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Scale of harvesting by non-industrial private forest landowners ☆

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Abstract

We examine the intensity of harvesting decision by non-industrial landowners at the lowest price offer they deem acceptable, using a multiple bounded discrete choice stated preference approach that draws upon and connects two subfields of forestry, one identifying characteristics of landowners important to past harvesting or reforestation decisions, and another proposing how landowners evaluate price offers for forest harvesting decisions. Variables important to harvest intensity choices when the landowners find an acceptable price have only been considered for those landowners who actually have participated in harvesting markets, whereas here we examine the behavior of these individuals as well as those who are on the margin (i.e., have not harvested at prevailing current or past market prices). We show that harvest intensity depends critically on the extent of urbanization, indicated by the presence of structures on a parcel as well as forested tract size, along with landowner characteristics such as absenteeism and length of ownership. The results are useful for understanding the timber management behavior for a majority of landowners who may not harvest at prevailing prices, but may participate should prices reach a level acceptable to them,

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where this level is determined by individual preferences for standing timber resources.

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Introduction

Non-industrial private forest landowners account for a majority of forest land ownership in the US (Alig and Plantinga, 2004). They are critical to future timber supply in the southern and eastern US given continuing declines in harvesting on government land and rapid urbanization (Argow, 1996; Birch, 1996).[1] It is not surprising that non-industrial landowner harvesting behavior has been an active area of empirical research for decades.[2] Most previous work seeks to identify a few characteristics of landowners, generally demographic ones, which can explain past harvesting or reforestation decisions. Participation of landowners in reforestation/cost share programs (e.g., Doolittle and Straka, 1987; Royer, 1987; Romm et al., 1987), and intentions of landowners to bequeath timber and land have also been studied (Hulkrantz, 1992; Amacher et al., 2002). The importance of non-timber amenities to the harvesting decisions of these landowners is a common theme in much of the literature (Kuuluvainen et al., 1996; Pattanayak et al., 2002; Conway et al., 2003).

There are at least two dozen articles written since 1980 that address the harvesting behavior of non-industrial private forest landowners using empirical data.[3] These studies typically evaluate landowner harvesting behavior during a specific time period, encompassing either a range of years or a single year, by analyzing data only from the respective time period sampled. There are commonalities among these studies with regard to exogenous variables that are found to significantly influence landowner harvesting behavior. For instance, income, tract size, and a measure of timber volume, are often significant. However, these studies found that price did not always have a positive or significant affect on harvesting by NIPF landowners.

Many studies point to the difficulties using general price indices to evaluate non-industrial landowner behavior, especially for those landowners who do not harvest (e.g., see Kuuluvainen and Salo, 1991; Bolkesjø and Baardsen, 2002). Not surprisingly, existing work does not account for individual-specific prices that

[1]NIPF lands account for 70% of the 200 million acres of forestland in the Southeastern states (Brunson et al., 1996). In Virginia alone, approximately 15.5 million acres of land are forested, with approximately 77% of these forested lands owned by NIPF landowners (Shaffer and Meade, 1997). Roughly 75% of the timber for forest industries in Virginia is supplied by NIPF land (Birch et al., 1998). The forest industry is one of the primary manufacturers in the state (Hodge and Southard, 1992).

[2]For recent surveys of this voluminous literature, see Amacher et al. (2003) and Pattanayak et al. (2002).

[3]These include Binkley (1981), Boyd (1984), Hyberg and Holthausen (1989), Jamnick and Beckett (1988), Dennis (1989, 1990), Kuuluvainen and Salo (1991), Kuuluvainen et al. (1996), Zhang (2001), Bolkesjø and Baardsen (2002), Munn et al. (2002), and Conway et al. (2003).

landowners accept, nor do they reveal what an acceptable price might be for landowners who have not harvested timber during the period covered by sampling. This omits a potentially large number of landowners important to the study of timber supply given the possibility of future price changes.

Our purpose is to examine the behavior of landowners who have not necessarily harvested, but who might as prices become higher. We do this using a recently developed stated preference approach, called multiple bounded discrete choice (MBDC) theory (e.g., see Welsh and Poe, 1998), to identify landowner intensity choices at the lowest price they find acceptable among a range of possible price offers. This allows us to examine the correlation between the price acceptable to landowners and their harvesting decisions in ways that previous studies cannot, because we include both landowners who have and have not previously harvested in our analysis.[4]

Our MBDC approach involves asking each landowner to indicate their acceptance of a price from a set of prices offered for harvesting a hypothetical acre of mature hardwood timber. The mature forest stand condition is proposed to each landowner given that pre-testing determined that landowners in our sample region were rarely aware of the actual volume of forest on their land. Thus, our approach places all landowners sampled in a similar situation, which then allows us to determine if factors other than volume and species are important in the intensity of timber harvesting decisions of landowners.

The motivation behind using our MBDC approach follows from the now well-known reservation price literature in forest economics (see Fina et al., 2001 for a review of this literature). A landowner's 'reservation price' is the minimum price offer that a landowner would accept to harvest at a given point in time. Since a landowner's acceptance of a price offer depends on individual preferences, observing landowners accepting prices for actual harvesting in a market reveals only that the market price meets or exceeds their own minimum price. Our MBDC experiment allows landowners to reveal their lowest acceptable price. Thus, we can examine harvest intensity decisions for those landowners who find an acceptable price offer (which may be above prevailing market prices), and not just those who have previously harvested. This distinguishes our work from all existing survey-based non-industrial landowner studies we are aware of (Amacher et al., 2003; Pattanayak et al., 2002 present comprehensive reviews of this literature).[5] Our contribution is to understand harvesting behavior for landowners who might be beyond the margin of market participation at prevailing prices – this could very well make up a majority of landowners.

