2010

Massachusetts Landowner Participation in Forest Management Programs for Carbon Sequestration: an Ordered Logit Analysis of Ratings Data

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MASSACHUSETTS LANDOWNER PARTICIPATION IN FOREST MANAGEMENT PROGRAMS FOR CARBON SEQUESTRATION: AN ORDERED LOGIT ANALYSIS OF RATINGS DATA

A Thesis Presented

by

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Submitted to the Graduate School of the

University of Massachusetts Amherst in partial fulfillment

Of the requirements for the degree of

MASTER OF SCIENCE

May 2010

Department of Resource Economics

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ACKNOWLEDGEMENTS

This study is based on a landowner mail survey conducted by the Family Forest Research Center. Thanks to all those who designed and executed the survey, in particular Lisa Romano. Thanks to Justin Renaud for inputting most of the 1,400 survey entries into a spreadsheet. Thanks to Marla Lindsay for her help navigating the carbon sequestration literature.

I would not have been able to write this thesis without the initial request for my involvement in the study and subsequent unwavering technical and emotional support of Tom Stevens. Thanks to Dan Lass and Sylvia Brandt for their invaluable guidance with respect to the econometric theory used in this study. Thanks to John Spraggon for help with software issues.

Finally, I owe much of the success of my education in general to the Resource Economics Department and all its staff and faculty. Without the unbelievable funding and teaching opportunities I've been privileged with, I would not have made it through these two years in the graduate program. Thanks in particular to Julie Caswell and Nathalie Lavoie for guidance through the program.

ABSTRACT

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The Family Forest Research Center recently conducted a mail survey of about 1,400 Massachusetts landowners. Respondents were given questions about themselves and their land and were then asked to rate three carbon sequestration programs in terms of their likelihood to participate. An ordered logit model is used to estimate probabilities that landowners would participate in various improved forest management programs. There are several estimation issues to consider with the ordered logit model. The relative merits of alternative models, including the multinomial and binomial logit, rank-ordered logit, binary logit and mixed ordered logit are discussed.

Results of the ordered logit indicate that older males with less education and who own less than 100 acres are less likely to participate in an improved forest management program. All landowners are less likely to participate in a program that requires a management plan and that has a lengthy time commitment, low revenue stream and early withdrawal penalty. Policy implications and direction for future research are discussed.

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CHAPTER 1

INTRODUCTION TO GLOBAL WARMING AND IMPROVED FOREST MANAGEMENT

1.1 Background

Global warming is already affecting weather and other elements of our planet's ecosystem. Overwhelming scientific evidence indicates that the warming is largely human caused. Burning of fossil fuels, other industrial processes and deforestation have contributed to rising levels of atmospheric greenhouse gases (GHGs), which trap solar energy in the earth's atmosphere (Peschel, et al., 2007). According to the Intergovernmental Panel on Climate Change, the earth will experience regional warming, changes in precipitation, extreme weather, more drought, earlier snowmelts, rising sea levels, problems with water supply and other changes as a result of global warming over the next several decades. Even If GHG emissions were completely halted today, the earth would still warm for the next 100 years or so (Intergovernmental Panel on Climate Change, 2007).

In the northeast US the average temperature has risen by 0.45 degrees Fahrenheit per decade since 1970. Average annual precipitation in the northeast has seen a 0.4 inch per year increase. Scientists project that by 2050, northeast summers will be two degrees Fahrenheit warmer and winters four degrees warmer. More rain, heavier storms and even drought caused by shifting precipitation timing are expected (Perschel, et al., 2007). Many more effects have been documented both globally and locally, but will not be covered here.

The solution to excessive GHGs lies not just in cutting back carbon emissions from industry. Carbon emitters can buy time to develop greener technologies by offsetting emissions through the funding of emissions-reducing projects or carbon sequestering activities elsewhere. Carbon emitters can arrange to capture methane emitted from landfills and agriculture for use in energy production. Though carbon dioxide is still released, atmospheric effects are far less than if the methane were allowed to escape. Carbon emitters can also arrange to capture and recycle sulfur hexa-fluoride, a powerful greenhouse gas emitted from electrical transformers. An end-use emissions reduction offset is making non-power generation sources of carbon dioxide more efficient, such as improving large buildings' heating systems. Carbon emitters can even plant trees to sequester carbon (Farnsworth, 2007). Another type of forestry-based offset is improved forest management (IFM), which are explained below. The domain of this paper is limited to IFM offsets. These other offset types will not be discussed further.

Forests naturally sequester carbon through the photosynthesis process. IFM techniques have been developed to help forests sequester carbon more efficiently. According to the US Forest Service, good forest management can double the quantity of carbon sequestered (American Forest Foundation, 2009).

There are several distinct IFM techniques. The most basic type of IFM is the implementation of low-impact logging in conventionally logged forests. In contrast to conventional logging, low-impact logging involves more selectivity in harvesting trees. Canals are not used to export the logs because they remove peat, thereby increasing emissions of carbon dioxide. Skid trails are more carefully planned to reduce soil erosion. Another type of IFM consists of simply converting currently logged forests into protected forests. A third type involves allowing timber forests to grow longer before cutting. Finally, forests that are not currently logged can be actively managed to improve carbon sequestration. The stocking of fast-growing trees in poorly stocked forests can increase sequestration. The density of trees in a forest can be increased. In some cases, fertilization and liming can greatly increase the carbon stock of a forest (Voluntary Carbon Standard, 2007).

IFM offsets are potentially a substantial source of net carbon emissions reduction. Ten percent of US carbon emissions are absorbed by America's forests each year. Around 35 percent of all the forestland in the US is family owned (American Forest Foundation, 2009). US forest owners can play a significant role in climate change mitigation through IFM.

There are several potential and actual opportunities for the US non-industrial private forest (NIPF) owner to implement IFM techniques on his or her land and sell the resulting carbon offsets. These include several current domestic cap and trade programs including the California Climate Action Reserve, Western Climate Initiative, Regional Greenhouse Gas Initiative, and a possible national cap and trade system currently moving through Congress. Opportunities also exist in the form of the voluntary Chicago Climate Exchange and over the counter offset markets.

1.2 Objectives

The purpose of this paper is to predict the probability that Massachusetts landowners will participate in various hypothetical offset programs. A landowner survey conducted by the Family Forest Research Center is used in conjunction with an ordered logit discrete choice model to that end. Within the analysis, marginal probabilities for individual characteristics and program attributes are also estimated. This information will be invaluable to the policy maker invested in designing an optimal IFM offset program.

A review of all relevant policies, programs and markets related to IFM offsets follows in chapter 2. The Kyoto Protocol, Regional Greenhouse Gas Initiative, Western Climate Initiative, California's cap and trade program, a potential national cap and trade program in the House and Senate climate bills and voluntary carbon markets are covered therein. A literature review of studies investigating the likelihood of NIPF landowner participation in carbon offset programs as well as a description of the landowner survey used in this study follow in chapter 3. A consideration of several discrete choice model candidates for analysis of the survey data and a theoretical framework for the ordered and mixed ordered logistic models for use in the final analysis are presented in chapter 4. Ordered logit regression results as well as predicted and marginal probabilities of participation are discussed in chapter 5. In chapter 6, policy implications of these findings are summarized and directions for future research are suggested. Chapter 7 summarizes and concludes this paper.

CHAPTER 2

POLICIES, PROGRAMS AND MARKETS: IFM OFFSET OVERVIEW

There are markets for buying and selling the carbon sequestration services that IFM provides. Some of these markets are the result of cap and trade programs while other markets are strictly voluntary. There are several programs designed specifically to encourage participation of the American NIPF landowner. The purpose of this chapter is first to determine the offset markets and any other carbon sequestration programs that are relevant to the Massachusetts NIPF landowner. The other motivation is to establish a list of program or policy parameters that a prospective participant is likely to face.

All markets and programs with potential and actual relevance to the Massachusetts NIPF landowner are detailed below. Cap and trade programs, voluntary offset markets and the Chapter 61B current tax use program are considered. A literature review of the topic of landowner participation in carbon sequestration programs follows. Finally, a summary of the relevant programs associated parameters of involvement is presented.

2.1 Cap and Trade Programs

A carbon cap and trade program consists of two parts. First, the government decides a cap – a maximum allowable quantity of emissions units. Second, carbon emitters included in the program are allowed to trade emissions unit permits. That way, an emitter who has a higher cost associated with reducing emissions can buy permits from an emitter with lower costs of emissions reduction. Some cap and trade programs also allow carbon emitters to count offsets – created through the funding of projects and activities that reduce atmospheric carbon – toward the emissions reduction target.

International and domestic cap and trade programs are described below in terms of their use or non-use of IFM offsets and their relevance to the NIPF landowner.

2.1.1 Kyoto Protocol and Copenhagen Accord

The Kyoto Protocol is an international agreement that sets binding carbon emissions reduction targets for 37 developed nations. The US has not signed on. Reduction targets average five percent lower than 1990 levels, to be achieved between 2008 and 2012 (United Nations, 1998). The Protocol is a cap and trade program wherein countries and industries can sell carbon allowances if they surpass their target and buy allowances if they struggle to meet it. One of the flexibility mechanisms designed to make this process as cost-effective as possible is the Clean Development Mechanism (CDM). The CDM allows an industrialized country trying to use emissions reductions from an approved green development project in a developing nation toward its own emissions target. The only forestry projects allowed are reforestation and afforestation (United Nations, 1998). The Kyoto Protocol therefore has no relevance to IFM projects at all.

The Copenhagen Accord is a far less detailed international agreement on climate change. The Accord does not set any legally binding emissions reductions targets for any country. It is immaterial to IMF offset markets as well (Copenhagen, 2009).

2.1.2 California Climate Action Reserve

Several domestic cap and trade programs have been or are being established. California has a cap and trade program, the California Climate Action Reserve (CAR), that allows for limited IFM offsets. The California Air Resources Board recently developed protocols for trading IFM offsets as directed by SB 812. Currently California has three such pilot projects in operation. They are large in scale and government administered (Nickerson, 2008). At present, the CAR program is not relevant to NIPF landowners.

2.1.3 Regional Greenhouse Gas Initiative

Ten northeast states have signed onto the Regional Greenhouse Gas Initiative (RGGI), a regional cap and trade program. The program is operational as of 2009. It aims to stabilize carbon emissions between 2009 and 2015 and to reduce emissions by 10 percent by 2019. RGGI currently does not allow for IFM offsets. However, the Post Model Rule Action Plan leaves room for additional sources of offsets, including IFM, to become eligible later (Perschel, et al., 2007). RGGI is not currently relevant to the NIPF landowner

2.1.4 Western Climate Initiative

The Western Climate Initiative is another regional cap and trade system, developed in 2007. It involves California, Washington, Oregon, New Mexico, Arizona, Utah, Manitoba and British Columbia. The goal of the program is to reduce carbon emissions to 15 percent lower than 2005 levels by 2020 (Perschel, et al., 2007).

Carbon offset rules are still being developed. It is known only that offsets will be limited to 49 percent of total emissions reduction targets. Whether or not IFM offsets will be allowed is unclear at this time (WCI Recommendations, 2010).

2.1.5 Possible National Cap and Trade System

In 2009, the U.S. House passed the Waxman-Markey bill, also called the American Clean Energy and Security Act of 2009. The legislation outlines a national cap and trade system that includes liberal use of offsets. IFM is eligible for use in the offset market, but regulations regarding specific programs are not explicit. Relevance to NIPF landowners is uncertain. The EPA, in cooperation with a specially assigned committee, will determine eligible offset programs over the two years following passage of a final bill (American Clean Energy and Security Act, 2009).

The Senate is currently debating the Kerry-Boxer bill, officially known as the Clean Energy Jobs and American Power Act, which closely mirrors the House version (U.S. Climate Legislation, 2009). There are many reasons to expect IFM offsets to play a significant role in the final legislation. The US Environmental Protection Agency (2009) projects that 81 percent of domestic offsets for the beginning years of this cap and trade program will need to come from forestry offsets.

A study by the Congressional Budget Office predicts that demand will outstrip supply of offsets in the early years of the cap and trade program. If that happens, offset prices will likely be high (Congressional Budget Office, 2009). The language of the two climate bills indicates that offsets already purchased voluntarily or as part of a regional cap and trade program will be eligible for use in the new cap and trade system. Consequently, demand for offsets from groups like New Forests – a company that evaluates and implements forest carbon offset projects – has risen dramatically (U.S. Climate Legislation, 2009).

At present, this national cap and trade program does not represent an opportunity for the NIPF landowner to sell IFM offsets, but may soon. Both the House and Senate bills set aside two billion annual tons of carbon emissions reduction to come from offsets (one billion domestic and one billion international). IFM will likely be an acceptable source of offsets. In that scenario, it is easy to imagine a role for the NIPF landowner (Environmental Protection Agency, 2009).

