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Integrating Geographic Information Systems and Remote Sensing with Spatial Economic and Mixed Logit Models for Environmental Valuation

Aaron Raymond Wells
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a dissertation written by Aaron Raymond Wells entitled "Integrating Geographic Information Systems and Remote Sensing with Spatial Economic and Mixed Logit Models for Environmental Valuation." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Natural Resources.

Donald G. Hodges, Major Professor

We have read this dissertation and recommend its acceptance:

David Ostermeier, Bill Park, Mary Evans, Chris Clark

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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INTEGRATING GEOGRAPHIC INFORMATION SYSTEMS AND REMOTE SENSING WITH SPATIAL ECONOMETRIC AND MIXED LOGIT MODELS FOR ENVIRONMENTAL VALUATION

A Dissertation
Presented for the
Doctorate of Philosophy
Degree
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Aaron Raymond Wells
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Abstract

This research focuses on the Emory and Obed Watersheds in the Cumberland Plateau in Central Tennessee and the Lower Hatchie River Watershed in West Tennessee. A framework based on market and nonmarket valuation techniques was used to empirically estimate economic values for environmental amenities and negative externalities in these areas. The specific techniques employed include a variation of hedonic pricing and discrete choice conjoint analysis (i.e., choice modeling), in addition to geographic information systems (GIS) and remote sensing. Microeconomic models of agent behavior, including random utility theory and profit maximization, provide the principal theoretical foundation linking valuation techniques and econometric models. The generalized method of moments estimator for a first-order spatial autoregressive function and mixed logit models are the principal econometric methods applied within the framework.

The dissertation is subdivided into three separate chapters written in a manuscript format. The first chapter provides the necessary theoretical and mathematical conditions that must be satisfied in order for a forest amenity enhancement program to be implemented. Such a program is possible and would yield an efficient outcome under three conditions: (1) contributors are willing to pay an amount that maximizes the utility they derive from forest amenities; (2) an intermediary party sets a compensation price based on contributor aggregate willingness to pay such that the social value of the program is maximized; and (3) a participating landowner maximizes profit given this incentive. The second chapter evaluates the effect of forest land cover and information about future land use change on respondent preferences and willingness to pay for alternative hypothetical forest amenity enhancement options. Land use change information and the amount of forest land cover significantly influenced respondent preferences, choices, and stated willingness to pay. Hicksian welfare

estimates for proposed enhancement options ranged from \$57.42 to \$25.53, depending on the policy specification, information level, and econometric model. The third chapter presents economic values for negative externalities associated with channelization that affect the productivity and overall market value of forested wetlands. Results of robust, generalized moments estimation of a double logarithmic first-order spatial autoregressive error model (inverse distance weights with spatial dependence up to 1500m) indicate that the implicit cost of damages to forested wetlands caused by channelization equaled –\$5,438 ha^{-1}.

Collectively, the results of this dissertation provide economic measures of the damages to and benefits of environmental assets, help private landowners and policy makers identify the amenity attributes preferred by the public, and improve the management of natural resources.

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Part 1

Introduction and Overview

1. Introduction

The absence of a property rights structure for environmental amenities such as clean air, clean water, and landscape aesthetics precludes the application of traditional market mechanisms for assigning monetary values to improvements in or damages to these amenities. However, environmental amenities influence the preferences and decisions of consumers in the market. Similarly, the market actions of consumers affect, both positively and negatively, the quality and quantity of environmental amenities. Thus, the problem exists to quantify the external effects of amenities on consumer behavior and the effects of consumers on the environment in order to develop policies that will facilitate progress toward a sustainable level of environmental quality.

The discipline of environmental valuation (EV), or more generally, natural resource and environmental economics, has evolved to link activity in the economy to the functioning of the environment. This link is based on models adapted from microeconomic theory of agent behavior including utility and profit maximization. While casual observation would imply a clear connection between the environment and the economy, with the former serving as a primary source of raw materials and waste disposal for the latter, efforts to connect the two have proven to be complicated and suspect (Hausman 1993). However, in cases of natural resource damage assessment (NRDA) or national economic development (NED) benefits the link between the environment and the economy must be made and quantified. Moreover, for more general policy evaluation or in the early stages of policy formation, information concerning the relationship between the environment and the economy can provide useful insight into potential tradeoffs or consequences of alternative actions. Thus, environmental valuation may be seen as unavoidable for some while a significant contribution to the improvement of the environment, and correspondingly, society, for others.

Environmental valuation researchers have developed and refined specific techniques over several decades to quantify this relationship in economic terms, i.e., prices. These techniques rely on the preference structure of the consumer and utilize either stated (direct) or revealed (indirect) methods to equate the consumer's held preferences into willingness to pay (WTP) estimates. In stated preference (SP) methods, researchers apply a survey format to establish a hypothetical market for environmental goods and services (EGS). Market participants are directly questioned about their preferences for EGS and willingness to pay to secure improvements in them. Standard administration formats for SP surveys, or constructed markets, include telephone, mail, and in-person interviews. Contingent valuation (CV) and conjoint analysis (CJ) are two principal methodologies. Both CV and CJ have been accepted by the Federal government as means of assessing the nonmarket values, in particular, nonuse values, in cases of natural resource damages (Arrow et al. 1993).

Stated preference methods have been criticized on a number of grounds but primarily for the lack of realism in the constructed market and hypothetical nature of willingness to pay (Diamond and Hausman 1994). The criticism stems from market participants expressing only *intended* behavior through choices and stated WTP that is in turn contingent upon hypothetical scenarios specified by the researcher. For example, a researcher may ask the respondent to choose their most preferred stream restoration plan from a set of proposed plans and then how much they *would* be willing to pay to have the plan enacted. The argument is that the hypothetical context in which WTP is solicited should yield hypothetical monetary values for EGS. Accordingly, the question is raised: Should hypothetical values be applied in lawsuits where significant fines are assessed to the damager or for evaluating alternative policies that could have significant welfare implications?

Revealed preference (RP) methods offer an alternative to the hypothetical data generating process of SP methods by inferring prices for EGS through analysis of consumer behavior for related market goods. Hedonic pricing and the travel cost method are two principal techniques. In the case of hedonic pricing, economic values for EGS are derived by econometrically decomposing the market price of a good (typically housing) into prices for individual attributes defining the good. Assuming environmental conditions are an element of this attribute set, an economic value can be similarly assigned to varying levels of these conditions. The travel cost method relies on a comparable methodology in that the expenditure and number of trips outdoor recreationists incur during pursuit of their activities can be incorporated into econometric models to derive the economic value of changes in environmental conditions at visited sites. Complications with RP methods include an indirect relationship between EGS and the market good, large data sets (given the predominantly cross sectional nature of RP studies), omitted variable bias, multiple purpose trips, substitute sites, and multicollinearity, to name a few.

Given the assumptions and econometric difficulties associated with revealed and stated preference approaches, the opportunity cost method (OCM) presents a viable alternative for environmental valuation. The OCM is used to value environmental goods and services by computing the economic value of opportunity costs, in terms of forgone market benefits, associated with environmental protection. This method may be preferred over the aforementioned alternatives because derived economic values for EGS are based on a direct relationship to market goods. For example, the monetary value of a wetland being considered for a residential subdivision would be calculated as the net present value of the revenue stream associated with the development. Mathematically,

$$P_{wetland} \geq \sum_{t=0}^{T} \{ \rho^{t}(| -B_{D,t} |) \} \equiv P_{OC,D} \qquad [1]$$

where P denotes market price, B denotes net monetary benefits of development D, ρ is the discount rate equal to $(1+\phi)^{-1}$, with ϕ denoting rate of time preference, t indexes time, and OC represents opportunity costs. This calculation can be performed with relative ease, especially in comparison to SP and RP methods, since market data are readily available. However, a tradeoff of the simplistic mathematical (and data) structure of OCM arises if we interpret equation [1] as stating that the market price of a wetland must be at least as great as forgone market benefits (i.e., opportunity costs) of development. This interpretation implies the OCM can only yield relative magnitudes, as opposed to specific values. In certain circumstances, such as preliminary policy evaluation, the limitations of OCM may not be of consequence and derived values can provide useful information. However, for NRDA and NED cases, specific values for EGS are necessary and thus computed using stated or revealed preference methods. I do not pursue further the application of OCM but consider a comparison of estimates derived with this methodology and those computed in this dissertation to constitute a worthwhile study.

To that end, this dissertation applies both revealed and stated preference techniques for the valuation of environmental quality in two Tennessee watersheds. In concert with these applications, geographic information systems (GIS) are used to analyze spatial factors affecting individual preferences and willingness to pay for EGS. Geographic information systems (GIS) and remotely sensed data (e.g., satellite images of vegetative ground cover) are quickly becoming cornerstones in environmental and natural resource economic research (Bateman et al. 2002). These tools enable researchers to model the spatial complexities involved in environmental issues, for example, the scale of an oil spill in a natural resource damage assessment case or spatial autocorrelation in hedonic price studies (Anselin 2001).

Moreover, GIS and remote sensing may provide for more efficient means of benefit transfer (e.g., transferring benefits from one study area to another based on groupings of pixels with similar spectral reflectance properties). GIS and remote sensing, though, may contribute the most by focusing research (e.g., in a survey study, GIS can be used to identify upstream and downstream residents and then model their responses as a function of location) and reducing the time involved with planning, acquiring, and analyzing spatial and non-spatial data. As time progresses, more of the geographic information necessary for environmental and natural resource economic research will become available and at a lower cost. Increased access to higher quality spatial data will prove to yield significant improvements in EV in the future. The research for this dissertation will be using the latest remotely sensed imagery (LandSat 7 ETM+), the most advanced spatial imaging and analysis software (ArcGIS and Imagine), and readily available geographic data (e.g., streets and streams).

The principal purpose of this dissertation is to demonstrate that environmental valuation techniques, geographic information systems, and remote sensing can serve a role in the sustainable use of forests, streams, and natural landscapes of Tennessee. These natural resources generate multiple public benefits but the supply is held predominantly by private landowners; approximately 89 percent of all forested land in Tennessee is privately owned (Schweitzer 2000). With private landowners holding a disproportionate share of forestland, the public must work with these landowners to increase the supply of environmental benefits. However, private landowners are under no obligation to undertake management activities to improve the supply or refuse bids to convert the land to another use. Government programs designed to compensate willing (or participating) landowners for activity costs are limited, in both personnel and funds. Thus, similar to the problem given in the introductory paragraph, the challenge is to design a system to assess the public's willingness to pay, extract such payments (either through voluntary contributions to a non-profit organization or tax increases), and then compensate landowners for incurred expenditures related to resource enhancing management activities. Such a framework would protect and improve the supply of natural resources, and in particular, environmental amenities such as wildlife habitat, for current and future generations.

I present this framework in Part 2 and in Part 3 discuss the results of a stated preference, choice modeling based constructed market applied in the evaluation of willingness to pay, and more generally, support for improving the current stock of forest amenities. Comparing principal results between the two chapters, I find that people are willing to pay (approximately $25) but that landowners are not willing to manage. This discrepancy between supply and demand represents a significant hurdle that will require extensive landowner education to overcome.

In contrast to the case presented above where landowners are encouraged to improve public benefits, landowners can produce a portion of the negative externalities that impact forests, streams, and natural landscapes. For example, harvesting activities conducted too close to a stream can lead to increases in stream temperature, which has consequences for stream biodiversity and productivity, as well as reductions in water quality due to increased sediment from erosion. Additionally, management activities dominated by poor harvesting practices (e.g., high grading) will eventually result in a forest comprised of overstory and understory species that contribute little to society both monetarily and non-monetarily. It is clear from the examples that landowners' activities can reduce resource quality and public benefits. In these cases, environmental valuation provides unique information that can help landowners, non-landowners, and policy makers collectively work together to improve management practices and progress toward environmental sustainability within the context of further economic growth and development.

Part 4 presents one such case of lost public benefits due to past agricultural, forestry, and channelization activities. The combination of these activities has resulted in excessive sedimentation in streams of the Lower Hatchie River Watershed, which has in turn substantially reduced forest value, biological productivity, biodiversity, and hydrological functioning. In this case, a revealed preference method was applied to compute economic values for damages associated directly with channelization and indirectly, damages from excessive sedimentation. I present the results, or prices, as representing a new source of information that would enable policy makers to evaluate in equivalent economic terms costs associated with the current level of damage and benefits of alternative restoration projects.

Supplemental to valuing benefits and costs for policy and management evaluation, environmental valuation plays a role in private resource conservation decisions and land use planning in Tennessee. Resource conservation organizations may rely on economic valuation of environmental assets to justify land purchases or projects that would otherwise not be feasible when evaluated on market values. For example, a large forested tract near an urban area will be valued for its potential developable use but the true value may be much greater as the tract provides wildlife habitat, scenic beauty, and erosion control. Environmental valuation techniques provide the tools an organization needs to derive public welfare estimates that could then be combined with market values to more accurately evaluate the project. Similarly, in a land use planning context, EV techniques provide planners the capability to gather information on public preferences for alternative proposals while simultaneously determining the social welfare (in economic terms) of each alternative. Accordingly, EV can lead to more comprehensive project analysis and ultimately, a more efficient allocation of land among preservation, conservation, and development objectives. This application of EV may assume an even more important role in the future as land use continues to change from natural (agricultural, forest, and open space) to developed (transportation networks, urban, and industrial).

2. Objectives

The goal of this research was to develop prices for externalities and public goods on both public and private lands using forest valuation, environmental valuation, and spatial data analysis techniques. Principal methods included a variation of hedonic pricing, choice modeling, and geographic information systems (GIS). Study areas included the Emory and Obed Watersheds on the Cumberland Plateau in Central Tennessee and the Lower Hatchie River Watershed in West Tennessee. Specific objectives for this research include the following:

1.) Establish theoretical and mathematical conditions for aligning the behavior of people willing to contribute to a program designed to improve the supply of forest amenities, landowners who control the available supply, and a third party non-profit organization who serves as a bridge between contributors and landowners.

2.) Develop a multi-class land cover classification of the Emory-Obed watershed using remotely sensed imagery, geographic information systems, and field data.

3.) Apply choice modeling in Cumberland and Morgan counties to assess willingness to pay for a program designed to provide landowners compensation in exchange for managing their land for improved non-timber forest benefits. Additionally, test whether different specifications of the choice scenario and the amount (m^2) of forest cover within a 100m radius of each respondent influence choice and willingness to pay.

4.) Construct a spatial theoretic, implicit valuation model to monetize impacts of specific ecological and anthropogenic factors on forest productivity in the bottomland hardwood forests along the Hatchie River and tributaries of the Hatchie.

3. Study Area Descriptions

The study areas for this research include the Lower Hatchie River Watershed and the Emory-Obed Watershed. These two watersheds are spatially and ecologically distinct yet share a common lack of biological and economic information. For this reason and due to concerns over environmental quality, they were selected for analysis. Specific reasons underlying selection of each watershed as well as short area descriptions are provided below.

The Lower Hatchie River Watershed (LHRW) (HUC 08010208) is located in West Tennessee and includes the counties of Chester, Lauderdale, Madison, Hardeman, Fayette, Haywood, and Tipton. The watershed comprises approximately 3,820 square km, 56,994 ha of which is bottomland hardwood forest (BLH), and contains the State designated Scenic Hatchie River (EPA 2004). The Hatchie River is one of the longest unchannelized rivers remaining in the Lower Mississippi Alluvial Valley and has been named one of the "Last Great Places" by the Nature Conservancy. One of the unique features of the Hatchie is that it flows northward, from its point of origin in northern Mississippi to the Mississippi River in northwestern Tennessee.

The LHRW is marked by flat topography, seasonal and permanent flooding, and soils dominated by fine wind-blown soil (loess). These natural features are significant factors in the ability of the watershed to provide highly productive wildlife habitat, biodiversity, landscape aesthetics, timber production, and opportunities for recreation. Channelization, levee construction, excessive sedimentation, and subsequently, BLH conversion, are the primary factors affecting the stability of the LHRW. Channelization is an anthropogenic practice intended to focus stream and river reaches to narrow channels in order to increase the amount of allowable forest and agricultural land. Levee construction can occur during channelization activities and is another means of decreasing the area drained by a watercourse. The excessive amount of sediment being deposited in tributaries of the Hatchie River and in the river itself is due primarily to upland agricultural and forestry activities but is magnified by the highly erodible loess. The excessive sedimentation in the LHRW has resulted in the formation of valley plugs and shoals, degraded fish habitat, diminished floodplain functioning, and increased mortality of BLH (from prolonged flooding and root suffocation). Conversion of BLH refers more to the loss of BLH from excessive sedimentation than to urban development pressures. The collective detrimental impacts of channelization, levee construction, and excessive sedimentation on floodplains and bottomland hardwood forests in the LHRW include diminished capabilities to assimilate and store nutrients and pollutants, recharge aquifers, and abate floods. Furthermore, significant reductions in biological productivity, ecological stability, biodiversity, and forest value have been noted (see Part 4).

