short, they are the critical link between the timber resource and wood-based manufacturers. Given their central role in the wood products marketplace and in sustaining timber supply, it is important to examine these assumptions about a universally harvestable resource given recent trends in forest parcelization and logging sector mechanization.

Despite some hints about the ability of the logging sector to respond to issues like land tenure changes and parcelization, we could find no empirical studies that directly link the logging sector to forest ownership and timber supply. In this paper, we investigate the role forest ownership plays within the logging sector. Specifically, we develop a metric of land ownership specialization that we term "harvest concentration ratio", which allows us to identify firms that are more or less dependent on a particular ownership category for the timber they harvest. Next, we identify differences in timber sale and production characteristics among NIPF dependent and non-dependent firms. We then develop an explanatory model of NIPF dependency based on individual firm characteristics. Through our analysis, we answer two important questions. First, how do logging firms that depend on NIPFs for their stumpage differ from those that are not NIPF dependent? And second, can basic firm characteristics (e.g., harvest system, owner age, etc.) be used to predict NIPF dependency? The answers to these questions provide greater insights into the mechanisms of timber supply in the United States that may assist resource managers and policy-makers when assessing the potential impacts of institutional programs, such as forest certification, tax incentives, and landowner assistance efforts, on the logging sector. It is quite possible that such programs could have differential effects on logging firms depending upon their level of NIPF dependency. This study may also provide foresters and resource analysts with a new lens to view conventional timber inventory information, one that explicitly considers the operational accessibility of the forest resource.

Methods

Study area

The study area encompasses the 22 northernmost counties in Wisconsin and the 15 counties of Michigan's Upper Peninsula. Forests are the dominant land use in the area, occupying some 7.6×10^6 ha, or 77.2% of the land area. Ownership of these lands is diverse, with NIPFs accounting for 27.6% of the timberland in the Upper Peninsula, 43.8% in northern Wisconsin, and 36.2% overall (Table 1). Several studies indicate that parcelization is occurring in the study area, particularly in Wisconsin, and that it may be affecting timber supply (e.g., Moore and Rockwell 2001; Radeloff et al. 2001; Rickenbach and Gobster 2003). In terms of forest composition, the late-successional maple–birch–beech cover type is dominant, followed by aspen–birch and spruce–fir, with pines, oak–hickory, and other types being minor components. These forests support a vibrant and economically important industrial sector that includes pulp and paper manufacturers, sawmills, and numerous other primary and secondary wood-using industries.

A large and diverse logging sector supplies the region's forest products industry (Rickenbach et al. 2005). The majority of logging firms (65.4%) are fully mechanized operations in which the entire production of timber from stump to landing is accomplished by mechanical means. These include cut-to-length operations consisting of a harvester and forwarder (38.1% of firms); feller–buncher operations em-

Table 1. Area, ownership, and forest composition of timberland in the study area.

	Upper Peninsula	Northern Wisconsin	Combined
Timberland area (10^3 ha)	3399	3885	7284
Timberland ownership by category (%)			
Federal	19.8	14.4	16.9
State	18.5	4.8	11.2
County or local	1.2	19.0	10.7
Tribal	0.2	3.6	2.0
Timber industry	18	10.3	13.9
Corporate	14.7	4.3	9.1
Nonindustrial private	27.6	43.8	36.2
Timberland composition by forest type (%)			
Aspen–birch	17.2	28.9	23.5
Maple–birch–beech	44.4	36.7	40.3
Oak–hickory	0.8	7.1	4.2
Pine spp.	7.8	7.0	7.4
Spruce–fir	24.8	12.6	18.3
Other spp.	5.1	7.7	6.5

ploying one or more feller–bunchers that work in conjunction with grapple skidders, delimbers, and slashers (17.2% of firms); multiple operation firms that use both cut-to-length and feller–buncher systems (8.1% of firms); and other operations that include in-woods chipping or nonstandard system configurations (2.1% of firms). The balance of firms, 35.6%, consists exclusively of chainsaw-based operations in which tree felling and processing are accomplished manually.