2.2 Voluntary Carbon Offset Markets

Cap and trade programs can create offset markets driven by the need of carbon emitters to find cheaper ways to reduce net emissions. There are also voluntary carbon offset markets driven by the desire of anyone wanting to buy or sell carbon offsets created by various projects and activities. Buyers and sellers can be individual people or large firms. There are two voluntary markets in the U.S. These are described below in terms of their relevance to the NIPF landowner.

2.2.1 Chicago Climate Exchange

The Chicago Climate Exchange (CCX) is a rules-based voluntary carbon offset market. It allows and has specific protocols for IFM offsets. The CCX is currently developing a California Climate Exchange, a New York Climate Exchange and a Northeast Climate Exchange for trading offsets in regional cap and trade programs (Chicago Climate Exchange, 2007).

Costs of getting certified and meeting other requirements are too high at the individual family forest scale for the NIPF landowner to sell IFM offsets on the CCX. There are several offset aggregation programs around the country designed to create the economies of scale necessary to sell on the CCX by pooling the IFM offsets of NIPF landowners. These programs are jointly run by state government agencies and private forestry companies. The parameters of involvement in these programs are detailed below.

An apparently successful example is a pilot program called the Michigan Working Forest Carbon Offset Program (MWFCOP). The non-profit Delta Institute aggregates credits from many small landowners and trades with the CCX. Landowners are annually paid the net revenues from their credits after accounting for aggregation and trading fees. Fees include a $0.20/ton of carbon credits earned and a ten percent charge on gross carbon revenues (Delta Institute, 2009).

In accordance with CCX protocol, landowners are not paid for 20 percent of estimated carbon sequestration as insurance against harvest or catastrophic loss. Each year, that 20 percent goes into a reserve pool. If by 2010 the reserve pool is positive, the landowner can sell the credits. If by that year the reserve pool is negative, the landowner is required to purchase credits to make up the difference. If the forest landowner does not comply with the prescribed sustainable forestry management plan, he or she must return the carbon credits earned during the project years, and may also be permanently banned from participation in the CCX. The landowner can cancel the contract if the Delta Institute agrees to it. For a fee, the Michigan DNR can provide landowners with technical assistance in assessing carbon stocks, etc (Delta Institute, 2009).

To be eligible, a working forest must be actively managed and enrolled in a forest stewardship program through a prescribed list of organizations, including the Sustainable Forestry Initiative. In order to participate in the MWFCOP, the landowner must establish a baseline inventory of the carbon stock, report annual changes from harvesting or weather damage, be verified annually by a CCX-approved third party, and write a letter indicating commitment to an approved forest management plan (Delta Institute). Landowners recently enjoyed an $8 per acre return (Oregon Small Woodlands Association, 2009).

Inspired by the success of the Michigan pilot program, two other programs in that region have emerged. One is the Michigan Conservation and Climate initiative, and the other is the Illinois Conservation and Climate Initiative. The requirements for participation, fees and costs associated with these programs are identical to the Michigan pilot project (Michigan Conservation & Climate Initiative, 2010).

A similar program is operating in the Western United States. Woodlands Carbon, a corporation formed in 2008 by the Oregon Small Woods Association (OSWA) and the American Forest Foundation (AFF), aggregates and trades offset credits from NIPF landowners on the CCX. Contracts with Woodlands Carbon last 15 years. As with the Michigan program, 20 percent of credits earned must be set aside as insurance. Up to an additional 10 percent may be deducted to account for error in sequestration estimation. Liability from catastrophic weather is limited to 20 percent of carbon credits; the 20 percent can be sold at the end of a market period if it is not lost (Oregon Small Woodlands Association, 2009).

Startup costs for a prospective participant include the cost of certifying the land, unless the landowner is already certified by an approved organization. Woodlands Carbon offers loans for certification costs, eliminating the need for out-of-pocket expenditure. The required OSWA membership costs $135 for owners of more than 70 acres and $85 for owners of less than 70 acres. Woodlands Carbon charges a percentage of carbon revenues for aggregation and trading services. There are financial penalties for non-compliance with the contract. In accordance with CCX protocol, all forestland owned by an individual must be enrolled. Thus, a landowner cannot set aside some of his land for timber and other land for carbon credits (Oregon Small Woodlands Association, 2009).

To be eligible, the land must meet certain productivity and inventory requirements. Any acreage is eligible, but plots of less than 100 acres are not likely to be profitable. One person needs to be authorized to make decisions regarding forest management. The forest owner needs to be enrolled in the American Tree Farm System and must maintain Tree Farm Certification for 15 years from the time the contract with Woodlands Carbon begins. The owner needs to be a member in good standing with OSWA for the 15 year contract. The owner must inventory carbon stocks in accordance with CCX protocol and present the data in the approved Woodlands Carbon format annually. Any timber sales contracts by the owner must include a stipulation maintaining ownership of the carbon stored in the timber. Audits are infrequent but may happen at any time (Oregon Small Woodlands Association, 2009).

A Northeast pilot project is also under way. CarbonTree, LLC was formed by the Empire State Forest Products Association (ESFPA) and the American Forest Foundation to aggregate and trade sequestered carbon offsets on behalf of private Northeast forest landowners. The structure of the program is nearly identical to that administered by Woodlands Carbon. ESFPA membership is required. It costs $120 per year for owners of more than 500 acres and $60 per year for those owning less. Excluding certification and annual verification costs, CarbonTree charges 12 percent of all sales. The same eligibility requirements apply as with Woodlands Carbon (CarbonTree, 2009).

In short, the parameters of participating in these aggregation programs are fairly consistent. A prospective participant must be willing to sign a 15 year contract and file a management plan. The participant usually will face penalties for breaking the contract. If the Michigan pilot program is a good indicator, it is only worth participating for landowners with over 100 acres. Landowners can expect around $8 per acre per year.

2.2.2 Over the Counter Markets

While the CCX is a centralized, closely monitored rules-based market, over the counter (OTC) markets do not operate under any required set of protocols. OTC markets are not bound by any rules whatsoever. OTC market interactions can be as simple as a single project developer selling his offset credit to a single willing buyer or as complicated as an aggregator buying from many projects and selling wholesale to a retailer, who then sells the offsets to willing buyers (Hamilton, et al., 2008).

To make trades more transparent and credible, most forestry offset sellers obtain certification through one of several common standards. The most popular standards used by offset suppliers in early 2008 were the Voluntary Carbon Standard, the Gold Standard, the VER+, and the Climate, Community and Biodiversity (CCB) Standard. There are several purposes that a standard can serve: accounting standards, monitoring, verification and certification standards, and registration and enforcement systems. Some standards, known as full-fledged carbon offset standards, serve all of these functions. VCS, the Gold Standard, and the VER+ are full-fledged standards, while the CCB is a project design standard (Kolmuss, et al., 2008). The Gold Standard does not cover IFM projects, so is not described in detail here. As the CCB standard is not comprehensive, it is not covered here either. Below is a brief description of the requirements of the VCS and VER+ standards.

The VCS does cover IFM projects, provided that they are not earning some other type of environmental credit elsewhere. There are no restrictions on project size or location, though a "micro" project is defined as one that offsets under 5,000 tons of carbon per year. There are comprehensive additionality and baseline requirements. Projects are required to be above and beyond any regulation – they must be proven to be totally voluntary. The crediting period of VCS projects is 10 years. There is a registration fee for each Voluntary Carbon Unit (VCU) accredited of four euro cents. Additional account fees are set by the VCS approved registries (Kolmuss, et al., 2008).

The VER+ standard also includes rules for IFM offset projects. There are no size restrictions on VER+ projects. Additionality and baseline methodologies are developed on a project by project basis. Verification and registration of projects is conducted by an accredited auditor and is based on validation reports of the project developer. Verification fees depend on the rates of VER+ approved auditors, but range between 5,000 and 15,000 Euros. Registration fees range between 1,500 and 3,000 Euros (Kolmuss, et al., 2008).

There are many opportunities for large carbon emitters (or anyone else) to offset their emissions using the voluntary market standards detailed above. There are equally many opportunities for large-scale retailing of carbon offsets through IFM projects. As with the CCX, the individual NIPF landowner cannot sell certified IFM offsets on OTC markets because of the high startup costs. There are offset aggregators for voluntary markets, including New Forests and Forecon. However, these aggregators are not geared toward the NIPF landowner. The voluntary market is irrelevant to the NIPF landowner at the present time.

2.3 Chapter 61B

In Massachusetts, there are three current use tax programs. Landowners can enjoy reduced property taxes for restricting the use of the their land to a specific purpose. The Chapter 61B program in particular provides substantial tax incentives in return for providing wildlife habitat and local timber products. The program is covered here because it can be considered as a non-market carbon sequestration program that does not require participants to file a management plan, has a minimal time commitment, high revenue and a penalty for early withdrawal.

To be eligible to participate, the landowner must have at least 5 acres, excluding residence and other buildings. Land use is restricted to either open space or recreation. Open space means land retained in a substantially natural, wild, or open condition; land retained in a landscaped or pasture condition; or managed forest under a state-approved forest management plan. Public access is not required for open space use. Recreation means land that is available for recreational purposes that do not harm the environment. Under the recreation category, the land must be accessible to the public or to members of a nonprofit organization. The landowner is permitted to charge an access fee.

The landowner is not required to file a management plan with the state unless he or she plans to harvest timber. Harvesting timber on Chapter 61B land is allowed provided the landowner files an approved management plan. If the landowner changes use of the land within five years of enrolling in the program, there is an early withdrawal penalty consisting of back taxes. Should the landowner sell the property for a change in use within ten years of enrolling, the back tax penalty also applies. After those times, no early withdrawal penalties will be incurred.

If the landowner sells the property for residential, commercial, or industrial use while enrolled in Chapter 61B or within a year of leaving the program, the town has the right to match any offer for the land and purchase it. There is no fee charged to the landowner to enroll or to transfer land use to another Chapter 61 program. The value of the land is determined by its recreational use value. Non-eligible sections of the land are taxed at normal rates (Chapter 61B).

2.4 Summary

There are only a few opportunities for the NIPF landowner to sell IFM offsets. All of the cap and trade programs mentioned either do not allow IFM offsets or are not geared toward NIPF landowners. However, new climate legislation could change that if the Senate bill is passed. NIPF landowners may be able to sell IFM offsets in a national cap and trade system.

Over the counter offset markets are also inaccessible to the NIPF landowner. The economy of scale is too small at the individual small landowner level. Startup costs and fees are too high for selling IFM offsets to be profitable.

The only offset programs geared specifically toward the small forest owner consist of IFM offset aggregation for the CCX. These programs generally require participants to file a management plan, have a 15 year time commitment, $8 per acre annual revenue and an early withdrawal penalty. Only one of these programs – the New York based CarbonTree – is accessible to the Massachusetts NIPF landowner.

There is also a land use tax program in Massachusetts that resembles a carbon sequestration incentive program. Though carbon sequestration is not the explicit goal of Chapter 61B, the program can be considered a relatively unrestrictive, high-revenue incentive program for carbon sequestration. This program does not require participants to file a management plan unless the participant plans to harvest timber, has a minimal time commitment, and no early withdrawal penalty in most circumstances. The tax savings can be quite substantial, translating into a much higher revenue than the CCX-based programs.

In the next chapter, the available literature about landowner participation in carbon sequestration programs is reviewed. A survey of Massachusetts landowners designed to assess likelihood of their participation in such programs is summarized.

CHAPTER 3

HOW LIKELY ARE NIPF LANDOWNERS TO PARTICIPATE IN CARBON MARKETS?

The literature regarding NIPF landowner participation in carbon markets is extremely sparse. What little information is available in the literature until now is presented below. Following that is a description of the landowner survey used in the present study. This survey was designed with the intention of gaining a better understanding of Massachusetts landowner attitudes toward participation in carbon markets.

3.1 The Literature

There is very little information available about the likelihood that NIPF landowners will participate in IFM offset markets. To the author's knowledge, there is only one study that investigates the topic quantitatively. The available literature is summarized below.

Cason, et al. (2006) promote the use of university extensions in convincing and helping NIPF landowners to participate carbon sequestration programs in the American southeast. The authors present a qualitative discussion of carbon sequestration easement programs in Mississippi but do not provide a quantitative analysis of the likelihood of landowner participation.

The only study at present to have explicitly analyzed the likelihood of NIPF landowner participation in carbon offset markets is a pilot study conducted by Fletcher, et al. (2009). The authors present IFM offset programs like the CCX aggregation programs detailed in chapter 2 to a focus group of Massachusetts landowners. Participants are asked to rate six programs each on a scale of 1 to 10, where a 10 represents absolute certainly that the landowner will participate in the program. Program attribute variables include whether or not an official management plan must be filed, per acre annual revenue from the carbon offsets ($5, $15 and $30), time commitment (five or ten years) and whether or not there is a penalty for early withdrawal from the program.

