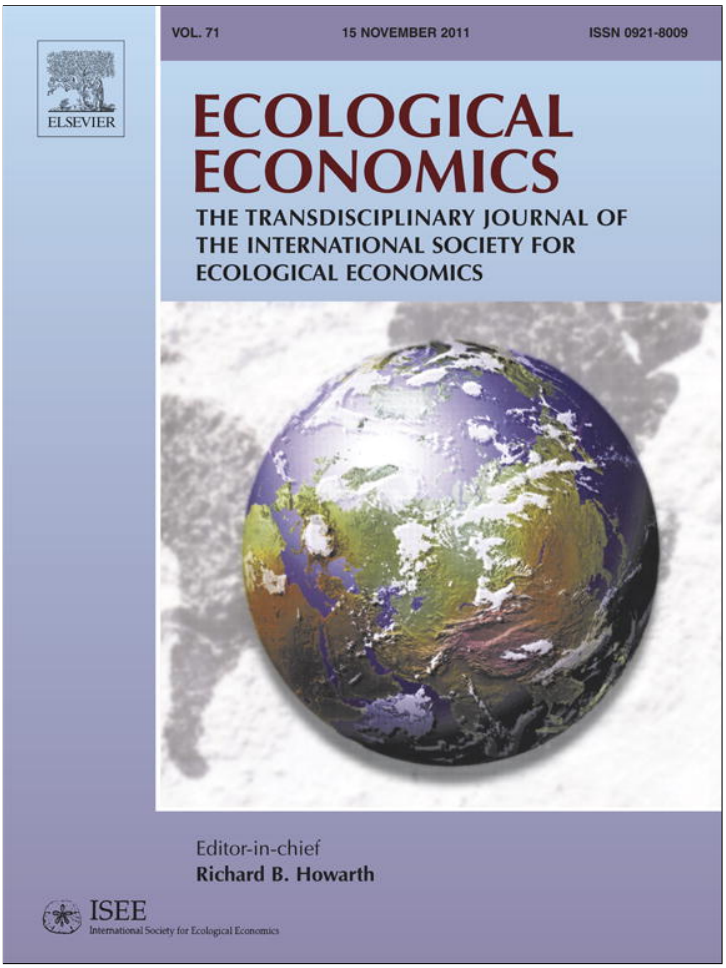

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Analysis

Barriers to Massachusetts forest landowner participation in carbon markets

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ABSTRACT

U.S. forests, including family-owned forests, are important carbon sinks and sources for carbon sequestration. Family forest owners constitute a significant portion of the overall forestland in the U.S., but little is known about their preferences for participating in carbon sequestration programs. The goal of this research is to understand what motivates Massachusetts family forest owners to participate in carbon markets. The study estimates the probability these landowners would engage in carbon sequestration programs using data from a survey of 930 Massachusetts family forest owners. Results from a random effects ordered probit indicate that under a carbon scenario similar to the current voluntary scheme, very few of these landowners would be interested in participating. Supply analysis indicates these landowners are more influenced to participate by factors other than price. Regression analysis results suggest that survey respondents are concerned about early withdrawal penalties, additionality requirements, and contract length. Forest owner harvesting plans, opinions about forest usage, and beliefs about climate change all play a significant role in the decision to participate. The study suggests that policy makers should consider the reasons behind these low participation rates, because private forest owners could play a pivotal role in the carbon sequestration potential of forests.

1. Introduction

Forests and forest products are crucial for protecting existing carbon sinks and promoting additional carbon sequestration (NEFA, 2002). Forest management efforts can maintain or improve forest carbon stock through a variety of techniques (e.g., thinning, increasing rotation length). Afforestation activities create new carbon sinks by establishing forest on non-forested land. Reforestation increases carbon stocks by reestablishing forest cover following a timber harvest. Avoided forestland conversion also helps to maintain or improve forest carbon stocks. (CAR, 2010; CCX, 2009; Helmes, 1998).

This article focuses on land with established forests. In these areas, forest management efforts are the relevant activities for maintaining and improving forest carbon stocks. In particular, we focus on established forests owned by families.

Family forest owners have the potential to play an important role in carbon sequestration. Over half the forestland in the U.S. is privately owned, and nearly two-thirds of that land is in the hands of family forest owners (Butler, 2008). In the Northeast, those percentages are even greater. For example, in Massachusetts, over half of the forests are family-forest owned, approximately 1.7 million acres (Butler, 2008). As trees grow on these private lands, they sequester considerable quantities of carbon each year. Forest owner participation in carbon markets could increase sequestration, but carbon markets are currently in a state of flux, and few programs have direct provisions for involvement from small-scale forest owners. For example, during its existence (2000–2010), the Chicago Climate Exchange (CCX), a voluntary greenhouse gas reduction and credit trading market, had a detailed protocol for enrolling forestry projects as carbon offsets (see CCX, 2009). Highlights of protocol requirements included:

- Establishment of baseline sequestration levels and subsequent annual verification;
- Forestry management plans that would lead to increased carbon sequestration over baseline levels, above and beyond standard business practice (i.e., additionality);
- Minimum enrollment amounts (all acreage unless an exemption is explicitly granted);
- Regular reports of land disposition and harvesting information;
- 15 year time commitment; and
- Start-up fees and insurance retainers.

To enter this market, small-scale forest owners had to work with an aggregator (i.e., carbon credit buyers who aggregate carbon credits

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from multiple small landowners into lumps of tradable units (Birdsey, 2006)), because the market was geared towards large-scale transactions. Examples of U.S. aggregators included: Appalachian Carbon Partnership; CarbonTree, LLC; Illinois Climate and Conservation Initiative; Michigan Climate and Conservation Initiative; Michigan Forest Carbon Offset and Trading Program; and Woodlands Carbon.

Although the aggregator market enabled the small-scale forest owner to trade on the CCX, family forest owner participation was low. For example, out of the roughly 12 million acres of privately held forestland in Michigan, between 2007 and 2008, only 36 forest owners and 72,972 acres were enrolled. Between 2009 and 2010, Massachusetts offered a cost-share to forest owners to become involved in the offset market, but not a single one chose to enroll. For policymakers to establish an effective climate change policy, it is important to understand, in detail, family forest owner decision-making with respect to participation in carbon sequestration programs, which is the focus of this paper.