The results of our study will be important to future work in predicting how landowners on a landscape will respond to changes in prices outside the range of

[4]While our assessment of landowner harvest intensity behavior involved placing landowners into a hypothetical market situation, we note that our results should be taken within the context of our approach, like in all stated preference analyses.

[5]Indeed, others have noticed this, arguing the difficulty in establishing the correct rejection price for harvesting, i.e., the limiting bounds of acceptable prices (see Kuuluvainen and Salo, 1991; Bolkesjø and Baardsen, 2002).

prevailing prices, as well as changes in landowner characteristics. The common assumption in all previous empirical work is that landowners are price takers, and so characteristics of the individual do not affect the price *actually* received. However, individual characteristics are expected to affect a landowner's *willingness* to accept a price offer and their harvesting behavior at this offer. Our results reveal this, showing that harvest intensity choices at the lowest price landowners will accept depend on landowner and parcel characteristics such as landowner type (absentee vs. resident), forested tract size, the presence of structures on the property, and the length of ownership. We also establish how preferences for non-consumptive and consumptive non-timber-related activities undertaken by landowners affect a landowner's harvest intensity decisions. The scale (or intensity) of harvesting decision of landowners who choose to harvest at any of the prices offered in our study (some beyond prevailing prices) is the cornerstone of our study.

Empirical model

We study landowner behavior regarding the intensity of harvesting at the lowest possible price offer landowners accept through our MBDC procedure. We are not interested in determining specifically what price a landowner would be willing to accept for harvesting of their own timber, but rather we examine a hypothetical situation where landowners are offered prices for harvesting as if they had mature hardwoods on their property at a given point in time. How the landowner would react here is indicative of their choices at a point in time where they had mature hardwoods and were considering harvesting; such an assumption is often made within the stated preference literature upon which the MBDC approach is based.[6] This point-in-time decision of harvest intensity also mimics the situation modeled in the reservation price literature, except there it has always been assumed that all of the forest is harvested once a price is accepted.[7] As a result of this hypothetical setting, the results should be interpreted with care.

With this in mind, suppose at time t, the probability that a landowner will accept a price offer from a set of potential price offers $P_j \in P$ can be written:

$$Pr(h_i = 1) = Pr[P_1 \leqslant \min\{P_j\}] \forall P_j \in P, \tag{1}$$

where $h_i = 1$ denotes landowner i choosing to harvest (i.e., accepting the price offer with probability 1), and P_1 is the landowner's lowest acceptable price offer to harvest at time t (i.e., it is the reservation price). The reservation price literature has

[6]In reservation price studies, there are search costs the landowner responds to in making decisions about acceptance or rejection of a price offer. These search costs depend on the opportunity cost of the landowner's time, how impatient the landowner is for money or their risk preferences for holding timber. Cost of time could be indicated by their income or other variables, such as whether the landowner is absentee or not.

[7]The common assumption is that all timber in an age class, if not the entire forest, is removed upon realization of the reservation price (Brazee and Mendelsohn, 1988). However, this practice is not typical of forest management in the type of forests, i.e., mature hardwood that we are examining here.

established that P_l is generally unknown by researchers (i.e., it is only revealed through the choice of acceptance), time dependent, and is a function of landowner preferences and characteristics (Fina et al., 2001).

The harvesting intensity decision of a landowner at time t who has been offered a price exceeding their lowest acceptable one, i.e., $P_j \geqslant P_l$, is simply given by a timber supply function for the individual non-industrial landowner. This should follow a specification that has landowner preference and characteristic variables driving the lowest acceptable price, as well as other variables known to be important to harvesting in the NIPF literature, i.e., reflecting harvest behavior at an actual price.[8] Because in our empirical analysis we will ask landowners to choose an intensity of harvesting *at* their lowest acceptable price from the set P, we can write the harvest intensity function in stochastic form as follows:

$$H_{it} = H(A, S, D, M, P_l, \varepsilon_h; \Omega), \tag{2}$$

where H_{it} is some measure of the intensity of harvesting by landowner i at time t, and ε_h is a random error term. Other factors affecting the harvest intensity decision are: the net assets (A) of the landowner at time t, S is a vector of forest land characteristics that might be important in the decision to harvest or accept an offer for harvesting at time t (such as the presence of structures), D is a vector of landowner demographic and other variables important to harvesting, M is a vector of expected future and current market factors, P_l is the landowner's stated lowest acceptable price indicated by the landowner from the set P, and Ω represents a vector of landowner preferences, amenities received, and other objectives for use of their forested lands.

This model is related to our empirical analysis discussed below. There, we use a MBDC approach to offer multiple prices to landowners (the set P in (1)), and then ask about their intensity of harvesting at the lowest acceptable price. This is a unique way of estimating Eq. (2). Further, because the MBDC is applied at one point in time, t is no longer an explanatory variable, and the remaining explanatory variables take on their time t values in Eq. (2).

In the empirical analysis, we also propose discrete choices of harvest intensities to landowners, because pre-testing showed that landowners understood and were more likely to respond to this format than an open-ended assessment of harvesting intensity. This implies we can estimate the harvest intensity decision as a multinomial logit problem.[9] For example, if landowners were offered k possible intensities for harvesting at the lowest acceptable price, then the probability that any one intensity would be chosen, i.e., $x_k = 1$, can be estimated using a multinomial logit problem procedure. Using Eq. (2), estimation of the probability of choosing any particular

[8]This intensity of harvesting decision is different from previous NIPF harvest behavior research that has considered mainly characteristics driving the decision to harvest or not.