The authors use a tobit model to estimate the effect of program attributes on rating level and a logit model to estimate landowners' willingness to sell carbon offsets. To render the ratings data usable for the logit model, the authors code a 1-8 rating as a "no" and a 9 or 10 rating as a "yes." Socioeconomic variables were excluded from the final model due to insignificance of the parameter estimates. However, the authors caution that the insignificance is likely a result of such a limited sample size (only 17 landowners). They note that previous research demonstrates the importance of landowners' characteristics in determining their responses to other types of management programs (Finley and Kittridge, 2006).

Tobit results indicate that that landowners give higher ratings to programs that do not require a management plan, have higher revenue stream, and do not have an early withdrawal penalty. Surprisingly, a higher time commitment leads to a higher rating. there is no penalty for early withdrawal.

Logit results suggest that only five percent of landowners would participate at an annual per acre payment of $15 where other attributes are held constant at their means. About 13 percent would take part in a program with a $30 per acre per year payment and 33 percent would participate where the per acre annual revenue is $50. The authors note that at the current carbon price of $6 per ton on the CCX, an average Massachusetts forest that sequesters one to three tons per year translates to an annual per acre revenue of $6 to $18.

3.2 A Massachusetts Landowner Survey

Massachusetts can and should play a role in climate mitigation; about 62% of its land is forested. Furthermore, 235,000 private individuals own 78% of that land (Alerich, 2000). To assess the feasibility of a carbon sequestration program in this state, it is critical to understand how these landowners feel about enrolling their land in various hypothetical programs.

To that end, the Family Forest Research Center recently conducted a mail survey of Massachusetts landowners with funding from the Massachusetts Agricultural Experiment Station and UMass Extension. An unusually high response rate of around 50% was achieved (The Potential for Carbon Sequestration on Family Forest Land, 2010). However, of the 1,403 returned surveys, only 910 were complete.

Respondents answered questions about themselves and their land and then were asked to rate, on a scale of 1 to 10, three different hypothetical carbon sequestration programs. The rating question was worded such that a 10 should indicate absolute certainty on the part of the landowner that he or she would participate in the program given the opportunity, while a 1 should indicate absolute certainty of the opposite. Any rating in the middle should indicate varying levels of uncertainty on the part of the landowner. Prior to the rating questions, respondents were asked to read about a page of background information on CCX aggregator programs so they could understand what they were rating. This information is included in Appendix C.

The programs varied along the following lines: whether or not a management plan is required of the landowner, how long is the time commitment, what is the per-acre net revenue, and whether or not there is a penalty for early withdrawal from the program. These four attributes were used because they are representative of the parameters of involvement of the CCX aggregation programs and Chapter 61B described in chapter 2.

There were four versions of the survey, each with a distinct set of three programs. Thus, there are 12 distinct programs with ratings data for each. The levels and attributes associated with each program are listed in table 1 below. This table is also in appendix A for reference.

Table 1: Attributes and Levels for Each of the 12 Programs

	Version 1			Version 2			Version 3			Version 4		
Attr.	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3
Plan	No	no	No	no	no	no	yes	Yes	yes	yes	Yes	yes
Time	5	10	10	5	5	10	5	10	10	5	5	10
Rev.	15	5	30	5	30	15	15	5	30	5	30	15
Pen.	No	no	Yes	no	yes	yes	no	Yes	no	yes	No	yes

Plan: Management plan required?
Time: Time commitment, in years.
Rev.: Expected per-acre revenue, net of all costs ($)
Pen.: Penalty for early withdrawal?

A fractional factorial design was used to decide attribute levels for each program. Care was taken to avoid dominant or reverse-dominant programs that all respondents would likely rate 10 or 1, respectively. For example, a program with no required management plan, minimal time commitment, high revenue stream and no early withdrawal penalty would be a dominant program. A reverse-dominant program would include a required management plan, high time commitment, low revenue and a penalty for early withdrawal. Such universally popular or unpopular programs would not yield information about the tradeoffs landowners make when considering program attributes.

Individual characteristics obtained from the survey and used for analysis include acres owned, age, level of education and gender. Many more attitudinal questions were asked in the survey but are not included for this analysis. The characteristics used in this study and their associated variable names are listed in table 2 below and are also listed in appendix B.

Table 2: Explanation of Variables Used

Plan: Management plan required is a 1; not required is a 0.

Time: Time commitment, in years. Takes on values of 5,10, and 15 years.

Rev: Revenue net of costs, in dollars per acre per year. Takes on values of 5, 15, and 30 dollars per acre per year.

Pen: Penalty for early withdrawal is a 1; no penalty is a 0.

Acre: Respondent owns 100 acres or more is a 1; fewer than 100 acres is a 0.

Older: Respondent is 66 years or older in age takes a 1; younger than 66 takes a 0.

LowerEd: Respondent's education level is high school diploma or less takes a 1; some college or more takes a 0.

HigherEd: Respondent has more than a college degree is a 1; a college degree or less is a 0.

Male: Respondent is male takes a 1; female takes a 0.

Plan*Older: 1 if management plan is required and respondent is 66 years or older; else 0.

Rev*Older: Revenue for respondents 66 and older.

Plan*LowerEd: 1 if management plan is required and respondent has a high school diploma or less; else 0.

Rev*LowerEd: Revenue for respondents with a high school diploma or less.

Time*Male: Time commitment for males.

In the survey, respondents were asked to indicate their age by checking one of five age categories. These were condensed into just two categories for the analysis. Similarly, there were five categories of education in the survey. These were condensed into three categories. The survey asked respondents to indicate how many acres they own with an open-ended question. Those numbers were converted to a dummy variable indicating more than 100 acres for the analysis.

3.3 Summary

There is almost no literature on the likelihood that NIPF landowners will participate in carbon offset markets. The one study that explicitly investigates the topic is limited in scope; it is a pilot study of Massachusetts NIPF landowners. The study's authors find low probabilities of Vermont and Massachusetts landowner participation in CCX aggregation programs. They conclude that landowners give lower ratings to programs that require them to file a management plan and have a penalty for early withdrawal. Landowners give higher ratings where revenue and time commitment are greater. Individual characteristics are insignificant as independent variables. These conclusions are tempered with the warning that they are based on a small, non-random sample. The present research is largely inspired and informed by that study. The mail survey of Massachusetts landowners conducted by the Family Forest Research Center is used to answer the question of how likely landowners are to participate in carbon sequestration programs.

Econometric methodology for analyzing the survey data are detailed in the next chapter. Several possible discrete choice models are considered. The ordered and mixed ordered logit models are described in detail. Estimation pitfalls are discussed.

CHAPTER 4

METHODOLOGY

4.1 The Most Common Choice Models

There is a great number of possible discrete choice models available to the researcher. The models considered for this analysis are briefly outlined for the purpose of emphasizing a few of the many considerations the researcher has to make in choosing a model. Included in the discussion are the linear and tobit, multinomial logit, censored rank-ordered logit, binomial and binomial logit, and ordered and mixed ordered logit models. The ordered and mixed ordered logit are shown to comprise the best approach; as such, they are covered in detail. Estimation problems with the ordered models are discussed as well.

4.1.1 Linear and Tobit

The linear and tobit models were immediately discarded as possibilities. The ratings data are ordinal, but not interval. The difference between moving from a 2 to a 3 does not necessarily have the same meaning as moving from a 9 to a 10. Interpretation of linear and tobit regression results is therefore not possible. Furthermore, probabilities of participation cannot be obtained (Borooah, 2002).

4.1.2 The Multinomial Logit

The multinomial logit (MNL) is based on random utility theory of consumer behavior. Choices made by a decision maker are modeled as follows. A decision maker with a vector of characteristics chooses from a set of discreet choices, each assigned a probability of selection. Each alternative comprises a vector of attributes.

Utility derived from a given alternative is assumed to be a linear function of two components, one deterministic one random. The deterministic component of utility is a function of individual characteristics and alternative attributes. The random component results from the researcher's inability to observe all the attributes of the decision maker and not from actual random utility (Hensher, et al., 2000). This component is assumed to follow the logistic distribution. Thus, individual choice, described completely by varying levels of common attributes like socioeconomic background and a set of alternatives, is defined as a draw from a multinomial distribution with selection probabilities.

Two major assumptions must be made to render the model operational. The first assumption is known as the Independence from Irrelevant Alternatives Axiom, and posits that ratio of probabilities of choosing one alternative over another is unaffected by the presence or absence of other alternatives in the choice set. There are tests to establish whether this is reasonable or not for a given study (Hensher, et al., 2000). The second assumption is that the choice set covers all relevant alternatives, so that respondents consider only the alternatives presented in the survey (DeShazo, et al., 2009).

A MNL model is theoretically possible for use with this data set. To convert the program ratings into choice data, the highest rating of the three programs would be coded as a 1, indicating a "yes," while the other two programs would be coded as zeros, or "no's". There are several critical flaws in this approach.

As mentioned above, a basic assumption of the MNL is that the choice set facing respondents is complete. There is no exit option in the survey question. Respondents were not asked to rate the status quo as an alternative. Another major problem is that the highest rating might be a 2 or 3. To code that as a "yes" is not reasonable. Even if it were, there is a more practical concern. A substantial portion of respondents (30 percent) chose the same rating for all three programs. Those respondents would have to be trimmed from the model.

A related model, the censored rank-ordered logit, is outlined by Layton and Lee (2006). This involves converting ratings into rankings. The authors point out that tied ratings do not necessarily indicate indifference, but might mean instead that the scale is not large enough. For example, an apparent tie on a Likert scale of 1-10 might disappear on a scale of 1-100 – a 9 versus 9 might become 92 versus 97. Thus ties are censored from the model. However, this approach is discarded because 30 percent of respondents rated their three programs the same and would have to be censored.

4.1.3 The Binomial Logit

A special case of the MNL is also considered – the binomial logit model. Each rating can be viewed as a choice between the status quo (doing nothing) and the program. Following Fletcher, et al. (2009), the ratings could be recoded to fit that type of choice. A slightly more conservative coding than that used by Fletcher, et al. involves coding a10 – indicating certainty of participation – as a yes (to the program). A 1-9 could be coded as a no. The no to the program is taken as a yes to the status quo.

Each individual’s three ratings could be viewed as three binomial choices between the program and the status quo. However, there is no reasonable way to parameterize the status quo for each individual. The status quo could involve selling timber, enrolling in a conservation program, or just passively enjoying the land.

4.1.4 The Binary Logit

The binary logit is more feasible. As with the binomial approach, a10 is coded as a 1 (yes) while a 1-9 is coded as a 0 (no). The probability of a yes is modeled without consideration of alternatives (Borooah, 2001).

There is evidence that certainty on a Likert scale closely resembles an actual "yes" in the real world (Stevens, et al., 2000), yet the binary logit is not the best option. The data are ordinal in nature, not binary. Coding the data as mentioned entails ignoring any behavior in the 1 to 9 category and prevents analysis of the lower ratings. Furthermore, insignificance of important variables is likely because of the lack of variation in the binary-coded data. That happens with the binary coding of ratings data by Fletcher, et al. (2009).

None of the models presented thus far are adequate for the data at hand. A more appropriate model, the ordered logit, accounts for the ordinal nature of the ratings data. This model is used in the final analysis and is detailed in the next section.

4.2 The Ordered Logit : A Model Suited for Ratings Data

The ordered logit model, also known as the cumulative logistic model, fits the dataset best. Note that the ordered probit model was discarded because of a paper by Kropoko (2008), who conducts a comprehensive set of simulations showing that the probit generally results in significantly more biased estimates than the logit.

4.2.1 Model Setup

The ordered logit is related to the latent class model. An unobserved (latent) dependent variable is a function of observed and unobserved variables:

$$r^* = \sum \beta_k{}' x_k + \varepsilon_k$$

Note that r* is an unobserved, continuous, underlying tendency behind the observed ordinal response (rating). The X's represent individual characteristics and program attributes, while the β's represent the associated parameters. The error term captures stochastic (unobserved) variation. It is assumed to be distributed logistically.

What we do observe is:

$$R = 1 \; if \; r^* \leq \mu_1$$

$$R = 2 \; if \; \mu_1 < r^* \leq \mu_2$$

...

$$R = 10 \; if \; \mu_9 < r^*$$

where R is the rating and the μ's represent thresholds of y* that delineate the categories of the ordered response variable. These threshold parameters are restricted to be positive where each one is greater than the previous. The first parameter μ_1 is normalized to 0 so that one less parameter has to be estimated. That is not a problem because the scale of the latent variable is arbitrary (Borooah, 2001).