2. Background

The existing carbon sequestration literature, although expansive and very informative, does not fully address the question of what motivates a private forest owner to participate in a carbon sequestration program. Previous carbon sequestration studies for forestland have mainly focused on:

- The biophysical potential of carbon sequestration on forestland under various policy and management regimes (e.g., Alig et al., 2006; Asante et al., 2010; Davis et al., 2009; Hudiburg et al., 2009; Nunery and Keeton, 2010; Stainback and Alavalapati, 2002). In addition, Uusivuori and Laturi (2007) present a theoretical model and conduct a numerical analysis examining the impact of potential climate policy options on the timber and carbon content of private forests.
- The financial costs of carbon sequestration on forestland. Systematic reviews of this literature include Richards and Stokes (2004), Stavins and Richards (unpublished results) and van Kooten et al. (2004). Other studies in this genre of literature include Huang and Kronrad (2001), Han and Youn (2009), and Lubowski et al. (2006).
- Potential market instruments for encouraging the sequestration of carbon (e.g., Bigsby, 2009; Cairns and Lasserre, 2004; Lippke and Perez-Garcia, 2008; Wayburn and Passero, 2004).
- Theoretical models that measure the welfare impacts of carbon sequestration policies (e.g., Adams et al., 1999; Alig et al., 1997; and Im et al., 2007).

Some studies have focused on the factors that influence participation in carbon sequestration (e.g., Shaikh et al., 2007a,b; van Kooten et al., 2002), These studies consider farmer participation in afforestation efforts, but they do examine characteristics similar to those relevant for forest management activities (e.g., contract length, payment, landowner characteristics); however, afforestation is not relevant for the majority of Massachusetts forest owners,

A number of articles have been published on the broader topic of participation in incentive programs for family forest owners. For example, Daniels et al. (2010) found that landowner purchase and management decisions were motivated, in part, by benefits to the owner and doing the "right thing" (p. 49). Jacobson, et al. (2009a,b) surveyed forestry officials responsible for forestry incentive programs and found programs could be improved through increased visibility, availability, simplified administrative process and long term consistency. Following an extensive literature review, a survey of program administrators, and focus groups with family forest owners, Kilgore et al. (2007) concluded that "financial incentive programs have limited influence on forest owners' decisions regarding the management and use of their land" (p. 184) and the most desired assistance was for a forester to walk the woods with them. A study of Minnesota landowners found compensation, total acres owned, intention to obtain a management plan, program awareness and other factors to influence enrollment in a forest stewardship plan (Kilgore et al., 2008).

Studying the preferences and attitudes towards carbon sequestration on family forest lands (i.e., the largest single segment of private ownership nationwide) is the key to understanding participation rates in carbon sequestration markets. A multitude of factors may influence forest owners' decisions to participate in carbon markets: program characteristics (e.g., length of contract); current activities occurring on their land; their own attitudes and opinions about the use of their land, climate change, program implementer, and socioeconomic characteristics. Using the CCX protocol as a guide, program characteristics most likely to affect forest owners may include: requirement of a management plan, required amount of enrolled acreage, time commitment, requirement of undertaking forest activity to ensure carbon is sequestered above and beyond baseline levels (i.e., additionality), program revenue, and early withdrawal penalty. Land characteristics and activities that might affect a forest owner's participation include whether or not the owner has previous experience with harvesting trees from their property, whether the owner is open to harvesting in the future, whether their forest land is currently enrolled in another management program, and how much forested acreage is owned. Forest owner beliefs that may affect participation include whether timber production drives their management decisions, or whether they believe their land should be left unmanaged. Opinions on climate change and program implementer may drive participation in a carbon sequestration program.[1]

Very few studies have examined the factors that motivate family forest owners to participate in carbon sequestration programs for established forests. A recent Master's Thesis by Dickinson (2010) employed a survey to analyze Massachusetts forest owner participation in carbon sequestration programs. The carbon sequestration program question was part of a larger mail survey sent to private forest owners in Massachusetts to gauge their use of land management information. Respondents were asked to rate three carbon sequestration programs in terms of their likelihood to participate. Four characteristics varied by program: requirement of a written management plan to participate, length of time commitment, expected per-acre net revenue, and existence of a penalty for early withdrawal. A standard ordered logit analysis of the data from the 910 individuals who rated all three programs indicates that the likelihood of carbon sequestration program participation decreases with the requirement of a management plan, an early withdrawal penalty, and a longer time commitment, and increases with higher revenue amounts. The likelihood of higher participation is associated with forest owners who owned more than 100 acres of forestland and who had higher levels of education. Dickinson estimates predicted probabilities of choosing each rating for each program respondents were asked to evaluate. The calculated probabilities for each survey version and program number provided to respondents indicate that the most popular program receiving a rating of 10 (i.e., "definitely would enroll") requires a management plan, has a 5 year time commitment, provides $30 per acre annual revenue, and has no penalty for early withdrawal; this program has a probability of acceptance of 31.5%. The calculated probabilities also indicate that the program that could be deemed the closest to CCX requirements (i.e., management plan required, 10 year time commitment, $5 per acre per year revenue, early withdrawal penalty) had an acceptance rate of only 4%.[2]

Dickinson's study is helpful in understanding some of the elements that motivate private forest owners about a carbon sequestration program, but the questions asked describe programs that fall short of some important carbon sequestration program characteristics. The scenarios

[1] Focus groups (discussed below) indicated forest owner concern about the entity implementing the program.

[2] It is worth noting that results from this study were similar to those derived in an earlier pilot study (see Fletcher et al., 2009).

have the respondent assume a carbon program similar to one that would trade on the CCX, however two key elements are missing: proof that management plans would lead to increased carbon sequestration over baseline levels (i.e., additionality) and minimum enrollment amounts. Further, CCX protocol reflected a longer time commitment (15 years) than described in the scenarios used in the Dickinson analysis (5 and 10 years). One would expect that these three important elements would influence participation levels. Dickinson's analysis also excludes key land characteristics and forest owner beliefs that we believe would influence participation.

Maraseni et al. (2008) interviewed Australian family forest owners to explore their perceptions of the barriers to participate in a carbon trading scheme. In particular, Maraseni et al. (2008) are concerned with understanding landowner perspectives about expanding forest land area from marginal pastures in Australia. This study acknowledges that the published literature does not consider whether a carbon trading scheme would be successful from a landowner perspective. Interviewees indicate three general areas that could hinder participation: uncertainty of the rules that would govern a carbon trading policy in Australia; lack of knowledge of how to measure and sell carbon credits; and uncertainty over whether such a program would be profitable. While helpful, this study does not explicitly indicate what specific carbon program characteristics are likely to influence forest owner decisions.

Other studies have examined factors motivating family forest owners to participate in carbon sequestration programs to varying degrees. Charnley et al. (2010) provide an overview of current and potential opportunities for family forest owners to contribute to carbon sequestration in the U.S. This study discusses how various issues limit participation in carbon markets, including: low carbon prices and high market entry costs; market access difficulties for small landowners; management plan and certification requirements; and whether participation in carbon markets is consistent with other forest management goals. Thompson (2010) uses the theory of planned behavior to measure the intentions of private forestland owners to participate in carbon markets and finds that 50% of respondents are somewhat interested in exploring opportunities. This study does not provide respondents with a description of carbon program details. It excludes for example, program requirements and potential carbon prices or offset income. Fischer and Charnley (2010) review the published literature to characterize the social and cultural influences on family forest owners' willingness to manage their forest for carbon and engage in carbon sequestration policies. Fischer and Charnley conclude that family forest owners may not be eager to participate in carbon sequestration programs because they place such high value on privacy and autonomy, but not much on financial reward. While interesting, this study does not directly survey forest owners. Alig (2003) synthesizes existing research findings to broadly consider how landowner behavior, forestry practices and socioeconomic conditions may affect forest carbon stores through land use and land cover change.