Research was conducted in the upper section of the Lower Hatchie River Watershed to price the negative effects of excessive sedimentation and channelization on the bottomland hardwood ecosystem. The LHRW was selected for its unique and ecologically diverse bottomland hardwood ecosystem, complex of nonindustrial private landowners and objectives, supply of productive wildlife habitat, significance in water provision and quality maintenance, and role in the central and western Tennessee economies. Each of these reasons underscores the prominence of the LHRW in both private and public goods provision.

The Emory/Obed Watershed (EOW) (HUC 06010208) is located in East Tennessee and includes the counties of Bledsoe, Cumberland, Fentress, Morgan, and Roane. The EOW drains 2,258 square km with approximately 92% of the area located in Cumberland and Morgan Counties (EPA 2004). The federally designated Natural Wild and Scenic Emory and Obed Rivers flow through the EOW. These rivers provide multiple recreational opportunities, in particular, whitewater paddling and rock climbing. The economy in the EOW is predominantly dependent on manufacturing and retail trade with supplementary income from outdoor recreation-based activities (Census Bureau 1997). Second home construction, retiree emigration, and parcelization are the primary threats to the viability of the ecosystem in the EOW. This research intends to provide results that will help land managers, land use planners, residents, and private landowners realize the full economic value of the natural resources in the EOW and incorporate that information into improved natural resource and economic development.

4. Methods Review

The following brief reviews of the hedonic price method and discrete choice conjoint analysis, or choice modeling, serve as precursors to more detailed examinations in later chapters. The first review covers the revealed preference method of hedonic pricing and the second review concerns the stated preference method choice modeling.

4.1. Hedonic Price Method

The purpose of this review is to set the stage for extending the hedonic price method (HPM) to the theory and estimation procedures of spatial econometrics. Part 4 provides an extensive review of spatial econometrics as applied to forested wetland valuation, yet requires a basic understanding of hedonic pricing.

The theoretical model most widely applied in hedonic studies was developed by Rosen (1974) and Freeman (1993) and is based on Lancaster's (1966) theory that a consumer's preferences are dependent on the characteristics of the goods, not just the goods themselves. The characteristics theory of Lancaster provides the essence of HPM in that the economic value of a non-priced attribute defining a market good can be uncovered through decomposition of the good's market price. The term decomposition implies a statistical procedure of regression analysis. Thus, the HPM provides a construct consistent with economic theory and well-known statistical methods. For this reason, it has received considerable attention in the environmental valuation literature.

There are essentially two stages in estimation of the hedonic price method, with the first stage involving derivation of marginal implicit prices for goods attributes and the second calculating welfare estimates based on first stage estimates. For the purpose of the review, and dissertation, I will only discuss the first stage. The following discussion is based on Rosen (1974) and Freeman (1993).

The first stage of the hedonic price method identifies the market price of good m as a function of its characteristics:

$$P_m = p(\boldsymbol{Z}_m) \qquad m = 1,\ldots,r \qquad [2]$$

where P is market price, $\boldsymbol{Z}$ is an $n \times k$ vector of attributes describing the good, and $\boldsymbol{r}$ is the total number of goods under evaluation. Equation [2] is referred to as the hedonic price function. If the good is taken to be a house, then equation [2] can be written as:

$$\boldsymbol{P} = p(\boldsymbol{L}, \boldsymbol{S}, \boldsymbol{N}, \boldsymbol{Q}) \qquad [3]$$

where $\boldsymbol{P}$ is an $n \times 1$ vector of transaction prices, $\boldsymbol{L}$ is an $n \times 1$ vector of lot sizes, $\boldsymbol{S}$ is an $n \times k$ vector of structural characteristics (e.g., number of rooms and age), $\boldsymbol{N}$ is an $n \times k$ vector of neighborhood characteristics (e.g., location to a major thoroughfare and quality of schools), and $\boldsymbol{Q}$ is an $n \times k$ vector of environmental amenities.

The link between market prices for homes, attributes describing each home, and attribute prices is the direct utility function of individual homebuyers. In this framework, individual i purchases the m^{th} home from all other homes $-m$ because that particular home contains the optimal mix of attributes. That is, the combination of attributes provides the greatest utility to individual i, given budgetary constraints. We can formally define this relationship with the following:

$$\begin{aligned} &max_{x,z}\ U_i(X, \boldsymbol{Z}_m) \\ &s.t.\ Y_i = X + \delta(\boldsymbol{Z}_m) \end{aligned} \qquad [4]$$

where U denotes direct utility, X denotes a composite commodity with price normalized to one, $\boldsymbol{Z}$ denotes attributes of the home, Y is income, and δ denotes price of elements in $\boldsymbol{Z}$. Equation [4] states that individual j will choose levels of X and $\boldsymbol{Z}$ such that constrained utility will be maximized. Violation of utility maximization behavior in the housing market would undermine the use of hedonic pricing for environmental valuation and imply that consumers are irrational decision makers. An additional assumption for equation [4] holds that consumer preferences for housing bundles are weakly separable, which allows the researcher to investigate the demand for housing characteristics independent of the prices of other goods (Freeman 1993, p. 371).

Combining equations [3] and [4] allows us to derive a mathematical expression for the marginal implicit price of any element in $\boldsymbol{Z}$. For the case of an environmental amenity q in vector $\boldsymbol{Q}$, the implicit price is calculated by partially differentiating the hedonic price function with respect to q and setting the solution equal to the ratio of levels q^* and X^* that maximize the Lagrangian of equation [4]:

$$(\partial U / \partial q^*) / (\partial U / \partial X^*) = \partial P / \partial q^* \qquad [5]$$

Equation [5] represents the first order condition for the choice of the environmental amenity. The left hand side corresponds to the marginal rate of substitution between the amenity and the composite commodity, or equivalently, the marginal willingness to pay for the environmental amenity. The partial derivative (right hand side of equation [5]) yields the marginal implicit price for the good, or the additional amount that must be paid by an individual to move to another home with more of the environmental amenity, all other things being equal (Freeman 1993). Given a linear functional form of the hedonic price function (equation [3])

$$P = \alpha + \boldsymbol{\beta Z} + \varepsilon \qquad \varepsilon \sim N(0, \sigma^2) \qquad [6]$$

where P is house sale price, β is a conformable vector of weights for housing attributes, and ε is a random error term, the marginal implicit price is simply the coefficient β_q from ordinary least squares estimation.

Economic theory does not suggest a specific functional form for the hedonic price function and as a result, this issue has received considerable attention in the literature. Rosen (1974, p. 37) states that the linear form is not consistent with economic theory since it implies perfect substitution between housing attributes (he refers to this as costless repacking), thus it should not be applied in empirical analysis. Based on this assertion, various nonlinear functional forms have been applied and include quadratic, semi-logarithmic, double-logarithmic, and Box-Cox transformations (Box and Cox 1964). The general conclusion from these applications has been that the choice of the appropriate representation of the hedonic price function should be determined on a case by case basis with emphasis on the form that provides the best fit of the data (Cassel and Mendelsohn 1985, Halstead et al. 1997). Functional form specification is an important issue in hedonic studies because application of an incorrect form can yield errors in the implicit prices (Cropper et al. 1988) and significantly affect the conclusions (Halvorsen and Pollakowski 1981). We test several functional forms in the analysis in Part 4 to evaluate potential differences.

4.2. Choice Modeling

Discrete choice conjoint analysis or choice modeling (CM) is a multiattribute stated preference method for determining the economic value of environmental goods and services. Choice modeling is one of four specific types of conjoint analysis, which is a survey based methodology developed by mathematical psychologists for the marketing profession in the

1960's (Farber and Griner 2000). Ratings, rankings, and graded pair comparisons comprise the other three elicitation formats (Louviere 1988).

Generally, in a CM survey the participant is asked to evaluate simultaneously several policy options that will provide a good or service at varying quality levels. The participant then chooses the option that contains the levels she most prefers. The multiple attribute format of CM allows the researcher to determine the relative worth of each attribute quality level and establish a preference structure for survey participants. From this structure, preference orderings are determined (e.g., respondents prefer policy option A to option B and C), willingness to pay measures estimated, and changes in welfare calculated. Recently, environmental economists have applied CM for these reasons and because it allows for the evaluation of tradeoffs (through the inclusion of substitutes), more detailed presentation of the good, reduced framing bias, and wider applicability of the results compared to contingent valuation (Hanley et al. 1998).

Similar to contingent valuation (CV), though, choice modeling is a utility based method in that the option chosen by the individual is revealed preferred to all other feasible options. Additionally, for both methods standard utility theory is extended to allow for unobservable elements not captured in the survey instrument that influence the survey participant's choice. In order to account for these elements, utility includes an error term that varies randomly across survey participants. This formulation of the basic microeconomic model of utility maximization is referred to as random utility theory (RUT) and is based on the work of Luce (1959) and McFadden (1974). Following RUT, the utility function applied in hedonic pricing for participant i (equation [4]) can be separated into a linear combination of systematic (V) and random (e) components:

$$U_{ik}{*} = V_{ik}(\boldsymbol{Z}_{ik}, \boldsymbol{R}_i) + e_{ik} = X_k\beta_i + e_{ik} \quad k \in K \qquad [7]$$

where $\boldsymbol{Z}$ is a vector of attributes of the k^{th} option in the choice set, $\boldsymbol{R}$ is a vector of individual characteristics, $\boldsymbol{X}$ is a vector of observed option and individual attributes, β a conformable vector of parameters or part-worths, and a stochastic term e. Equation [7] states that survey participant i derives latent, or unobservable, utility U^* from option k in the set of all options K and that the systematic component is the only part that can be measured by the researcher. A linear functional form is typically specified for the systematic term.

Since there are multiple options in K the participant can choose, the researcher is interested in uncovering elements in $\boldsymbol{R}$ and $\boldsymbol{Z}$ that influence the participant's choice of a particular option k. Thus, a probability function based on equation [7] for explaining choice of option k over h can be constructed:

$$Pr_i(k = 1 \mid \boldsymbol{W}) = Pr_i\{\boldsymbol{X}_k\boldsymbol{\beta}_i + e_{ik} > \boldsymbol{X}_h\boldsymbol{\beta}_i + e_{ih}\} \qquad \forall\, k \neq h \text{ and } k, h \in K \qquad [8]$$

or by simply rearranging the expression:

$$Pr_i(k = 1 \mid \boldsymbol{W}) = Pr_i\{\boldsymbol{X}_k\boldsymbol{\beta}_i - \boldsymbol{X}_h\boldsymbol{\beta}_i > e_{ih} - e_{ik}\} \qquad [9]$$

where $\boldsymbol{W}$ is an aggregate term denoting measured and unmeasured factors. Equations [8] and [9] state that option k will be chosen over some other option h if latent utility survey participant i derives from k exceeds that from h. Equation [9] gives rise to a cumulative distribution function which can be econometrically modeled given certain distributional assumptions on e. As a note, since utility U^* is unobservable the mean and variance of e are not identified and the researcher must impose structure or a specific distribution on *e*. If the error terms are assumed to have a Weibull distribution (i.e., identically and independently distributed with a Type I extreme value distribution), the probability of choosing option *k* over *h* is given by the conditional logit model (McFadden 1974):

$$Pr_i(k = 1 \mid W) = Pr_i\{U_{ik}^* > U_{ih}^*\} = \exp(X_k\beta_i) \, / \sum_{s=1}^{K} [\exp(X_s\beta_i)] \qquad [10]$$

The conditional logit model is an appropriate econometric representation of survey participant choices in discrete choice conjoint analysis because it models choice probabilities as a function of the attributes and levels in the selected option as well as those in the options not selected.[1] However, the conditional logit model assumes that the probability of choosing *k* is invariant to the addition or exclusion of other options from *K*. This assumption is referred to as the Independence from Irrelevant Alternatives or IIA. Since this assumption may be violated in our analyses and due to the modeling of participant choice over multiple choice occasions (thus giving rise to a panel data set), mixed logit models will also be estimated.[2]

The conditional logit model is estimated with maximum likelihood methods and the resulting coefficients can be used to estimate the welfare gain or loss associated with decreases or increases in certain elements of *X*. Accordingly, the compensating variation (*CV*)

[1] Equation [10] may be referred to as the multinomial logit model since vector *X* includes individual specific attributes that do not vary across choices. These attributes are included in econometric estimation of equation [10] by interacting each with an alternative specific constant.

[2] Mixed logit models (Train 2003) account for correlation in the unobservable components of choice, i.e., $E[e_{ik}, e_{ij}] \neq 0$, across individuals and choice occasions. Thus, the IIA assumption is not required in mixed logit models. Additionally, mixed logit models explicitly incorporate individual effects that persist over time (i.e., over choice sets) whereas multinomial or conditional logit models are intended for cross-sectional data.

welfare estimate can be computed for an improvement in environmental quality from q to q' ($q' > q$):

$$CV = 1/\beta_P * \ln\left[\sum_{i=1}^{n} \exp(X_{k^0}\beta_i) \;/ \sum_{i=1}^{n}\sum_{k=1}^{K} \exp(X_{k'}\beta_i)\right] \qquad [11]$$

where option k^0 captures the status quo level q, k' captures the improvement q', β_P is the maximum likelihood coefficient for the payment to secure q', β is a vector of estimated parameters (except for β_P), i indexes survey participants ($i = 1,\ldots,n$), and CV measures the change in the individual's income (holding utility constant) that would leave her as well off at the status quo level k^0 as she would be at the higher level k'. Thus, through the application of choice modeling and the responses of individuals to options presented in the survey, an economic value (CV) can be placed on improved environmental quality q'.

The remainder of the dissertation is organized into three separate parts written as publishable manuscripts and a concluding part that summarizes and links all of the results. The second part is purely theoretical and serves as a foundation for the applied analysis in Part 3. The third chapter applies the stated preference technique choice modeling to the valuation of forest amenities and evaluates spatial and aspatial information effects in constructed markets. Finally, Part 4 presents a new method for developing a set of prices for externalities and ecological relationships in forested wetlands. This method is based on the theory of hedonic pricing and tested using spatial econometric models. Part 2 has been submitted to the *Journal* *of Forest Economics* and Part 4 to the *Journal of Environmental Economics and Management*. The third chapter will be submitted to *Land Economics.*

Within this dissertation, I do not present a detailed discussion of the development of the land cover classification for the Cumberland Plateau (Objective 2). I provide a brief overview of the process on page 70 but refer readers to Strickland (2003) for a comprehensive, detailed description. As a comment on this process, Jeff Strickland and I dedicated approximately three months of six to seven days per week in front of a computer analyzing pixels on remotely sensed (i.e., satellite) imagery in order to develop the classification. We are pleased to report an overall accuracy of 90 percent for these efforts. The forest class of the land cover classification was applied in the choice modeling analysis of Cumberland and Morgan county residents' preferences and stated willingness to pay for improved forest amenities (Part 3).

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Part 2

Forest Amenity Provision Within a Compensation Framework

This chapter is a slightly revised version of a paper by the same name submitted to the *Journal of Forest Economics* in 2004 by Aaron R. Wells. ......

Abstract

A compensation framework based on a microeconomic analysis of agent behavior is developed for the case of improved forest amenity provision. The lack of funding and competitive enrollment in current federal programs and non-profit and private initiatives for private landowners coupled with forest product prices that do not reflect the amenity value of forests highlight the importance of a forest amenity enhancement program. We show that such a program is possible and would yield an efficient outcome under three conditions: (1) contributors are willing to pay an amount that maximizes utility they derive from forest amenities; (2) an intermediary party sets a compensation price based on contributor aggregate willingness to pay such that the social value of the program is maximized; and (3) a participating landowner maximizes profit given this incentive. Changes in these conditions and the incorporation of stated and revealed preference nonmarket valuation techniques are future directions for the framework.

Keywords: Nontimber values; Public goods; Direct compensation; Behavioral analysis; Stated preference

1. Introduction

Forest ecosystems provide a unique set of benefits that are neither recognized nor traded in traditional markets. Scenic beauty, carbon sequestration, wildlife habitat, and soil stabilization represent a few of the multiple nonmarket goods and services or alternatively, forest amenities, supplied by forests. The public goods nature of forest amenities impedes markets from capitalizing these benefits into land values. Additionally, prices for forest products, such as timber or ginseng, do not reflect the value of forest amenities or the effects of product removal on their integrity. Thus, landowners have limited monetary incentive to improve the supply of these amenities. The lack of market based incentives for improved forest management has typically been filled by landowner assistance programs funded by government and private entities. However, current assistance programs are either underdeveloped or marked by limited funding and competitive enrollment, which can act to discourage potential landowners.