Thus the cumulative probability of choosing a particular rating or lower is found using the logistic cumulative density function

$$P(R \leq j) = \frac{\exp\,(\mu_j - \sum \beta_k x_k)}{1 + exp\left(\mu_j - \sum \beta_k x_k\right)}$$

which can be expressed more simply as

$$P(R \leq j) = \frac{1}{1 + exp\left(-(\mu_j - \sum \beta_k x_k)\right)}$$

Probabilities of lower ratings are subtracted from the cumulative probability of the rating of interest to find its probability of occurrence. This is shown below for the specific rating values (Liao 1994). Note that F() is the logistic cumulative density function, defined above.

$$P(R=1) = F\left(\mu_1 - \sum \beta_k x_k\right)$$

$$P(R=2) = F\left(\mu_2 - \sum \beta_k x_k\right) - F\left(\mu_1 - \sum \beta_k x_k\right)$$

$$P(R=3) = F\left(\mu_3 - \sum \beta_k x_k\right) - F\left(\mu_2 - \sum \beta_k x_k\right)$$

...

$$P(R=10) = 1 - F\left(\mu_9 - \sum \beta_k x_k\right)$$

The likelihood of having observed the sample choices is therefore:

$$L = [P(R=1)]^{N_1}[P(R=2)]^{N_2} \dots [P(R=10)]^{N_{10}}$$

where the N's represent number of respondents in the sample who selected the corresponding rating. To obtain estimates for the regression coefficients and latent variable cutpoints, the log of the likelihood function

$$LL = \sum \mathrm{N_j} * \ln{[P(R=j)]}$$

is maximized with respect to the coefficients and cutpoints.

4.2.2 How to Interpret an Ordered Logit Model

There are three steps for interpreting the results of an ordered logit model. The first step (and least intuitive) is to look at the marginal effect of a change in X on the odds ratio

$$\frac{P(R \leq j|x)}{1 - P(R \leq j|x)} = \exp{(\mu_j - \sum \beta_k x_k)}$$

The coefficients in the regression results represent the marginal effect of a change in X on the log-odds. The effect on the odds ratio (given that the other independent variables are held constant at their means and/or modes) is obtained simply by exponentiating the parameter estimate. Thus, the exponentiated coefficient is the effect that a one unit increase in the independent variable has on the odds ratio of the individual choosing one rating over all the other ratings (Liao 1994).

A more sensible interpretation of the regression output involves predicting the probabilities for each category of the dependent variable at the means of the independent variables. To get those probabilities, all that is necessary is to plug the coefficients and X means into the equations below:

$$P(R = 1) = F\left(-\sum \beta_k x_k\right)$$

$$P(R = 2) = F\left(\mu_2 - \sum \beta_k x_k\right) - F\left(-\sum \beta_k x_k\right)$$

$$P(R = 3) = F\left(\mu_3 - \sum \beta_k x_k\right) - F\left(\mu_2 - \sum \beta_k x_k\right)$$

...

$$P(R = 10) = 1 - F\left(\mu_9 - \sum \beta_k x_k\right)$$

A finer analysis of the predicted probabilities is possible. Probabilities for each category at each level of a particular independent variable can be predicted. The other independent variables will of course be held at their means.

Additionally, estimated marginal effects of independent variables on the probabilities of being in each category can be calculated. Differentiating the above set of equations with respect to x_k yields

$$\frac{\partial P(R = j)}{\partial x_k} = [F(\mu_j - \sum \beta_k x_k) - F(\mu_{j-1} - \sum \beta_k x_k)]\beta_k$$

With dummy variables, this differentiation method will lead to biased results. A better way to get the marginal effect for a dummy variable is to calculate the probabilities for each category at X=0 and at X=1, and take the difference. While the bias will not be substantial enough to effect broad conclusions, it will mire a finer analysis (Liao 1994).

4.3 Possible Problems with the Standard Ordered Logit

Though the ordered logit model is much better suited for ratings data than the models listed in the first section, it is not totally ideal. There are still potential sources of bias and other estimation problems. These are described in the sections below.

4.3.1 Choice Task Complexity and Protest

Though the ordered logit is considered the best possible model for this dataset, several caveats must be offered before estimation. There is ample research indicating that choice complexity and protest attitudes can affect consistency of regression results.

Moon (2004) shows that higher choice complexity leads to a higher likelihood of choosing the status quo alternative, suggesting that respondents choose the status quo because it is easiest to understand. For the survey in the present study, that problem would likely manifest itself in lower ratings among people who have difficulty understanding the programs. Adamowicz, von Haefen and Massey (2005) deal with serial nonparticipation – protest against the tradeoffs presented or suggested in the survey, or against all government action. These authors suggest that protest attitudes in the respondents can bias results because the choice selections are not sincere.

DeShazo and Fermo (2002) develop five measures of choice task complexity in determining whether it is a problem with respect to consistency of estimation results. They too find a serious complexity effect, but offer a couple of solutions to deal with it.

They suggest that there are two stages in the experimental process where researchers can intervene to mitigate the complexity effect. First, researchers should choose the optimal number (identified via pre-testing) of alternatives, being careful about attribute correlation structures. Second, researchers can deal with complexity issues using a heteroskedastic logit model at the estimation stage (this requires non-constant complexity throughout sample).

Of the 1,403 completed surveys in the present study, 493 did not contain any ratings data for the programs – respondents simply left that section blank. If the reason was choice task complexity or protest attitudes, there is a possibility of bias in using only the 910 completed surveys. The bias mitigation measures detailed in this section are unfortunately not possible for this study as the survey is already completed.

4.3.2 Hypothetical Bias

Hypothetical bias is a well-documented problem in stated preference studies. Participants often overstate willingness to pay for goods in the absence of a real-world budget constraint (Brown, et al., 2003). The problem of course can manifest itself in hypothetical willingness to accept as well. The present study includes willingness to accept measures in the per acre annual revenue variable. If NIPF landowners' choices in the survey differ from what their choices would be in the real world because of the hypothetical nature of the revenue variable, estimates of the effect of per acre annual revenue will be biased.

Murphy, et al., (2005) conduct a meta analysis of stated preference studies – that elicit both hypothetical and real willingness to pay – in order to determine the magnitude of hypothetical bias and its underlying causes. They find an average ratio of hypothetical to real values of 2.35 and a median of only 1.35. The ten highest ratios averaged 10.3, indicating an extreme right skew. Thus hypothetical bias may not be such a serious problem in many studies.

Murphy, el al. investigate the factors behind hypothetical bias using a log-log model with natural log of actual value as the dependent variable. On the right hand side are natural log of hypothetical value and square of hypothetical value, along with several dummy variables. The authors conclude that greater bias results from higher stated hypothetical values, and that the relationship is positively quadratic. They determine that conducting studies using students and in group settings leads to greater hypothetical bias, but the student effect could not be extracted from the group effect.

The last significant result of these authors' work is that studies employing dichotomous/polychotomous choice, referendum, payment card and conjoint choice elicitation methods yield lower hypothetical bias than pricing elicitation methods. Several other variables, including whether a private good is involved, whether the comparison is within-group, and whether a calibration technique such as budget reminders or "cheap talk" is used, are included in the model. However, the significance of these factors depends on model specification. The authors recommend against focusing on these individually, though as a whole they explain a significant portion of variation between studies (Murphy, et al, 2005).

There is evidence that asking (but not requiring) participants to sign an oath to respond honestly substantially reduces hypothetical bias in stated preference studies. Economic literature is sparse in the area of oath-taking. Shogren, et al. (2009), use psychology literature to inform their exploration of preference elicitation under oath.

Commitment theory in psychology suggests that the strongest commitments are freely made (under no pressure), publicly expressed and with consequences. The oath used in these experiments could not be made publicly or have serious consequences if broken. However, the participants were allowed to participate and given any monetary incentives regardless of whether or not they signed the oath.

Shogren, et al. (2009) conduct four treatments each of an induced value and a homegrown auction. The four treatments consist of a baseline with no monetary incentives and no oath, the baseline with an oath, an auction with monetary incentives but no oath, and an auction with monetary incentives and an oath. In the induced value experiments, the authors find that without the oath there is a significant difference between bidding behavior and perfect demand revelation, regardless of the monetary incentive. The bidding behavior under oath with a monetary incentive is also insincere. Bidding behavior under oath with no monetary incentive, however, matches perfect demand revelation. The authors discover similar results in the homegrown auctions – the oath seems to keep people from overstating high bids and understating low bids.

Though hypothetical bias is always a concern in stated preference studies, there is no reason to believe that the present study suffers from serious bias. The meta-analysis mentioned above indicates the hypothetical bias is usually quite low. In addition, a polychotomous choice/conjoint elicitation method was used and the willingness to accept numbers – in the form of revenue – are small. Unfortunately, an oath could not be used in the present study and the survey used does not include any measures to deal with choice task complexity or protest attitudes.

4.3.3 The Proportional odds Assumption

A critical issue peculiar to the ordered logit model is the proportional odds assumption. An assumption behind the basic ordered logit model is that the effect of the regressors (except the intercept) is the same for all ratings. SAS provides a Chi-Square test of this assumption (Liao, 1994). However, this test is sensitive to large sample sizes (Long & Freese, 2001).

4.3.4 The Repeated Choice Problem: Correlated Error Structure

Another potential problem with using the basic ordered logit model is the repeated choice nature of this data set. Each individual chose a rating for each of the three programs presented. In that sense, the data can be viewed as having a panel structure with cross-sections (individuals) and time-series (three ratings). The three ratings are not truly time series because they were presented side by side on the same page, leaving respondents the option to review all programs before deciding on ratings. Yet the problem is mathematically identical.

The ordered logit model treats an individual's three ratings as three separate choices made by identical triplets, not as three choices made by one person. Yet decisions are likely correlated among individuals across the three choices. If that correlation can be fully explained by variation in observed independent variables then there is no problem. However, if there is unobservable correlation then the error structure is no longer in accordance with model assumptions. Regression results will be inconsistent (Train, 2009).

4.4 Possible Solution for the Proportional odds and Repeated Choice Problems: The Mixed Ordered Logit

A mixed ordered logistic model can be used to deal with correlated errors. Unlike the standard logit, mixed logit estimation allows for random taste variation among respondents, unrestricted substitution patterns, and correlation among random terms over time (Train 2009).

The model setup is similar to the basic ordered logit, only the random coefficients are drawn from a nondegenerate mixing distribution rather than fixed. There are several ways of representing the model. Hedeker (2006) is followed here in that regard. The conditional probability of an individual i choosing a particular rating in time period j is

$$L_{ij1} = \frac{1}{1 + \exp\left(x_{ijk}\beta_k + z_{ijr}v_{ir}\right)}$$

$$L_{ij2} = \frac{1}{1 + \exp\left(-\left(\mu_2 - (x_{ijk}\beta_k + z_{ijr}v_{ir})\right)\right)} - \frac{1}{1 + \exp\left(x_{ijk}\beta_k + z_{ijr}v_{ir}\right)}$$

$$L_{ij3} = \frac{1}{1 + \exp\left(-\left(\mu_3 - (x_{ijk}\beta_k + z_{ijr}v_{ir})\right)\right)} - \frac{1}{1 + \exp\left(-(\mu_2 - (x_{ijk}\beta_k + z_{ijr}v_{ir}))\right)}$$

...

$$L_{ij10} = 1 - \frac{1}{1 + \exp\left(-(\mu_9 - x_{ijk}\beta_k + z_{ijr}v_{ir})\right)}$$

where $i = (1,2, \dots, N)$ with N being sample size, $j = (1,2,3)$ refers to the choice number, k is number of fixed coefficients, and r is number of random coefficients. Thus x_{ijk} is a N x k matrix of independent variables, β_k is a k x 1 vector of fixed coefficients, z_{ijr} is a N x r matrix of independent variables, and v_{ir} is a r x 1 vector of random coefficients.

The mixing distribution governing the behavior of the random coefficients, v_{ir} , is frequently assumed to be a multivariate normal distribution of r dimensions, with mean vector b and covariance matrix W (Train 2009). In order to obtain those probabilities, estimates of b and W must be obtained as well as of β and μ. The unconditional probability of individual i choosing rating c in time period j is the integral of the conditional probability times the mixing distribution evaluated over all possible values of the random coefficients:

$$P_{ijc} = \int L_{ijc}(\beta, v_{ir}) * m(v_{ir}|b, W)dv_{ir}$$

This is of course not a closed form expression.

In order to overcome that obstacle, simulation is conducted. A random draw is taken from the multivariate standard normal distribution for each of an individual's three choices. Each draw is "unstandardized" using the unknown b and W. The resulting v_{ir}'s are plugged into

$$L_{ij1} = \frac{1}{1 + \exp\left(x_{ijk}\beta_k + z_{ijr}v_{ir}\right)}$$

$$L_{ij2} = \frac{1}{1 + \exp\left(-\left(\mu_2 - (x_{ijk}\beta_k + z_{ijr}v_{ir)}\right)\right)} - \frac{1}{1 + \exp\left(x_{ijk}\beta_k + z_{ijr}v_{ir}\right)}$$

$$L_{ij3} = \frac{1}{1 + \exp\left(-\left(\mu_3 - (x_{ijk}\beta_k + z_{ijr}v_{ir})\right)\right)} - \frac{1}{1 + \exp\left(-(\mu_2 - (x_{ijk}\beta_k + z_{ijr}v_{ir)})\right)}$$

...

$$L_{ij10} = 1 - \frac{1}{1 + \exp\left(-(\mu_9 - (x_{ijk}\beta_k + z_{ijr}v_{ir}))\right)}$$

to get simulated conditional probabilities for each individual's ratings for choices 1-3. The conditional probability of all three ratings from individual i is obtained by multiplying the simulated probabilities above:

$$l_i = \prod_{j=1}^{3} \prod_{c=1}^{10} (L_{ijc})^{r_{ijc}}$$

where r_{ijc} = 1 if individual i chooses rating c in time period j and 0 otherwise. For each individual, that whole process is repeated, perhaps 1,000 times. The average of the 1,000 simulated conditional probabilities across time associated with each individual is taken as the simulated closed-form solution to the previous open-form unconditional probability expression:

$$p_i = \frac{1}{D}\sum_{d=1}^{1,000}[\prod_{j=1}^{3}\prod_{c=1}^{10}(L_{ijc})^{r_{ijc}}]$$

Finally, the simulated log likelihood function is then:

$$SLL = \sum_{i=1}^{N}\ln(p_i)$$

This function is maximized with respect to β,μ, b and W to yield estimates for the mixed ordered logit model with repeated choices.