[9]This is similar to estimation carried out by Munn et al. (2002). However, our analysis differs in that we study timber management behavior of both those landowners who would enter the market at current market prices and those who may be on the margin of market entry. We also use a stated preference approach to assess the lowest acceptable price and examine the intensity decision, and we allow for greater variation of intensities.

intensity from k choices at time t is

$$Pr(H_{it} = x_k) = \frac{e^{\gamma \tilde{Z}_j}}{(1 + e^{\gamma \tilde{Z}_j})} \forall k, \tag{3}$$

where x_k is the discrete intensity choice, γ represents the coefficients to estimate for this decision, and j represents each possible harvest intensity choice. Given that we will ask landowners questions about harvest intensity at the lowest price of the set P that they indicated as acceptable, this lowest price P_l should also be an explanatory variable in (3), so that $\tilde{Z}_j = \{A, S, D, t, M, P_l; \Omega\}$. Again, given the harvest intensity decision will be examined at one point in time, t is not an argument in $\tilde{Z}_j$ and the remaining explanatory variables and the dependent variable take on time t values.

Methods

Our econometric approach to examining (3) relies on a survey instrument where landowners were offered a set of potential price offers $P_j \in P$ from Eq. (1), and then asked whether or not they would harvest at various intensities, for the lowest price they indicated was acceptable (if in fact they did accept one of the price offers). Discrete harvest intensities of 25%, 50%, and 100% were proposed to each landowner. Because it was not possible to survey the actual forest characteristics of each landowner in the survey, and because pre-testing and focus groups revealed that landowners did not generally know the timber volume and species types on their land,[10] we proposed price offers to landowners in a hypothetical forest setting. That is, the landowner was asked about acceptance of price offers and intensity of harvesting they would undertake at the lowest acceptable price for an acre of mature hardwoods that were ready to harvest on their property. The hypothetical nature of this questioning means that the results below must be taken in context. However, there is also an obvious advantage – by placing all sampled landowners in the same position regarding their forests, it is possible to uncover specifically how landowner characteristics affect their harvest intensity decisions. Moreover, the questions and price ranges used closely mimicked actual forest and market conditions in the sampling region.[11]

Appendix 1 presents the critical question from the survey. The price offer table follows the MBDC approach of Welsh and Poe (1998) and referendum design as summarized by Carson et al. (1998). In our application of this approach, respondents were asked whether or not they would accept a given amount to give up a resource, i.e., harvest their standing timber, and then asked to state their confidence in their

[10]Hodge and Southard (1992) also found this for a survey of 3000 non-industrial landowners in Virginia, as did Conway et al. (2003) and Sullivan et al. (2005).

[11]Most of the forest stands in our survey region are primarily hardwood and not actively managed, and thus are not multi-aged. Therefore, a landowner selecting the 100% harvest intensity is effectively indicating that they would manage their stand using a clearcutting regime, while the 50% and 25% intensities are indicative of management via selective harvesting practices for our sampling area.

answer for each dollar amount offered. The MBDC approach applied at one point-in-time for the landowner is consistent with the idea of a reservation price strategy (that is, a landowner observes a set of possible offers at a point-in-time and chooses one if it equals or exceeds their otherwise unobserved point-in-time lowest acceptable price). The inclusion of other questions in our survey instrument focusing on landowner objectives, demographics, and characteristics of the property, are consistent with the known determinants of harvesting reported in the previously mentioned existing econometric studies of landowner behavior.

For each price offer, landowners could select 'definitely not', 'probably not', 'not sure', 'probably yes', and 'definitely yes' to state their preference for accepting each price offer to harvest. Each landowner was also given the option of not harvesting at the range of prices offered. The question format provides an advantage in that it allows for possible uncertainty landowners have with regards to harvesting at various prices.[12] Most importantly, the lowest price offer at which landowners were willing to harvest an acre is a convenient means for identifying a bid closest to their unobserved reservation price. The 'not sure' option is required in these types of stated preference surveys to minimize bias concerning uncertainty (Carson et al., 1998).

After landowners responded to the price offer table, they were then asked at what intensity they would harvest on the acre in question for the lowest price they indicated was acceptable.[13] An acceptable price was defined as one where the landowner indicated either 'probably yes' or 'definitely yes' to the price offers (we examined two definitions of the lowest acceptable price in the analysis that follows, one indicated by selection of 'definitely yes' and the other indicated by selection of either 'probably yes' or 'definitely yes'). Landowners were asked whether they would or would not harvest 25%, 50%, and 100% of their total forest stocks, again maintaining the assumption of considering one acre of mature hardwoods.[14]

The per acre price offers in US dollars for harvesting were constructed using published data and survey pre-test results. In the pre-test landowners were given open-ended questions regarding the lowest price that they would consider harvesting an acre of mature hardwoods. These answers provided an overall range between lowest and highest offers. Other information on returns and prices were collected for the sample area from Timber Mart South (2000). A midpoint return per acre was then derived using Timber Mart South prices and hardwood yield tables for the

[12]Allowing the landowner to state the certainty they have with their decision is unique to the MBDC approach. For a comparison of this approach with other stated preference approaches, see Welsh and Poe (1998).

[13]It is well known that market prices are sensitive to forest quality. However, this idea would have been difficult to implement into our survey, as landowners may not understand the relationship between quality and prices. Therefore, landowners were told a range of prices for mature hardwoods in their area that were a subset of the possible price offers. Again, our purpose is not to test how market prices depend on forest attributes, but rather what variables predispose a landowner to select a particular harvest intensity when an acceptable price is offered.