Most logging firms in the study area (60.7%) are organized as one-person, owner–operator enterprises with no employees. These firms typically subcontract a portion or portions of the harvesting process, such as primary or secondary transport. The remaining firms (39.3%) employ 4.5 full-time equivalent workers on average; less than 8% of the firms have 8 or more employees.

Operational scale varies considerably among logging firms. Annual firm production ranges from 360 $m^3 \cdot year^{-1}$ to more than 200 000 $m^3 \cdot year^{-1}$, with a median value of 12 700 $m^3 \cdot year^{-1}$. At the aggregate level, production is concentrated among mechanized firms that, as a group, account for 85% of all timber harvested. Chainsaw-based operations generate only 15% of the region's total production despite the fact that they represent a full one-third of all logging firms.

Data set

We surveyed logging firms based in the study area in spring 2004. Through prospective timber-buyer lists maintained by public agencies and logger training databases, we constructed a cleaned database that contained approximately 1200 entries, of which 1063 firms were selected at random to participate in our study. Our survey was a traditional multiwave mail survey (i.e., full mailing, postcard follow-up, and two additional full mailings to nonrespondents) that included a \$2 incentive in the first mailing (Dillman 1978). The 11-page questionnaire elicited information on firms' 2003 production, procurement, and general profitability level (i.e., very poor, poor, broke even, good, or excellent); harvest system configuration(s); employees; business outlook and perspective; and other owner and firm characteristics.[2] Questions regarding procurement asked respondents to provide their best estimate of the percentage of their 2003 production by ownership (e.g., 30% NIPFs, 30% state forests, 25% county forests, and 15% industrial) and to identify the counties in which they harvested timber. Given that our interest was individual, firm-level data, our cover letter asked that the owner or someone with similar knowledge complete the questionnaire.

Responses were screened and the smallest operations, that is, those producing less than 100 cords per year (362 m^3) were dropped from the sample under the assumption that these were part-time operations. Excluding these nonsample firms and undeliverable addresses, the number of sample cases was 921. Our total response was 513 firms for an overall response rate of 55.7%. Of the 513 firms that responded, 417 sufficiently completed the questionnaire to allow for categorization as NIPF dependent or not and are the basis for this study.

Harvest concentration and NIPF dependency

We adapted the concept of location quotient from the field of community economics and planning (Shaffer et al. 2004) to explain the extent to which logging firms depend on different forest ownerships for their supply of timber. We refer to this measure as "harvest concentration ratio" and denote it H_i. It is calculated by dividing the percentage of a logging firm's production harvested from a particular ownership category by that ownership category's presence in the firm's wood basket (eq. 1):

$$[1] \qquad H_{j,i} = \frac{Q_{j,i}}{B_{j,i}}$$

where

[2] Survey questions were based on imperial units (e.g., cords, thousand board feet, tons, acres). For consistency and to facilitate transferability, imperial units are used in this paper when reporting survey results, with their metric equivalents given in parentheses.

$H_{j,i}$ is the harvest concentration ratio of firm j for the ith forest ownership category;
$Q_{j,i}$ is the percentage of the total production of firm j from the ith ownership category;
$B_{j,i}$ is the percentage of the ith ownership category present in the wood basket of firm j; and
i is NIPF, public, and industrial–corporate forest ownerships.

The numerator is the firm's self-reported percentage of harvest for one of three broad ownership categories, namely NIPF, public, and industrial–corporate. The denominator is the percentage of all timberland ownership[3] in the same ownership category that falls within the firm's wood basket. Thus, we employ timberland ownership as a proxy measure of the total commercial stumpage volume available by ownership group in the firm's wood basket. Although it is not an exact measure of volume, we believe timberland area yields a reliable estimate of stumpage availability given the relatively close correspondence between forest land area and timber volume at relatively large (i.e., county and multicounty) spatial scales. The location and extent of each firm's wood basket was determined from the firm's self-reported list of counties in which they harvest timber. (See Rickenbach and Steele (2005) for more detailed information on the wood basket concept and its derivation.) For example, if a firm harvested 50% of their timber volume from NIPFs and NIPFs accounted for 30% of timberland ownership in their wood basket, the firm's NIPF harvest concentration would be 1.67.