To obtain probabilities for each rating given average values of the independent variables, the average values b are used in place of v_{ir}. The same techniques can then be applied as with the standard ordered logit to get average marginal effects of changes in independent variables on the probability of choosing a rating.

In theory, the mixed ordered logit model will be ideal for analyzing this survey data. It has none of the limitations of the multinomial, binomial or binary logit models. It is not limited by the proportional odds assumption of the standard ordered logit and allows for intra-person correlation among rating choices. The only issues it does not account for include choice task complexity and protest attitudes. However, the mixed ordered logit model is not used in the final analysis for reasons that will be made clear in chapter 5.

4.5 Summary

In this chapter, several possible discrete choice models are considered for analysis of the survey ratings data. The ordered logit is the best candidate among the non-mixed models. Hypothetical bias is always a potential problem with stated choice data but is not viewed as a serious issue for the present study. The ordered logit model does have estimation pitfalls. It does not account for choice task complexity, protest attitudes, or the repeated choice nature of the data set. If the proportional odds assumption behind the ordered logit is unreasonable, results will be biased; yet assessment of the assumption's validity is difficult because the test is sensitive to large sample sizes. The mixed ordered logit would solve all of those problems except for choice task complexity and protest attitude biases. This model will not be used in the final analysis, however, for reasons enumerated in the next chapter.

In chapter 5, the survey data are analyzed using the standard ordered logit model. Estimation of the mixed ordered logit is attempted but fails. Odds ratio effects, probabilities for each rating by program, and partial effects are presented.

CHAPTER 5

DATA ANALYSIS

5.1 Programs at a Glance

A descriptive analysis of the data shows a tri-modal or bi-modal distribution of ratings for each program. The bulk of respondents seem to rate programs at a 1, 5, or 10. Figures 1-12 below show the distribution of responses for each program presented in the survey. The attributes for each program are detailed in Appendix B.

Figure 1: Distribution of Ratings for Survey Version 1 Programs

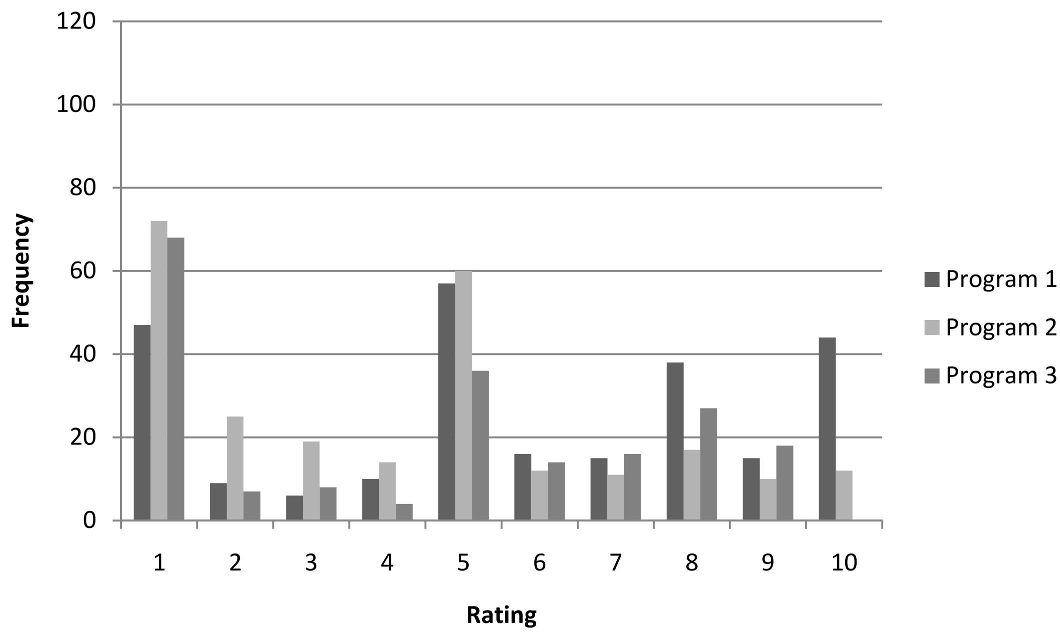


Figure 2:Distribution of Ratings for Survey Version 2 Programs

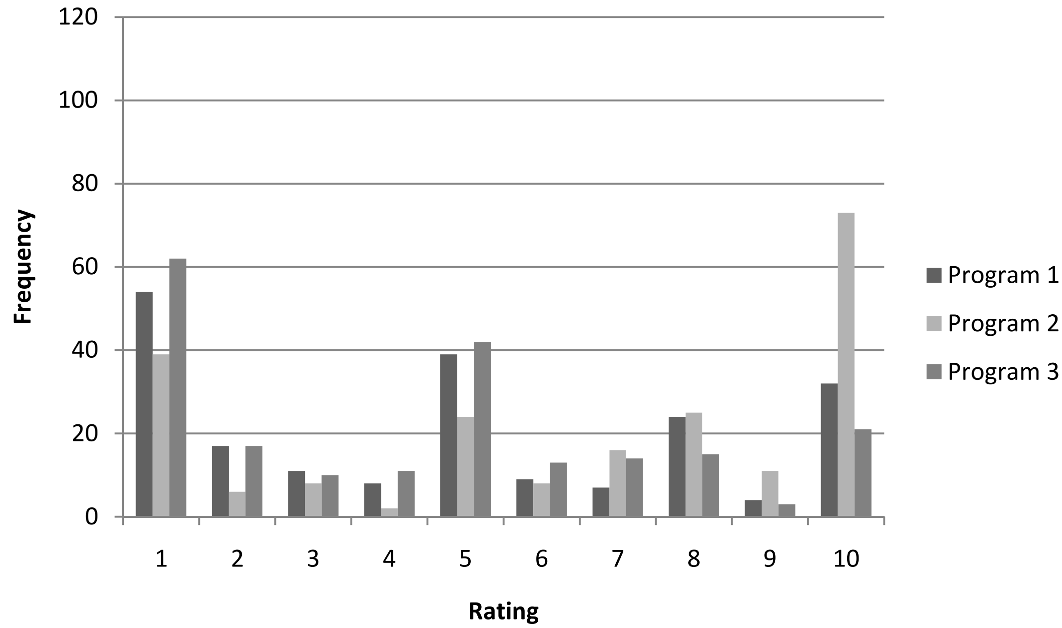


Figure 3: Distribution of Ratings for Survey Version 3 Programs

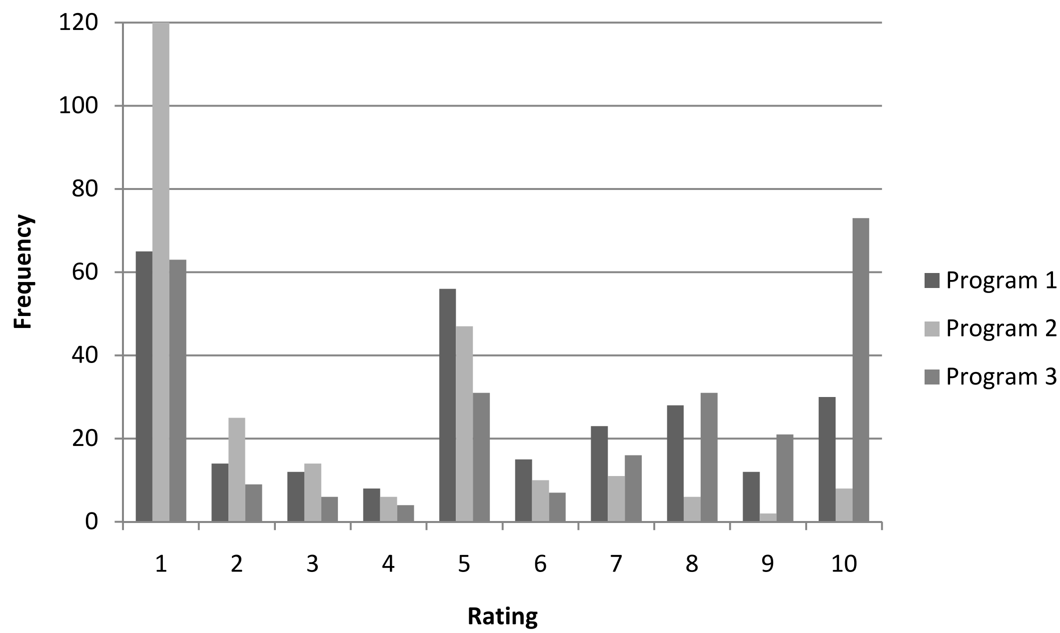
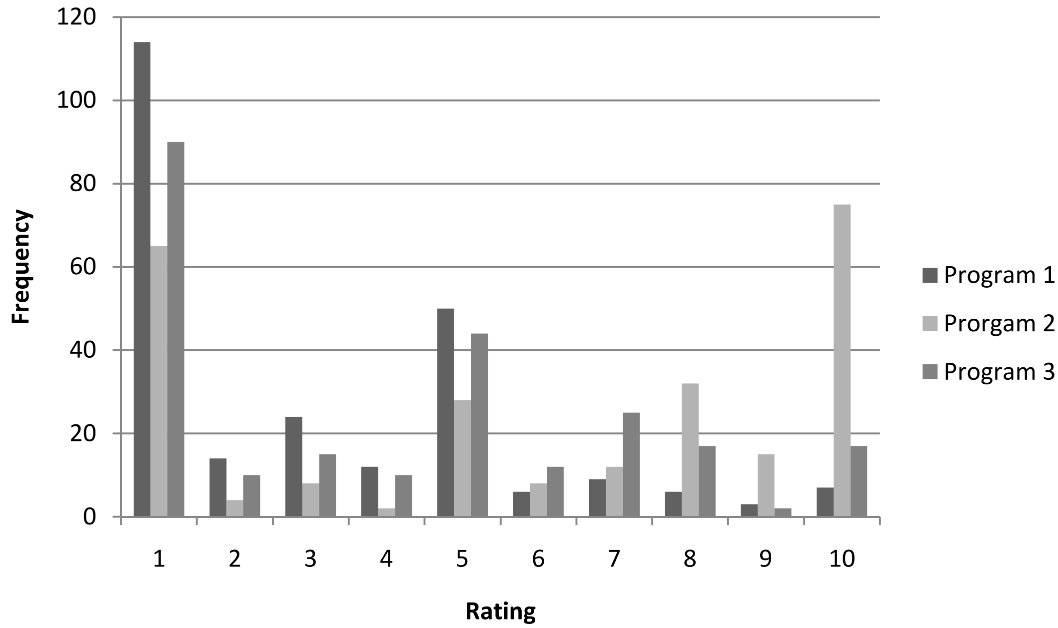


Figure 4: Distribution of Ratings for Survey Version 4 Programs



The popularity of a particular program can be roughly assessed at a glance by noting whether category 1 or category 10 has a higher frequency of ratings. Table 3 below provides additional information on respondents' ratings by program.

Table 3: Summary Statistics on Ratings by Program

	Program Number	Rating Statistic: Average	Median	Mode	Standard Deviation
Survey 1	1	5.8	5	5	3.1
	2	4.1	4	1	2.8
	3	5.6	6	1	3.5
Survey 2	1	4.9	5	1	3.3
	2	6.6	8	10	3.4
	3	4.4	5	1	3.0
Survey 3	1	5.0	5	1	3.1
	2	3.0	2	1	2.5
	3	6.1	7	10	3.6
Survey 4	1	3.1	2	1	2.5
	2	6.1	7	10	3.6
	3	4.1	4	1	3.0

Program 2 in survey version 3 appears remarkably unpopular. Other seemingly unpopular programs include numbers 1 and 3 in survey version 4. Program 2 of survey version 4 is notably popular. Respondents seem to feel relatively positive about programs 2 and 3 of survey versions 2 and 3, respectively. Respondents appear less unified in their attitudes toward remaining programs. Probabilities for landowner participation are expected to follow these observations.