It is the goal of this research to expand on the tentative, preliminary findings of Dickinson (2010) and to further explore what motivates the family forest owner in Massachusetts to participate in carbon sequestration programs. As the eighth most forested state in the country (by percent of land use), Massachusetts has the opportunity to contribute to climate change mitigation. The state has a large population of family forest owners with diverse backgrounds, needs and concerns. Massachusetts is the third most densely populated state in the U.S. The residents of Massachusetts live in close proximity to the forestland, resulting in development pressure, higher land values, and smaller parcel size. Approximately 63% of the state is forested and 53% of that land base is owned by roughly 293,000 family forest owners with an average parcel size of 6 acres (Butler, 2008; Smith et al., 2009). A high number of these families place low priority on timber income from their land, and family owner preferences are primarily focused on passive benefits (e.g., aesthetics, recreation, nature, and privacy) (Butler, 2008). While there is an increased likelihood of timber harvesting from east to west in the state (i.e., from urban to rural), forest types, forestry activities and high land values are largely homogeneous across this small state (D'Amato et al., 2010). It is the collective decisions of these forest owners that will shape the potential of carbon sequestration in Massachusetts' forests. Our research suggests that it is possible to target certain groups of forest owners for carbon program enrollment, but given current requirements, participation rates are still likely to remain quite low.

3. Methods

We developed a mail survey for the purpose of investigating family forest owner participation in carbon sequestration programs in Massachusetts. Four focus groups held across Massachusetts gauged comprehension of the survey instrument questions that we were testing and gained deeper insight into forest owner motivations. Four additional focus groups provided forest owners' general impressions of carbon sequestration programs. The final survey asked questions about land ownership (e.g., size of landholdings, history and future of land management activities, current land management program enrollment), owner beliefs (e.g., reasons for owning forestland, beliefs about climate change), socioeconomic characteristics (e.g., age, gender, income, education), and carbon program options.

Conducted in May, 2010, the survey was mailed to a random sample of 930 individuals who own at least 10 acres of land in 152 cities and towns reflecting the ecological diversity of forestland in Massachusetts. Property tax rolls provided the information on these individuals who may or may not reside within Massachusetts. We developed the survey following Dillman's Tailored Design Method (Dillman et al., 2009): pre-notice postcard sent three days prior to the mail survey; mail survey including a detailed cover letter explaining the importance of responding; thank you post card sent one week later expressing appreciation or reminding individuals to respond; replacement mail survey and detailed cover letter sent 3 weeks after previous survey mailing. The response rate was 43%.

The survey presented respondents with information defining and describing carbon sequestration programs. Each respondent was then asked to rate, on a scale of 1 to 5, three different hypothetical carbon sequestration programs and one program described as the status quo (i.e., do not join any program, keep the status quo). The rating question was worded such that a 5 indicates that the forest owner definitely would enroll in the program given the opportunity, while a 1 indicates that the forest owner definitely would not enroll in the program. Any rating in the middle indicates varying levels of likelihood of enrollment on the part of the forest owner.

The programs varied according to: whether or not a management plan is required of the forest owner, the amount of required enrolled acreage, contract length, whether or not management of the land is required to satisfy additionality requirements, expected net revenue after paying enrollment costs, whether or not the program has a withdrawal penalty, and whether the program is implemented by the public or the private sector. The CCX required that all forested acreage be enrolled unless an exemption is explicitly granted by the CCX Forestry Committee. As such, we test 100% enrollment as well as 50% enrollment. For contract length, we test two values: 15 years and 30 years. The CCX protocol had a 15 year time commitment, but we test a longer time commitment to determine if it affected participation, because other carbon markets have longer commitments (e.g., California Climate Action Reserve requires a 100 year commitment, Voluntary Carbon Standard requires a commitment between 20 and 100 years). The net revenue values used in the survey ($10/acre/year, $100/acre/year and $1,000/acre/year) were designed to test a very wide range of values, including those well out of current market range. There is considerable uncertainty about how the market might evolve in the future given potential passage of a cap-and-trade or

Table 1
Means and definitions of variables for random effects ordered probit sample.

Variable	Mean (Std. dev.)	Definition
Management plan	0.44 (0.50)	Management plan required (1 if yes, 0 otherwise)
Enrolled acreage	0.67 (0.36)	Percent of woodland required for enrollment (50 or 100)
Contract length	17.80 (10.90)	Length of contract in years (15 or 30)
Additionality	0.40 (0.49)	Required to manage land so that trees sequester more carbon than if nothing was done (1 if yes, 0 otherwise)
Program revenue	$273.66 (416.60)	Expected net revenue per acre per year after paying enrollment costs in 2010 dollars ($10, $100, $1,000)
Early withdrawal penalty	0.47 (0.50)	Must re-pay earnings plus a 20% fee (1 if yes, 0 otherwise)
Implementer	0.47 (0.50)	Public sector (1), private sector (0)
Trees harvested in past	0.43 (0.50)	Has had trees harvested and sold since acquisition (1 if yes, 0 otherwise)
Plans to harvest in future	0.56 (0.50)	Plans to harvest and sell trees from land in future (1 if yes, 0 otherwise)
Forested acres owned	48.38 (64.69)	Amount of forested acres owned
Owner not active with land	0.56 (0.35)	Not enrolled in any program, does not have a written forest management plan, does not farm (1 if yes, 0 otherwise)
Chapter 61 enrolled	0.41 (0.49)	Enrolled in a current use plan (1 if yes, 0 otherwise)
Manages for timber	0.20 (0.40)	Land is important/very important for the production of timber products (1 if yes, 0 otherwise)
Manages for nature	0.35 (0.48)	Important/very important to leave land unmanaged and let nature take its course on the land (1 if yes, 0 otherwise)
People cause climate change	0.48 (0.50)	Owner strongly agrees that human activity causes climate change at unprecedented rates (1 if yes, 0 otherwise)
Trees help climate change	0.61 (0.49)	Owner strongly agrees that forests can help reduce the impact of climate change (1 if yes, 0 otherwise)
Age 65 years or older	0.31 (0.46)	Respondent is 65 years or older (1 if yes, 0 otherwise)
Lower education	0.16 (0.37)	Respondent has a high school diploma or less (1 if yes, 0 otherwise)
Higher education	0.59 (0.49)	Respondent has Bachelor or Graduate degree (1 if yes, 0 otherwise)
Income less than $50,000	0.23 (0.42)	Household annual income less than $50,000 (1 if yes, 0 otherwise)
Income more than $100,000	0.39 (0.49)	Household annual income $100,000 or greater (1 if yes, 0 otherwise)
Gender	0.77 (0.42)	1 if male, 0 if female

other state/federal carbon legislation, potential coordinated efforts between U.S. and other international markets, and the fact that the CCX market itself closed in late 2010 after carbon traded close to $0 for months.