Firms that harvest from an ownership category in equal proportion to that category's timberland area would have a harvest concentration ratio of 1.00. A concentration ratio less than 1.00 implies that the firm procures relatively less wood from that ownership category in comparison to the category's presence in the firm's wood basket. Conversely, H_i greater than 1.00 indicates the firm harvests relatively more wood from that particular ownership. Thus, the harvest concentration ratio can be used to identify firms that specialize in the harvest of NIPFs. This approach is similar to the manner in which location quotients are used to identify industrial specialization within local or regional economies (Shaffer et al. 2004).

Our interest, however, extends beyond ownership specialization. Specifically, we wish to identify those logging firms that are clearly dependent upon NIPFs as a source of stumpage, particularly in comparison to their peers. Unlike specialization by community economies, there are no established rules or criteria for assessing ownership dependence. Consequently, for the purposes of this study, we define a firm as "NIPF dependent" if two criteria are met. First, the firm's harvest concentration ratio for NIPFs (H_{NIPF}) has to be greater than the concentration ratios for the other ownership categories (i.e., $H_{\text{Industrial}}$, H_{Public}). Second, the NIPF harvest concentration ratio has to exceed 1.33, the median NIPF harvest concentration ratio in the study area. Together, these criteria allow us to classify firms into one of two categories: NIPF dependent or not. Returning to our previous example, the hypothetical firm would be classified as NIPF dependent given a harvest concentration ratio of 1.67 (i.e., above the median value) and assuming smaller $H_{\text{Industrial}}$ and H_{Public} values.

Data analysis and model estimation

Our analysis proceeds in two steps. First, we examine whether the timber sales of NIPF-dependent firms differ from those of nondependent firms in terms of their size, frequency, harvest volume, products, silviculture system, and profitability. To do this, we use a two-tailed t test to compare parameter means or a χ^2 test to compare parameter distributions. All statistical analyses employ a critical value of α = 0.05 and proceed under the null hypothesis that there is no difference between the timber sales of NIPF dependent and nondependent firms. For t tests, we calculate either a Student's t statistic or the Cochran–Cox approximate t statistic, depending on the presence of statistically similar variances between the NIPF dependent and nondependent populations (Zar 1974). Use of the Cochran–Cox approximation is denoted by t' when reporting test results.[4] For two of the three χ^2 tests (i.e., harvested volume by ownership and harvested volume by product class), respondents provided their distribution across classes by percentages, not actual volumes. We calculated the means for each class for both firm types (i.e., dependent and nondependent) to determine the type-wide distribution. Chi-square calculations were then weighted by the number of firms in each type. For the remaining chi-square calculation (i.e., sale distribution by acreage class), respondents reported the actual number of sales and no weighting was used. In the second component of our analysis, we construct a firm-level model to predict NIPF dependency using binomial logistic regression and a suite of firm-specific characteristics as explanatory variables.

Results

The NIPF harvest concentration ratio ranged from 0 to 6.69, with a median of 1.33 and a mean of 1.60 (n = 417). As noted previously, we defined a firm as NIPF dependent if its NIPF harvest concentration ratio was higher than that of other ownerships and was above the median. Under this definition, 201 firms were NIPF dependent and 216 were not.

NIPF dependent versus nondependent logging firms

NIPF-dependent firms differed significantly and strikingly from nondependent firms on the ownerships from which they harvested timber (χ^2 = 174.0, df = 5, p < 0.0001; Table 2). NIPF-dependent firms relied on NIPFs for 87.5% of their timber compared to 24.0% for nondependent firms. One hundred and twenty dependent firms (59.7%) indicated that they derived a full 100% of their harvest volume from NIPFs. In addition, no other stumpage source for NIPF-dependent firms individually accounted for more than 5% of the firms' timber supply. Conversely, nondependent firms had a much more diversified stumpage supply, with public sources contributing 42.6% of the firm's harvest volume on average and industrial–corporate sources adding another 33.3%.

[3] County-level timberland ownership information was obtained from the last complete statewide forest inventories for Wisconsin in 1996 (Schmidt 1997) and Michigan in 1993 (Leatherberry and Spencer 1996).