Non-industrial, private forest landowners own approximately 58 percent of forestland in the United States, representing a majority share of the land capable of producing forest amenities. However, only 5 percent of landowners have a written management plan and 97 percent hold their land for reasons other than timber production. Approximately 70 percent of forestland is in ownerships exceeding 40 ha, with more than 85 percent of the landowners holding less than 20 ha (Birch 1996). This characterization of forest landowners presents a set of challenges for the provision of forest amenities for three primary reasons. First, economies of scale may prevent small landowners from entering into the amenity program while enabling large landowners to capture all of the compensation. Second, highly fragmented or parcelized holdings may not provide the area (ha) necessary to provide some amenities (namely, habitat for forest interior birds). Third, expected participation rates, based on the current number of owners with a management plan, may be too low to justify implementing the program. Alternatively, a compensation program may be feasible given that nearly all landowners have preferences for nontimber amenities. If these landowners value the change in land rent from entering the program (i.e., marginal benefits) more than the additional costs associated with entry (i.e., marginal costs), then, as rational economic agents, landowners would be willing to participate and the amenity program justified. Attention is directed toward the issue of landowner participation, and not on contributor or third party participation, because we view this as the most significant hurdle to the implementation of the program.

The objective of this paper is to demonstrate through utility and profit maximization models that a direct form of monetary compensation in return for forest amenity provision is a feasible mechanism for increasing net social benefits of forests. We show that a utility maximizing contributor would be willing to pay an amount that when aggregated across all contributors and distributed by a value oriented third party satisfies supply conditions for participating rent-seeking landowners. The framework formalizes and extends the direct compensation mechanisms currently employed by various types of conservation-guided organizations, such as The Nature Conservancy and Defenders of Wildlife (see Ferraro 2001).

While the programs provided by these organizations provide a useful basis for our framework, the case of hunting leases presents a more interesting structure. At present, hunting leases are the only tangible contract under which private, monetary compensation is transferred to private forest landowners in exchange for a nontraditional forest product (i.e., recreational access).[3] There are other examples of recreational access compensation schemes, involving off-highway vehicles and rock climbing, but these schemes are not as common as hunting leases.[4] Regardless of the user group, the compensation mechanism for recreational access provides insight into the possible use of private lands for public goods provision: landowners who enter into these agreements maintain profit (rent) maximizing (seeking) behavior, even though the activity generating the costs and revenues is a nonmarket forest

[3] Recreational opportunities on private lands are presently not considered a public good and excluded from the framework we propose because these opportunities imply a type of right to the payee granted by the landowner that can be used to exclude other parties.

[4] An example of the growing popularity of hunting leases on private forestland is the publication by Timber Mart South, a principal source of forest product prices in the southern United States, of average, per acre price estimates by state for these leases (Timber Mart South 2003). To our knowledge, a series of published prices for other outdoor recreational leases does not exist.

good. Thus, the amenity program should be designed to appeal to the profit (rent) enhancing opportunities generated by forest amenity provision. On the other hand, research on the harvesting behavior of private forest landowners indicates that landowners may not be driven by profit motives since they currently provide forest amenities without compensation (Lee 1997, Scarpa et al. 2000). While this research shows that landowners are willing to manage for forest amenities, it underscores the importance of assuming active landowners manage with the intent of maximizing profit. Under our framework, landowners would be compensated for managing forest amenities, which may increase participation rates among owners, increase competition and output in amenity production, and lead to profit (rent) maximizing behavior.

The remainder of the paper is outlined as follows. Section 2 presents the framework from the perspective of a contributor, third party organization, and participating landowner. Section 3 provides a discussion of the model results and possible extensions to the framework. A concluding section summarizes the paper and offers an assessment of the practicality of the proposed compensation program.

2. Compensation Framework

The forest amenity compensation framework is based on three representative agents: contributor, conservation guided third party, and private landowner. A contributor is defined as an individual that is willing to pay some nonnegative sum of money in return for an improved stock of forest amenities. The third party is essentially an intermediary institution that collects and distributes contributions, approves participating landowners, and monitors the forest amenity enhancement program. The representative landowner is a nonindustrial, private forest landowner that meets certain land size requirements and is willing to accept contributions in return for incurred costs of improving on-site forest amenities. In addition to these agents, the compensation framework is based on two models of utility theory – each borrowing from different economic perspectives on the preference structure of the agent, and a simple profit function. Random utility theory, which incorporates a stochastic element in preference modeling, and a Cobb-Douglas value function describe the decision calculus for the contributor and third party, respectively. The profit model for the landowner contains an environmental ethic term that helps to explain why an owner may participate in the proposed framework; this additional term is not typically included in forest supply analyses. In all models, we assume the agents have perfect information on the benefits of forest amenities, the outcome from their respective actions is common knowledge, and agents are risk neutral. Additionally, assume there are a large number of contributors and landowners so that one individual from either group cannot influence any outcome.[5] For each utility function, assume strict quasi-concavity, continuity and transitivity of preferences, and local nonsatiation. Similarly, assume the profit function is continuous and strictly convex in prices. Finally, assume the functions are twice differentiable and monotonic and that all agents know their preferences and act on these preferences rationally.

For these three models, T is the aggregate current level of forest amenities and T' is the level of forest amenities that would be provided if the amenity program were active ($T' >> T$). We define *level* in both quality and quantity terms, with quality referring to more productive (e.g., greater habitat diversity) or aesthetically appealing (e.g., lower stand density) amenities and quantity representing the aggregate number of hectares in a forest amenity class. Both T and T' are vectors of h elements ($h = 1,\ldots,H$), with each element representing a specific level of a forest amenity (e.g., 25 ha of moderate quality wildlife habitat). The basis of the

[5] A consequence of this assumption is a possible increase in the incentive to free-ride. That is, by increasing the number of contributors, it is easier for the marginal contributor to decide that a sufficient number of individuals have contributed such that their additional contribution will not change the overall outcome. Thus, he does not contribute.

proposed program is that landowners can improve the level of forest amenities through land management practices, accordingly $T' = \sum_i \sum_h t_{ih}'$, where i indexes participating landowners ($i = 1,\ldots,I$) and t_i' denotes the aggregate contribution (ha) of amenities by i under the program.[6] Since T' is a continuous public good (i.e., nonrival and nonexcludable in production and consumption), each contributor consumes the same amount of T' regardless of their contribution and the third party compensates participating landowners an amount equal to a share of the sum of individual contributions.[7]

The principal qualification for landowner participation in the program is approval by the third party of a forest amenity enhancement plan written by an approved forest manager. Additional requirements include a minimum and maximum number of hectares in order to keep enrollment competitive and a minimum number of years enrolled (e.g., 10 yrs) so that management recommendations can be fully implemented and possibly evaluated. Contributors face a reduced set of enrollment constraints and are principally bound by a voluntary contract to contribute an annual monetary payment for a specified number of years (e.g., 5 yrs). Finally, a third party will support the program only if the sum of contributions equals or exceeds the costs of administering the program.

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[6] For notational convenience, $\sum_{i=1}^{I} = \sum_i$.

[7] The opportunity for individuals to free-ride on the contributions of others to the improved supply of forest amenities is a concern given the public goods nature of these amenities. To address this problem, we assume that contributors aware of free-riders account for them by either lowering (possibly, out of frustration) or increasing (to take into account lower aggregate level of contributions) their contribution amount (i.e, willingness to pay). Contributors oblivious to free-riding simply contribute the amount that maximizes their utility (given budgetary constraints). In any case, the mean or median contribution from these three types of contributors serves as a useful measure of society's willingness to pay for improved forest amenity provision – this value (whether mean or median) is applied in our analysis. We present the framework and model solutions as conditional on the efficiency reducing, distortionary influence of free-riders.

2.1. Utility Maximization: Contributor

A basic assumption underlying the contributor component of the forest amenity compensation program is that rational, economic agents derive utility from forest amenities:

$$u = u(T, z, q) \qquad [1]$$

where T is a vector of current forest amenities, z is a composite good, and q is a vector of attributes of all other nonmarket goods and services. In equation [1], the individual does not necessarily consume forest amenities, as she would the composite good, and instead gains satisfaction from their mere existence. A contributor (or, non free-rider) is defined as an agent that is indifferent between paying some positive sum of money for improved amenity provision and remaining at the status quo:

$$v_o'(m_o - \varphi_o, p_o) = v_o(m_o, p_z) \qquad \forall o \in O;\ o \in I;\ o \neq i;\ I \subset O$$

$$\varphi_o > \bar{\varphi} > 0 \qquad [2]$$

where o indexes each contributor and a contributor can be a landowner $(i,\ldots,I)$, but not the landowner generating the forest amenities.[8] The remaining notation is explained as follows: $v_o(\bullet)$ is the indirect utility function, m_o denotes income, φ_o is a continuous contribution amount that must be greater than some minimum threshold set by the third party, and p_o is a vector of prices for all other goods. Equation [2] identifies the tradeoffs between forest amenities and other household goods and services a contributor must evaluate when determining an amount

[8] In order for the analysis to proceed and for the compensation framework to be legitimately established, we assume that the number of contributors exceeds the number of participating landowners (i.e., $I \subset O$).

to contribute. The existence of φ_o in equation [2] implies the amenity program has been implemented, thus T' replaces T in equation [1]. In this case, φ_o enters directly as an element of $p_o = (\varphi_o, p_z)$. For each contributor, φ represents a contributor's willingness to pay (WTP), which we assume is equal to her maximum WTP for improved forest amenity provision. Furthermore, for all o, φ_o can be interpreted as that point along the budget line that is just equal to the marginal rate of substitution between T' and z. In both equations [1] and [2], the contributor gains utility at a decreasing rate from increases in T', q, and $m_o - \varphi_o$ (refer to Table 1).

If we model the contributor's preferences from the perspective of the third party using random utility theory (McFadden 1981), there will be elements that the contributor is aware of but that have not been revealed to the third party. The third party will need to account for this discrepancy and can do so through the inclusion of a stochastic term with elements of the contributor's preferences that can be measured (the following borrows from Hanemann 1999, pp. 35–48):

$$u_o(T_j, z_{oj}, q_{oj}, \varepsilon_{oj}) = u(T_j, z_{oj}, q_{oj}) + \varepsilon_{oj} \qquad [3]$$

$u(\bullet)$ represents the deterministic or measurable component of the contributor's direct latent utility associated with a particular state j ($j = 1,\ldots,J$) and ε_{oj} is the random error term. It is important to model the preferences of the contributor from the perspective of the third party and with a stochastic term for two reasons. First, if the forest amenity program were to be implemented, the third party would need to know the manner in which forest amenities enter into the preferences of a contributor and the extent of aggregate willingness to pay. Second, if

Table 1
Expected signs and interpretations for equations [1] – [20] in the amenity compensation framework

Expected Sign	*Interpretation*
$\partial u_o/\partial \partial T' > 0, \partial^2 U_o/\partial \partial T'^2 < 0$	Diminishing marginal utility of forest amenities to contributor *o*
$\partial u_o/\partial z_o > 0, \partial^2 U_o/\partial z_o^2 < 0$	Diminishing marginal utility of the composite good
$\partial u_o/\partial q_o > 0, \partial^2 U_i/\partial q_o^2 > 0$	Strictly increasing marginal utility with increases in goods attributes
$\partial v_{ol}/\partial m_{ol} > 0, \partial^2 v_{ol}/\partial m_{ol}^2 < 0$ §	Diminishing marginal indirect utility of income for contributor *o*
$\partial v_{ol}/\partial \varphi_{ol} < 0$ §	Indirect utility will decrease with increases in the contribution amount
$\partial v_{ol}/\partial p_{ol} < 0, \partial^2 v_{ol}/\partial p_{ol}^2 < 0$ §	Strictly decreasing indirect utility with increases in goods prices
$\partial v_{ol}/\partial x_{ol} > 0, \partial^2 v_{ol}/\partial x_{ol}^2 < 0$ §	Diminishing marginal indirect utility of goods consumed under program *l*
$\partial v_{ol}/\partial q_{ol} > 0, \partial^2 v_{ol}/\partial q_{ol}^2 > 0$ §	Strictly increasing marginal indirect utility with increases in the attributes of goods consumed in program *l*
$\partial V_g/\partial T' > 0; \partial^2 V_g/\partial T'^2 < 0$	Diminishing marginal value to third party *g* of providing additional hectares in the forest amenity program
$\partial V_g/\partial L > 0; \partial^2 V_g/\partial L^2 < 0$	Diminishing marginal value to *g* of providing added support to all other programs
$\partial T'/\partial W_g > 0$	Level of forest amenities under the compensation program increases with increases to the budget of *g*
$\partial T'/\partial \delta > 0; \partial^2 T'/\partial \delta^2 < 0$	Level of forest amenities increases at a decreasing rate with increases in the compensation price paid by *g* to *i*
$\partial v_g/\partial \delta < 0; \partial^2 v_g/\partial \delta^2 > 0$	Indirect utility for *g* decreases at an increasing rate with increases in the price paid to participating landowners
$\partial v_g/\partial W_g > 0; \partial^2 v_g/\partial W_g^2 > 0$	Strictly increasing, indirect marginal value of supplemental contributions
$\partial v_g/\partial \Psi < 0$	Increasing transaction costs associated with the amenity program diminish the indirect utility *g* derives from supporting the program
$\partial \delta^*/\partial W_g > 0$	Increases in contributions will lead to an increase in the price paid to *i* for hectares enrolled
$\partial \delta^*/\partial \psi < 0$	Compensation paid to *i* by *g* decreases with increases in program related transactions costs
$\partial \delta^*/\partial T' < 0; \partial^2 \delta^*/\partial T'^2 > 0$	Per unit compensation price decreases at an increasing rate with increases in the aggregate number of hectares enrolled in the program
$\partial \pi_i/\partial \delta > 0$	Participating landowner profit is an increasing function of the price paid for forest amenities ***h***
$\partial \pi_i/\partial f_i > 0; \partial^2 \pi_i/\partial f_i^2 < 0$	Timber harvesting initially increases landowner profit; after some point, additional harvesting degrades the site to the point that remediation costs are incurred
$\partial \pi_i/\partial d_i > 0; \partial^2 \pi_i/\partial d_i^2 < 0$	Decreasing marginal returns to profit are realized from additional passive rent generating activities; this occurs due to the carrying capacity of the land being exceeded (i.e., too many activities degrade the site)
$\partial \pi_i/\partial t'_i > 0; \partial^2 \pi_i/\partial t'^2_i < 0$	Landowner profit increases at a decreasing rate with increases in the number of hectares enrolled in the program; results from the direct relationship between area (ha) and costs associated with forest amenity management
$\partial f_i/\partial a_i$? 0	Ecological and environmental conditions have diverse and factor specific effects on the amount of timber harvested by *i*
$\partial f_i/\partial c_i > 0$	Improvements in timber attributes (e.g., higher valued species) will increase *i*'s profit
$\partial f_i/\partial e_i \geq 0$	The environmental ethic of *i* may or may not influence the amount of timber harvested
$\partial f_i/\partial \beta_i \geq 0$	Similar to the above, the amount harvested by *i* may or may not be responsive to *i*'s hurdle rate
$\partial d_i/\partial f_i$? 0	A functional dependence exists between passive rent generating activities and timber harvesting; the sign would be determined by the management actions of each *i*

Table 1 (continued)

Expected Sign	*Interpretation*
$\partial t'_i/\partial f_i$? 0	Timber harvesting will be necessary in some cases to enhance forest amenities (e.g., harvesting to increase scenic beauty) and in other cases it will have deleterious effects (e.g., harvesting in riparian areas)
$\partial t'_i/\partial e_i > 0$ $(e_i > \underline{e}_i)$	The stronger *i*'s environmental ethic, which includes personal beliefs on land stewardship and the importance of sustainable forest management, the more likely *i* will enroll in the program (given that *i*'s ethic is at least as strong as some threshold level, below which *i* would choose not to participate)

§ For all *l* programs; $j, j' \in l$.

the third party assumed that it could measure all significant elements of the contributor's utility and designed the program around this assumption, deviations from its expected contributions would threaten the viability of the program. A drawback to the above random utility representation of contributor preferences is that the third party cannot model the influence of each contributor's actions on the behavior of the other contributors, which is the standard form for analyzing private provision of continuous public goods (Varian 1992, p. 420; Hanley et al. 1997, p. 44).

Given the random utility (RU) theory framework, the contributor will seek to maximize direct utility from forest amenities, given by equation [3], subject to a budget constraint:

$$p_{oj}T_j + z_{oj} = m_o \qquad [4]$$

where the price of the composite good is normalized to one and income is constant across all states *J*. Restrictions placed on equations [3] and [4] under RU limit the contributor to purchasing only discrete quantities of T_j, $T_j = T_{j'}$ or T, where in the latter case no price is paid, and enjoying increasing levels of forest amenities as long as the level of the composite good is nonzero (i.e., weak complementarity holds). If the contributor chooses state j', which includes T', then the indirect utility she derives from improved forest amenities can be written as

$$v_o(m_{oj'}, p_{oj'}) = v(m_o - p_{oj'}, T_{j'}, q_{oj'}) + \varepsilon_{oj'} \qquad [5]$$

where $v(\bullet)$ on the right hand side represents deterministic indirect utility and ε captures stochastic elements in utility associated with state j.