The 192 possible programs were reduced to 30 using the standard fractional factorial design and then grouped into ten survey versions – each version containing a distinct set of three carbon programs. Each of the ten survey versions also contained the choice not to join any program and keep the "status quo." Appendix A contains the background information and an example choice set scenario for one version of the survey presented to respondents.

Although every respondent had the option not to join any program and keep the status quo, the status quo could differ across respondents. This choice set "program" was coded individually for each respondent, using information provided in the survey. The survey information indicated that there were five different status quo program possibilities: those who do not farm and are not enrolled in any current use program; those who are enrolled in a current use taxation program requiring a management plan, (e.g., Chapter 61, a program for owners of at least 10 acres of contiguous forest land interested in keeping their land in its current undeveloped use; Chapter 61 requires long-term, sustainable timber management based on a state-approved management plan that must be renewed every 10 years. Enrolling in Chapter 61 reduces forest land valuation to reflect its value for growing timber instead of houses); those who are not enrolled in a current use program but have a written management plan; those who have a farm and are enrolled in a current use program that does not require a written management plan (Chapter 61a); and those who do not farm and are enrolled in a current use program that does not require a written management plan but offers a smaller reduction in assessed valuation than Chapter 61 (Chapter 61b). Each of the five status quo possibilities has a unique combination of values for the seven program characteristics. Thirteen individuals who could not be classified into one of the five status quo options were removed from the sample.

The survey gathered forest ownership information including the amount of forested acreage owned in Massachusetts, whether trees have been harvested and sold from the Massachusetts land since it was acquired, and whether the respondent has any plans to harvest and sell trees from the Massachusetts land in the future. In addition, two questions reflect how engaged the owner is in traditional forestry: is the respondent's land enrolled in any type of current use property tax program (Chapter 61, 61a, 61b), and does the respondent have a written management plan.

The survey asks several questions about forest owner opinions and beliefs. Respondents rated, on a scale of 1 to 5, how important ownership of their land was for production of saw logs, pulpwood or other

timber products, and how important the owner believes it is to leave their land unmanaged and to let nature take its course. "Not important" on the scale is reflected in a rating of 1 and "very important" in a rating of 5.

The survey asks respondents to rate on a scale of 1 to 5 how much they agree with four statements regarding climate change: "Human activity is causing climate change at unprecedented rates"; "Forests can help to reduce the impact of climate change"; "Cap-and-trade legislation would be the best way to reduce overall emissions from current polluters"; and "A carbon tax legislation would be the best way to reduce overall emissions from current polluters." A rating of 1 means the respondent strongly disagrees, while a rating of 5 means the respondent strongly agrees, or the respondent could say "Don't Know."[3]

Gathered socioeconomic characteristics include age, education level, income, and gender. Respondents checked one of seven age categories to indicate their age. Based on results from previous research (see LeVert et al., 2009 and Stevens et al., 2002), we are able to condense these into two categories for the analysis: those 65 years old and older and those younger than 65 years old. Education is coded as three categories: a high school diploma/GED or less, some college or associate/technical degree, and bachelor/graduate degree. Three categories describe household income: income less than $50,000 per year, income between $50,000 and $100,000 per year, and income greater than or equal to $100,000 per year. Table 1 lists the variables used in our analysis, their means, and their associated variable definitions.

4. Model

Our theoretical model considers the respondent facing the decision of how to rate each of the four choice set programs provided in the survey. An appropriate way to understand these ordinal ratings data is through the use of a latent variable that governs rating choices. We assume that respondents make choices that increase their utility or satisfaction, and that there is a continuous, unobservable variable that represents opinion level or utility associated with rating each carbon sequestration program (Train, 2003). We define the utility derived by the *i*th respondent from the *j*th carbon sequestration program (U_{ij}) as:

$$U_{ij} = Z_j\beta_j + C_i\beta_i + \varepsilon, \tag{1}$$

where Z is a vector of program attributes, C is a vector of individual and land characteristics, the β's are associated unknown parameter vectors, and ε is a normally distributed random component.

We do not directly observe respondents' utility for each program, but rather the discrete rating they choose, varying from 1 (definitely would not do) to 5 (definitely would do). Following Klosowski et al. (2001), we assume that respondent *i*'s observed rating for program *j* (r_{ij}) is related to respondent utility through a transformation function, *h*:

$$r_{ij} = h\left(U_{ij}\right). \tag{2}$$

Eq. (2) provides the basis for each respondent's rating of a carbon sequestration program to be dependent on the program, individual and land characteristics described above.

From these relationships, we construct an ordered probit model, wherein we define unknown utility cutoffs that delineate the five ratings (see Greene, 2007). That is, if a respondent's utility is below the first cutoff, he or she chooses a rating of 1. If utility is between the first and second cutoffs, the rating is 2, etc. If utility is above the fourth cutoff, the rating is 5. The relationship between ratings and utility cutoffs are represented by the following equation, where the first cutoff is normalized to zero, as is standard practice:

$$\begin{aligned} &r_{ij} = 1 \text{ if } U_{ij} \le \mu_1 \\ &r_{ij} = 2 \text{ if } \mu_1 < U_{ij} \le \mu_2 \\ &r_{ij} = 3 \text{ if } \mu_2 < U_{ij} \le \mu_3 \\ &r_{ij} = 4 \text{ if } \mu_3 < U_{ij} \le \mu_4 \\ &r_{ij} = 5 \text{ if } \mu_4 < U_{ij}. \end{aligned} \tag{3}$$

Because each individual provided ratings for four programs, we expect to find correlation among the four responses from each individual. The random effects ordered probit model (see Greene and Hensher, 2010) allows for this correlation in the unobserved error term, ε. That is, the error term, originally presented in Eq. (1), is now composed of a random, normally distributed portion, v_{ij}, and an individual-specific disturbance, δ_i. This relationship is represented by Eq. (4):

$$\begin{aligned} &\varepsilon_{ij} = v_{ij} + \delta_i \\ &Var\left(\varepsilon_{ij}\right) = \sigma_v^2 + \sigma_\delta^2 = 1 + \sigma_\delta^2 \\ &Corr\left(\varepsilon_{ij}, \varepsilon_{is}\right), = \rho = \sigma_\delta^2 \Big/ \left(1 + \sigma_\delta^2\right) \end{aligned} \tag{4}$$

The correlation among responses from the same individual accounts for a fraction of the total variance of the error term in the model; this fraction is measured by the correlation coefficient, ρ.