[4] The number of degrees of freedom (df) for a Cochran–Cox approximate t test is indeterminate and lies between $n_1 - 1$ and $n_2 - 1$. In this case, n_1 and n_2 correspond to the sizes of the NIPF dependent and nondependent samples, respectively.

Table 2. Distribution of harvested volume across forest ownership categories by type of logging firm (NIPF dependent or nondependent).

Ownership category	Volume (%) Dependent (n = 201)	Nondependent (n = 216)
Nonindustrial private forests	87.5	24.0
Industrial and corporate forests	3.3	33.3
National forests	1.7	11.1
State forests	3.4	12.7
County forests	4	18.8
Other	0.1	0.1
Total	100.1[a]	100.0

[a]Value does not total 100 because of rounding.

Table 3. Distribution of timber sales across harvest area size classes by type of logging firm (NIPF dependent or nondependent).

Harvest area size class	Timber sales (%) Dependent (n = 1172)	Nondependent (n = 1828)
0–5 acres (0.0–2.0 ha)	5.9	2.5
6–10 acres (2.1–4.0 ha)	5	3.9
11–20 acres (4.1–8.1 ha)	10.2	9.3
21–40 acres (8.2–16.2 ha)	30.1	26.3
41–80 acres (16.3–32.4 ha)	31.7	30.7
81–160 acres (32.5–64.7 ha)	9.7	16.1
≥161 acres (≥64.8 ha)	7.3	11.2
Total	99.9[a]	100.0

[a]Value does not total 100 because of rounding.

The extent of dependency on NIPFs suggests that NIPF-dependent firms should harvest more extensively from smaller timber sales with fewer acres and less volume. Our data support both of these hypotheses (Tables 3 and 4). In comparing the number of timber sales across seven acreage classes, we found that of the 3000 total sales represented in the survey, the distribution of sale sizes differed significantly between NIPF dependent and nondependent firms ($\chi^2 = 60.6$, df = 6, $p < 0.0001$). NIPF-dependent firms were more likely to have sales of 40 acres (16 ha) or less, while nondependent firms were more likely to harvest tracts of 81 acres (33 ha) or more. The portions of sales in the 41–80 acre class (17–32 ha) were similar for NIPF dependent and nondependent firms. This finding of smaller sale size is further substantiated by a statistical difference in the mean harvest volume per timber sale ($t' = 4.93$, df = 186–195, $p = 0.0001$): NIPF-dependent firms harvested approximately 680 cords (2465 m^3) per sale compared to 1060 cords (3842 m^3) for nondependent firms. This result is consistent, as one would expect sales that are smaller in area would yield a correspondingly smaller harvest volume.

Our data also show that NIPF-dependent firms were more likely to have profitably harvested small sales (40 acres; 16 ha) than nondependent firms. Along with reporting the total number of sales by acreage class, respondents also provided the number of profitable sales by acreage class. As a percentage of all small sales, NIPF-dependent firms reported that 72% of such sales were profitable compared to 62% among nondependent firms: a significant difference ($t = -1.97$, df = 289, $p = 0.0497$).[5]

Along with their greater reliance on and profitability from smaller sales, NIPF-dependent firms worked on fewer, less intensely harvested timber sales (Table 4). Nondependent firms worked on 9.3 sales in 2003, statistically more than the 6.3 sales of NIPF-dependent firms ($t' = 3.95$, df = 186–195, $p = 0.0001$). The average volume per acre was significantly lower among NIPF-dependent firms (12 vs. 15 cords·acre^{-1}; 106 vs. 133 $m^3 \cdot ha^{-1}$), which suggests less intense harvesting ($t = 2.43$, df = 381, $p = 0.0155$). NIPF-dependent firms indicated that partial harvests as opposed to clearcuts accounted for a statistically higher portion of their total annual volume than did nondependent firms: 84% versus 77%, respectively ($t = -2.81$, df = 396, $p = 0.0052$)

Despite the substantial differences in timber sale characteristics between NIPF dependent and nondependent firms, we found no statistically significant difference in the distribution of products removed ($\chi^2 = 1.2$, df = 6, $p < 0.9429$; Table 5). Regardless of ownership dependency, firms harvested primarily hardwood pulp (51.4%), followed by softwood pulp (19.7%) and hardwood sawtimber (14.6%). This is consistent with product mix for the region, which depends on hardwood pulp, particularly aspen, as a basis for paper production. Nor did NIPF dependency affect firms' self-reported overall 2003 profitability ($t = 1.48$, df = 412, p = 0.1399), where ratings hovered at the midpoint, corresponding to "average (broke even)", with 1 being very poor; 2, poor; 3, average; 4, good; and 5, excellent (Table 4).