Suppose instead that the contributor decides to remain at the status quo state j ($T_j = T$), which does not include improved forest amenities. The contributor will do so only if the indirect utility from j is greater than the utility from j':

$$v_o(m_{oj}, p_z) - v_o(m_{oj'}, p_{oj'}) = \begin{cases} > 0 & \text{if } \varepsilon_{oj'} - \varepsilon_{oj} < v_{oj} - v_{oj'} \quad [6a] \\ = 0 & \text{if } \varepsilon_{oj'} - \varepsilon_{oj} = v_{oj} - v_{oj'} \quad [6b] \\ < 0 & \text{if } \varepsilon_{oj'} - \varepsilon_{oj} > v_{oj} - v_{oj'} \quad [6c] \end{cases}$$

Equations [6*a*] and [6*b*] contradict equation [5], where the contributor chose j' because it provided the greatest indirect utility. Equation [6*c*], then, is the only response that coincides with the preferred state j' and can be written more directly as

$$v_{oj'} - v_{oj} = \{[v(m_o - p_{oj'}, T_{oj'}, q_{oj'}) - v(m_o - p_z, T_{oj}, q_{oj})] + (\varepsilon_{oj'} - \varepsilon_{oj})\} > 0 \qquad [6c']$$

However, since ε is a random error term and because the third party does not know *ex ante* the true preferences of the contributor over the possible bundles, the third party estimates the probability that the contributor will choose j' over j. Given equation [6c′], the probability of choosing between two mutually exclusive states j' and j is given by

$$Pr_{o,j'>j} = Pr(v_{oj'} - v_{oj}) > 0 \qquad \forall o \ ; \ j', j \in J \qquad [7]$$

If we assume a linearly additive indirect utility function, the deterministic component for state j' in equation [7] becomes

$$v_{oj'} = X_{oj'}\phi_{o'} + \varepsilon_{oj'} \qquad [8]$$

where $X_{oj'}$ is a vector of independent variables from equation [5] and $\phi_{o'}$ is a vector of parameters measuring the influence of each variable on contributor utility. Equation [8] gives the utility of the maximizing contributor when she chooses state $j' = (T_{j'}, z_{j'})$ with prices $p_{oj'} = (\varphi_o, p_z)$ and attributes $q_{j'}$, subject to a budget constraint. Finally, substituting equation [19] into equation [18] specifying a specific distribution (typically Wiebull) to the stochastic term, the contributor willingness to pay (i.e., contribution amount) φ_o* is given by

$$\varphi_o^* = WTP_o = \phi_m^{-1} \ln[\exp(v_{oj'}) / \textstyle\sum_j \exp(v_{oj})] \qquad \forall o \qquad [9]$$

where ϕ_m is the parameter estimate for income.

2.2. Value Maximization: Third Party

A third party is defined to be a conservation-guided, intermediary institution with the administrative infrastructure capable of collecting and dispersing funds and information with some degree of efficiency. The inclusion of an intermediary body in the compensation framework is necessary for three primary reasons. Foremost, third parties, such as non-profit organizations, are value and not profit oriented, which is a more consistent preference structure when the provision of public goods is the issue. A third party is distinguishable from governmental bodies (although this may not always be true), an important distinction in the case of using private lands for public goods provision. That is, private landowners and contributors may not participate if they believe there is some connection between their efforts and increasing regulations on private lands. Third, since contributors are mostly familiar with the organizational framework and objectives of intermediary institutions, transactions costs for the proposed forest amenity program may be lower than if the program was implemented privately or federally.

The basic value structure of a third party depends on maximizing societal value of its programs, given a budget balancing condition between contributions and operating costs. Assume in the present case the third party implicitly derives value from the total number of hectares funded through the forest amenity program (T') and all other programs (L):

$$V_g = V(T', L) \qquad [10]$$

where g indexes the third party.[9] Equation [10] can be explicitly represented by a Cobb-Douglas functional form:

[9] We index the third party because it is possible to have more than one party facilitating the transfer of donations from contributors to landowners. The case of forest certification is a good example.

$$V_g = V(T', L) = AT'^{\alpha}L^{1-\alpha} \quad [11]$$

where A is a constant of value. A Cobb-Douglas form was selected to model contributor preferences for several reasons. Namely, this function has positive but diminishing marginal values of T' and L ($\partial V/\partial T' > 0$; $\partial^2 V/\partial T'^2 < 0$; $\partial V/\partial L > 0$; $\partial^2 V/\partial L^2 < 0$), permits the marginal value of T' to increase with contributions ($\partial^2 V/\partial T' \partial W_g > 0$), and the elasticity of marginal value with respect to all other programs is less than one (Max and Lehman 1988). Moreover, the exponents can be interpreted as the shares of the third party's value allocated to T' and L.

The third party maximizes equation [11] given a budget balancing condition[10]:

$$W_g = L + \delta T' + \psi_r \; ; \; \delta = \delta(\kappa_i) \quad [12]$$

where W is the aggregate level of donations or alternatively, the budget size ($\varphi^* \in W_g$; $\varphi^* = \Sigma_o \varphi_o^*$), δ is the average price per unit of forest amenity (i.e., ha) paid to participating landowners, ψ is a parameter measuring transaction costs associated with administering and monitoring the program in each region r, κ represents the landowner's amenity management intensity, and the price for L has been normalized to one. Following Kant (2000, 2003), transactions costs ψ are strictly positive and vary across regions due to different socioeconomic conditions in each region. Equation [12] can be interpreted as the participation constraint for the third party, where the program will be administered only if the costs (right-hand side) are less than or equal to aggregate contributions. Note that the third party sums vertically the willingness to pay of each contributor when setting δ since all contributors consume the same amount of forest amenities. The compensation price δ is constant across

[10] We assume the third party realizes income solely from contributions.

forest amenities h but varies with the intensity of amenity management pursued by the landowner. For example, a landowner could decide to either designate a 30 m riparian buffer (implying a restricted management zone) and plant tree seedlings within the buffer or simply leave a 10 m buffer. The landowner would be compensated an amount δ' [$\delta' = \zeta\delta + \delta$; $\zeta \in (0,1)$] for the additional effort.

By substituting the constraint (equation [12]) into the objective function (equation [11]) and solving the first order condition for T' we obtain

$$T'^* = \alpha(W - \psi_r) / \delta \qquad [13]$$

Equation [13] implies that the optimal number of hectares funded by the third party for forest amenity management is a decreasing function of the price paid to participating landowners ($\partial T'^*/ \partial\delta < 0$) and an increasing function of the budget size ($\partial T'^*/ \partial W > 0$). These results are consistent with *a priori* beliefs about the relationship between variables (see Table 1).

Applying the result from equation [13], the indirect value the third party derives from providing the amenity program and all other programs is given by

$$v_g(\delta, \psi, \boldsymbol{p}, W) = A[\alpha(W - \psi_r)/\delta]^{\alpha}L^{1-\alpha} \qquad [14]$$

where v is the indirect value function, $\boldsymbol{p}$ is a vector of prices for all other programs L, and all other terms defined earlier. The basic properties of $v(\bullet)$ are satisfied in equation [14], that is, $v(\bullet)$ is non-increasing in program costs and non-decreasing in contribution receipts (refer to Table 1 for additional interpretations). Given that the third party faces strictly positive costs for providing the programs, it will maximize equation [14] over δ, ψ, and $\boldsymbol{p}$ subject to the budget constraint in equation [12]:

$$\underset{\delta,\ \psi,\boldsymbol{p}\ >>\ 0}{\text{Max}} \quad A[\alpha(W-\psi_r)/\delta]^{\alpha}[(1-\alpha)(W-\psi_r)]^{1-\alpha} \qquad [15]$$

where ψ and $\boldsymbol{p}$ have been normalized to one. The first order condition for δ yields

$$\delta^* = \alpha(W-\psi) \qquad [16]$$

Equation [16] gives the minimum price δ^* at which $T^{\prime *}$ would be the value maximizing choice for the third party. The price is consistent with *a priori* expectations that the minimum price paid to participating landowners will increase with increases in the budget ($\partial\delta^*/\partial W > 0$) and decrease with increases in program related transactions costs ($\partial\delta^*/\partial\psi > 0$). Dividing equation [16] by $T^{\prime *}$ yields the minimum, per unit (ha^{-1}) price, which decreases at an increasing rate with increases in the number of hectares enrolled in the program (see Table 1).

2.3. Profit Maximization: Participating Landowners[11]

We extend Birch's (1996) definition of a non-industrial, private forest landowner to include any individual that owns at least two hectares of land that contain a minimum forest stocking of 0.7 square meters of basal area on at least 20 percent of the property and that does not hold any wood production facilities. A landowner is considered a participant if the third

[11] A utility-based behavioral model, similar to that applied to the contributor, could have been used to analyze landowner reactions to the amenity program. However, in our compensation framework, landowners are paid to provide an improved set of forest amenities. Faced with the opportunity to earn income on a service once provided for free (passive provision), or possibly at a loss (active provision), landowners have an incentive to supply a level of amenities that will generate the most income. Thus, a profit maximization framework seems appropriate.

party endorses his forest amenity enhancement plan, which is prepared by an approved forest manager, and agrees to follow this plan for a set number of years. In order to simplify the analysis and make the end result more tractable, we make the following assumptions. First, the market for forest amenity provision is competitive such that one landowner cannot unduly influence the price received or aggregate quantity supplied of forest amenities. Second, each landowner is constrained in the management activities he undertakes, whether for timber production or amenity enhancement, by the ecological capacity of the land. We assume that landowners do not account for the management actions of other participating landowners when choosing a profit maximizing level of amenity provision (except for the case of landowner collaboration in connecting adjacent parcels). This assumption seems reasonable given the high information costs associated with each landowner obtaining information on all other participating landowners and then using that information to update his management plan. Finally, we assume that the set of possible management plans (Y_i) from which landowner i selects the profit maximizing strategy can be written as:

$$Y_i(z, g \mid e) = \{(z_i, g_i, f_i, d_i, t_i') \mid z_i = \bar{z}_i, g_i = \bar{g}_i, e_i, t_i' \geq 0\} \quad [17]$$

where z is the quantity of land owned by i, fixed at $\bar{z}_i$, g denotes the ecological capacity of the land, held fixed at $g_i = \bar{g}_i$, e is a measure of the landowner's environmental ethic, f_i denotes quantity (e.g., thousand board feet) of stumpage available for harvest, d_i denotes passive rent generating activities (such as hunting leases), and t_i' is given by a convex production function and represents the aggregate number of hectares dedicated to amenity management by i under the program. t_i' is a feasible element of any management plan selected by a landowner based on evidence that amenities influence the forest management activities undertaken by an owner

(Binkley 1981, Max and Lehman 1988, Dennis 1989, Birch 1996, Lee 1997, Schaberg et al. 1999, Scarpa et al. 2000).

Similar to the contributor and third party analyses, landowners face participation constraints. Principally, landowners will participate in the program if the benefits from doing so are greater than the benefits derived from some other set of management activities:

$$\delta^* t_i' + p_i' m_i' > p_i m_i \qquad [18]$$

where m' and m are feasible management plans (m', $m \in Y_i$) and p is the price received for each plan. The constraint in equation [18] could also be interpreted as the price that compensates owners for the difference between what they could have made selling timber on an optimal economic rotation versus a longer rotation that includes forest amenities. A second participation constraint is embodied in the environmental ethic of the landowner, where we would expect to observe higher rates of participation among landowners with stronger feelings towards stewardship and sustainable forestry (see last row of Table 1). This constraint is based on research that shows a significant relationship between the environmental ethic of a landowner and participation in an incentive based program (Kurtz and Lewis 1981, English et al. 1993, Weaver 1996, Luzar and Diagne 1999) and decisions regarding management activities (Bliss and Martin 1989, Bliss et al. 1997).

Given the above assumptions and constraints, a participating landowner will maximize profit from the sale of timber, rents generated through passive activities, and hectares dedicated to the enhanced provision of forest amenities:

$$\pi_i(\delta^*, \mathbf{p}, f_i, d_i, t_i') = B_i + p_f f_i(a_i, s_i; e_i, \beta_i) + p_d d_i(f_i) + \delta^* \textstyle\sum_h t_{ih}'(f_i, \kappa_i) - c_f(f_i) - c_d(d_i) - c_{t'}(t_i') \qquad [19]$$

where $\boldsymbol{p}$ is a vector of market prices, B denotes the agglomeration bonus, a denotes a vector of ecological and environmental conditions specific to the property (e.g., soil composition and slope), s denotes a set of timber attributes (e.g., species and volume), β denotes the hurdle rate, subscripts f and d on p denote prices of standing timber and passive activities, respectively, h denotes the number of hectares dedicated to the management of a specific amenity (e.g., scenic beauty), and c denotes activity costs.[12] The costs associated with providing t_i' include both transformation (combining physical inputs to provide improved amenity outputs) and transaction (third party verification and assessment) costs (Kant 2003, p. 43). These costs may be significant and greater than the benefits of program participation if the landowner pursues simultaneous management of timber and nontimber outputs across large tracts of forestland due to complex spatial coordination problems (Swallow and Wear 1993). Regarding the agglomeration bonus B, only adjacent landowners that agree to collectively manage their adjoining parcels according to a single management plan qualify (see Parkhurst et al. 2002). The variables measuring the influence of site specific factors on timber productivity and the passive rent generating capability of the land are expected variables for this type of function. However, the inclusion of an environmental ethic term is an important distinction from previous models (Newman 1987, Hellsten 1988, Newman and Wear 1993), excepting Binkley (1981), because it directly enters into the decision calculus of the landowner. The functional dependence of passive rent generating activities and amenity management on timber harvesting (and vice versa) implies that the activities are not mutually exclusive. We cannot

[12] An obvious limitation of this model is the assumption of a linearly additive functional form, which assumes separability and perfect substitutability between factors. Kant (2003) raises this issue as a shortcoming of standard neoclassical approaches to modeling complex, interrelated and inherently nonlinear ecological processes. Our only defense is that this simple (and somewhat over specified) model is intended to emphasize the multitude of decision variables an everyday forest landowner might take into account and a possible, simplistic strategy that owner may apply when allocating efforts across activities.

say, *a priori*, if the sign of the relationship between the sets of terms is positive or negative since that result would seem to be landowner specific (see Table 1).

Applying Hotelling's lemma to equation [19] and evaluating the profit function at the optimal compensation level (δ^* from equation [16]), the net supply function for private provision of forest amenities is given by:

$$\partial\pi_i(\delta^*, \boldsymbol{p}, f_i, d_i, t_i')/\partial\delta^* = \Sigma_h t_{ih}'^*(f_i, \kappa_i) = t_i'^*. \qquad [20]$$

The result from equation [20] is optimal in the sense that it maximizes a participating landowner's profit, given that contributors are contributing an amount that maximizes their utility and the third party is allocating contributions to maximize the social value of its programs. However, inherent in any model of private provision of public goods is free-riding, which causes the solution to be inefficient and suboptimal (Myles 1995, pp. 279–284, Hanley et al. 1997, p. 45). Thus we can only state that equation [20] is a second best solution possible within the outlined compensation framework.

3. Model Discussion

Forest amenities represent a unique set of public goods and include carbon sequestration, soil stabilization, and wildlife habitat. Private landowners are responsible for a significant share of forest amenities, yet many are unaware of the potential to improve their provision. Current assistance programs and incentive schemes are designed to inform landowners and share the costs of implementing amenity-based management plans, but are either marked by limited funding or have not been fully developed. Thus, we construct a compensation framework to demonstrate the dependence of society on landowners and landowners on society and the interaction that must occur in order for landowners to recognize the significance of their property in forest amenity provision.

The results given in equations [9], [16], and [20] imply four potential solutions for the efficient provision of forest amenities within the compensation framework. First, if contributors are not willing to pay (i.e., $\varphi_o^* = 0$) and landowners are not willing to manage for improved forest amenities ($t_i' = 0$), then $T'^* = 0$ and the solution is simply T (the current level of amenities). However, if contributors are willing to pay but landowners are not willing to manage, then equation [9] does not hold and the solution is inconsistent. In other words, landowners are not acting as profit maximizers. This result also represents a disconnect between contributors who demand increased forest amenities and forest landowners who collectively control the supply of amenities. If landowners are willing to manage for improved amenities but contributors are not willing to pay, the efficient level cannot be met. The approach of Cornes and Sandler (1996, pp. 240–343) to the private provision of public goods provides an interesting interpretation of this outcome: if landowners provide some improved level of forest amenities and this is an increase in endowment to others and forest amenities are a normal good, additional contributions may result (depending on the shape of the Nash-Cournot reaction functions). Thus, if landowners are willing to take the first step and show their commitment to improving forest amenities, then regardless of initial contributor behavior the supply of amenities will approach T'^*. Furthermore, it is possible for landowners to improve the current level of forest amenities without compensation; this result would rely heavily on the environmental ethic of the landowner. Finally, if landowners are willing to manage for improved forest amenities and contributors are willing to pay, the optimal level is satisfied ($T = T'^*$).[13] Figure 1 provides a map of all four possible solutions.