The equations above provide the basis for the derivation of the probit cumulative density function which is used to set up the probability of choosing any particular rating or lower (i.e., the cumulative probabilities of the ratings). Probabilities for each marginal rating category are derived from these cumulative probabilities. The likelihood function is the product of all the probabilities associated with each observed rating and is maximized with respect to the unknown parameters. We use the Gauss–Hermite quadrature method in Stata 11 to evaluate the resulting integral.

5. Results

Of all 402 survey respondents, 293 individuals provided ratings for all four programs they were presented with in the survey. Of those, 249 individuals provided enough information to be included in the analysis. This section (and Table 1) reflects statistics for respondents who provided ratings for all four programs ($n = 293$). It is worth noting that the characteristics of the full sample ($n = 402$) and analysis

Table 2
Mean values for respondent agreement with climate change statements.

Climate change statement	Mean[a] (Std. dev.)	Percent of sample who responded "Don't Know"
Human activity is causing climate change at unprecedented rates.	3.83 (1.43)	4%
Forests can help to reduce the impact of climate change.	4.43 (0.94)	5%
Cap-and-trade legislation would be the best way to reduce overall emissions from current polluters.	2.34 (1.40)	49%
A carbon tax legislation would be the best way to reduce overall emissions from current polluters.	2.78 (1.53)	36%

[a] Mean and standard deviation reflects the sample of respondents who did not say "Don't know" to the statement. That is, they provided a number on the Likert scale ranging from 1 to 5 where 1 is "Strongly disagree" and 5 is "Strongly agree."

[3] As pointed out by an anonymous reviewer, these opinion-based questions may be affecting the choice set results. As discussed in the literature (e.g., Dillman, et al., 2009), the existence and ordering of opinion questions are likely to influence other survey responses. Our questions were presented before the choice set questions and were not randomized.

Table 3
Comparison of random effects ordered probit, ordered probit and ordered logit results.

Variable	Random effects ordered probit[a]	Ordered probit[a]	Ordered logit[a]
Management plan	−0.0161	−0.0255	−0.0441
Enrolled acreage	−0.1212	−0.0997	−0.1570
Contract length	−0.0365***	−0.0339***	−0.0557***
Additionality	−0.3004***	−0.2753***	−0.4666***
Program revenue	0.0004***	0.0003***	0.0005***
Early withdrawal penalty	−0.3310***	−0.3172***	−0.5295***
Implementer	0.1210	0.0905	0.1269
Trees harvested in past	−0.0248	−0.0392	−0.0370
Plans to harvest in future	0.2519**	0.2760***	0.4809***
Forested acres owned	0.0002	−0.0005	−0.0009
Owner not active manager	−0.3458	−0.3305*	−0.5518*
Chapter 61 enrolled	0.0013	0.0061	0.0027
Manages for timber	−0.2420**	−0.2327**	−0.3626**
Manages for nature	−0.0239	−0.0513	−0.0565
People cause climate change	0.0421	0.0409	0.0850
Trees help climate change	0.1659*	0.1593**	0.2675**
Age 65 years or older	−0.1618*	−0.1347*	−0.2615**
Lower education[b]	−0.1534	−0.1824*	−0.2981
Higher education[b]	0.2016**	0.1814**	0.3036**
Income less than $50,000[b]	−0.0993	−0.1133	−0.1812
Income more than $100,000[b]	0.0563	0.0298	0.0127
Gender	−0.1114	−0.1118	−0.2156
Cutpoint 1	−1.3966***	−1.3715***	−2.2823***
Cutpoint 2	−1.0593***	−1.0630***	−1.7701***
Cutpoint 3	−0.4474	−0.4921*	−0.8277**
Cutpoint 4	0.1716	0.1011	0.1751
Rho	0.0898**	n/a	n/a

[a] Significance denoted as: ***1%, **5%, *10%.
[b] To avoid the so-called "dummy variable trap" the analysis omits "Middle education" and "Income between $50,000 and $100,000 per year."

sample ($n = 249$) do not deviate substantially from that sample; in some cases, statistics are identical.

Approximately 31% of the sample are over the age of 65, 38% are between 55 and 64 years old, and 31% are younger than 55. The majority (77%) of respondents are male. Over half the sample (59%) has either a bachelor's or graduate degree, and nearly a quarter has some college or an associate/technical degree. Over 75% of the sample has household income greater than $50,000.

On average, respondents own 48 acres of forest, and 18% of the respondents are farmers. In each case, over half the sample said that the following are very important reasons to own their land: to enjoy beauty or scenery, for privacy, and as part of a home or vacation home. Nearly 43% said they had experience with harvesting and selling timber in the past, while 44% said they would never harvest in the future. Approximately 26% have a written management plan for their land, 55% of the respondents are not involved in any forest management, do not farm, and do not have a written forest management plan.

It is interesting to consider the responses to the four statements that examine respondent opinion of climate change (See Table 2). Respondents generally agreed with the statements that "Human activity is causing climate change at unprecedented rates" and "Forests can help to reduce the impact of climate change." However, many individuals responded "Don't Know" to the two statements about climate change legislation. For those who provided an opinion on the legislation statements, respondents generally disagreed that either cap-and-trade or carbon tax legislation would be the best way to reduce overall emissions from current polluters. Because so many individuals responded "Don't Know" to the legislation statements, these variables were excluded from the analysis.

We tested for non-response bias by calling a random sample of 10% of non-respondents and obtaining answers to key survey questions. We selected survey questions that describe respondent landholdings (acreage), behavior (traditional forestry participant) and attitudes (about climate change). A statistical comparison of the response and non-response groups (t-test) indicates that there is no difference between them for any of the three questions asked: acreage of forestland owned in Massachusetts; whether or not they have a written forest management plan; and to what extent they agree (on a scale of 1 to 5, where 1 is strongly disagree and 5 is strongly agree) that "Human activity is causing climate change at unprecedented rates." We might have expected greater acreages or existence of a management plan to influence the economic viability of participation and climate change attitudes to affect willingness to respond, but this was not the case.

The estimation results from the random effects ordered probit model indicate that several program characteristics, forest owner activities, beliefs and characteristics play a role in determining the likelihood of participation in a carbon sequestration program. Table 3 presents these regression results.[4]

As expected, respondents preferred programs with greater net revenue, no withdrawal penalty, shorter contract lengths, and no additionality requirements (i.e., no requirement that forests must be managed to sequester more carbon than if nothing was done).

Significant forest owner characteristic results conform to expectations. Respondents who plan on harvesting and selling trees from their land in the future are more likely to rate the programs higher, all else remaining equal. This is not unexpected, because individuals who are willing to harvest in the future are open to outside individuals participating in the management of their land. In addition, these individuals are actively planning to manage their land, and because carbon sequestration programs essentially are a type of management activity, they may be more open to participation, all else equal.[5] Individuals who own forests for the production of saw logs, pulpwood or other timber products are less likely to rate programs higher. These respondents may be satisfied with the level of management they currently have on their property and may be uninterested

[4] As shown in Table 3, ordered probit and ordered logit models were also estimated to determine sensitivity of results to estimation technique. These results are discussed later in this paper.
[5] Owners who are not active managers are more likely to rate carbon programs lower in the ordered probit and ordered logit models (significant at the 10% level), but this characteristic was insignificant in the preferred model.