A model of NIPF dependency

The comparative findings above suggest that NIPF-dependent firms are substantially different on key timber sale and harvest characteristics, but not on the products harvested or their self-assessments of overall profitability. We surmised that to effectively and profitably operate in these two distinct arenas, logging firms organize themselves differently (i.e., specialize), and we developed a logistical model of NIPF dependency based on individual firm characteristics to test this hypothesis.

Based on the findings presented previously, we inferred that NIPF-dependent firms are smaller than nondependent ones (i.e., they have fewer employees) and that smaller firms concentrate their activities over a smaller land area. However, firms might organize themselves with NIPFs in mind through specific hiring practices. For example, logging firms

[5]As a rule, one should exercise caution when analyzing logging firms' self-assessment of profitability as the potential exists for inconsistent or incorrect responses. We addressed this concern early in our study by subjecting the survey instrument to a thorough pretest conducted by experts familiar with the regional logging sector. Their comments were incorporated into the final version of the questionnaire in an attempt to ensure respondents' clear and consistent interpretation of the survey instrument. Nonetheless, the reader should not infer statistically different profitability levels between NIPF dependent and nondependent firms when harvesting small timber sales. Rather, our results provide statistical evidence that NIPF-dependent firms are more likely to simply perceive their small-tract harvests to be profitable as compared to their nondependent counterparts.

Table 4. Comparison of mean timber harvest production, profitability, and timber sale characteristics in 2003 between NIPF dependent and nondependent logging firms.

	Dependent			Nondependent				
	n	Mean	SD	*n*	Mean	SD	Test statistic[a]	*p* value
No. of sales	187	5.8	4.2	196	9.3	11.4	3.95*	0.0001
Portion of sales <40 acres (16 ha) profitable	149	0.716	0.412	142	0.621	0.415	–1.97	0.0497
Avg. volume per sale (cords)	187	683	663	196	1 061	828	4.93*	0.0001
Avg. volume per acre (cords·acre^{-1})	187	12.4	9.2	196	14.7	9.5	2.43	0.0155
Portion of volume from partial harvests	187	0.837	0.23	211	0.773	0.22	–2.81	0.0052
Overall profitability[b] rating	199	3.1	0.9	215	2.9	1.0	1.48	0.1399

Note: SD, standard deviation.
[a]Means were compared using either a two-tailed Student's *t* test or a Cochran–Cox approximated *t* statistic (denoted by *).
[b]Firms rated their 2003 profitability on a five-point Likert scale: 1, very poor; 2, poor; 3, average; 4, good; 5, excellent.

Table 5. Distribution of harvested volume across product categories by type of logging firm (NIPF dependent or nondependent).

	Volume (%)	
Product category	Dependent (n = 200)	Nondependent (n = 214)
Veneer	5.5	4.4
Hardwood sawtimber	15.5	13.7
Softwood sawtimber	6.8	5.9
Hardwood pulp	48.8	53.8
Softwood pulp	20.1	19.4
Other	3.4	2.9
Total	100.1[a]	100.1[a]

[a]Value does not total 100 because of rounding.

that hire a forester for procurement or landowner assistance could be logically assumed to target NIPFs as a source of stumpage. In contrast, there is little or no need for nondependent firms to employ a forester, since timber sales on public or industrial lands are typically set up by agency or industry staff. Evidence from several past studies (Greene et al. 1997; Rickenbach and Steele 2005) suggests that the type of harvest system(s) a firm employs might also be a factor, with fully mechanized firms less likely to depend on NIPFs. Fully mechanized operations are generally characterized by high productivity, high capital costs, and high intersale moving costs, and stumpage from NIPFs might not present sufficient economies of scale for these firms to operate profitably. Consequently, firms with high levels of mechanization might focus their stumpage procurement efforts on larger public and (or) industrial timber sales. We also assume that experience can affect the type of timber sales a particular firm acquires. For example, many NIPF timber sales are sold directly to loggers based on referrals or recommendations, without going through a formal advertising or bidding process. Well-established firms with solid reputations and extensive experience could have a market advantage when purchasing stumpage from NIPF holdings. As a proxy measure of experience, we use the firm owner's age. Lastly, we include a dummy variable for firms based in Michigan's Upper Peninsula, as there are institutional, cultural, and regulatory differences between the two states. Thus, a model of firm NIPF dependency can be expressed in mathematical terms as