[14]It is assumed that landowners behave rationally and that any treatment applied to an individual acre, would be representative of typical forest management behavior for multiple acres given the type of forests present in the sampling region.

survey area. Prices above and below this midpoint were computed using a logarithmic distribution, which follows the literature on simple referendum elicitation methods (Cameron and James, 1987).[15]

A mail-out-mail-back survey containing the question in Appendix 1 was sent to Virginia landowners in the hardwood region during Fall of 2000 and Spring of 2001. Initial pretests were performed on landowners from Montgomery County (e.g., see Kennedy, 2001). The full survey was then mailed in August 2000, followed by reminder postcards. The same procedure was followed for a second mailing conducted in April 2001. Survey question design, mailing, and follow-up procedures followed Dillman (1978).

The Fall 2000 sample of four western Virginia counties; Giles, Montgomery, Pulaski, and Roanoke, consisted of 1240 mailed surveys. County sample sizes were based on a combination of county acreage, number of landowners in each county, and number of parcels. County tax records were used to obtain names, addresses, and parcel sizes. Landowners selected did not include corporate landowners, those living in residential neighborhoods, or those holding less than 20 acres. The Spring 2001 survey was performed in order to provide a broader sample of landowner data. The second sampling included another 478 landowners in Montgomery County who had not been previously surveyed. The response rate for the initial pretest was 40% (Kennedy, 2001) and the response rate for the Fall 2000 survey was 36% (Kennedy, 2001). The response rate for the Spring 2001 survey was 34%. These response rates are higher or within range of those reported for other landowner surveys recently conducted in the region (Conway et al., 2003; Hodge and Southard, 1992).

Table 1 presents descriptive statistics of selected variables. These results are similar to those in previous surveys of Virginia landowners (e.g., Hodge and Southard, 1992; Birch, 1996; Conway et al., 2003). Approximately 49% of landowners actually resided on the surveyed property. Absentee landowners, defined as those not residing on their property and living more than 50 miles away, comprised 16% of the respondents. The average age of respondents was 59.7 years, the majority of which were employed (54%) or retired (45%). Landowners who acquired their land through inheritance represented 27.5% of the respondents. We found in the survey that some landowners inherited a portion of the surveyed parcel, and purchased an additional portion, explaining why more than 100% of the surveyed population is represented in the land acquisition variables. The average respondent owned a parcel 85.4 acres in size, of which an average of 64.7 acres was forestland. Average length of ownership was approximately 23 years and mean income of respondents was just under $80,000. The majority of responding landowners, 74%, planned to leave their land to heirs, while only 39% had future plans to bequeath standing timber to heirs. Respondents stated that owning land for future generations was relatively important

[15]While it is true that any landowner may eventually accept a price offer as the set of offers approaches infinity, we constructed our highest price offer using pre-testing, so that most landowners who do not pick a price from the range offered would never harvest at any price that could exist in the market now or in the future. Thus, our analysis is only for those landowners who would enter the market under reasonable conditions.

Table 1. Descriptive statistics and units of measurement for Virginia forest landowner survey 2001

Variable	Mean	Standard deviation
Age (years)	59.731	13.206
Income ($)	79,591.03	58,091.88
Debt ($)	70,386.82	145,051.55
Married (0,1)[a]	0.804	
Number of children	2.29	1.51
Completed high school (0,1)	0.172	
Completed some college (0,1)	0.195	
Completed college (0,1)	0.554	
Agricultural acres	34.596	81.029
Forested acres	64.717	103.879
Open land acres	6.926	18.244
Other land acres	1.402	8.165
Roads (miles)	0.995	1.832
Employed (0,1)	0.542	
Retired (0,1)	0.450	
Bought land (0,1)	0.762	
Inherited land (0,1)	0.273	
Sold timber in past (0,1)	0.260	
Days spent hunting	12.368	43.566
Days spent in non-consumptive activities	241.93	403.31
Years owned property	23.327	17.999
Absentee (0,1)	0.158	
Reside on property (0,1)	0.487	
Importance of ownership for environmental reasons (1–5)[b]	3.719	
Importance of ownership for future generations (1–5)	4.079	
Importance of ownership for and investment (1–5)	3.261	
Give land to heirs (0,1)	0.740	
Give timber to heirs (0,1)	0.394	
Refusal of all prices offered (0,1)	0.217	
Indicated 'definitely yes' for a price offered (0,1) ('Firstprice')	6400.58	3573.03
Indicated either 'probably' or 'definitely' yes for a price offered (0,1) ('Firstprice')	4878.21	3321.01
Harvest at 25% intensity	0.186	
Harvest at 50% intensity	0.353	
Harvest at 100% intensity	0.380	

[a](0 = no; 1 = yes).
[b]1 = not important; 5 = very important.

with a mean score of 4 (out of 5). The importance of environmental reasons for holding land, e.g., protection of habitat, water quality, and protection against soil erosion, had a mean score of 3.7 out of 5.0, which corresponds roughly to the results in Brunson et al. (1996). The motivations of land investment/real estate for owning land were also found to be somewhat important, although not as important as environmental reasons. A lower value of importance attached to land investment is typical for Virginia forest landowners; Birch (1996) found that 12% of landowners considered land investment a primary reason for owning land.

Estimation results

We turn now to estimating the intensity of harvesting decision (Eq. (3)) at each landowner's lowest acceptable price offer, where the harvest intensity choices are discrete mutually exclusive choices (see Appendix 1).[16] Two indications of the lowest bid a landowner would choose to accept were used. The first was defined using the lowest price offer that the landowner indicated 'definitely yes' to accepting in the payment table. The second was defined as the lowest bid that the landowner indicated either 'definitely yes' or 'probably yes' to accepting in the payment table (see Appendix 1). In what follows, the first case will be referred to as 'FPDY', while the second case will be referred to as 'FPE'.