[13] We again stress the significance of free-riding in undermining the optimality of this solution.

		Landowner	
		Unwilling to manage	Willing to manage
Contributor	Unwilling to pay	T ($T > 0$; $T'^{*} = 0$)	$T'^{*} < T$ ($T, T'^{*} > 0$)
	Willing to pay	Inconsistent	$T = T'^{*}$

Notation: T = current level of forest amenities; T'^{*} = optimal level of forest amenities with the compensation program, conditional on inefficiency effects of free-riders.

Figure 1
Potential solutions for the provision of forest amenities.

The above solutions are dependent on a number of assumptions, such as utility and profit maximization as agent objectives, but most importantly on a belief system. An individual will contribute to the forest amenity program if she believes her contribution will improve the level of amenities by some measurable amount.[14] Likewise, a landowner will participate if he believes land management activities can increase the level of forest amenities and the compensation for such actions is at least as great as the costs. A third party acts as the mediator between the two agents and will do so if it believes cooperation is possible, its budget balancing condition is satisfied, and social welfare will be improved. This belief system is characterized by high information costs in that each agent forms their belief on verifiable information that an outcome more favorable than the status quo ($T' > T$) is possible. Decades of research in natural resource management show demonstrably that proper land management practices can improve the quality of forest ecosystems and the level of forest

[14] This response ignores the possibility of contributing based on a "warm-glow" feeling the agent may achieve through the act of giving.

amenities. However, transferring this information in a format the average contributor and landowner can understand is a significant task.

The compensation framework could be extended to include the belief system through expected utility and profit models. For example, we could assume agents seek strategies that have the greatest probability of returning positive profit or greater utility (Kant 2003). Additionally, the effects of imperfect information, nonuniform agents, and different attitudes toward risk (i.e., risk averse or inclined) would be worthwhile extensions to the framework. Modeling non-convexities in amenity production is another feasible extension. Calish et al. (1978) and Swallow et al. (1990) show how management objectives, such as managing for different types of wildlife, and forest policies are sensitive to the assumption of convex production functions. The authors provide detailed examples and mathematical expressions showing that biological functions of a forest ecosystem should only be modeled by function specific non-convex production functions; by not modeling the process in this manner, the effectiveness of the objectives and policies could be compromised. Non-convexities can be incorporated in the present framework by allowing compensation (equation [16]) to depend on the type of forest amenity h managed by i. Additional improvements include modeling the influence of one contributor's contribution on another contributor's utility and similarly, the effect of the level of amenity production chosen by one landowner on another's behavior. Changes in the assumption of competitive supply conditions is a possible extension, given that 70 percent of forest land in the U.S. is controlled by less than 10 percent of landowners (Birch 1996).

One of the more promising extensions of the framework involves incorporating contributor willingness to pay (WTP) information obtained through stated and revealed preference nonmarket valuation methods, such as choice modeling (CM) and hedonic pricing. CM involves the creation of a hypothetical market through surveys in which participants select a preferred policy from a collection of policies. Each policy is defined by the same set of attributes, including a cost term, but different attribute quality (cost) levels. The random utility model is used to explain the respondents' choices and is consistent with several limited dependent econometric procedures, namely multinomial and mixed logit models, which enable estimation of equation [9]. The hedonic price method (HPM) could be used to uncover the marginal implicit prices of each contributor for forest amenities by analyzing their housing choices. The HPM relies on a different utility theoretic and estimation procedure than CM, thus providing a richer picture of the contributor's WTP.[15] The combined application of these methods to estimate WTP is important to the compensation framework because our subsequent analyses of third party and landowner behavior, and ultimately, the supply of forest amenities, rely on equation [9].

4. Conclusion

Forest amenity management is an integral component of sustainable forest management that has not yet been widely promulgated in landowner assistance programs. The Environmental Quality Incentive Program and the Forest Land Enhancement Program specifically address forest amenities by providing guidance and cost-share assistance to landowners in exchange for management that improves amenities, restores damaged ecosystems, and promotes long-term forest sustainability (USDA 2003). These and related programs are limited in their funding and technical resources, consequently discouraging many landowners from participating or simply leaving landowners unaware of the

[15] Combining revealed and stated preference valuation techniques has become an important research method because of the gains in information and reductions in uncertainty surrounding true WTP (Cameron 1992, Adamowicz et al. 1994, Adamowicz et al. 1997, Earnhart 2001).

opportunities. However, there are examples of programs such as the Conservation Reserve Program and Wildlife Habitat Improvement Program where positive outcomes result because landowners are informed and given equitable incentives. We believe these two elements are the key to success for any program designed to improve forest amenity provision.

The framework we develop for improved forest amenity provision is based on incentives, a conservation-guided third party, and a belief system. The framework explicitly incorporates forest amenities in the utility and profit functions of contributors and landowners who have voluntarily agreed to participate in a program administered by the third party. We show that if each agent acts rationally on his or her preferences for forest amenities, a compensation amount can be derived that would lead to a higher level of amenities. The framework accounts for the environmental ethic of each landowner by modeling participation as an increasing function of a landowner's commitment to stewardship. The concept of cooperative landowner management is also incorporated because in some cases, such as endangered species, cooperative management may be the only feasible strategy to pursue. The weaknesses of the framework include high information requirements, convex functions in amenity production, and a profit maximization model for landowners. Addressing these issues and incorporating the results from stated and revealed preference studies are the focus of future research.

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Part 3

Information Effects in Choice Modeling: A Spatial and Aspatial Case Study

This chapter is a slightly revised version of a paper by the same name to be submitted to the journal *Land Economics* by Aaron R. Wells and Donald G. Hodges. My use of the word "we" in this chapter refers to my co-authors and myself. My primary contributions to this paper include (1) development of the problem into a work relevant to my study of environmental valuation, (2) incorporation of geographic information systems and remote sensing, (3) most of the gathering and interpretation of the literature, (4) econometric models, (5) most of the analysis, and (6) most of the writing. ......

Abstract

This study evaluates the effect of forest land cover and information about future land use change on respondent preferences and willingness to pay for alternative hypothetical forest amenity enhancement options. Respondent choices among 11 options were modeled in correlated coefficients, panel random parameters logit model. Land use change information and the amount of forest land cover significantly influenced respondent preferences, choices, and stated willingness to pay. Hicksian welfare estimates ranged from $57.42 to $25.53, depending on policy specification, information level, and econometric model. These results provide further evidence of choice sensitivity to constructed market framing and indicate a role for GIS and remote sensing in stated preference research.

Keywords: Stated preference, GIS, Remote sensing, Information effects, Mixed logit

1. Introduction

The basic premise of any study investigating information effects within a constructed market posits the context in which a decision is made affects the outcome and changes in context should yield different outcomes (Randall et al. 1983). Typically, changes are exogenously induced by the researcher in hopes of testing a hypothesis about expected consumer behavior. A standard hypothesis given in the literature states the probability a consumer will choose to pay for an environmental good, conditional on new positive information introduced into the market setting, will increase relative to the control market, assuming all other aspects of the market remain the same (Munro and Hanley 1999). Correspondingly, stated willingness to pay for the good should increase (Cummings et al. 1986). This hypothesis has been modified by several researchers to analyze consumer choice conditional on different levels of information (Poe and Bishop 2001) as well as information regarding possible uses of the valued good (Bergstrom et al. 1990), substitute and complementary environmental goods (Whitehead and Blomquist 1991), and resource quality (Blomquist and Whitehead 1998; Hoehn and Randall 2002). Additionally, the effect of too much information (Bergstrom and Stoll 1990) and respondent effort to obtain more information (Berrens et al. 2004) has been tested within the information effects framework. To date, though, the standard hypothesis has not been extended to the analysis of consumer behavior when information about future urbanization that could reduce both quality and level of the environmental good is introduced into the constructed market. Moreover, the hypothesis has not been extended to investigate the effects of spatial land cover information on respondent preferences and stated choices.

The information effects hypotheses we tested are divided into aspatial and spatial categories differentiated by the source of the underlying data and the source of the effect yet linked by a common respondent. For the aspatial test, the data are generated by market participant attributes, choices, and choice characteristics while for the spatial test, data are objectively generated by measuring the amount of forest land cover around each participant. The aspatial information effect is researcher controlled and implemented by simply augmenting the control market with new, potentially negative information. The information we introduce informs the respondent of the possibility a hypothetical 50-acre tract of forest land in their area will be converted to a residential subdivision. Regarding the spatial information effects test, we hypothesize that the amount of forest land cover surrounding a respondent is an element of the respondent's information set and changes in the amount of forest cover, due to land use change, for example, influence her decision making process. The source of the information effect for the spatial test is exogenous to the researcher and instead determined by each respondent's discrete housing choice. Collectively, we econometrically test each information effects hypothesis with generalized nonlinear probability models.

The constructed market setting for investigating these information effects is a survey administered by mail to 3000 residents in 2 counties on the Cumberland Plateau in Tennessee. The basis for the survey is an assessment of preferences for current forest amenity levels, proposed (hypothetical) changes to these levels, and willingness to pay to secure such changes. The survey was designed consistent with the stated preference method of choice modeling, and correspondingly, random utility theory, and consists of 5 choice sets with 3 options within each set. One option always remains the same with 10 alternative forest amenity enhancement options presented to the respondent over the course of the survey. We employed choice modeling, as opposed to contingent valuation, because this method permits evaluation of multiple management options (plans) within a single instrument. From an econometric perspective, the additional variability in choice attributes and choices per respondent improves estimation efficiency and applicability of results. Relatively few studies have applied stated preference techniques for forest amenity valuation. A review of this literature shows an interesting division in that most of the earlier studies employ the contingent valuation method (Walsh et al. 1990, Hanley and Ruffell 1993, Macmillan and Duff 1998) while many later studies apply choice modeling or another form of conjoint analysis (Adamowicz et al. 1998, Hanley et al. 1998, Schaberg et al. 1999, Baarsma 2003, Xu et al. 2003).

2. Random Utility Model

We specified a random utility model to explain respondent behavior for forest amenities as well as to test for the effects of land use change information and surrounding forest land cover on participant choices and willingness to pay within the constructed market. The basis of random utility theory is the division of latent utility an individual derives from a given bundle of goods and services into two components, one which the researcher is able to measure and the other capturing unobservable elements. The combination of these two terms permits the development of a probability model for individual choice which, given certain distributional assumptions, can then be applied over all choices and individuals in a limited dependent variable econometric model. Following Hanemann (1999),

$$u_{ijt}(x_i, e_{ijt}, l_i, z_i) = v(y_i, e_{ijt}, l_i, z_i) + \varepsilon_{jt} \quad [1]$$

where u_{ijt} denotes latent direct utility individual i derives in state j at time t from composite good x, which is not state dependent, forest amenity quality e as specified by the researcher, the amount (m^2) of forest land cover l around an individual, and individual specific demographic attributes z. In a choice modeling based constructed market, subscript t denotes choice sets or collections of alternative policy options with similar attributes but varying attribute quality levels. The specification of time indicates the panel nature of the data generating process in multiple choice set, constructed markets. The additional term l is unique to this study and captures the influence of environmental setting that is exogenous to both the researcher and the respondent. The right hand side of equation [1] represents the indirect utility i derives from e, l, and z, in addition to net income y, and ε is an econometric error term that provides a measure of the unobservable or unmeasured factors that influence utility. The indirect utility term in random utility theory is commonly referred to as the systematic component since it is observable over all choices and given a linear functional form:

$$v(y_i, e_{ijt}, l_i, z_i) = h_{jt}'\beta_i^h + w_j'\beta_i^w \qquad [2]$$

where h is a vector of choice specific attributes that change with t and w is a vector of individual specific attributes that do not change with t.

Choice modeling provides a measurement framework consistent with random utility theory in that multiple options are evaluated by each respondent and the option chosen is revealed preferred to all other feasible options. Since we observe the option chosen, options not chosen, choice specific characteristics, and individual specific attributes but cannot observe or fail to measure other factors influencing choice, a probabilistic model based on random utility theory can be constructed to investigate the likelihood that an option will be selected. Accordingly,

$$\pi_{it}(j = 1 \mid w, M) = \pi_{it}\{\, u_{ijt} > u_{ikt} \mid M \,\} \qquad j \neq k; j, k \in S$$
$$= \pi_{it}\{\, u^* > \upsilon \mid M \,\} \qquad [3]$$

where π denotes the probability function, w represents choice variant and invariant characteristics, M denotes the information content in the survey, u^* denotes difference in indirect utility between preferred state j and state k, υ captures differences in error terms between states, and S denotes all states available to individual i. Equation [3] states that individual i will choose state j at time t if latent utility derived in this condition exceeds that in any other state k. For example, when deciding upon which forest amenity enhancement plan to support an individual evaluates several alternative plans but ultimately chooses only one.

Given that u^* is unobservable, the mean and variance of u^* are not identified and the researcher must impose a specific distribution to the error term. If we assume υ to be independent and identically distributed over time for each individual and to follow a Type I extreme value distribution, then equation [3] can be empirically modeled by the multinomial logit model (MNL):

$$\pi_{it}(j = 1 \mid w, M) = \exp(h_j'\beta_{ti}^{h} + w_j'\beta_{ti}^{w}) \,/\, \Sigma^{S}_{s=1}\exp(h_s'\beta_{ti}^{h} + w_s'\beta_{ti}^{w}) \qquad [4]$$

Elements in w that do not change across choices must be interacted with an alternative specific constant in order for the model to be identified. Subscript t is irrelevant in equation [4] since the MNL treats each choice made in each choice set as from separate individuals, even though the same individual made multiple discrete choices within a single survey. Estimates of β from the MNL are assumed known and constant across all survey respondents. Since this may not be the case such that β varies across the sample of respondents, a random parameters specification of the mixed logit representation of choice (equation [3]) may be more appropriate. Specifically, a panel specification of random parameters logit (PRPL) may be preferred in order to capture individual specific effects across choice sets.

Within the PRPL framework, choice probabilities are based on the MNL probability function (equation [4]) yet account for multiple choice sets with index t and explicitly model the randomness of parameters throughout the sample via the mixing distribution $f(\beta|\theta)$. Accordingly,

$$\pi_i^{PRPL}(j = 1 \mid w, M, t) = \int \prod_{t=1}^{T} \exp(h_{tj}'\beta_i^{h} + w_{jt}'\beta_i^{w}) \,/\, \Sigma^{S}_{s=1}\exp(h_{st}'\beta_i^{h} + w_{st}'\beta_i^{w})\, f(\beta \mid \theta)\mathrm{d}\beta \qquad [5]$$

where a specific distribution for $f(\beta|\theta)$ is determined by the researcher, for example, normal, and θ denotes parameters for the mean and covariance of the chosen distribution (Train 2003). Equation [5] states the probability a respondent will choose choice j across choice sets T is the product of multinomial logits integrated over all possible values of β. PRPL probabilities are computed numerically using simulation methods for specified values of θ

$$\pi_i^{PRPL(S)}(j = 1 \mid w, M, t) = R^{-1}\{\sum_{r=1}^{R} \prod_{t=1}^{T} \pi_{it}(\beta^r)\} \qquad [6]$$

where R is the number of simulated draws. Simulation of equation [6] progresses by drawing a value of β from the mixing distribution $f(\beta|\theta)$ in iteration r and estimating the multinomial logit component of equation [5] with this draw. The process is repeated for number of draws R with the average of such draws representing the simulated probability. By construction, $\pi_i^{PRPL(S)}$ an unbiased estimator of π_i^{PRPL} and has variance inversely related to R (Train 2003, p. 148). Since $\pi_i^{PRPL(S)}$ is strictly positive, the log of equation [6] exists which allows estimation of the simulated log likelihood function

$$\text{SLL} = \sum_{i=1}^{N} \sum_{k=1}^{K} I_{ik} \ln\pi_i^{PRPL(S)} \qquad [7]$$

where I is an indicator variable equal to one if the respondent chose k and zero otherwise. Parameters for β including a direct effect and standard deviation, which measures the variability of each parameter throughout the sample, are estimated by maximizing equation [7] with respect to β. Computed variances for each direct effect and standard deviation permit hypothesis testing of direct effects and fixed (constant) coefficient values for the sample.