$$\text{Prob}(D_j) = f(A_j, L_j, F_j, E_j, \boldsymbol{T}_j, \text{UP}_j) \quad [2]$$

where

D_j is a binomial (0 or 1) variable reflecting the NIPF dependency of firm j;
A_j is the natural logarithm of area of timberland in the wood basket of firm j;
L_j is the total number of full-time-equivalent workers employed by firm j;
F_j is a binomial (0 or 1) dummy variable indicating whether firm j employs a forester;
E_j is the age of the owner of firm j;
$\boldsymbol{T}_j$ is a vector of dummy variables that reflect the type of harvesting technology used by firm j; and
UP_j is a binomial (0 or 1) dummy variable indicating whether firm j is based in Michigan's Upper Peninsula.

$\boldsymbol{T}_j$, the measure of firm j technology, consists of a vector of dummy variables that classify each firm into one of five technology categories based on the type of harvesting system(s) they employ. Categories include nonmechanized, cut-to-length, feller–buncher, multiple systems, and other harvesting systems. Table 6 provides an overview of the explanatory variables, their expected signs, and associated descriptive statistics.

Model fit and significance

Exploratory analyses on a subset of the data revealed that the explanatory variable F, employment of a forester, was insignificant as a main effect when predicting NIPF dependency. Consequently, the model was respecified, dropping F and adding an interaction term $L_j \times F_j$, that is, the combination of total employment and the presence of a forester on staff. This final model was significant in predicting NIPF dependency within the regional logging sector (χ^2 = 74.7, df = 9, p < 0.0001); thus, providing statistical evidence that firms do structure themselves differently depending upon their source of stumpage (Table 7). The Hosmer and Lemeshow goodness-of-fit test was not significant (χ^2 = 5.7, df = 8, p = 0.6823), suggesting that the model's fit was adequate. Despite the model's overall significance and general performance, the explanatory power was relatively low (max-rescaled R^2 = 0.2240). The fact that our model does not explain a considerable portion of the variability in the data is the product of the diversity of firms, products, markets, harvesting systems, and resource attributes that characterize the region's logging sector; moreover, it points to the complexi-

Table 6. Variable definitions, descriptive statistics, and hypothesized signs (n = 406).

(A) Response variable.

Variable	Definition
D_j	A binomial variable (0 or 1) equal to 1 if firm j is NIPF dependent; 0 otherwise

(B) Continuous explanatory variables.

Variable	Definition	Mean	SD	Hypothesized sign
A_j	The natural log of timberland area (acres) in the wood basket of firm j	13.9	0.59	–
L_j [a]	The number of full-time-equivalent workers employed by firm j	2.3	4.2	–
E_j	Firm j owner's age (years)	47.6	10.9	+

(C) Categorical explanatory variables.

Variable	Definition	Frequency	% of occurrence	Hypothesized sign
F_j	A binomial variable equal to 1 if firm j employs a landowner assistance or procurement forester; 0 otherwise	28	6.9	+
$T_{\mathrm{Manual},j}$ [b]	A binomial variable equal to 1 if firm j employs a chainsaw-based harvesting system(s); 0 otherwise	139	34.2	
$T_{\mathrm{FB},j}$	A binomial variable equal to 1 if firm j employs feller–buncher harvesting system(s); 0 otherwise	68	16.8	–
$T_{\mathrm{CTL},j}$	A binomial variable equal to 1 if firm j employs cut-to-length harvesting system(s); 0 otherwise	157	38.7	–
$T_{\mathrm{Manual},j}$	A binomial variable equal to 1 if firm j employs both feller–buncher and cut-to-length harvesting systems; 0 otherwise	33	8.1	–
$T_{\mathrm{Other},j}$ [c]	A binomial variable equal to 1 if firm j employs a nonstandard or other harvesting system(s); 0 otherwise	9	2.2	+ or –
UP_j	A binomial variable equal to 1 if firm j is based in Michigan's Upper Peninsula; 0 otherwise	172	42.4	+ or –