Table 4
Estimated probabilities of participation across models.

Model	Scenario 1[a] Management plan 100% required enrollment 30 year commitment Additionality $10/acre/year Penalty Private implementer	Scenario 2[a] Management plan 50% required enrollment 30 year commitment No Additionality $100/acre/year Penalty Public implementer	Scenario 3[a] No management plan 50% required enrollment 15 year commitment No Additionality $1000/acre/year No penalty Public implementer
Status quo alternative varies by respondent (preferred specification)			
Random effects ordered probit[b]	2.0%	6.1%	37.8%
Ordered probit	2.8%	7.1%	37.5%
Ordered logit	4.0%	7.9%	36.3%
Non-demanders removed from model			
Random effects ordered probit	2.0%	5.5%	35.6%
Ordered probit	2.5%	6.2%	36.1%
Ordered logit	3.8%	7.0%	34.5%
All program characteristics set to 0 for status quo alternative			
Random effects ordered probit	1.7%	5.4%	35.0%
vOrdered probit	2.4%	6.4%	35.2%
Ordered logit	3.8%	7.4%	33.7%
Status quo alternative dropped from the model			
Random effects ordered probit	0.1%	0.8%	22.9%
Ordered probit	2.1%	5.0%	28.0%
Ordered logit	3.2%	5.8%	26.3%

[a] All independent variables not specified are set to their mean value, see Table 1.
[b] Preferred model.

in additional levels of management. Also, as we learned from the focus groups, these individuals may fear that carbon sequestration programs would interfere with their harvesting practices. As expected, respondents prefer carbon programs if they strongly believe that forests can help to reduce the impact of climate change. Respondents older than 65 years are less likely to rate programs higher. As we learned from the focus groups, these individuals are likely considering legacy issues and could be unwilling to encumber their land in management. Finally, respondents with higher education levels are more likely to rate the programs higher.

The correlation coefficient, ρ, accounts for a fraction of the total variance of the error term in the model and is statistically significant; however, its value is only 0.09. We explore this result by also running an ordered probit and an ordered logit model with the data (see Table 3). These models remove the random effects component, treat each observation as independent, including those responses for multiple programs by each respondent. The results, as presented in Table 3, are not sensitive to these alternative specifications. The low correlation coefficient and insensitivity to alternative specifications suggest that the random effects model is probably not needed, nonetheless we maintain it as our preferred model because it is theoretically consistent with the data structure.

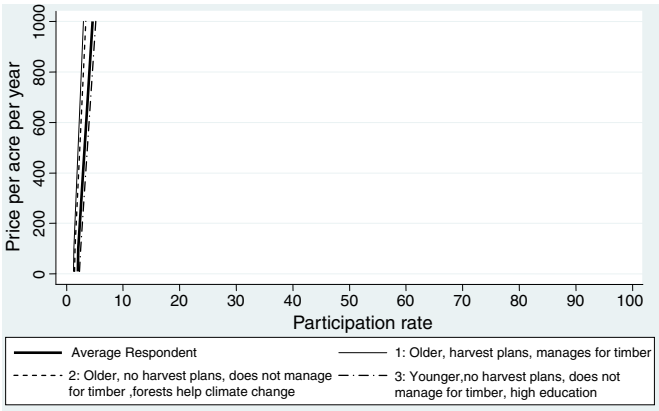

Fig. 1. Scenario 1 supply response. Supply response by landowner group for hypothetical carbon program Scenario 1 (i.e., requires a management plan, 100% enrollment, 30-year commitment, additionality, and an early withdrawal penalty; provides $10/acre/year; and is implemented by the private sector).

5.1. Probability Results

From a policy perspective, it is useful to explore whether respondents voted "for" programs with fewer requirements and greater revenue and "against" programs that were more onerous and less profitable. We calculate the probability that respondents said they "definitely would" join the program given the opportunity (i.e., respondent rated the program as a 5) for three types of programs: those for which we would expect to have low, medium, and high probabilities of participation. The program characteristics vary by scenario, and we evaluate the non-program variables at their sample means. The program we would expect to have the lowest chance of participation (Scenario 1) requires a management plan, 100% enrollment, 30-year commitment, additionality, and an early withdrawal penalty; provides $10/acre/year; and is implemented by the private sector.[6] This program most closely represents most current carbon program characteristics. The random effects ordered probit model has the lowest estimate of participation at 2%, and the ordered logit the highest estimate at 4% (see Table 4). The program we would expect to have a mid-level of participation (Scenario 2) requires a management plan, 50% enrollment, 30-year time commitment, and an early withdrawal penalty; does not require additionality; provides $100/acre/year; and is implemented by the public sector. The range of participation for this program is between 6% and 8%. Finally, the program we would expect to have the highest level of participation (Scenario 3) does not require a management plan, additionality or a penalty; requires 50% enrollment and a 15-year time commitment; provides $1000/acre/year; and is implemented by the public sector.

[6] While we vary the managing entities for these three scenarios (i.e., public or private implementer), we do not have priors about how the managing entity affects participant burden or profitability; we include a random value for this characteristic as part of each scenario simply because it is a program characteristic.

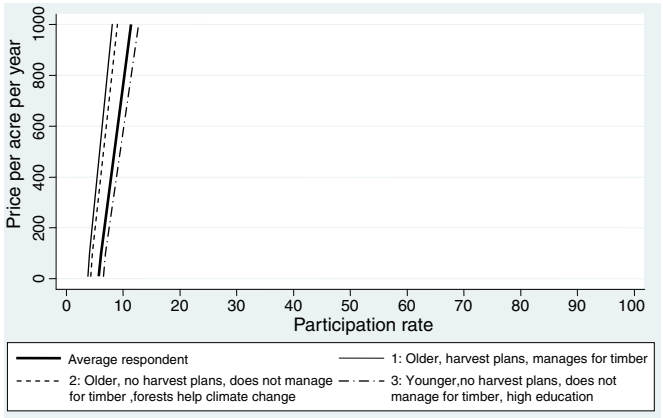

Fig. 2. Scenario 2 supply response. Supply response by landowner group for hypothetical carbon program Scenario 2 (i.e., requires a management plan, 50% enrollment, 30-year time commitment, and an early withdrawal penalty; does not require additionality; provides $100/acre/year; and is implemented by the public sector).

The range of participation is estimated between 36% and 38%. Table 4 shows that the probabilities across the three models are consistent.