In estimating the model, there was some potential endogeneity in the data due to survey instrument design. Recall from (3) that the harvest intensity regression must have the lowest price the landowner was willing to accept as an explanatory variable. As this price is a choice for the landowner in the survey, it is potentially correlated with the error in choosing the intensity of harvesting.[17] Therefore, we take two approaches to investigating harvest intensity behavior of landowners indicating an acceptable price for timber harvesting. One approach assumes that the price choice is jointly determined with the choice of intensity, and another which assumes that these two choices are not jointly determined. For the joint case, instrumental variable methods were utilized, where we obtained a first stage prediction of this lowest accepted price as a function of exogenous variables, and then use the prediction in place of the lowest price accepted when estimating the regression for intensity of harvesting. For the non-joint case, the lowest acceptable price is assumed to be exogenous (i.e., not correlated with the choice of harvest intensity). Finally, some other explanatory variables could also be endogenous to intensity of harvesting choices, such as days spent hunting or days spent in other non-consumptive

[16]There is no sample selection problem with the data, because no landowner who filled out the price table also indicated that they would not harvest at the range of prices given. Thus, the choice to accept a price completely removed landowners who would not harvest at the range of prices offered. These landowners are of no interest to us, but we must caution that our results must be taken within the context of this sample.

[17]While landowners are assumed to be price takers when they participate in the market, those who do not harvest at a given price are effectively rejecting it.

Table 2. Estimated coefficients of multinomial logit model of the harvest intensity decision by NIPF landowners when the lowest acceptable price (firstprice) is assumed to be endogenous

Variable	100% Harvesting scale		50% Harvesting scale	
	FPDY	FPE	FPDY	FPE
Constant	−12.615	−2.093	−10.753	−0.594
Absentee	−1.398	−0.525	0.646	0.379
Income	1.44E-5	2.75E-6	1.17E-5	6.08E-6
	(9.23E-6)	(6.56E-6)	(8.20E-6)	(4.87E-6)
Timber bequest	1.599	1.085	1.659	1.176*
Land bequest	0.618	−5.44E-2	1.789*	0.476
Inherited land	1.153	2.064*	0.786	1.462
Length of roads on property	−2.38E-2	0.259	0.257	−0.159
	(0.605)	(0.337)	(0.471)	(0.281)
Years property owned	6.47E-2*	5.95E-2**	4.87E-2	2.34E-2
	(3.52E-2)	(2.63E-2)	(3.38E-2)	(2.41E-2)
Risk perceived with growing trees	−0.259	−9.36E-2	−0.180	−1.07E-3
Risk perceived with tree loss	0.121	−3.68E-2	−0.134	−8.76E-2
Forested acres owned	−9.48E-3	−1.33E-2**	−3.17E-3	7.45E-4
	(6.65E-3)	(6.17E-3)	(5.08E-3)	(3.63E-3)
Number of children	0.974**	0.828***	0.681*	0.458*
	(0.409)	(0.303)	(0.394)	(0.272)
Employed	−0.917	−0.462	−8.08E-2	−0.386
Sold timber in past	0.378	−0.142	1.782**	0.779
Structures present on land	−3.26***	−2.648***	−0.975	−0.267
Preference to hold land as investment	0.739**	0.486*	0.421	0.155
Completed college	−0.745	−0.408	0.211	−0.423
Firstprice	1.92E-3	4.05E-4	1.85E-3	2.65E-4
	(2.20E-3)	(1.58E-3)	(1.99E-3)	(1.38E-3)
Predicted non-consumptive days	1.72E-2*	1.10E-2	7.14E-3	3.36E-3
	(1.03E-2)	(1.19E-2)	(1.12E-2)	(1.07E-2)
Predicted hunting days	−0.528*	−0.312	−0.583**	−0.239
	(0.295)	(0.294)	(0.277)	(0.263)

***Significant at p-level of 0.01, **significant at p-level of 0.05, *significant at p-level of 0.1. Standard deviations indicated in parenthesis.

recreational activities since these variables are closely related to harvesting preferences. These will also be treated using the instrumental variable method in both cases examined.

Tables 2 and 3 present results for the multinomial logit model applied to harvest intensity choices. Table 2 contains results where the lowest price indicated as acceptable is assumed endogenous to the harvest intensity choice, while Table 3

Table 3. Estimated coefficients of multinomial logit model of the harvest intensity decision by NIPF landowners when the lowest acceptable price (firstprice) is assumed to be exogenous

Variable	100% Harvesting scale		50% Harvesting scale	
	FPDY	FPE	FPDY	FPE
Constant	−0.213	0.541	0.461	1.174
Absentee	−1.961	−0.573	0.632	0.418
Income	2.06E-5**	5.72E-6	1.38E-5*	8.24E-6*
	(9.93E-6)	(6.24E-6)	(8.30E-6)	(5.01E-6)
Timber bequest	2.130*	1.227	1.960*	1.369*
Land bequest	0.468	1.13E-2	1.695*	0.545
Inherited land	1.330	1.850*	0.653	1.256
Length of roads on property	−0.183	0.331	0.174	−0.134
	(0.651)	(0.338)	(3.48E-2)	(0.282)
Years property owned	7.06E-2**	6.81E-2**	5.20E-2	3.22E-2
	(3.60E-2)	(2.78E-2)	(3.48E-2)	(2.53E-2)
Risk perceived with growing trees	−0.128	−0.152	−0.169	−5.19E-2
Risk perceived with tree loss	0.171	−6.89E-2	−0.197	−0.145
Forested acres owned	−1.21E-2	−1.47E-2**	−2.73E-3	2.78E-4
	(7.55E-3)	(6.21E-3)	(5.01E-3)	(3.68E-3)
Number of children	0.755*	0.760***	0.514	0.402
	(0.402)	(0.306)	(0.382)	(0.276)
Employed	−0.347	−0.463	0.236	−0.394
Sold timber in past	−0.306	−0.246	1.614*	0.722
Structures present on land	−3.822***	−2.672***	−1.030	−0.244
Preference to hold land as investment	0.811**	0.467*	0.477	0.150
Completed college	−0.457	−0.544	0.597	−0.499
Firstprice	−3.80E-4***	−2.10E-4**	−1.31E-4	−1.42E-4
	(1.45E-4)	(1.07E-4)	(1.17E-4)	(9.32E-5)
Predicted non-consumptive days	1.06E-2	7.54E-3	1.61E-3	7.98E-4
	(8.25E-3)	(6.55E-3)	(8.88E-3)	(5.70E-3)
Predicted hunting days	−0.264*	−0.202**	−0.367**	−0.158*
	(0.148)	(9.89E-2)	(0.153)	(8.94E-2)