Note: SD, standard deviation.
[a]Firms reported the number of their full-time and part-time employees. Part-time workers were assumed to equal 0.5 full-time-equivalent employees.
[b]Manual, chainsaw-based harvesting operations represent the base scenario among the vector of technology dummy variables. As such, there is no coefficient directly estimated for the variable T_{Manual}. Descriptive statistics are reported for completeness.
[c]Other harvesting systems include in-woods chipping operations or nonstandard system configurations.

Table 7. NIPF dependency model results.

Variable	Coefficient estimate	SE	p value
Intercept	5.7424	2.9830	0.0542
A	–0.4715	0.2098	0.0246
L	–0.1658	0.0393	<0.0001
$L \times F$	0.1124	0.0324	0
E	0.0262	0.0104	0.0117
T_{FB}	–0.2289	0.2786	0.4113
T_{CTL}	–0.2235	0.2364	0.3444
T_{Multiple}	–0.0649	0.3915	0.8683
T_{Other}	0.2694	0.5999	0.6534
UP	–0.3273	0.1153	0.005

Note: Model performance statistics include n = 406; maximum likelihood χ^2 = 74.7, df = 9, p < 0.0001; Hosmer and Lemeshow χ^2 = 5.7, df = 8, p = 0.6823; max-rescaled R^2 = 0.2240.

ties underlying individual firm behaviors. Nonetheless, the model does yield important insights into some of the drivers of NIPF dependency.

The coefficient for total employment, L, was negative and significant, indicating that larger logging firms are less likely to depend on NIPFs. Interestingly, the total employment effect is muted (but not reversed) by the positive interaction coefficient for $L \times F$. Intuitively, this makes sense: logging firms that employ a procurement or landowner assistance forester would be more likely than similarly sized firms to depend on timber from NIPFs. Experience (E), as measured by owner age, was a significant and positive explanatory variable. The inference here is that as the owner's age increased so too did the likelihood of being NIPF dependent.

The model incorporated state differences through the dummy variable UP, the coefficient for which was significant and negative. Firms based in Michigan's Upper Peninsula were less likely to be dependent on NIPFs as compared to firms based in Wisconsin, other things being equal. The estimated coefficient for the size of a firm's wood basket, A, was also significant and negative. Nondependent firms drew from a larger wood basket than NIPF dependent firms. This variable was weakly correlated with total employment (L), but an alternative model that excluded timberland area did not change the signs or significance and had little effect on the magnitude of the other model coefficients.

The signs of the technology coefficients were as expected — negative for the fully mechanized operations; however, none of the four technology dummy variables were statistically significant in explaining NIPF dependency. This suggests that the adoption of highly mechanized technologies by NIPF-dependent firms is slightly less but not significantly different than nondependent firms. Thus, it appears that, in general, logging firms within the study area have not adjusted their level of mechanization and capital inputs in response to their sources of stumpage supply.

Discussion

Collectively, our results indicate that there are substantial differences between logging firms that depend on NIPFs and those that do not. Notably, NIPF-dependent firms are more likely to operate on fewer, smaller, less intensely harvested sales. Firms also differ on the ownership source of their timber, with nearly 88% of the timber coming from NIPFs for dependent firms as opposed to more balanced sourcing among nondependent firms. Nevertheless, all logging firms in our study harvested a similar mix of products and indicated similar perceptions of profitability. In seeking to explain these differences empirically through firm characteristics, we found that NIPF dependency was negatively correlated with total number of employees, timberland area in the firm's wood basket, and whether the firm was based in the UP and positively correlated with the owner's age. The presence or absence of a forester on staff reduced, but did not reverse, the negative influence of the total number of employees. Although more research is needed, taken together these findings suggest that some logging firms are concentrating their timber harvesting activities on NIPFs and structuring their businesses accordingly with respect to the number and types of workers they employ.