5.2 Individual Characteristics

The Family Forest Research Center achieved a high response rate to the mail survey of around 50 percent. However of those 1,403 respondents who returned surveys, only 910 rated the three programs. There were no follow-up questions to assess whether these resulted from protest attitudes or choice task complexity issues. However, the potential for bias is estimated by comparing characteristics of those respondents who rated the three programs to all respondents generally. If the group that rated the programs is significantly different from the group as a whole in terms of independent variables used in the ordered logit analysis then protest attitudes, choice task complexity, and/or sample selection bias is present.

Table 4 below shows proportions of respondents with particular individual characteristics for the group that rated all three programs and for all survey respondents as a whole. The table also gives the probability value associated with a two-tailed Z test of the difference between the two proportions.

Table 4: Differences in Characteristic Proportions Between All Received Surveys and Only Surveys with Three Program Ratings

	Acre	Older	LowerEd	HigherEd	Male
Surveys with three ratings	0.525	0.231	0.147	0.398	0.747
All received surveys	0.545	0.292	0.168	0.359	0.736
Difference	-0.020	-0.061	-0.021	0.039	0.012
P > |Z|	0.346	0.001	0.179	0.056	0.531

The proportion of respondents with over 100 acres who rated all three programs is less than for all survey respondents. The same is true for respondents over the age of 65 and for those with a high school diploma or less. The proportion of respondents with more than a college degree and who are male is higher among those who rated all three programs compared to all survey respondents.

The only significant differences between the program raters and all respondents as a whole, however, are with respect to age and higher education using a five percent level of significance. Significantly fewer people over the age of 65 rated the three programs while significantly more respondents with more than a college degree rated the three programs compared to all survey respondents. If difference in proportions with respect to respondents with a high school diploma or less is tested with a one-tailed test, the difference between program raters and respondents as a whole is significant at the ten percent level of significance. Significantly fewer respondents with a lower level of education rated the three programs.

It would not be far fetched to suppose that the proportion differences with respect to education level reflect choice task complexity issues. Aggregation for selling carbon offsets on the Chicago Climate Exchange is not a simple concept to convey to the uninitiated (see Appendix C). There is no way to verify either choice task complexity or protest attitude problems; yet it is clear that these differences probably bias results of the ordered logit regression. The analysis proceeds having offered this caveat.

5.2 Estimation Problems: The Mixed Ordered Logit

Estimation of a mixed ordered logit model failed. An optimum could not be reached when maximizing the simulated log-likelihood function. To find an optimum, numerical integration is performed in as many dimensions as there are random coefficients in the model. That complexity combined with fact that there are 10 different category ratings appears to render the model intractable given the data set.

5.3 Standard Ordered Logit Results

An assessment of potential sources of bias mentioned in the previous chapter is conducted below. The repeated choice and proportional odds assumption problems are reconsidered. The stepwise procedure used to select indicator and interaction variables is shown. Ordered logit regression output and interpretation are then presented.

5.3.1 The Repeated Choice Problem

The standard ordered logit was ultimately used in place of the mixed model. Results are interpreted with the precaution that there is the potential for bias because the model does not account for correlation of individual choices across time. Results are robust in so far as any intra-person correlation is successfully explained by variation in program attributes.

5.3.2 The Proportional Odds Problem

An additional precaution is that the proportional odds assumption appears to be violated. The associated Chi-Square test compares the likelihood ratio of the standard ordered logit to that of a nonproportional odds model (a multinomial logit). The test statistic is highly significant at 112 degrees of freedom; however, the test is sensitive to large sample sizes. Furthermore, the only alternatives are not reasonable. One is to run a binary logit for each of the 10 ratings and estimate different sets of coefficients for each rating. Around 140 parameters would have to be estimated. That approach is inefficient and is not considered. The other alternative is to conduct a multinomial logit analysis wherein each rating is treated as a non-ordinal choice. This approach ignores the ordinal nature of the ratings data. The ordered logit analysis continues having offered these caveats.

5.3.3 Indicators and Interactions: A Stepwise Procedure

A stepwise procedure was used with the ordered logit to determine which individual characteristic and interaction variables to include in the final model. The base model included just the management plan requirement indicator, time commitment, per-acre revenue, and early withdrawal penalty indicator. Using a series of likelihood ratio tests, characteristics and interactions were added and accepted or rejected one by one.

The effect of the continuous variable, acres owned, was rejected while a dummy variable indicating that the respondent owns 100 acres or more was included. Age was broken into three categories: 66 and older, 51-65 and 50 or younger. Only the 66 and older indicator was retained. A gender dummy indicating male was included. Level of education was split into three categories: a high school diploma or less, some college or a college degree, and beyond a college degree. With the middle category represented by the intercept, both the lower and higher education indicators were included in the model.

All possible interactions were considered. Only five remained after likelihood ratio testing. These include management plan with older than 65; revenue with older than 65; management plan with lower education; revenue with lower education; and time commitment with male.

5.3.4 Regression Results

Regression results show that every rating level is significant. That suggests that each cutpoint is statistically important and cannot be viewed as measurement error. Results of the regression are included in table 5 below:

Table 5: Ordered Logit Results

Parameter	Estimate	Odds Ratio	Chi-Square	Pr>ChiSq
Cutpoint 1	-1.047	0.35	19.688	<.0001
Cutpoint 2	-0.769	0.46	10.673	0.001
Cutpoint 3	-0.534	0.59	5.159	0.023
Cutpoint 4	-0.384	0.68	2.664	0.103
Cutpoint 5	0.416	1.52	3.133	0.077
Cutpoint 6	0.639	1.89	7.376	0.007
Cutpoint 7	0.970	2.64	16.930	<.0001
Cutpoint 8	1.557	4.74	43.045	<.0001
Cutpoint 9	1.875	6.52	61.765	<.0001
Plan	-0.215	0.81	6.790	0.009
Time	-0.086	0.92	9.583	0.002
Rev	0.060	1.06	214.468	<.0001
Pen	-0.419	0.66	32.859	<.0001
Acre	0.121	1.13	3.050	0.081
Older	-0.090	0.91	0.252	0.615
LowerEd	-0.122	0.89	0.316	0.574
HigherEd	0.431	1.54	32.873	<.0001
Male	-0.636	0.53	6.428	0.011
Plan*Older	-0.348	0.71	4.451	0.035
Rev*Older	-0.025	0.98	9.926	0.002
Plan*LowerEd	-0.384	0.68	3.665	0.056
Rev*LowerEd	-0.018	0.98	3.580	0.059
Time*Male	0.059	1.06	3.507	0.061

All attribute and characteristic coefficients are significant except for the age (66 or older) and education (high school diploma or less) indicators. All estimates have the expected signs. The odds of choosing a higher rating are lower by a factor of 0.81 where a management plan is required, by a factor of 0.92 with an additional year of time commitment, and by 0.66 where there is an early withdrawal penalty. Odds of a higher rating decrease by a factor of 0.91where the respondent is 66 or older, by 0.89 for the lower education level and by 0.53 where the respondent is male. The odds decrease even more where a management plan is required for older (by a factor of 0.71) and less educated respondents (0.68). Odds decrease less at higher time commitments for males than for females. The odds decrease less by a factor of 1.06 for an extra year where the respondent is male. A higher per-acre annual revenue increases odds of a higher rating less by a factor of 0.98 for older and also by 0.98 for less educated respondents than for others, though odds do increase for those two groups with increased revenue. Odds of a higher rating increase with higher per-acre revenue generally (by a factor of 1.06 for a $1 per acre per year increase) and when the respondent is from the higher education category (1.54) and owns 100 acres or more (1.13).

5.4 Binary Logit: A Comparison

It is clear from the significance of the cutpoints in the ordered logit model that the binary logit, which codes 1-9 as 0 and 10 as 1, misses a great deal of information. To further investigate the apparent problem with the binary model, regression results are included in table 6 below.

Table 6: Binary Logit Results

Parameter	Estimate	Odds Ratio	Chi-Square	Pr>ChiSq
Intercept	2.411	11.145	43.293	<.0001
Plan	-0.342	0.710	5.440	0.020
Time	-0.068	0.934	2.437	0.119
Rev	0.082	1.085	136.121	<.0001
Pen	-0.513	0.599	13.726	0.000
Acre	0.113	1.120	0.955	0.329
Older	-0.135	0.874	0.146	0.703
LowerEd	-0.084	0.919	0.030	0.863
HigherEd	0.329	1.390	7.358	0.007
Male	-0.216	0.806	0.305	0.581
Plan*Older	-0.497	0.608	2.810	0.094
Rev*Older	-0.014	0.986	0.938	0.333
Plan*LowerEd	-0.780	0.458	3.381	0.066
Rev*LowerEd	-0.008	0.992	0.144	0.705
Time*Male	0.008	1.008	0.027	0.870

Indeed, many of the coefficient estimates in the binary model are insignificant, though signs are identical and magnitudes at least comparable. The only significant coefficients are the intercept, management plan, revenue, penalty, age and the interactions between management plan and age and education. These results are consistent with expectations; the binary model ignores important information in the 1-9 ratings.

In spite of the insignificance of many of the binary estimates, probabilities for a 10 rating are expected to be close between the ordered and binary models. Table 7 below shows the probabilities of each rating associated with each of the 12 programs for the ordered model. At the bottom are the binary model probabilities.

Table 7: Probabilities of Ratings by Program for Ordered and Binary Models

	Survey 1			Survey 2			Survey 3			Survey 4		
	P2	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3
	Ordered Logit											
P(R=1)	0.190	0.396	0.181	0.299	0.126	0.353	0.225	0.553	0.152	0.446	0.105	0.403
P(R=2)	0.046	0.068	0.045	0.061	0.034	0.066	0.052	0.067	0.039	0.069	0.029	0.068
P(R=3)	0.045	0.059	0.044	0.056	0.034	0.058	0.049	0.054	0.039	0.058	0.030	0.059
P(R=4)	0.031	0.037	0.031	0.037	0.025	0.038	0.034	0.032	0.028	0.036	0.022	0.037
P(R=5)	0.190	0.179	0.188	0.195	0.165	0.188	0.196	0.136	0.178	0.167	0.151	0.177
P(R=6)	0.055	0.041	0.056	0.049	0.054	0.044	0.054	0.027	0.055	0.036	0.051	0.040
P(R=7)	0.079	0.052	0.080	0.065	0.082	0.057	0.075	0.033	0.082	0.045	0.081	0.051
P(R=8)	0.122	0.067	0.125	0.090	0.141	0.077	0.111	0.041	0.134	0.058	0.145	0.066
P(R=9)	0.053	0.026	0.055	0.036	0.067	0.030	0.047	0.015	0.061	0.021	0.072	0.025
P(R=10)	0.187	0.076	0.196	0.112	0.272	0.090	0.157	0.042	0.230	0.063	0.315	0.074
	Binary Logit											
P(Yes)	0.173	0.062	0.234	0.085	0.301	0.082	0.130	0.027	0.266	0.038	0.338	0.060
% Dif.	2.705	3.222	4.083	2.764	3.253	3.283	2.609	3.528	3.687	3.072	3.024	3.243

For both models, the probabilities are calculated with program attribute levels corresponding to the version and program number and individual characteristics corresponding to the sample modes (they are all indicator variables). As expected, binary and ordered probabilities are close. They differ by no more than 4 percent. However, results of the ordered logit model give more information about ratings 1-9 and show nearly all coefficients to be significant, as indicated above. The ordered logit is used for the remainder of the analysis.

The least popular program – that is, the program with the lowest probability of a rating for a 10 – among modal respondents is program 2 in survey version 3. That matches preliminary findings from the distribution of ratings presented above. This program requires a management plan, has a 10 year time commitment, offers only a $5 per acre annual revenue, and includes a penalty for early withdrawal from the program.

The most popular program is the second in survey version 4. That program has a management plan, a five year time commitment, a $30 per acre annual revenue, and no penalty for early withdrawal.

5.5 Partial Effects

Partial effects can be calculated for any combination of program attributes and individual characteristics. The conventional way to present partial effects is to use average or modal values for the independent variables. Below, two sets of partial effects are calculated. Both sets use modal individual characteristics, but the first uses average program attributes (averaged using the 12 programs from the survey). The second set uses more realistic program attributes that correspond to real CCX aggregator programs.

Those attribute levels are as follows. A management plan is required. There is a 15 year minimum time commitment. Expected revenue is $8 per acre annually. There is a penalty for early withdrawal. Results for average attributes are summarized in table 8 below:

Table 8: Partial Effects on Probability of a 10 Rating Using Average Program Attributes and Modal Individual Characteristics

Variable	Effect	Variable	Effect
Plan	-0.028	HigherEd	0.070
Time	-0.015	Male	-0.010
Rev	0.010	Plan*Older	-0.093
Pen	-0.051	Rev*Older	-0.003
Acre	0.016	Plan*LowerEd	-0.102
Older	-0.042	Rev*LowerEd	-0.002
LowerEd	-0.052	Time*Male	0.010

Results obtained using the more realistic attribute levels are summarized in table 9 below:

Table 9: Partial Effects on Probability of a 10 Rating Using CCX-Like Attributes and Modal Individual Characteristics

Variable	Effect	Variable	Effect
Plan	-0.011	HigherEd	0.025
Time	-0.004	Male	-0.011
Rev	0.003	Plan*Older	-0.018
Pen	-0.024	Rev*Older	-0.001
Acre	0.005	Plan*LowerEd	-0.023
Older	-0.005	Rev*LowerEd	-0.001
LowerEd	-0.011	Time*Male	0.003

Partial effects are universally smaller in magnitude when evaluated at more realistic program attribute levels. The cause is probably the relative unpopularity of the realistic attribute levels across all types of respondents. These partial effects give more useful information, since the program attribute levels in the other set of partial effects are unlikely. These effects are discussed below.