5.2. Supply Response

These probabilities enable us to construct a supply curve of participation, and consider how that supply curve shifts with different types of forest owners. We identify groups of forest owners for illustrative purposes to show that policy makers may want to target specific groups when considering how to engage forest owners in carbon sequestration. "Group 1" owners are older individuals who manage their land for timber and have future harvest plans (i.e., Age 65 years or older = 1; Manages for timber = 1; Plans to harvest in future = 1). This group represents 7% of the sample. "Group 2" owners are older individuals who do not manage their land for timber, do not have future harvest plans, but believe that management of forests can help to reduce the impact of climate change (i.e., Age 65 years or older = 1; Manages for timber = 0; Plans to harvest in future = 0; Trees help climate change = 1). This group represents 7% of the sample. "Group 3" owners are younger individuals who do not manage their land for timber, do not have future harvest plans, and are highly educated (i.e., Age 65 years or older = 0; Manages for timber = 0; Plans to harvest in future = 0; Higher education = 1). This group represents 19% of the sample. These groupings are reasonably consistent with a principal components analysis of the independent variables describing respondent characteristics.

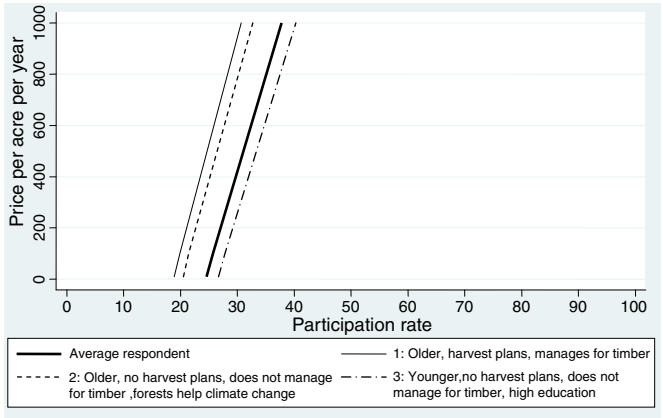

Fig. 3. Scenario 3 supply response. Supply response by landowner group for hypothetical carbon program Scenario 1 (i.e., does not require a management plan, additionality or a penalty; requires 50% enrollment and a 15-year time commitment; provides $1000/acre/year; and is implemented by the public sector).

Table 5
Estimated price elasticity of supply by scenario and sample group.

Sample group	Scenario 1[a]	Scenario 2[a]	Scenario 3[a]
Average respondent	0.28	0.22	0.13
Group 1: Older than 65 years, future harvest plans, manages land for timber. 7% of sample	0.31	0.24	0.15
Group 2: Older than 65 years, no harvest plans, does not manage for timber, believes forests can help with climate change. 7% of sample	0.30	0.24	0.14
Group 3: Younger than 65 years, no harvest plans, does not manage for timber, high education. 19% of sample	0.27	0.21	0.12

[a] Preferred model used; elasticities estimated at mean revenue per acre per year ($273.66). For each group, all independent variables not specified are set to their mean value (see Table 1).

For each scenario, we show four supply curves: one associated with the "average" respondent and one for each of the three groups defined above. For all scenarios, we found that the group most likely to participate is Group 3, the younger individuals who do not manage for timber, followed by the average respondent (all variables set to their mean value), Group 2 (older individuals who do not manage for timber but have strong beliefs about climate change and forests), and then Group 1 (older individuals who manage for timber). Figs. 1, 2 and 3 show the supply responses for these groups by scenario.

The supply curves for each group provide information on the price elasticity of supply. Using the preferred model and calculating elasticity at the mean sample revenue of $273.66/acre/year, each supply curve and scenario indicates that forest owner participation in a carbon sequestration program is not greatly influenced by a change in price (i.e., revenue per acre per year). Across the board, the price elasticity of supply is inelastic (See Table 5). Group 3 (the group most likely to participate) has the least inelastic supply curve of all the samples; however, it is still very inelastic. In order to engage forest owner participation in carbon sequestration markets, a policy would clearly need to include other factors important to a landowner besides a payment mechanism.

5.3. Alternative Specifications

We are interested in testing the assumptions of our model as well as some common issues raised in the literature. First, some respondents in our sample could be considered to be non-demanders, and therefore not be willing to pay or accept anything for the scenario presented (Carlsson and Kataria, 2008). Our test of non-demander bias removes respondents who said they would never harvest any of their forest. Previous research on Massachusetts forest owners has identified a distinct segment that is quite averse to harvest (Finley and Kittredge, 2006). Carbon programs have typically required some harvesting, however because some of our scenarios do not require harvesting, this test is a crude one. After removing this subsample, for the most part, the variable significances in this model are the same as for the preferred model, but two variables become insignificant ("Age 65 years or older" and "Trees help with climate change") and "Gender" becomes significant at the 5% level. The correlation coefficient for the random effects ordered probit is even lower at 0.06. Table 4 shows that the estimated probabilities for these models are not sensitive to this specification. We conclude that it is more important to leave these respondents in the sample because of the information their responses provide for the alternatives that do not require harvesting.

Second, we re-specified the status quo alternative such that it was the same for all respondents to test our specification that it differed by respondent. The regression results were not sensitive to this alternative way of specifying status quo, and the correlation coefficient for the random effects ordered probit remains at 0.09. Table 4 shows that the estimated probabilities for this specification are slightly lower than for the preferred specification, with differences in probabilities ranging from only 0.2% to 2.8%. Interestingly enough, Massachusetts policy makers did create a carbon credit program for private forest owners, offering to underwrite the expense of enrollment and providing education for landowners, but after two years, none chose to participate. This is a rather unique validation of our research results, whereby an analogous public policy was actually launched and promoted, and behaved as our results would predict (i.e., failure).

Third, we removed the status quo alternative completely from the model to test for status quo bias (Samuelson and Zeckhauser, 1988). Based on the literature, we would expect there to be a bias associated with removing the status quo. The variable significances in the random effects probit specification are the same as for the preferred model. The correlation coefficient for the random effects ordered probit increases to 0.55. Table 4 shows the decrease in probabilities for the different program scenarios. The participation range drops from 2.0% to 0.1% at the low end and 37.8% to 28.0% at the high end. As expected, the results were sensitive to this alternative specification, and consistent with the literature our preferred model contains the status quo option.

6. Conclusions

Much of the current U.S. policy discussion regarding climate change has been on cap-and-trade mechanisms that would create a carbon market similar to the voluntary CCX. This study considers one potential player in this market – the family forest owners in Massachusetts who collectively own a significant portion of the forestland in that state. We find that if a policy were to be established similar to the current voluntary scheme, our model estimates that very few of these landowners would be interested in participating. Policy makers should understand the reasons behind these low participation rates, because private forest owners could play a pivotal role in the carbon sequestration potential of forests.