3. Survey and Data

A multiple choice set, discrete trichotomous choice survey, or constructed market, designed accordingly to the choice modeling framework (Louviere et al. 2000) was used to assess public preferences for forest amenities. In particular, the goal of the survey was to evaluate the feasibility of developing a framework in which nonindustrial, private forest landowners would be compensated for managing their lands for improved forest amenities. Three thousand choice surveys were mailed to residents in Morgan and Cumberland counties, located on the Cumberland Plateau in central Tennessee. This location was selected because the Plateau provides a number of resource use conflicts between new residents, recreationists, and extractive industries such as mining and logging, that threaten the sustainability of the forest resource. Additionally, both counties are experiencing population growth rates exceeding the national average of 1.3 percent (SSDAN 2000), with Cumberland experiencing an annual rate of 3.4 percent and Morgan 1.4 percent. In line with population growth, these counties have experienced increased conversion of forest and agricultural land to urban uses (Strickland 2003). Urbanization is not localized to our study area and has been found to be a primary driver for land use change throughout the South (Wear 2002). Due to increasing population and urbanization, which underlie present resource conflicts in our area, we found it relevant to investigate how public preferences for forest amenities might change if we informed residents of the possibility of further land use change.

We introduced the constructed market to respondents through two cover letters and a survey, with the letters explaining to the respondent forest amenities, the role of private landowners in forest amenity supply, and how the respondent's answers to questions in the survey could help improve future levels of forest amenities. Within the survey, this information was reiterated and new information was provided explaining the layout of the survey, payment vehicle, and policy relevance. We informed respondents that the survey was not a means to justify additional taxes or introduce new legislation but instead a way for us to gain a better understanding of public preferences and values for forest amenities in the area. The payment vehicle was specified as an annual, voluntary contribution for five years to a non-profit organization that would then use these donations to fund initiatives providing land management assistance to private landowners.[16] We presented the compensation mechanism as a means of helping landowners who manage their land do so in a manner that provides the most public benefits and for landowners that do not manage their land, the incentive to do so and in a socially desirable way. The extended time frame of five years, as opposed to the standard one or two years, was necessary to allow sufficient time for forests to respond to management activities.

The layout of the survey included 5 choice sets with 3 generic (i.e., non-labeled) options within each set. These options were described to the respondent as alternative forest amenity enhancement plans a hypothetical, representative landowner in the study area would implement if compensated for doing so. If the respondent chose the status quo (Plan A), then the landowner would not manage her property for improved forest amenities and the stock of amenities would remain the same. However, if the respondent chose either forest amenity enhancement Plan B or C then the landowner would implement the selected plan and use the

[16] To improve incentive compatibility, a payment vehicle such as a sales or property tax (Tennessee does not have an income tax) could have been applied. However, at the time of survey design and administration the Tennessee State Legislature approved a sales tax increase that resulted in some areas paying an approximate 10 percent sales tax on purchases. Due to the strong objections of residents toward this increase and the desire to have a reasonable response rate, we elected to use the less incentive compatible payment vehicle of private contributions.

respondent's contributions to offset management expenses. In total, a respondent evaluated 11 alternative forest amenity enhancement plans with each plan decomposed into 4 amenity attributes (recreational access, scenic beauty, stream quality, and wildlife habitat) and a voluntary contribution. The forest amenity attributes were assigned one of three quality levels, Low, Medium, or High, and in the case of the voluntary contribution, one of four levels ($20, $35, $50, $75), according to a fractional factorial design algorithm (see Appendix A).[17] The status quo was presented to the respondent as Low for recreation, scenic beauty, and wildlife habitat, Medium for stream quality, and zero contribution. We include a status quo option since forest amenities, as defined in the survey, will continue to be provided regardless of the program. Figure 2 provides an example choice set presented to survey respondents.

In order to test the effect of information about future possible urbanization on public preferences and stated willingness to pay (WTP) for improved forest amenities, we designed two versions of the survey identical in all respects except the specification of the choice scenario. In the control version, the representative landowner is described to the respondent as owning 50 wooded acres comprised of both hardwood and evergreen tree species and several streams, approximately 10 miles from a major interstate ("no development" specification). In the experimental version, we describe the same landowner (50 acres, 10 miles from interstate) but introduce information that she has been approached by a residential developer to sell the land for a future subdivision. Additionally, we state that the representative landowner would forgo this development option if compensated for providing forest amenities. Thus, we exogenously alter the available information set and if the respondent reads and comprehends this new information then we should observe an effect on preferences and stated WTP, compared to the control.

[17] We identified quality levels by these simplistic terms after discovering through focus groups that more detailed quality level descriptions overloaded the respondent with information. Contribution levels are based on actual costs given in Dubois et al. (2001).

SCENARIO 1

<u>Note</u>: Please refer to the Definitions page to clarify unfamiliar terms.

<u>Reminder</u>: Choose <u>one</u> Option that has your favorite quality levels (in the middle) and the amount you are willing to pay.

The "Annual Contribution" represents your willingness to pay annually for 5 years in the form of a voluntary contribution to fund the Option you select.

<u>Directions</u>: Choose either Choice A, Choice B, or Choice C at the bottom of the set.

Non-Timber Forest Benefit	**Option A** CURRENT + DEVELOPMENT PRESSURE	**Option B** ALTERNATIVE	**Option C** ALTERNATIVE
Recreational Opportunities	LOW	LOW	LOW
Stream Quality	MEDIUM	HIGH	HIGH
Scenic Beauty	LOW	LOW	MEDIUM
Wildlife Habitat	LOW	MEDIUM	HIGH
Annual Contribution	$0.00	$20.00	$35.00

Please respond by checking (√) the option that you most agree with and that you can afford with your present budget:

☐ **I prefer Option A** ☐ **I prefer Option B** ☐ **I prefer Option C**

Figure 2
Example choice set from Forest Amenity Improvement Survey.

Based on these two survey versions we conducted several focus groups and a pre-test mailing of 100 surveys. Principal findings from these meetings and initial surveys include the following: forest amenity attributes and quality levels were overspecified (too much descriptive information), too many choice sets (originally 7), and unreasonable maximum payment level ($320). After taking into consideration these findings, 2000 surveys were mailed to Cumberland County and 1000 to Morgan County following a three-phase Dillman design (Dillman 2000). The first phase consisted of a short cover letter informing the potential respondent of the upcoming survey. One week following this letter, a full cover letter and survey were mailed; a post card reminder was sent two weeks post the second phase. A second mailing of the survey was not undertaken as we did not believe the expected increase in response rate would justify the additional cost. The unequal division in survey mailings across counties was due to prior knowledge of inadequate mailing address information in Morgan County.[18] All addresses were generated by random digit dialing procedures by Survey Sampling, Inc and used to georeference each respondent.

Table 2 provides descriptions for variables adapted from the choice modeling instrument (see Appendix B for an overview of all survey questions). Most of the variables are standard to choice analysis with the exception of *Knowledge* and *Plan Score. Knowledge* is a measure of the respondent's perceived knowledge of forests and trees as measured by their choice of a score between zero and five, with five indicating complete knowledge and zero indicating no knowledge. We assume a direct relationship between increases in *Knowledge* and the probability a survey respondent will choose a forest amenity enhancement plan (option). The *Knowledge* question was presented to survey participants after evaluation of the choice sets. *Plan Score* is an aggregate index capturing the total effect of each enhancement plan in each

[18] We have also conducted a hedonic price analysis of housing prices and forest amenities in these two counties and found significant gaps in address information for Morgan County. A principal reason for this data gap is the lack of a well-developed 911 emergency response system.

Table 2
Variable identification and descriptive statistics based on respondent answers to Forest Amenity Improvement Survey

Variable	Definition	Mean	Std. Dev.
Demographic Variables			
Cumberland	= 1 if respondent lives in Cumberland County; = 0 if Morgan County	0.753	0.431
Land Size	Median number of acres of forestland owned by respondent (derived from six land size categories ranging from zero to 100 acs or more)	9.718	19.814
Attitudinal Variable			
Knowledge	Respondent's selection to the following: "How would you rate, on a scale of 0 to 5, your knowledge of forests and trees"	2.805	1.108
Spatial(GIS/RS) Variable			
Forest Cover	Natural log of total amount (m^2/1000) of deciduous and evergreen forest land cover within a 100m radius of each respondent	1.501	1.205
Survey Design Variables			
Develop	= 1 if Status Quo information contains Development option; = 0 if No Development option	0.440	0.496
Plan Score	Aggregate score for each forest amenity enhancement plan (status quo Plan A and alternative Plans B and C) across choice sets 1 through 5 presented to the respondent; log scores were calculated for each attribute level to avoid linearity assumptions and then summed across attributes for each option; score ranges from 0 (status quo) to 3.99 (highest level of forest amenities)	2.069	1.093
Contribution	Annual dollar amount respondent is voluntarily willing to contribute for five years for the enhancement plan chosen; ranges from 0 (status quo) to $75; contribution amounts vary independently across respondents and assigned to each plan by the researcher according to actual cost of implementation	25.000	22.138
Contribute ASC	Alternative specific constant = 1 for both contribution options (i.e., forest amenity enhancement Plans B and C); = 0 if status quo option	0.667	0.471

choice set on preferences. We indexed forest amenity attributes and associated quality levels due to high levels of multicollinearity.[19] The index was computed by first assigning order-preserving values of one through three to quality levels Low, Medium, and High, respectively, and then summing these levels over all forest amenity attributes within each plan and choice set:

$$\sum_{a=1}^{A} q_{ajt} = Plan\ Score_{jt} \qquad [8]$$

where q denotes quality levels, a denotes forest amenity attributes (recreational access, scenic beauty, stream quality, or wildlife habitat), j indexes individual plans, and t indexes choice sets. Equation [8] represents a simple linear combination of attributes and attribute quality levels and implies the effect on respondent preferences of a change from quality level Low to Medium is equal to a change from Medium to High. In order to avoid this result we computed several transformations of equation [8] including quadratic, exponential, and logarithmic. Each of these transformations specifies a nonlinear relationship between respondent utility and increasing attribute quality levels, which yields a more theoretically consistent depiction of the importance of quality levels to a respondent. We employed each transformation in combination with the remaining regressors in the econometric analysis of choice and found the exponential transformation of *Plan Score* to be insignificant and the logarithmic transformation to provide the best model fit.

[19] The minimum and maximum Pearson correlation coefficients between any two attributes were 0.04 and 0.94, respectively, with both mean and median value approximately 0.64. A complete matrix of correlation coefficients is available from the authors. The multicollinearity is a result of relaxing orthogonality between attributes and quality levels in the design phase.

4. Information Effect: Forest Cover

Within the context of environmental valuation research, remotely sensed imagery and geographic information systems have been predominant in revealed preference studies (Bateman et al. 2002). Examples include Dubin (1988), Can (1992), Geoghegan et al. (1997), Mahan et al. (2000), and Kim et al. (2003) in the hedonic literature and Bateman et al. (1996) in the travel cost literature. The advantage of a spatial perspective is that it allows researchers to investigate the relationship between preferences and surrounding environmental conditions and how this relationship might change when conditions are altered. More importantly, welfare measures, such as compensating variation, are conditioned on preferences for environmental settings and failure to address this linkage may result in biased welfare estimates. This in turn would affect policy formation, choice, and evaluation.

The constantly increasing computing capability, advancements in geographic information systems, and more readily available, high resolution remotely sensed imagery enable researchers to integrate spatial variables in valuation models. Stated preference research inherently involves a spatial perspective and until recently, has been ignored. Farber and Griner (2000) incorporate a distance measure with stated choices to investigate the influence of proximity to affected streams on willingness to pay for improvements to these streams. Results suggest stated willingness to pay decreases with increasing distance (implying a distance decay effect) for stream users while no such relationship exists for non-users. Their work represents the first study to incorporate a GIS derived variable in a choice modeling context. In a contingent valuation study of protecting forests from increased flooding, Bateman et al. (2000) find a significant distance decay relationship between willingness to pay and respondent distance from the site under valuation.[20] GIS and remote sensing, though,

[20] Sutherland and Walsh (1985) and Pate and Loomis (1997) each find a significant distance decay relationship between stated willingness to pay solicited in contingent valuation experiments and

provide for more advanced treatment of space in valuation models than simple distance measures, as indicated by the aforementioned hedonic pricing studies. In the spirit of the advancements made in revealed preference research, we explore the role of forest land cover on preferences and willingness to pay using a methodology similar to Geoghegan et al. (1997).

Unlike states such as Maryland, the state of Tennessee has not yet developed a comprehensive, digital land cover classification. Thus, we developed a 12-class land cover classification for the Cumberland Plateau using Multi-Resolution Land Characteristics satellite imagery (30-m resolution) provided by the USGS, digital orthophoto quadrangles (resampled to 1m resolution), and the GIS Imagine. Digital data were supplemented with ground data collected throughout the study area to facilitate pixel classification and accuracy assessment. The general process involved a series of supervised classifications based on 400 individual signatures with an overall accuracy of approximately 90 percent (see Strickland 2003 for a complete methodological review). Survey responses were linked to the land cover classification by first geocoding each respondent's address. We then developed a program in the ArcInfo macro language to place a 100m buffer around each respondent's geocoded location, intersect this buffer with the land cover classification, and then sum over all categories. Finally, the category for forest land cover was selected for further analysis with the respondent's stated choices, demographics, and attitudinal responses (see Table 2 for variable description and descriptive statistics). We hypothesize that the amount of forest land cover around a respondent does influence choice, thus we should observe a significant parameter estimate for the variable *Forest Cover.*

distance to the valued good. However, in the former study GIS was not applied in distance calculations and in the latter no reference was made to the derivation of their distance measures.

5. Information Effect: Land Use Change

The random utility model specified in equations [32] through [34] provides a framework for exploring the conditional probability an individual will choose one of the forest amenity enhancement options described in the constructed market. Specifically, we are interested in the effect of information concerning the *possibility* of land use change from forest to residential.[21] The information provided to a respondent may not affect choice for several reasons: he/she did not read or understand the choice scenario, has preconceived views that are unaltered by new information, or believes the information to be erroneous and thus ignores it. When information is neutralized, we would expect the probability of choice to be independent of the information content in the survey such that $\pi^N(j = 1 \mid N) = \pi^D(j = 1 \mid D) = \pi(j = 1)$, where N denotes the no development scenario information and D the development information. However, theory and applied research shows that the probability of choice is conditioned on information such that the equality does not hold (see Munro and Hanley 1999).

This result gives rise to four possible outcomes that are contingent on both the level of information and the respondent's held beliefs. To explore these four cases, two separate random utility models with an expected utility dimension were specified:

$$\pi^N(j = 1 \mid w; N) = \pi\{ v(y - C, e, l, z)' + \varepsilon' > v(y, e, l, z)^Q + \varepsilon^Q \mid N \} \qquad [9]$$

and

$$\pi^D(j = 1|w; D) = \pi\{v(y - C, e, l, z)' + \varepsilon' > \delta[v(y, e, l, z)^Q + \varepsilon^Q] + \theta[v(y, e, l, z)^D + \varepsilon^D] |D\} [10]$$

[21] It is possible that the development information had the effect of creating two separate goods – forest amenities without development pressure and forest amenities with development pressure, instead of an information effect. A debriefing question was not included in the survey to help distinguish between the two potential types of effects, thus we cannot be sure of the dominant effect this information had on respondent preferences.

where j denotes a forest amenity enhancement option (Plan B or C), C denotes positive contribution to the forest amenity program, $v(.)^{j}$ indicates indirect utility derived from a forest amenity enhancement option, $v(.)^{Q}$ represents indirect utility from the status quo, $v(.)^{D}$ represents indirect utility given the development information, δ and θ are individual specific measures of risk with $(1 - \delta) = \theta$ and $0 < \delta < 1$, and individual and time subscripts suppressed for notational convenience. Equation [9] does not include the additional component included on the right hand side of equation [10] because under the no development specification, there is no other land use to consider. For the following cases, assume the perspective that an individual is responding to the development specification, that is, equation [10].

CASE I

If the respondent does not prefer residential development, then $v(.)^{D}$ represents the disutility an individual derives from the change and $v(.)^{Q} > v(.)^{D}$. Thus, the probability of choosing a forest amenity enhancement option will be greater under the development than no development information; we expect to observe a higher proportion of choices for an enhancement option from the development compared to no development responses. The testable null hypothesis is H_I: $\pi^{D}(j = 1 \mid w; D) > \pi^{N}(j = 1 \mid w; N)$. This outcome is not sensitive to the value given δ, but an interesting analysis arises under different risk assumptions. For more risk averse respondents, $\theta > \delta$ implying more weight assigned to the unfavorable outcome development, we would expect to observe a greater proportion of choices for the enhancement option than if respondents were risk inclined ($\delta > \theta$). If our survey had been designed to measure individual risk behavior, we could have stratified the analysis of choice and scenario specification by attitude toward risk to test these expectations.