The partial effects generally conform to expectations. Holding individual characteristics at their modes, eliminating the required management plan increases the probability of a 10 rating by 1.1 percent for people under the age of 66 who have some college or a college degree. Note that the effect shown in the table is negative to emphasize that landowners do not like the management plan. However, the effect is calculated by changing from a CCX-like program in which there is a required management plan, to a program that does not require one. Thus, the effect is described as positive. The same is true for the early withdrawal penalty effect. The management plan effect is 2.9 percent for older people with more than a high school diploma, 3.4 percent for younger people with less education, and 5.2 percent for those who are both older and less educated.

Taking off a year of time commitment from the 15 years increases the chance of a 10 rating by 0.4 percent for females and by 0.3 percent for males. An extra dollar per acre annual return on top of the $8 yields a 0.3 percent increase in probability for younger people with at least some college education. That number is 0.2 percent both for older and for less educated respondents. For respondents who are both older and less educated, that number is 0.1 percent.

Removing the penalty for early withdrawal makes respondents 2.4 percent more likely to give a 10 rating. Owning less than 100 acres makes people 0.5 percent less likely to choose a 10. Being over the age of 66 reduces the chance of a 10 by 0.5 percent. Having only a high school education or less means that chance is 1.1 percent lower. Having more education than a college degree leads to a 2.5 percent increase in the chance of a 10. Finally, being female leads to a 1.1 percent increase in that chance.

The marginal effects calculated at modal individual characteristics and CCX-like program attributes show the policy maker how probabilities change with changes in attribute levels or individual characteristics when the most prevalent type of landowner is considered. A more useful set of marginal effects can be calculated using the modal characteristics of landowners who gave a 6-9 rating for any given program. These landowners are not completely certain that they would participate in the given program, but at least feel somewhat positive about the possibility of participation. The policy maker interested in enticing greater participation should focus on that group. An IFM program could be developed with the intention of appealing to the type of landowner that feels at least a little positive about participating in any given IFM offset program. Marginal effects for program attributes are presented for this group in table 10 below.

The modal respondent who gave a 6-9 rating is slightly different from the general modal survey respondent. The only difference is that the modal respondent with a 6-9 rating has more than a college degree while the general modal respondent has more than a high school diploma but no more than a college degree. The modal respondent with a 6-9 rating, like the general modal respondent, owns more than 100 acres, is 65 years or less in age, and is male. The marginal effects of program attributes using realistic CCX-like parameters are presented below in table 10. The effects represent the change in probability of a 10 rating that results from removing the management plan requirement, decreasing the time commitment by a year, increasing the per acre annual revenue by $1, and removing the early withdrawal penalty.

Table 10: Partial Effects on Probability of a 10 Rating Using Modal Characteristics of Respondents with 6-9 Ratings

Variable	Effect
Plan	-0.014
Time	-0.006
Rev	0.005
Pen	-0.001

The magnitudes of the effects of eliminating the management plan, subtracting a year of time commitment, and adding a dollar per acre per year of revenue are slightly larger for the modal respondent who gave a 6-9 rating than for the general modal respondent. The effect of eliminating the management plan is to increase the probability of a 10 rating by 1.4 percent. Subtracting a year of time commitment and adding a dollar of revenue increase that probability by 0.6 and 0.5 percent, respectively. That indicates that the 6-9 modal respondent cares slightly more about those attributes than the general modal respondent. The opposite is true for the effect of eliminating the early withdrawal penalty; it is smaller in magnitude for the 6-9 respondent. The effect of removing the early withdrawal penalty is to increase the probability of a 10 rating by only 0.1 percent.

5.6 Summary

In this chapter, the ratings data are summarized with descriptive statistics. The standard ordered logit model is estimated with the caveat that the repeated choice and proportional odds assumption problems cannot be dealt with; the mixed ordered logit estimation failed. Ordered logit regression output and interpretation proceeds.

In accordance with the findings of Fletcher, et al., the requirement of a management plan and an early withdrawal penalty lead to lower probabilities of a 10 rating while higher revenue means a higher probability. In contrast to their findings, an extra year of time commitment appears to decrease the probability of a 10 rating. Also in contrast to the results of Fletcher, et al., several individual characteristics are significant, including acres owned, gender, age and level of education. This difference in findings is likely a result of the use of both a small sample size and the binary logit model in the previous study.

In chapter 6, policy implications of the ordered logit results are presented. Lessons learned from the survey and its analysis are discussed. Recommendations for future research in this are made.

CHAPTER 6

POLICY IMPLICATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

This chapter is intended to inform policy making in the area of carbon sequestration programs and to make recommendations for future researchers in this field. The section below shows how the policy maker faces a tradeoff in crafting an ideal carbon sequestration program. There is also a discussion of how the policy maker should consider the population of landowners of interest; the program can be targeted toward specific types of landowners. The second section covers lessons learned from implementing the landowner survey and from estimating the ordered logit model. Future research directions are suggested.

6.1 Policy Implications

The ordered logit results make clear that a policy maker interested in crafting a NIPF landowner-friendly carbon offset program faces a tradeoff between conflicting policy elements. There are two major issues a policy maker will likely consider in crafting such a program. First, there are the usual carbon offset considerations including verifiability, additionality and permanence. These issues are not dealt with here, but rather left to the carbon scientists. Second, the policy maker must consider the likelihood that forest owners will participate in the program. That issue is the motivation behind this study. Yet the two sets of issues contradict one another; the most sound carbon sequestration program will be the least agreeable for the average family forest owner.

6.1.1 Maximum Participation Versus Maximum Carbon Sequestration

Based on the estimated partial effects of program attributes, the ideal program – in terms of garnering maximum landowner participation – would have no management plan required, minimal time commitment, a high per-acre annual revenue stream, and no early withdrawal penalty. The Chapter 61B current tax use program closely resembles this type of program.

Yet a management plan is required for participation in the CCX aggregators currently in existence. A minimum of 15 years' time commitment is required. There is a penalty for early withdrawal. The reason for these conditions of involvement, of course, is that they help ensure that the carbon offsets created are verifiable, additional and permanent. Verifiability means it can be proven that the carbon offsets truly represent carbon sequestration. Additionality means the offsets are in addition to the carbon sequestration that would happen if there were no offsets. An offset is permanent if the sequestered carbon is taken out of the atmosphere forever. If no management plan is required of participants, there is no way to quantify the carbon sequestration that results from managing the land in a particular way. Offsets would probably not be verifiable and might not be additional or permanent. A very short time commitment would not result in permanent carbon offsets. The absence of an early withdrawal penalty in an offset program would mean there is no incentive to keep the carbon sequestered once payments are received by the landowner; permanence of the offset would be questionable.

The CCX-type aggregation program conditions, combined with a reasonable expected revenue of $8 per acre per year, closely resemble the least popular programs presented to survey respondents. A Chapter 61B-type program resembles the most popular program rated by survey respondents. There is a fundamental tension between the ideal program in terms of landowner participation and a program that results in verifiable, additional and permanent carbon offsets. The policy maker must balance these competing measures.

6.1.2 The Population of Interest

The policy maker should consider whether his or her population of interest resembles the modal values of individual characteristics included in this study. The modal respondent is a male below the age of 66, with some college or a college degree and who owns 100 acres or more. If the population of interest is highly educated females, the probability of rating a CCX-like program at a 10 is about 3.6 percent higher. If the population of interest consists of older males with only high school diplomas with less than 100 acres, the probability of a 10 rating is 4.2 percent lower.

The policy maker may want to consider the type of population that gave 6-9 ratings in the survey; that type of respondent feels positively if not certain about participation. The modal 6-9 rating respondent is the same as the general modal respondent except that he has more than a college degree. The probability of a 10 rating of a CCX-like program is higher for this group by about 2.5 percent than for the general modal respondent. The difference is much greater for a Chapter 61B-type program; the 6-9 modal respondent's probability of 10 rating is about 10 percent higher than for the general modal respondent.

6.1.3 Subsidies

Another consideration for the policy maker might be some form of subsidy to the prospective participant. For example, an agency that aggregates offsets for the CCX could absorb the early withdrawal penalties, eliminating that risk for the landowner. Or the agency might offer subsidies on top of the revenue earned in the offset market. A policy maker might even consider operating a program outside the offset market, simply paying landowners to sequester carbon. In that case, there need be no required management plan, no early withdrawal penalty and flexible time commitment and revenue possibilities. That type of program would be similar to the Chapter 61B current tax use program. The following table shows the probabilities that the modal respondent would give a 10 rating for several different attribute combinations.

Table 11: Probabilities of 10 Ratings for Modal Respondents at Different Program Attributed Levels

Required Plan?	Time Commitment	Revenue	Penalty?	Probability
yes	15	8	yes	0.050
yes	15	8	no	0.074
yes	15	30	yes	0.166
yes	15	30	no	0.233
no	5	5	yes	0.067
no	5	5	no	0.098
no	5	30	yes	0.244
no	5	30	no	0.329

The first program represents a CCX-like program. The second, third and fourth programs show how a government agency might sweeten the deal for participants in a CCX-like program by absorbing any early withdrawal penalties and/or subsidizing the per-acre revenue. The basic CCX-like program with no penalty absorption or subsidy has a probability of a 10 rating of only 5 percent. That probability jumps to 23.3 percent with a $22 per acre per year subsidy (on top of the CCX-earned revenue) and penalty absorption.

The last four rows show programs that an agency might consider outside the offset market, simply to persuade landowners to sequester carbon. The revenue in all four programs represents a pure subsidy. This might be a Chapter 61B-like program explicitly designed for carbon sequestration.

The probabilities depend largely on revenue. The first two Chapter 61B-like programs have probabilities of a 10 rating of 6.7 and 9.8 percent. They differ only in whether or not there is an early withdrawal penalty. The second and third Chapter 61B-like programs are the same as the first two except that revenue is $30 instead of $5. Those probabilities are 24.4 and 32.9 percent, respectively.

The program with the highest probability of a 10 rating is, not surprisingly, the one in which there is no required plan, five year time commitment, $30 per acre annual revenue and no early withdrawal penalty. This program has a 32.9 percent chance of a 10 rating. Of course, the merits of such a program are questionable at best in terms the verifiability, additionality and permanence of its carbon sequestration.

As mentioned above, the policy maker may wish to target the type of landowner who gave 6-9 ratings with its carbon sequestration program because that landowner feels somewhat positive about participation. Table 12 below shows the same set of probabilities of a 10 rating as in table 11, but calculated for the modal 6-9 rating respondent rather than for the general modal respondent.

Table 12: Probabilities of 10 Rating for Modal Respondents with 6-9 Ratings at Different Program Attribute Levels

Required Plan?	Time Commitment	Revenue	Penalty?	Probability
yes	15	8	yes	0.075
yes	15	8	No	0.110
yes	15	30	yes	0.235
yes	15	30	No	0.318
no	5	5	yes	0.099
no	5	5	No	0.143
no	5	30	yes	0.331
no	5	30	No	0.430

The probabilities are of course all much higher for the modal 6-9 rating respondent; that is because he has a higher level of education than the general modal respondent. Notably, this type of respondent is 2.5 percent more likely to give a 10 rating to a straight CCX-like program than the general modal respondent. The probability of giving a 10 rating for a CCX-like program in which a government agency has absorbed the early withdrawal penalty and subsidized $22 on top of the CCX-earned revenue is 31.8 percent – about 9 percent higher than for the general modal respondent.

The probability of a 10 rating for a Chapter 61B-like program is 9.9 percent where there is a penalty for early withdrawal and only a $5 per acre annual revenue. That is about 3 percent higher than for the general modal respondent. The highest probability of a 10 rating corresponds to the Chapter 61B-like program that has no early withdrawal penalty and a $30 subsidy. That probability is 43 percent – about 10 percent higher than for the general modal respondent.

6.2 Recommendations for Future Research

Another set of conclusions to draw from this analysis consists of recommendations for future research in the field of landowner participation in carbon sequestration programs. Recommendations for survey format, including a discussion of the particular method of choice elicitation and how to deal with choice task complexity and protest issues, follow in the sections below.