Pairing the supply response results with what we have learned from the focus groups and the comments provided in the survey provides us with a glimpse as to why these probability estimates are low. Group 1 represents the older individuals who manage their land for timber and have harvest plans. These individuals have strong opinions about their ability to manage their land. Many of these people mentioned that they were able to manage their land best and did not want to be told what to do, because they believe their experience enables them to manage. These individuals were the least likely to participate in carbon sequestration programs in comparison to other groups. Group 2 represents the older individuals who do not manage for timber or have harvest plans, but strongly believe that forests could help manage climate change. These individuals may have strong opinions about the importance of leaving their forest unmanaged. It makes sense that some of these individuals would be willing to participate because they believe that forests, as a natural resource, could help with the climate change issue, but this willingness may be tempered by their unwillingness to interfere with natural processes. Our results indicate that these individuals are only slightly more likely to participate in a carbon program than Group 1, on average by less than 1%. Relevant to both Groups 1 and 2, it is important to note that many individuals mentioned legacy issues as a concern. Many older individuals were hesitant about agreeing to a contract that could result in passing their land to their children with strings attached. Group 3 represents younger individuals who do not manage for timber, do not have harvest plans, and are highly educated. This group was the most open to participation, but participation rates are still low: for scenario 1 (the scenario most similar to 2010 CCX protocol), participation rates vary between 2% and 5% depending on the price offered. As can be seen from Figs. 1, 2 and 3, differences in participation among groups is very small.

While the preferred model and preferred specification (i.e., random effects probit model that provides for 5 different status quo possibilities) produces the highest estimated probabilities for the carbon sequestration program scenarios we considered, participation rates may actually be higher than reported. Hypothetical choice experiment literature touches on the concept that respondents' willingness to accept amount differs in reality from a hypothetical situation (i.e., hypothetical bias). Most of the hypothetical bias literature describes differences in willingness to pay responses, but researchers have acknowledged the parallel situation in willingness to accept situations. Nape et al. (2003) undertook experiments to test this bias and conclude that hypothetical bias in willingness to accept studies does exist, and, based on their experimental analysis, the authors conclude that people would actually accept a smaller payment than in a hypothetical situation. Thus, more people might participate in actual carbon programs than estimated from the hypothetical scenarios used in this study, but we are unsure by how much.

The results of this study show similarities to earlier forest owner studies of carbon sequestration programs (Dickinson, 2010; Fletcher et al., 2009) in that withdrawal penalties, contract length, and revenue are significant program attributes, but it also offers more information for the policy maker. Additionality, a key factor in current carbon sequestration programs, is a significant factor to forest owners. Our study shows that the survey respondents are also concerned about early withdrawal penalties, and contract length. Supply analysis indicates that forest owners are more influenced to participate by factors other than price; policymakers should consider this result when designing a carbon sequestration policy.

Our results have relevance to the way landowners make decisions about their land under conditions where it has considerable potential development value. Owners may choose to sell, develop or change land use and, in effect, voluntarily extinguish the carbon sequestration potential. In places where land use conversion of forest is prohibited by statute or regulation (e.g., zoning), land value is thus greatly diminished and the decision making framework of landowners is very different. In the U.S., landowners generally have the right to convert or develop, so our results could potentially be relevant in other U.S. contexts. In Europe and Scandinavia, land use is much more tightly controlled, and landowners generally do not have the choice to convert. Thus, the different decision framework or suite of choices suggests our results may be of lesser relevance.

Within the U.S., the National Woodland Owner Survey (NWOS) data on forest owners suggests nationwide they are older, more affluent, well educated, and interested in the environment and amenity values from their land (Butler, 2008); thus, they are not that different from the Massachusetts participants in our study. Most owners have no plans to sell timber in the future, which is characteristic of Groups 2 and 3 in our study. One important distinction is ownership size. Massachusetts ownerships are relatively small compared to other parts of the U.S., and there may be more interest in management and carbon credits in areas of larger ownerships. Overall, though this study's landownerships are in Massachusetts, in general, owners share many characteristics with other owners nationwide.

While our results indicate what matters to forest owners in Massachusetts, it is clear that forest ownership trends and behavior are variable across the U.S. Parcel size, socioeconomic characteristics, timber harvesting behavior, climate change beliefs, and feelings about government involvement, for example, are likely to differ across the country. To design a viable voluntary or market-based mechanism that engenders participation from family forest owners throughout the U.S., it is crucial for policymakers to consider what motivates family forest owners in other regions of the country.

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Appendix A. Background information presented to respondents and an example choice set scenario for one version of the survey

15. Now we would like to ask you about how you might want to use your woodland in the future.
    - Forests absorb greenhouse gases and store them in their tree trunks, branches, foliage and roots. This process is called carbon sequestration.
    - Some people believe that carbon sequestration can help reduce the effects of climate change.
    - As forest landowners, you could become involved by enrolling in a program that would pay you to ensure that your trees sequestered more carbon than if you had left them as-is.

    Suppose that you were approached about joining such a program:

    Enrollment responsibilities:

    - A professional forester must inventory your enrolled woodland.
    - Every year the forester must verify that you are complying with the program.
    - If you plan to harvest timber from your enrolled woodland, the harvested area needs to be re-inventoried after cutting.
    - For the time that you are enrolled, no new development (such as creation or sale of building lots) would be allowed to happen.

    We would like to know your interest in joining these types of programs. The next page gives you other aspects of the program to consider.

    We would like you to do two things on the next page:

    1) **RATE** each of the following four choices on a scale of 1 to 5, with 1 being a choice you **definitely *would not* do** and 5 being a choice you **definitely *would* do.**
    2) **RANK** the four choices using a letter scale: **A**, **B**, **C** and **D**.
    - **Rank A** would be your first choice,
    - **Rank B** would be your second choice,
    - **Rank C** would be your third choice, and
    - **Rank D** would be your last choice.

Question 15 continued	Choice #1	Choice #2	Choice #3	Choice #4
Management Plan Required	Yes. The cost of this is included below.	No.	No.	Do not join any program. Keep the status quo.
Enrolled Acreage	50% of your woodland.	100% of your woodland.	50% of your woodland.	
Contract Length	30 years.	15 years.	15 years.	
Woodland Activity	You must manage your land such that your trees sequester more carbon than if you had done nothing. For example: •Harvest slow-growing trees. •Favor certain types of trees (like red oak). •Grow trees until they are old.	None required.	You must manage your land such that your trees sequester more carbon than if you had done nothing. For example: •Harvest slow-growing trees. •Favor certain types of trees (like red oak). •Grow trees until they are old.	
Expected Net Income After Paying Enrollment Costs	$100 per acre per year.	$10 per acre per year.	$1,000 per acre per year.	
Withdrawal Penalty	None.	None.	You must re-pay your earnings from the program plus a 20% fee.	
Program Implemented By	Private sector.	Private sector.	Public sector.	
RATE each choice on a scale of 1 to 5, with 1 being a choice you **definitely *would not* do** and 5 being a choice you **definitely *would do.***				
	Choice #1 WOULD…….WOULD NOT DO DO 1……2……3……4……5	Choice #2 WOULD…….. WOULD NOT DO DO	Choice #3 WOULD…….WOULD NOT DO DO 1……2……3……4……5	Choice #4 WOULD…….WOULD NOT DO DO 1……2……3……4……5

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