CASE II

In contrast to CASE I, it is reasonable to believe that some individuals will perceive development as a positive alternative land use due to the potential welfare improving impacts of increased labor demand for home construction, increased property tax revenue, opportunities for business development, etc. That is, respondents would view residential use of the land as the highest valued and best use. In this case, $v(.)^D > v(.)^Q$, reflecting the utility an individual gains from the knowledge that the area will be converted to residential use. Accordingly, we expect to observe a lower frequency of choices for a forest amenity enhancement option with the development specification of the status quo over the no development specification. The null hypothesis is H_{II}: $\pi^N(j = 1 \mid w; N) > \pi^D(j = 1 \mid w; D)$. As before, specific values for δ would only change the distribution of choices and not the overall outcome.

CASE III

Respondents may not prefer to see the land use change from forest to residential but at the same time perceive forests to be unsafe because, for example, of a potential wildfire threat.[22] Consequently, they are indifferent to the development information in the description of the choice scenario. In this case, $v(.)^Q = v(.)^D$ and regardless of risk behavior $v(.)^Q + \varepsilon^Q \equiv \delta[v(.)^Q + \varepsilon^Q] + \theta[v(.)^D + \varepsilon^D]$ holds. Thus, we would expect to observe identical proportions of choices across the two scenario specifications with null hypothesis H_{III}: $\pi^D(j = 0 \mid w; D) = \pi^N(j = 0 \mid w; N)$, where j equal to zero indicates choice of the baseline or status quo (i.e., Plan A).

[22] Aggregating across both survey versions, 60 respondents (16% of total) stated that wildfire was the most significant threat to the future of Tennessee forests (as compared to urban/commercial development, chip mills/forest industry, and lack of State funding).

CASE IV

Last, if respondents prefer the status quo regardless of the information given in the scenario specification then $v(.)^D = 0$ (or $\delta = 1$) and $v(.)^Q > v(.)'$ in both equations [9] and [10]. This result implies that in either information setting respondents will choose the status quo option more frequently than a forest amenity enhancement option. Thus, the null hypothesis is H_{III}: $\pi^{D,N}(j = 0 \mid w; M) > \pi^{D,N}(j = 1 \mid w; M)$.

While Cases II through IV are immediately solved by the result for Case I, the contingency table applied in the analysis of I (Table 3) offers interesting insight into these potential outcomes. As an econometric test of an information effect, we tested the null hypothesis that the coefficient for dichotomous variable *Develop* (β_D) is not significantly different from zero (indicating no effect). The alternative hypothesis is that the development information will be perceived as negative by respondents and serve as an incentive to choose a forest amenity enhancement option (i.e., Case I). Accordingly, we expect to observe $\beta_D > 0$. Finally, we derived estimates of compensating variation to test whether respondent stated willingness to pay is different between the development and no development information specifications of the choice scenario. The testable hypothesis is H_a: $CV^D > CV^N$.

6. Results

6.1. Survey Respondents

Of the 3000 surveys mailed across 2 counties, 372 useable surveys were returned with 122 undeliverables, yielding a response rate of approximately 13 percent. While this rate is low compared to more traditional contingent valuation exercises it is within the range reported by previous studies employing a similar multiple choice set, choice modeling approach (Adamowicz et al. 1994, Farber and Griner 2000). Thirty percent of all choices ($N = 1860$)

Table 3
Conditional independence tests for choice by specification of choice scenario and land ownership[a]

Hypothesis Specification		Choice: Status Quo	Choice: Forest Amenity Improvement
Choice scenario			
No Development		345 (33%)[b]	700 (67%)
Development		216 (26%)	599 (74%)
Cochran–Mantel–Haenszel χ^2(df = 1)[c]	9.21*		
Land Ownership			
Less than 5 ac		380 (28%)	990 (72%)
More than 5 ac		181 (37%)	309 (63%)
Cochran–Mantel–Haenszel χ^2(df = 1)	14.99*		

[a] Conditional testing was also conducted by stratifying by county, gender, and land ownership with qualitative results consistent with those reported.
[b] Percentages in parentheses are calculated by dividing each cell value by its respective row total.
[c] Testing H_o: No association between specification and choice; * indicates significance at the 0.01 level.

were for the status quo (Plan A) payment level of zero, 23 percent for contribution amount $20, 29 percent for contribution amount $35, and the residual 11 and 7 percent for contribution amounts $50 and $75, respectively. Qualitatively, these results suggest that there is not a spike at either end of the contribution distribution and thus protest and yea-saying effects should be minimal. Analysis by county shows that Cumberland County recorded the greatest number of returned surveys with 279, representing 1395 individual choices, and Morgan County recorded 93 returned surveys with 465 choices. Relative to the number of surveys mailed to each county, Cumberland County reported a 14 percent response rate and 9 percent for Morgan County. The lower response rate for Morgan County was expected given its more rural status and may lead to a response bias in subsequent econometric modeling. A check for possible nonresponse bias was conducted via a short telephone interview with 100 randomly selected survey nonrespondents. Qualitative analysis of these results shows that on average nonrespondents were of similar age, held like attitudes toward forestry, and owned approximately an equal amount of land, yet were less educated and held lower household income when compared to respondents.[23] Thus, a potential response bias may be evident in the data.

Table 3 provides a contingency table of respondent choices by specification of the choice scenario. Analysis reveals that 67 percent (n_{12} = 700) and 74 percent (n_{22} = 599) of choices from the no development and development survey versions, respectively, were for one of the alternative forest amenity enhancement plans (i.e., non-zero contributions). Based on a Cochran-Mantel-Haenszel chi-square test of conditional independence between choice and specification of the choice scenario, the null hypothesis of no association was firmly rejected (p-value < 0.001). Thus, Case I in Section 3 represents the behavior of respondents to the development information. That is, respondents to the development specification of the choice scenario viewed this information negatively, or received disutility from the potential land use change, which then corresponded to a higher frequency of choices for an alternative to the status quo. As mentioned earlier, the result for Case I provides an immediate solution to Cases II through IV but further analysis of Table 3 reveals that a significantly lower proportion of zero contributions were stated by respondents given the development survey version (see Case III). Overall, these results indicate the significant influence researchers can have on respondent preferences and stated choices by simply altering the information set provided in constructed markets.

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[23] In total, 531 nonrespondents were randomly selected for the telephone administered nonresponse analysis. However, due to a variety of reasons, namely immediate refusal to participate in the telephone survey, only 100 surveys were completed. The most frequently reported reasons for not responding to the mail survey included: participants did not feel qualified to complete the survey (n = 16) and had no interest in forest amenities (n = 18). Least frequently reported reasons included budget constraints (n = 7) and survey was too long and complicated (n = 8). As a note, nearly two thirds of surveyed nonrespondents resided in Morgan County while for the sample of mail survey respondents three fourths resided in Cumberland County. A copy of the nonresponse interview form and complete analysis of the nonresponse component of this study are available from the authors.

6.2. Econometric Analysis

Results of multinomial logit (MNL) and panel random parameters (PRPL) model estimation of the pooled 372 completed surveys representing 1860 options chosen and 3720 options not chosen are listed in Table 4.[24] Since the PRPL model estimates the probability an individual will choose one of the forest amenity enhancement options (Option B or C) for each alternative, all of the information in the sample is applied in estimation. Accordingly, 5580 observations are applied in ML and only 1860 in MNL estimation. We present the results of a MNL model to illustrate the significant differences in preference modeling that can result if an inappropriate econometric model is applied to panel data generated within a discrete choice framework. As can be readily seen, all variables were significant and have one directional impact on the probability of choice in the MNL model while only 3 variables were significant and of one direction in the PRPL model. The policy implications of these inconsistencies are apparent and highlight the importance of searching out the most appropriate econometric representation of choice. The model fit is also greatly improved by modeling choice with the panel random parameters logit model, as indicated by the more positive log likelihood value and substantially higher value of McFadden's R^2. We apply results from the PRPL model for further analysis.

Similar to Revelt and Train (1998) and Train (1998), we believed certain variables would not explain choice independent of the others. Empirical model testing revealed that the coefficient for *Contribution Amount* was highly correlated with several variables, namely *Plan Score*. Logically, these two variables should move in a similar direction as it is infeasible to achieve a higher level of forest amenities without increasing the cost of provision. In order to

[24] A likelihood ratio test was conducted to test parameter (and preference) equality of respondents across the two survey versions. The null hypothesis H_o: $\gamma^N = \gamma^D$ was not rejected at any level (where γ is the vector of estimated parameters from the no development (*N*) and development (*D*) only samples; full estimation results are available from the authors).

Table 4
Multinomial logit and panel random parameters (PRP) logit model coefficients for choice among forest amenity enhancement options

	Multinomial Logit	PRP Logit (Corr. Coeff.)[a]	
Variable	Coeff.	Coeff.	Std. Dev.
Demographic Variables			
Cumberland	0.552	−3.371	4.048
	(4.524)[b]	(1.200)	(0.747)
Land Size	−0.011	−0.005	0.292
	(−4.198)	(−0.044)	(2.810)
Attitudinal Variable			
Knowledge	0.244	0.836	1.373
	(5.148)	(2.06)	(1.267)
Spatial (GIS/RS) Variable			
Forest Cover	−0.110	−0.251	2.686
	(−2.098)	(−0.455)	(2.105)
Survey Design Variables			
Develop	0.451	0.717	7.177
	(4.143)	(0.642)	(2.385)
Plan Score	0.506*	0.573	0.914
	(6.594)	(3.347)	(9.333)
Contribution	−0.025	−0.045	0.000
	(−9.208)	(−13.470)	(7.972)
Contribute ASC	−0.923	4.252	12.764
	(−3.948)	(1.253)	(2.0E+3)
$\ln L(\theta)$	−1939.91	−1596.12[c]	
Chi-square (df)	185.04 (8)	872.62 (38)	
McFadden's R^2	0.05	0.21	
N^d	1,850	5,580	

[a] Based on 1000 Halton sequences; normal distribution is specified for all coefficients; estimated in Limdep.
[b] Asymptotic *t*-statistic in parentheses.
[c] Simulated log likelihood value at convergence.
[d] Ten observations with missing information.

account for this interaction and other correlated variables, we report results of the PRPL specification with correlated coefficients. The PRPL model allows for multiple choices per person, yet spatial, attitudinal, and demographic attributes of each person remain constant across choices. In order for the model to be identified, these variables were interacted with *Contribute ASC*. All of the interaction terms except *Cumberland* were found to significantly influence choice and only *Knowledge* was found to have a one-directional impact on choice (Table 4). The coefficient for *Knowledge* is positive indicating perceived knowledge of forests and trees, and presumably, forest amenities, has a positive influence on the probability a forest amenity enhancement plan will be chosen. The insignificance of the standard deviation of *Knowledge* indicates this result held for all respondents. The marginal effect for *Knowledge* was also positive and implies that increasing perceived knowledge by one level increases the probability an enhancement plan will be chosen by 44 percent (see Table 5). These results suggest through improved education and outreach efforts (i.e., extension) residents in the study area may be more willing to support land management efforts that lead to improved forest amenities. If support did increase, landowners might have a viable alternative to preserve or enhance their forested holdings in the face of increasing development pressures.

Restricting attention to the coefficient column of the panel random parameters logit model, the insignificance of the mean coefficient value for *Forest Cover* suggests that there is no spatial information effect. However, since the PRPL model explicitly incorporates in estimation the randomness of the coefficient throughout the sample, measured by the coefficient's standard deviation, we find that the amount of forest land cover surrounding survey respondents does significantly influence their choice. A reason for the lack of significance in mean coefficient value for *Forest Cover* is the countervailing effects of the variable on respondents' decision-making process (Train 1998). For 54 percent of respondents

Table 5
Coefficient distribution and marginal effects[a]

Variable	Distribution[b]	Marginal Effects[c]
Land Size	(51 –, 49 +)	N.A.
Knowledge	N.A.	0.439
Forest Cover	(54 –, 46 +)	N.A.
Develop	(46 –, 54 +)	N.A.
Plan Score	(27 –, 73 +)	0.283
Contribution	(0 –, 100 +)	−0.268
Contribute ASC	(37 –, 63 +)	N.A.

[a] Based on coefficients from the panel random parameters logit model in Table 4. Notation N.A. pertains to coefficients that do not vary throughout the population (*Knowledge*) or do not have a significant mean parameter estimate (*Land Size*, *Forest Cover*, *Develop*, and *Contribute ASC*).
[b] The negative sign following the first value in each parentheses indicates the percent, or share, of respondents for whom the coefficient has a negative effect on the predicted probability of choosing a forest amenity enhancement option. Similarly, a positive sign indicates a positive effect on predicted probabilities. The distribution for each coefficient is calculated by constructing a standard normal deviate with the coefficient value and its respective standard deviation and then computing the probability of finding a value greater than the result (assuming standard normal distribution).
[c] Each marginal and partial effect measures the change in the probability an individual will choose one of the forest amenity enhancement plans (Plan B or C) given a change in the respective variable. Marginal effects are computed for each respondent and then averaged. We report the estimates for Plan C, which are nearly identical to those for Plan B.

forest cover negatively influenced their decision to choose a forest amenity enhancement plan while the influence was positive for 46 percent (Table 5). Based on respondent comments to the survey and the fact that the mean number of forested acres owned by respondents was approximately 10 while only 26 percent were landowners, the negative influence is driven by landowners in general and specifically, owners who would not manage their land for improved forest amenities if given the option. In order to statistically test this hypothesis we constructed an indicator variable separating landowners (*Land Size* > 5 ac) and non-landowners and then analyzed the frequency of choice by ownership category (Table 3). Similar to the earlier test of conditional independence for respondent choice by specification of the scenario, the results reveal significant association between forestland ownership and choice. The evidence against the null hypothesis of no association suggests landowners are less likely to choose a forest amenity enhancement option and more likely to choose the status quo compared to non-landowners.[25] Since forest landowners are surrounded by more forest land cover than non-landowners, we can tentatively conclude that responding landowners control the sign and distribution of the *Forest Cover* coefficient. Thus, a one directional affect cannot be determined and more weight lies in the negative tail of the distribution for *Forest Cover*.

The results for the coefficient distribution of *Land Size* nearly mirror those of *Forest Cover* and provide further evidence that owning land is a negative factor in the decision to contribute to improved forest amenities. For 51 percent of respondents, owning more land negatively influenced their choice of a forest amenity enhancement plan. However, by identifying and investigating the 49 percent of respondents for which land ownership positively influenced choice we may be able to identify a common set of factors that explain the relationship. Incorporation of this information in extension programs to landowners could improve the effectiveness of such programs and potentially increase landowner support for improving forest amenities.

The insignificant mean value and significant standard deviation for the *Develop* coefficient indicates that land use change information does affect respondent preferences and stated choices but not in a one directional manner. The new information was perceived as a potential detrimental outcome and served as an incentive to choose a forest amenity enhancement plan for 54 percent of respondents (supporting Case I). However, for the residual 46 percent the new information was perceived as providing potential positive benefits and thereby served as a disincentive to choose an enhancement plan (Case II). The distribution of the *Develop* coefficient provides evidence in support of the aspatial information effects hypothesis (H_a: $\beta_D > 0$), yet the large proportion of respondents for whom the information was perceived in a

[25] Landowners could have tended to choose the status quo more often than one of the forest amenity enhancement options because they already have a sufficient level of forest amenities. Thus, they are content with the status quo. The general result of choosing the status quo, though, does not exclude the possibility that landowners may be willing to manage their land for improved forest amenities.

positive light precludes broad generalization. Referring back to earlier discussion of the multinomial and panel random parameters logit models, if the MNL was the sole econometric model for analyzing choice we would have concluded strongly in favor of the hypothesis H_a: $\beta_D > 0$. This result, while generally in the right direction, would have implied that all respondents assign identical weight to the land use change information. The information gained from estimating PRPL models minimizes such generalized and possibly inaccurate conclusions.

The mean coefficient value for the variable measuring influence of aggregate forest amenity enhancement quality (*Plan Score*) on respondent preferences is highly significant and positive indicating that forest amenities collectively have a positive affect on choice. Additionally, the standard deviation is highly significant with the overwhelming majority of respondents (73 percent) preferring improved forest amenities. The marginal effect for *Plan Score* indicates that a one unit increase in the aggregate level of amenities increases the probability of choosing an enhancement plan by 27 percent. These results imply respondents prefer forest amenities and are willing to contribute to improve amenity supply. Comparison of the coefficient distribution for *Plan Score* and respondent land ownership yields an interesting correspondence between the number of responding landowners (98 or 26 percent) and the 27 percent of respondents for whom forest amenities had a negative affect on choice. This correspondence suggests that while the minority of survey respondents are landowners, they collectively control the physical supply of forest amenities (and coefficient distribution of *Forest Cover*) and are generally not in favor of undertaking management activities to improve them. A disconnect is clearly present between demand, represented by respondents that support enhanced forest amenities, and supply. Progress toward the improvement of forest amenities is contingent upon resolution of this issue, which in turn depends on increasing landowner knowledge of forest amenity benefits and development of additional compensation mechanisms.