***Significant at p-level of 0.01, **significant at p-level of 0.05, *significant at p-level of 0.1. Standard deviations indicated in parenthesis.

assumes that this lowest acceptable price is exogenous. Although survey participants were given the option of selecting more than one intensity level at their lowest acceptable price, nearly all respondents made a single selection. This allowed us to treat the selection of harvest intensities as mutually exclusive choices, thus requiring use of a multinomial logit regression. As we discussed above, in each table there are also two versions of the regressions that depend on how the landowner indicated

their lowest acceptable price. The columns in Tables 2 and 3 labeled 'FPDY' contain regressions that include as an explanatory variable the lowest price offer the landowner indicated they would accept by checking 'definitely yes' in the payment table. The columns labeled 'FPE' contain regressions that include as an explanatory variable the lowest price offer the landowner indicated they would accept by checking either 'probably yes' or 'definitely yes' in the payment table. These lowest acceptable prices are included as the explanatory variable labeled 'firstprice' in all of the regressions (see also Table 1).

Before discussing the results, note that Tables 6 and 7 present frequencies of actual and predicted outcomes for the multinomial logit estimation, as summarized by percent correct predictions. These summaries provide a reasonable assessment of goodness of fit for discrete choice models such as this (see Greene, 2000).

The coefficients resulting from the multinomial logit estimations present no meaningful interpretation due to the nature the estimation (i.e., see Greene, 2000; Maddala, 1983), and so we focus our interpretation of results from the estimated marginal effects. These are given in Tables 4 and 5. Looking at these tables, we find that some general trends are evident for both versions of the model. The presence of structures decreases the probability that a representative landowner would choose harvest at the 100% intensity, while it has a positive effect on the probability of selecting either the 50% or 25% intensity of harvesting. The probability of a landowner selecting the 100% harvest intensity is decreased by the number of forest acres, while that of harvest at the 50% intensity is increased by increasing forest acreage for both models, at a p-level of 0.01. This could reflect an "allowable cut effect", where a landowner receiving a higher price for timber may cut less timber if they are faced with other constraints or objectives, such as their individual preferences for amenities from standing timber. Also, absentee landowners who indicated 'definitely yes' to the lowest price have a decreased (increased) probability of selecting the 100% (50%) harvest intensity according to the marginal effects. The length of ownership increased (decreased) the probability of selecting the 100% (25%) harvest intensity for the FPE regression when all other explanatory variables are held at their mean values.

While the effects of the explanatory variables on the harvest intensity decision should be interpreted with care owning to the hypothetical nature of our price and harvesting question, some important insights follow from these results. Structures present on the property are an important indicator of forest land fragmentation in the sample area, as are the number of forested acres. As access improves and urbanized land use increasingly encroaches on forest land, the number of structures on the landscape typically increases. Structures may also be indicative of wealthier landowners, who are less likely to need supplemental income from harvesting, and thus are willing to harvest at lower intensities or delay forest income until a later date. Alternatively, the presence of structures could imply that these landowners have higher amenity values for standing timber near existing structures.

Our results also show that landowners with larger quantities of forested acres have decreased (increased) probabilities of harvesting at the 100% (50%) intensity in the

Table 4. Marginal effects of the multinomial logit model of the harvest intensity decision when the lowest acceptable price (firstprice) is assumed to be endogenous

Variable	100% Harvesting scale		50% Harvesting scale		25% Harvesting scale	
	FPDY	FPE	FPDY	FPE	FPDY	FPE
Absentee	−0.485**		0.459**			
Timber bequest			7.17E-2	9.91E-2		−0.141*
Land bequest			0.313*			
Inherited land		0.219				−0.213**
Years property owned	5.72E-3	9.67E-3**				−4.84E-3*
Forested acres owned		−3.24E-3***		−2.58E-3***		
Number of children	9.69E-2*	0.111**	−3.84E-2	−3.44E-2	−5.85E-2*	−7.65E-2**
Sold timber in past			0.363**			
Structures present on land	−0.602***	−0.569***	0.452***	0.409***	0.150*	0.161**
Preference to hold land as investment	9.38E-2	8.55E-2*				
Predicted non-consumptive days	−7.02E-3					
Predicted hunting days	−7.02E-3		−3.22E-2		3.93E-2**	

***Significant at p-level of 0.01, **significant at p-level of 0.05, *significant at p-level of 0.1.

Table 5. Marginal effects of multinomial logit model of harvest intensity behavior when the lowest acceptable price (firstprice) is assumed to be exogenous