Surprisingly, the type of harvest system(s) employed was not a significant explanatory variable in predicting NIPF dependency as we had expected. Prior studies on harvest productivity (Greene et al. 1997) and an exploratory study of Wisconsin logging firms (Rickenbach and Steele 2005) led us to speculate that logging firms with mechanized systems would likely seek out the larger sales found on public and industrial forests. We believe that there are two factors which might minimize the explanatory power of mechanized harvest systems. First, Table 3 indicates that for both NIPF dependent and nondependent logging firms, less than 22% of the timber sales were smaller than 20 acres (8 ha). Despite ongoing forest parcelization, parcel sizes may not yet be, on average, small enough to inflict meaningful cost constraints on mechanized systems. Second, small sales could be imposing higher costs, but logging firms may have adapted with strategies for minimizing these costs, such as reducing the price offered for stumpage or clustering several proximal sales. In doing so, dependent firms may more accurately account for the costs and returns in the bidding process. This would lend credence to owner age and experience and the potential role of a staff forester as significant factors in NIPF dependency. Whatever the underlying reason(s), NIPF-dependent firms report a higher likelihood of being profitable on timber sales smaller than 40 acres (16 ha) in size.

Implications and future research

A clear intent of this study from its initiation was to assess the impacts of forest parcelization on the logging sector and ultimately sustainable timber supply. In short, we would argue a simple answer, "not much", at least from what we can discern. Despite a slightly skewed distribution toward smaller sales and higher profitability on such sales, NIPF-dependent firms are still able to harvest nearly half of their supply (48.8%) from timber sales greater than 41 acres (17 ha) in size. Given the likelihood that most forest owners are unwilling to harvest more than half their property at once, NIPF-dependent firms are harvesting most of their timber from ownerships that are ≥80 acres (32 ha). Of course, unabated forest parcelization will eventually reduce the number of large NIPF parcels to such a point that supply does become restricted and firms will likely adapt their operations toward small parcels. As such, sales on small parcels will continue to be at a disadvantage in the marketplace. A key question will center on how the NIPF-dependent firms in this study, and those like them that have a competitive advantage on small sales, will adapt to remain profitable enterprises if parcelization continues. The majority of NIPF-dependent firms use mechanized systems that are commonplace in the region and incur similar levels of capital investment. At this point, NIPFs provide sufficient income to cover these investments, but a shift toward smaller parcels with higher fixed costs will prove a substantial barrier to anyone looking to harvest high volumes from NIPFs. Small-scale or "boutique" loggers will always have a niche, but it is unlikely that it will include being a major supplier to the region's pulp and paper sector. One obvious solution is to aggregate small sales together, but there is limited information and experience in North America as to how such arrangements might work, although that is changing (Bolen 1996; Rickenbach and Jahnke 2006).

In additional, anecdotal evidence suggests that the region has a shortage of loggers or, more precisely, logging capacity. Hence, logging firms that specialize on NIPFs are likely selecting the most profitable opportunities that usually exclude sales on smaller ownerships. While marginal logging capacity can be (and has been) increased through operational changes and (or) investments in new technology, substantial increases, either through firm expansion or new entrants, are less likely due to high capital requirements. In addition, modern mechanized harvest systems often require a skilled work force, where such skills are often learned "on the job".

Finally, our analysis and primary measure, NIPF dependency, hinge on a study area that includes the full range of ownership categories. The ability of this measure to capture important nuances in other regions, with less diverse ownership patterns, may be limited. Again, additional study and development are needed to validate and refine this approach. Nevertheless, in understanding the Lake states, NIPF dependency places procurement and timber supply in the context of ownership. By implication, future research might look to investigate the linkages between logging sector characteristics and behavioral studies of private forest owners or other ownership categories. It would also be useful to determine the extent to which the characteristics of NIPF-dependent logging firms are similar to those of firms that operate in places where the vast majority of ownerships are NIPFs. The answer to this would create evidence (one way or the other) as to the underlying relationship between the major supplier of US fiber (i.e., NIPFs) and those who harvest it.

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