6.2.1 Choice Elicitation Method: Ratings Versus Direct Choice

The format of the survey questions used in this study limited analysis of the data in some ways while enhancing the analysis in others. The panel structure of the rating choices cannot be modeled because a mixed ordered regression is intractable. The estimation results may consequently be somewhat biased. The ratings cannot reasonably be converted to ranking data for use in the censored rank-ordered multinomial logit model because too many observations would have to be cut. Nor can they be converted to choice data for use in an ordinary MNL model – there are too many tied ratings and there is no exit or status quo option.

A basic MNL or nested logit model could be estimated if respondents were asked to choose between the three programs and an exit, or status quo, option. The repeated choice problem would disappear. The choice set would be complete. Estimation would be quite simple.

However, there is an information cost to requiring respondents to make a direct choice. That method of elicitation does not allow for uncertainty on the part of the respondent. When respondents face the rating format, they can express uncertainty on the ordinal rating scale about whether they would participate or not while providing valuable information about the effect of independent variables on attitudes toward programs. A likely effect of not allowing respondents to express uncertainty is to force unsure respondents to choose the status quo. Someone who might have given a rating in the 6-9 range for each of the three programs would likely choose to participate in none of the programs with the direct choice format. A great deal of information would be lost. That would likely result in misleading insignificance of important independent variables.

Thus, the researcher faces a serious tradeoff when deciding between ratings and direct choice formats. Researchers in the field of discrete choice analysis should explore this tradeoff further. A survey could be conducted in which half of respondents face a rating format while the other half faces a direct choice format. The first half would be analyzed with an ordered logit model. A multinomial logit or one of its variants would be used for the second half. Parameter estimates, probabilities and marginal effects could be compared across the two models. If the results are not significantly different then direct choice and ratings formats are equally valid.

A significant difference between multinomial a ordered logit results would most likely manifest itself in lower probabilities of a yes and insignificant parameter estimates from the multinomial logit estimation. In that case it can be assumed that the direct choice format causes a serious loss of information. The ratings format and the ordered logit would give more accurate results because they account for uncertainty in responses.

The only serious limitation of the ratings format lies in model estimation. If a mixed ordered logit model could be used, the proportional odds and repeated choice problems detailed in chapter 4 would disappear. The problem encountered in this study of not finding an optimum in maximizing the simulated log likelihood function should be further investigated. There are numerous numerical integration techniques for maximizing simulated log likelihood functions in mixed models. Though it is beyond the scope of the present study, these techniques should all be explored to determine whether some work better with the ordered logit model.

A solution that makes possible estimation of a mixed ordered logit for the type of data used in this study would comprise the best possible procedure for similar research endeavors. The ratings format could be used without worrying about the issues surrounding the standard ordered logit.

6.2.2 Better Capturing of Choice Task Complexity and Protest Issues

The offset programs are probably difficult to understand for many respondents. There is undoubtedly a choice task complexity problem with this survey. That problem could easily be assessed and accounted for with a survey design that includes varying choice task complexity, as detailed by DeShazo and Fermo (2002). A heteroskedastic logit model would be estimated to account for the choice task complexity..

There was also very likely a protest attitude problem in the survey. Many respondents sent the survey back with angry words about government intrusion, refusing to rate the programs or simply giving all three programs a 1 rating. That too can bias results and should be accounted for with follow-up questions in the survey.

6.3 Summary

A policy maker interested in crafting a carbon sequestration program for Massachusetts, either by aggregating landowners' IFM offsets for the CCX or through pure subsidies as with a Chapter 61B-type program, faces an unfortunate tradeoff. He or she must balance the likelihood of landowner participation on one hand with verifiable, additional and permanent carbon sequestration on the other. The most popular carbon sequestration programs are the least legitimate.

The policy maker should consider what population to target in crafting the program. If he or she wants to target the most common type of landowner, there is one set of probabilities of a 10 rating corresponding to different types of programs. For this group, the least popular CCX-based program has a 5 percent chance of a 10 rating. The most popular Chapter 61B-based program has a 33 percent chance of a 10 rating.

A better approach may be to target the type of respondent who feels positively, though perhaps not certain, about participation. For that group there is another set of probabilities of a 10 rating corresponding to different program types. The least popular program has a 7.5 percent chance of a 10 rating while the most popular one has a 43 percent chance.

The researcher in this field of landowner participation in carbon sequestration programs faces a tradeoff as well. The tradeoff is between the benefits of using rating versus direct choice formats in the landowner survey. At present there is no obvious best survey format. Future research will hopefully identify an optimal procedure or at least further elucidate the problem. However, there are known methods for dealing with choice task complexity and protest attitudes that can bias results. An ideal survey with respect to those issues would have non-constant choice task complexity across surveys and several follow-up questions to assess the extent of protest attitudes.

CHAPTER 7

CONCLUSION

Overwhelming scientific evidence indicates that global warming is a serious, human-caused threat. American owners of non-industrial private forests (NIPF) can help mitigate global warming by managing their forests in a way that maximizes carbon sequestration. There are domestic markets for the trade of carbon offsets that come from such improved forest management (IFM), including over the counter markets and the Chicago Climate Exchange (CCX). Possible future opportunities for the Massachusetts NIPF owner to sell IFM offsets lie in the Regional Greenhouse Gas Initiative and a national cap and trade program outlined in the House and Senate versions of a new climate legislation.

At the moment there are scant opportunities for the Massachusetts NIPF landowner to participate in IFM offset markets. This paper examines the willingness of Massachusetts landowners to participate in either private aggregation programs for the CCX or in government-sponsored programs like Chapter 61B to induce carbon sequestration.

Using a recent landowner survey conducted by the Family Forest Research Center, an ordered logit model of respondents' ratings of hypothetical programs is estimated. Results indicate that landowners are less likely to give a 10 rating to a program that requires a management plan to be filed, has a higher time commitment, and has an early withdrawal. Landowners are more likely to give a 10 rating to a program with higher per acre annual revenue. Male, lower educated and older landowners are less likely to give a 10 rating to any program. Younger females with a higher level of education and who own more than 100 acres are more likely to give a 10 rating. Males are less concerned about higher time commitments than females, though the effect of a higher time commitment on probability of a 10 rating is negative for both. Lower educated and older respondents care less about the early withdrawal penalty and about revenue than other respondents.

Results show that the probability that the average respondent would give a 10 rating is very low – around five percent. Even those with more favorable demographics are not very likely to participate. That appears to be the result of low expected payment ($8 annually per acre) and an aversion toward a required management plan, lengthy time commitment and early withdrawal penalty.

To make landowner participation in IFM offset programs in Massachusetts more likely, a policy maker would have to change some or all of the policy attributes currently facing prospective CCX aggregation program participants. The probability that an average respondent would participate in a totally landowner-friendly program is around 33 percent. Such a program would have no required management plan, only a five year time commitment, a $30 per acre annual revenue and no early withdrawal penalty.

However, if the policy maker's goal is to maximize carbon sequestration, the deal should not be too sweet for landowners. Without a forestry management plan, serious time commitment and disincentive for quitting early, an IFM program would likely not result in verifiable, permanent or additional carbon sequestration.

The policy maker should consider the target demographic for his or her carbon sequestration program. Rather than targeting the most common type of landowner, a better approach might be to target respondents that feel more positive about participating.

That demographic has a higher level of education than the general modal respondent. The probability of a 10 rating for the least popular, CCX-based program is 7.5 percent – 2.5 percent higher than for the modal respondent. The chance of a 10 rating for the most popular, Chapter 61B-based program is 43 percent – 10 percent higher than for the modal respondent.

Several recommendations can be made regarding future research of this type. There is no clearly optimal survey format with respect to ratings versus direct choice elicitation for this type of study. The advantage of using ratings is that uncertainty on the part of the respondent is allowed, which yields more information about the landowner attitudes than a direct choice format. However, there are estimation problems associated with ratings data. The advantage of using a direct choice format is that many more options for estimation are available with direct choice data. The problem is that information is likely lost by forcing respondents to make an absolute choice. Surveys similar to the one used in this study might include non-constant choice task complexity across surveys as well as follow-up questions to assess any protest attitude issues. Finally, possibilities for mixed ordered logit estimation should be investigated, such as alternative numerical integration techniques.

APPENDICES

APPENDIX A

PROGRAMS FROM THE SURVEY

Attributes and Levels for Each of the 12 Programs

	Version 1			Version 2			Version 3			Version 4		
Attr.	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3
Plan	No	no	no	No	no	no	yes	yes	yes	yes	yes	yes
Time	5	10	10	5	5	10	5	10	10	5	5	10
Rev	15	5	30	5	30	15	15	5	30	5	30	15
Pen	No	no	yes	No	yes	yes	no	yes	no	yes	no	yes

Plan: Management plan required? A 0 indicates no.
Time: Time commitment, in years. Takes on values of 5 and 10 years.
Rev: Expected per-acre revenue, net of all costs ($). Takes on values of 5, 15 and 30 dollars per acre per year.
Pen: Penalty for early withdrawal? A 0 indicates no.

Notes: each respondent rated three of the above programs, depending on which survey version he or she received. In total, 12 different programs were rated by different respondents.

A fractional factorial design was used to decide the attribute levels for each program. There are no pure dominant or reverse-dominant programs administered in any of the survey versions.

APPENDIX B

EXPLANATION OF VARIABLES USED

Explanation of Variables Used

Plan: Management plan required is a 1; not required is a 0.

Time: Time commitment, in years. Takes on values of 5and 10 years.

Rev: Revenue net of costs, in dollars per acre per year. Takes on values of 5, 15, and 30 dollars per acre per year.

Pen: Penalty for early withdrawal is a 1; no penalty is a 0.

Acre: Respondent owns 100 acres or more is a 1; fewer than 100 acres is a 0.

Older: Respondent is 66 years or older in age takes a 1; younger than 66 takes a 0.

LowerEd: Respondent's education level is high school diploma or less takes a 1; some college or more takes a 0.

HigherEd: Respondent has more than a college degree is a 1; a college degree or less is a 0.

Male: Respondent is male takes a 1; female takes a 0.

Plan*Older: 1 if management plan is required and respondent is 66 years or older; else 0.

Rev*Older: Revenue for respondents 66 and older.

Plan*LowerEd: 1 if management plan is required and respondent has a high school diploma or less; else 0.

Rev*LowerEd: Revenue for respondents with a high school diploma or less.

Time*Male: Time commitment for males.

APPENDIX C

CHOICE ELICITATION SECTION OF THE SURVEY

Step 1: Please **read** the following description of the Michigan Working Forest Carbon Offset Program:

Michigan Working Forest Carbon Offset Program

Overview

The goal of the Michigan Forest Carbon Offset Program (MFCOP) is to provide landowners with financial incentives to engage in sustainable forest management, address climate change, support local natural resource economies and preserve family lands.

The Program allows landowners to generate revenue through the sale of carbon offset credits on the Chicago Climate Exchange.

The Chicago Climate Exchange (CCE) - a voluntary, member-based market comprised of large companies, municipalities and institutions - allows carbon sequestration benefits from conservation practices to be quantified, credited and sold. The credits are pooled from many different landowners and sold to CCE members who have made a commitment to reduce their greenhouse gas emissions. CCE members must reduce their emissions to meet legally binding targets or mitigate a portion of their emissions through the purchase of offset credits generated by eligible practices. The Delta Institute, a non-profit organization, pools and sells these credits on the CCE on behalf of the landowner. The revenue from the sale, minus pooling and trading fees, is returned to the landowner.

Landowners who sustainably manage forestlands provide a valuable public service through carbon sequestration. This rise of carbon credit trading has opened new financial markets for landowners. However, the complexities and costs to enter these markets are often a barrier to participation. The Michigan Working Forest Carbon Offset Program eliminates this barrier to entry, allowing landowners to earn revenue for providing a valuable ecosystem service.

Step 2: Please **rate** the options using the instructions below:

Please assume a similar forest carbon offset program will soon be developed in Massachusetts and complete the following. Please **rate each** of the following carbon offset programs on a scale of 1 to 10, with 10 being programs in which you would definitely enroll and 1 being programs in which you would definitely not enroll. Please look over all three of the alternatives before making your ratings. You may use any particular rating for more than one program if you feel equally about them.

	Carbon Credit Program 1	**Carbon Credit Program 2**
Eligibility	Requires management plan written by professional forester	Requires management plan written by professional forester
Time Commitment	5 years	5 years
Verification	Baseline carbon inventory calculated by forester; changes in carbon capacity must be reported annually	Baseline carbon inventory calculated by forester; changes in carbon capacity must be reported annually
Expected Payment	$5/acre/year	$30/acre/year
Early Withdrawal Penalty	$10/acre one time payment	None
	Rating (1 to 10 scale):______	**Rating** (1 to 10 scale):_____

	Carbon Credit Program 3
Eligibility	Requires management plan written by professional forester
Time Commitment	10 years
Verification	Baseline carbon inventory calculated by forester; changes in carbon capacity must be reported annually
Expected Payment	$15/acre/year
Early Withdrawal Penalty	$10/acre one time payment
	Rating (1 to 10 scale):______

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