Variable	100% Harvesting scale		50% Harvesting scale		25% Harvesting scale	
	FPDY	FPE	FPDY	FPE	FPDY	FPE
Absentee	−0.607***		0.563**			
Income	2.15E-6		−8.12E-7	1.01E-6		
Timber bequest	0.112		4.97E-2	0.118		−0.152*
Land bequest			0.327*			
Inherited land		0.200				−0.176*
Length of roads on property		0.101*				
Years property owned	6.39E-3	1.03E-2***				−5.39E-3*
Forested acres owned		3.48E-3***		2.77E-3***		
Number of children	7.72E-2	0.103**				−6.45E-2**
Sold timber in past	−0.408**		0.467***			
Structures present on land	−0.715***	−0.577***	0.532***	0.428***	0.182**	0.149*
Preference to hold land as investment	9.84E-2*	8.12E-2*			−4.99E-2*	
First price	−6.51E-5**	−2.30E-5	4.58E-5*			1.99E-5*
Predicted hunting days	1.19E-2	−1.80E-2	−3.73	−2.57E-3	−2.54E-2**	2.06E-2**

***Significant at p-level of 0.01, **Significant at p-level of 0.05, *Significant at p-level of 0.1.

Table 6. Frequencies of actual and predicted outcomes of multinomial logit model of harvest intensity behavior when the lowest acceptable price (firstprice) is assumed to be endogenous

Actual	Predicted			Total	% Correct
	25% Intensity	50% Intensity	100% Intensity		
First price 'definitely yes' (FPDY)					
25% Intensity	17	6	1	24	70.8
50% Intensity	2	28	11	41	68.3
100% Intensity	4	8	33	45	73.3
First price either 'probably yes' or 'definitely yes' (FPE)					
25% Intensity	18	15	2	35	51.4
50% Intensity	9	31	15	55	56.4
100% Intensity	5	9	42	56	75.0

FPE regressions.[18] An indication of changing landowner dynamics is the presence of absentee landowners, i.e., those landowners who do not live near the property that they own – this is a demographic change that accompanies increases in low density rural development. Many of these landowners are investors with little or no forestry knowledge, or those who hold land predominately for non-timber reasons; that is, these landowners may use their land mainly for vacationing, if at all. For the FPDY regressions, absentee landowners are less (more) likely to select the 100% (50%) harvest intensity, which is consistent with the above argument that these landowners may hold higher amenity values for these forested ownerships. Finally, our results also indicated that length of ownership was important to the harvest intensity decision despite the treatment of the timber price variable at a p-value $\leqslant 0.1$. Length of ownership increases investment in the property and possibly also increases familiarity with the property and thus we would expect landowners to show increased (decreased) probability of harvesting at the 100% (25%) intensity for the FPE regression.

Lowest acceptable price assumed to be endogenous

The version of the model that considers the lowest acceptable price as a potentially endogenous (jointly determined with the choice of intensity) explanatory variable in the harvesting intensity decision predicts the outcomes of this decision with an

[18]Landowners may also have simply been opposed to harvesting their forest at the highest intensity level offered and more willing to harvest at lower intensities, due to economies of scale, i.e., it is less costly to harvest at lower intensities when there are more acres to be harvested (to a point), and more costly to replant many acres that have been intensively harvested. Other studies have also found that tract size is positively related to harvest probability (see Amacher et al., 2003).

Table 7. Frequencies of actual and predicted outcomes of multinomial logit model of harvest intensity behavior when the lowest acceptable price (firstprice) is assumed to be exogenous

Actual	Predicted			Total	% Correct
	25% Intensity	50% Intensity	100% Intensity		
First price 'definitely yes' (FPDY)					
25% Intensity	17	5	2	24	70.8
50% Intensity	2	29	10	41	70.7
100% Intensity	4	5	36	45	80.0
First price either 'probably yes' or 'definitely yes' (FPE)					
25% Intensity	20	12	3	35	57.1
50% Intensity	8	33	14	55	60.0
100% Intensity	6	8	42	56	75.0

average percent correct prediction rate of approximately 71% for the FPDY regression and 61% for the FPE regression (Table 6). In analyzing the marginal effects (Table 4), the number of children was also significant and increased (decreased) the probability of selecting the 100% (25%) harvest intensity in the FPDY regression. This may be a function of the additional income needed, e.g., for medical or other expenses, when there are a large numbers of dependents in the household. Landowners who indicated they had sold timber in the past, a measure of experience with managing forest resources, showed an increased probability of selecting the 50% harvest intensity for the FPDY regression at a p-level of 0.05 (Table 7).

Lowest acceptable price assumed to be exogenous

When the lowest acceptable price is considered not to be jointly determined with the harvest intensity choice model, the FPDY regression indicates that price is significant and decreased (increased) the probability of selecting the 100% (50%) harvest intensity (see Table 5). If landowners are acting to maximize harvest revenues, i.e., to satisfy some income need, higher prices reduce the need to harvest at greater intensities, and thus would explain the above results.

Previous timber sale experience is not only positive and significant in the selection of the 50% intensity, but is also negative and significant in the selection of the 100% intensity. Landowners who have harvested timber resources in the past are more likely active participants in timber management, and thus may be more likely to harvest at lower intensities, especially considering the structure of forest that was proposed for management, i.e., mature hardwoods. Also, there is the presence of a potential income effect, as previously discussed. Another result that is similar to that

of the model that accounts for the potential endogeneity of the timber price variable is that the number of children is significant in its effect on the probability of selecting either the 100% intensity or the 25% intensity. However, here the number of children increases (decreases) the probability of the landowner selecting the respective intensity levels in the FPE regression (as opposed to the former case where similar signs were found in the FPDY regression).

Another expected result is the increased (decreased) likelihood of selecting the 100% (25%) intensity for the FPDY regression by landowners who indicated increasing importance of land ownership for investment/real estate purposes. It is most likely that such landowners are considering the value of the property for residential or possibly commercial uses, and thus could reap both the income from timber sale at the highest intensity level offered, as well as from sale of the land for another use. Overall, this model performed slightly better in predicting the frequencies and probability of choice occurrence with an average of approximately 74% and 64% correct for the FPDY and FPE regressions, respectively.

Conclusions

Previous empirical landowner behavior research has focused on estimating probabilities explaining previous harvesting and reforestation behavior at prevailing market prices. There has also been a separate set of theoretical literature that considers how landowners choose to accept or reject a given price offer for harvesting timber resources. In this work, the existence of a "reservation price" is assumed to be important to the probability of accepting an offer to harvest. Landowners who do not harvest at prevailing prices do so because the distribution of prices observed does not contain at least one price that meets their reservation price, which is theorized to be a function of landowner preferences and financial status. Thus, while landowners are price takers, their *willingness* to accept a price offer depends to a large extent on landowner-specific variables.

In this paper we examine harvest intensity choices at the lowest prices landowners find acceptable. We do this using the recent multiple bounded discrete choice (MBDC) method to offer a range of price offers to a sample of non-industrial forest landowners in the hardwood region of Virginia, asking landowners whether they were willing to harvest a hypothetical acre of mature hardwoods at the range of prices. At the lowest price landowners indicated they would be willing to accept, we then asked at what intensity landowners would consider harvesting this acre. The MBDC method allowed for two different definitions of the 'lowest price' chosen by landowners that depended on their confidence in selecting the prices, which is an important benefit of this particular stated preference approach.

We find that the intensity of harvesting at the lowest acceptable price for landowners in our sample depends on several variables including landowner characteristics and property access. We also establish that complete removal of marketable timber from all forested land once reservation prices are met cannot be

simply assumed. Characteristics of landowners that predispose them to harvest at high and low intensities, are therefore of great interest. Indeed once a landowner deems a price acceptable for harvesting, their intensity decision relies on the size of forested ownership, length of ownership, presence of existing structures, and whether the landowner was absentee, i.e., residing more than 50 miles from their parcel. For landowners in our sample, the highest intensity of harvesting (100%) can be expected as the number of years of ownership increases. However, landowners with structures on their property and larger forested parcels exhibit an increased likelihood of harvesting at lower intensities when they do enter the timber market. Lower intensity harvests can also be expected when the landowner is absentee. An interesting finding also concerns prices; even for relatively high timber prices, complete harvesting of forest stocks cannot be assumed, as indicated by the model that considers that price acceptance and harvest intensity decisions are not jointly made by the representative landowner, i.e., price is an exogenous factor in the selection of intensity.

It is also useful to compare market prices to the offers presented to landowners in our survey. Our payment table offers ranged from 500 to over 10,000 dollars per acre for harvesting mature hardwoods. Landowners, who found at least one offer acceptable, indicated that their lowest acceptable price offer was on average either 4878 or 6400 dollars per acre depending on how this price was defined. These offers are close to actual market returns for harvesting an acre of mature hardwoods in the sample area, indicating that the magnitudes of offered prices were reasonable for the sampling region. It also suggests that our estimated marginal effects, computed for the harvest intensity decision, might be used as a means for predicting how responsive landowners will be as market prices and surrounding land characteristics change.

In the future the approach here might be used to identify the probability that various types of landowners, or landowners holding land with different access and site characteristics, will enter the market and the extent of harvesting undertaken by a representative landowner. For instance, our results indicate that selective harvesting becomes much more likely than harvesting at the 100% intensity in areas experiencing development pressures, as indicated by an increase in the presence of structures on a parcel and a decrease in the size of the forested tract. The estimated equations could also be used to determine the probability of accepting potential price offers, even though the price offers might be different than prevailing prices. The probability of harvesting at different intensities could be estimated for different types of landowners, i.e., those with different preferences regarding bequests and non-timber activities. The estimated probabilities could then be integrated into spatially explicit models to assess how fragmentation and changing landowner characteristics will affect the pattern of harvesting and forest cover across a large geographic area.

Appendix 1. Payment table and harvesting scale questions

10. Forests can provide a number of goods and services. If forests are harvested, they provide income for the owner. Standing timber provides habitat for wildlife and

recreational opportunities for landowners. Forests can be harvested about once every 50 years in your area, and landowners typically receive $1000–6000 per acre when they harvest depending on the quality of the trees cut (an acre is roughly the size of a football playing field – 100 yards × 55 yards). In your area, a new forest will establish itself on cutover land if left alone. Harvesting of trees can also be done in a way to ensure that a new forest is established within one year after cutting.

Suppose you had mature hardwood forests right now on your property, and you were given a dollar offer for harvesting. The table below lists specific amounts you could receive per acre by harvesting. For every payment value in the table below, indicate your acceptance level to harvest one acre of your forest.

Would you accept any of the following single payments to harvest one acre of forest?

Payment made to you	Definitely not	Probably not	Not sure	Probably yes	Definitely yes
$500 per acre					
$1000 per acre					
$2000 per acre					
$3500 per acre					
$5000 per acre					
$6500 per acre					
$8500 per acre					
$10,500 per acre					
$13,000 per acre					

If you would never harvest your forest no matter what the amount offered, please check here: ☐

If you checked the NOT SURE box anywhere in the table above, could you tell us why?

___ I AM NOT FAMILIAR ENOUGH WITH MY PROPERTY TO ANSWER
___ I AM NOT THE DECISION-MAKER FOR THE PROPERTY IN QUESTION
___ I DO NOT KNOW IF I HAVE FORESTS ON MY PROPERTY
___ I DO NOT UNDERSTAND THE QUESTION
___OTHER (PLEASE SPECIFY):_____

For the LOWEST amount you checked PROBABLY YES or DEFINITELY YES, indicate how much of the forest on your property you would consider harvesting (check all that apply)

(SKIP THIS QUESTION IF YOU DID NOT ANSWER PROBABLY OR DEFINITELY YES IN THE TABLE)

25% _____
50%_____
ALL_____
OTHER_____

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