The negative and highly significant mean coefficient for *Contribution* accords with expectations and indicates that forest amenities are a normal good. Moreover, as expected increases in contribution levels negatively influenced the choice of a forest amenity enhancement plan for all survey respondents.[26] However, an increase in *Contribution* has the smallest marginal effect (in absolute value) on the probability a respondent will choose a forest amenity enhancement plan. The mean value of the coefficient for the alternative specific constant *Contribute ASC* is insignificant but the standard deviation is highly significant. The coefficient distribution for *Contribute ASC* implies that the majority of respondents (63 percent) have strong underlying preferences for an enhancement plan (Plan B or C) while only 37 percent prefer the status quo (Plan A).

7. Implications and Conclusions

The results of econometric modeling of respondent choice between forest amenity enhancement plans reveal the ability of researchers to influence preferences and ultimately, choice in constructed markets. It follows that if choice is conditional on market framing then stated willingness to pay should be as well. If WTP varied in predictable patterns based on changes in framing, then researchers and policy makers could account on an ad hoc basis for new information that came forward after the constructed market was administered or for mistakes in the original design by simply adjusting the results accordingly. However, WTP does not vary systematically and the direction of influence a researcher has on respondent preferences and choices can vary through the sample such that quantifying an adjustment

[26] Given that the sign of *Contribution* was negative for all respondents, we re-estimated the PRPL model with *Contribution* specified to follow a lognormal distribution. Estimation results between the two models are qualitatively similar.

factor would be complicated at best. Thus, information effects on choice and stated willingness to pay should be assessed on a case by case basis. In this study, we extend earlier findings of spatial and aspatial information effects to evaluate whether stated willingness to pay is influenced by new information and the amount of forest land cover surrounding a respondent as well as the specification of the econometric model.[27]

For the aspatial information effect, we compared differences in stated willingness to pay across choice scenario specifications for a policy change that involved an improvement in the current level of forest amenities from the status quo (*Plan Score* = 0) to a moderate level of provision (*Plan Score* = 2). WTP estimates for these two policy scenarios are based on estimated parameters from the multinomial (MNL) and correlated coefficients, panel random parameters logit (PRPL) models. Despite theoretical and mathematical differences between the two logit models the same equation is applied for calculating changes in WTP (Train 1998, p. 236). Accordingly, the change in willingness to pay for an improvement from the status quo level of forest amenities q^o to q^*, holding utility and all other factors constant, is given by:

$$CV = -1/\beta_{Contribute}\,(\gamma' x^o - \gamma' x^*) \qquad [11]$$

where CV is the Hicksian welfare measure, x is a vector that includes both choice variant and invariant attributes, superscript o denotes the status quo, the asterisk denotes the improved level, and γ is a conformable vector of estimated parameters. The estimation of CV by econometric model and choice scenario gives rise to four welfare estimates for the proposed policy changes. Controlling for information effects, Hicksian welfare estimates of \$25.53 and \$39.71, based on PRPL and MNL coefficients, respectively, result from increasing forest

[27] For this section of the analysis, we are interested in the magnitude as opposed to exact willingness to pay for improved forest amenities.

amenities to a moderate level (Table 6).[28] However, evaluating the same policy change but accounting for a situation where new information about possible future residential development is introduced into the constructed market yields Hicksian welfare estimates of $41.50 (PRPL) and $57.42 (MNL). A statistical comparison of these four estimates shows that the new information significantly increases *CV* both within and across model specifications with the MNL model consistently yielding higher estimates (Table 6). Thus, researchers can influence preferences, choices, *and* willingness to pay for environmental improvements solicited in choice modeling based questionnaires. Furthermore, econometric model misspecification can result in significant differences in estimated welfare impacts of alternative policies.

The test for differences in estimated Hicksian welfare values for the spatial information effects hypothesis was conducted by specifying the same policy change (*Plan Score* 0 to 2) but assuming a five percent reduction in mean forest cover. We based this reduction on a land use change analysis of our study area (Strickland 2003) that predicts 10 percent conversion of all forested areas to developed uses between year 2000 and 2010. Assuming a uniform conversion rate over the sampled time period (10 years), total forest loss during the 5 year time horizon for contributing to improved forest amenities, as specified in the survey, would approximate 5 percent. Incorporating this reduction into the proposed policy change yields Hicksian welfare estimates of $41.34 (MNL) and $27.64 (PRPL) (Table 6). These estimates are only $1.63 and $2.11 higher than similar estimates for a policy change with no accompanying forest conversion. The closeness of these values to each other and zero suggests that spatial information in the form of forest loss does not significantly change individual willingness to pay for improved forest amenities. However, this result is more than

[28] As a note, given the insignificance of the mean coefficient value and standard deviation of county residence indicator *Cumberland* there should be no county-induced response bias on any of the estimated welfare measures.

Table 6
Hicksian welfare estimates by econometric model and policy scenario for improved forest amenities[a]

Policy Scenario[b]	Multinomial logit coefficients	Panel random parameters logit coefficients
Aspatial Information Effect		
Develop = 0 (or 1)	\$39.71* (\$27.48, \$51.94)[c]	\$25.53* (\$18.43, \$32.64)
Develop = 0 vs. *Develop* = 1	\$57.42* (\$39.69, \$75.16)	\$41.50* (\$32.02, \$50.98)
Spatial Information Effect		
5% reduction in *Forest Cover*	\$41.34* (\$28.88, \$53.79)	\$27.64 (\$20.51, \$34.77)

[a] * indicates rejection at the 99 percent confidence level of H_o: $CV_i = CV_j$, where i and j ($i \neq j$) index estimated Hicksian welfare estimates, based on an asymptotic t test and the standard normal distribution. Hypothesis tests were not conducted across information effects.
[b] The same policy change of an increase in *Plan Score* from the status quo level of 0 to a moderate provision level 2 is specified for each set of welfare estimates. In the first set, the welfare estimates are invariant to the information effects dummy since all other factors remain constant except *Plan Score.*
[c] 95 percent confidence intervals calculated by the delta method (Greene 2000, p. 70).

likely driven by the proportion of responding forest landowners, who have greater mean levels of forest cover around their residences than non-landowners and generally prefer the status quo (and associated \$0 contribution amount). If this is the case, then an alternative interpretation of the low welfare estimates could be it is not the additional willingness to pay that should interest policy makers or forest managers but instead the number of potential new contributors. That is, individuals who transition over time from rural to urban as a consequence of land use change.

In summary, this study combined spatial data collected from geographic information systems and remotely sensed imagery and aspatial data from a choice modeling based constructed market to investigate information effects on stated preferences for forest amenity improvements. The results show that researchers can influence preferences and correspondingly, choice and willingness to pay, by altering the circumstances in which preferences are formed, choices are made, and WTP is stated. However, in both cases of information effects the direction of impact was not one-directional in that for a proportion of participants influence was positive and negative for the others. This result is provided by random parameters logit estimation of choice yet masked by multinomial logit estimation. Information about future potential land use change served as an additional incentive to contribute to improved forest amenities by the majority of respondents. The high number of respondents for which development was seen as a negative incentive to contribute reflects strong preferences for the benefits associated with urban development. Thus, the future of a program promoting improved forest amenity management will involve educating residents of the benefits of forest amenities and tradeoffs associated with development.

This study also found that the amount of forest land cover surrounding survey respondents influences choice for improved forest amenities. The uniqueness of this finding is that to date no other published study has incorporated spatial land cover information in a stated choice framework. The addition of a spatial variable allowed us to uncover interesting results relating increases in urbanization to potential increases in respondents willing to contribute to improve forest amenities as well as relating forestland ownership to preferences for the status quo level of amenities. These results support earlier findings that suggest a significant disconnect between forest amenity demand and supply. Increasing forestry knowledge for both landowners and non-landowners may be a promising means for aligning the disparate interests. Future research can build on these findings by investigating the effect of less subtle changes in market framing, incorporating additional land cover classes in the participant's information set, and applying nonlinear probability models that explicitly incorporate preference heterogeneity and panel data.

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Part 4

Toward Valuing Anthropogenic Impacts and Ecological Relationships in Forested Wetlands Using Spatial Econometric Models

This chapter is a slightly revised version of a paper by the same name submitted to the *Journal of Environmental Economics and Management* in 2004 by Aaron R. Wells, Aaron R. Pierce, and Donald G. Hodges. My use of the word "we" in this chapter refers to my co-authors and myself. My primary contributions to this paper include (1) development of the problem into a work relevant to my study of environmental valuation, (2) development of the implicit valuation model, (3) incorporation of geographic information systems, (4) most of the gathering and interpretation of the literature, (5) econometric models, (6) most of the analysis, and (7) most of the writing. ......

Abstract

This study presents economic values for specific ecological relationships and negative externalities associated with channelization that affect the productivity and overall market value of forested wetlands. To estimate these values, we develop and apply a spatial theoretic, implicit valuation model to microlevel ecological data in the Hatchie River Watershed, USA. Several functional forms for both the model and underlying spatial dependence are applied in nonparametric spatial econometric estimation of the valuation model. The results of robust, generalized moments estimation of double logarithmic spatial autoregressive error models (spatial dependence up to 1500m) indicate that the implicit cost of damages to forested wetlands caused by channelization is –\$5,438 ha^{-1}. Results presented here are subject to the usual disclaimer of being site specific and temporally sensitive, thus future research investigating additional variables across differing forested wetland conditions and periods is recommended in order to bring legitimacy to the proposed valuation model.

Keywords: Forested wetlands; Channelization; Implicit valuation; Spatial interaction

1. Introduction

The ecology of forested wetlands, or bottomland hardwood forests, has been researched extensively (Happ et al. 1940, Shelford 1954, Hosner 1960, Keeley 1979, Clark and

Benforado 1981, Wharton et al. 1982, Elder 1985, Gosselink et al. 1990, Kellison and Young 1997, Mitsch and Gosselink 2000). Research in these areas has provided valuable information toward appreciating and understanding the complex functions and values forested wetlands provide such as water quality enhancement, nutrient transformation, flood abatement, wildlife habitat, recreation, aesthetics, and wood products. Similarly, research has furthered the state of knowledge regarding anthropogenic impacts, primarily, agricultural development, timber harvesting, and hydrologic modifications such as channelization, on the ecological functioning of forested wetlands (Heitmeyer and Fredrickson 1981, Hupp and Simon 1991, Hunter et al. 1993, Hoover and Kilgore 1997, Lockaby et al. 1997, Perison et al. 1997). However, economic analysis of damages to and benefits of these ecosystems has been pursued to a lesser extent.

The objective of this paper is to introduce a framework for estimating the economic value of attributes affecting productivity and market value of forested wetlands in the Hatchie River Watershed, USA. Specifically, we employ spatial econometric procedures and a hedonic-type model to develop a set of implicit prices for the negative externalities associated with channelization and excessive sedimentation. Additionally, we empirically explore fundamental ecological relationships between the value of a forested wetland and its location. The appeal of the model we present is that it is spatial theoretic, based on a limited number of plausible assumptions, and capable of valuing cumulative damages to forested wetlands. To date, this damage valuation model and corresponding empirical methods have not been applied to the economic analysis of forested wetlands. Previous research has focused instead on the economic value that wetlands in general provide to society using aspatial econometric techniques or have applied nonmarket valuation methods for more site-specific valuation purposes (Kaxmierczak 2001, Woodward and Wui 2001). While this research helps to demonstrate the dependence of society on these unique ecosystems, and more importantly, draw attention to the significance of a diminishing supply, it does not address cumulative damages or specific factors affecting wetland functioning on any relevant temporal and watershed scale.

Alternative valuation methodologies that have been used to estimate damages to wetlands include individual service valuation (Hickman 1990), net factor income, replacement cost, and energy analysis approaches as well as nonmarket techniques.[29] The individual service valuation approach assumes that the value of a wetland can be determined by first subdividing the system into multiple, noncompetitive market-based services. For example, the benefits of employment and higher property values associated with fishery habitat and flood abatement services. The benefits of these services are then aggregated to derive the total economic value of the wetland. Problems with the individual service valuation approach include potential double counting of service benefits, focus on market as opposed to ecological benefits, and aggregation. Despite these problems, several valuation studies have been conducted on the basis of this method (Thibodeau and Ostro 1981, Thomas et al. 1981, Costanza et al. 1989, Whitehead and Blomquist 1991, Gren et al. 1995). Wetland valuation based on the net factor income approach relies on a direct relationship between the aerial extent of a wetland and firm profit or productivity. Increases in wetland acreage are assumed to result in increased firm profit, and benefiting firms are expected to be willing to pay for improved wetland services in order to secure this additional profit. The problem with the net factor income method is that it can only be used to measure the use values of a wetland in terms of its relationship to firm productivity (Whitehead 1990). The replacement cost method of wetland valuation simply

[29] Most of the published research in this area has focused on wetlands in general and not on forested wetlands in particular. Thus, emphasis is placed on wetlands valuation. Additionally, alternative valuation methods have been applied to wetlands, such as the value estimator model (Bergstrom and Stoll 1993) and the opportunity cost of forgone development (Batie and Mabbs-Zeno 1985), but are not discussed in detail here.

measures the value of wetland services as the economic cost of the least expensive alternative capable of achieving the same services (Bystrom 2000, Woodward and Wui 2001). A problem with this method is finding an alternative that can adequately replicate the services provided by the existing wetland resource and then gaining societal and/or (potential) damager approval of said alternative. Lastly, the energy analysis approach to wetland valuation assumes an ecological economic perspective in that the value of a wetland is reflected in the total work accomplished by the wetland for society (Gosselink et al. 1974, Farber and Costanza 1987, Costanza et al. 1989). The usefulness of this method is limited by a number of significant assumptions, notably, the sole value of the wetland is its energy content.

In contrast to the market and ecosystem perspectives of the above methods, nonmarket valuation techniques are based on the values individual economic agents hold for wetlands. Revealed preference nonmarket techniques, such as hedonic pricing and travel cost, are used to econometrically estimate the value of a wetland by relying on an indirect relationship between the wetland and individual transactions for related market goods. The values estimated are referred to as (indirect) use values and are a measure of the usefulness of wetlands to an individual (e.g., water filtration). Most of the revealed preference research for wetland valuation has applied the travel cost method with recreation as the related good (Raphael and Jaworski 1979, Miller and Hay 1981, Thibodeau and Ostro 1981, Farber 1988, Creel and Loomis 1992, van Vuuren and Roy 1993, Doss and Taff 1996, Mahan et al. 2000, Bennett and Whitten 2003). Primary drawbacks with using revealed preference methods for valuing changes in wetland quality and availability include site-specific information, which complicates aggregation, and failure to capture nonuse values of wetlands.

Stated preference nonmarket valuation techniques, such as choice modeling and contingent valuation, utilize hypothetical markets constructed within survey instruments to directly obtain the willingness to pay of an individual for wetland services. These techniques have the capability of deriving values society places on wetlands external to their role in the economy, e.g., value of habitat for endangered species, as well as use values. The majority of stated preference studies of wetland valuation have applied the contingent valuation method (Thibodeau and Ostro 1981, Farber and Costanza 1987, Farber 1988, Bergstrom et al. 1990, Whitehead 1990, Loomis et al. 1991, Lupi et al. 1991, Whitehead and Blomquist 1991, Stevens et al. 1995, Pate and Loomis 1997, Morrison et al. 1999, Oglethorpe and Miliadou 2000, Spash 2000, Bennett 2001, Randall et al. 2001, Johnston et al. 2002). A principal argument against stated preference techniques is that hypothetical markets yield hypothetical values, which should not be used for real world policy and project analysis, especially in the case of unique environmental assets such as wetlands.

The model we develop adopts a revealed preference methodology, in particular, the hedonic price method, such that the economic value of nonmarket attributes of forested wetlands is inferred through the prices buyers are willing to pay for merchantable wood. We assume that the values of these attributes vary across the watershed depending on their geographic location, that is, values are not randomly assigned, thus a form of spatial dependence or interaction is present. This dependence may help to explain variability in prices paid for merchantable wood and ignoring such dependence may result in a misspecified model that over or under reports the magnitude of nonmarket attribute values. We employ spatial econometric techniques to empirically test for and explicitly incorporate the influence of spatially interactive nonmarket attributes on predicted wood values in our valuation model. We then discuss the results from the perspective of justifying stream and wetland restoration efforts and improving resource management in forested wetlands.

The remainder of the paper is outlined as follows: section 2 describes the study area, identifies the issues, and explains the field methods; section 3 establishes the spatial theoretic model; sections 4 and 5 provide estimation results and the implicit values; a concluding section summarizes the research and recommends future directions for valuing damages to forested wetlands.

2. Study Area

2.1. Hatchie River Watershed

Our study area spans three counties (Haywood, Madison, and Hardeman) in the upper portion of the lower Hatchie River Watershed (HRW) in West Tennessee. The HRW lies within the Lower Mississippi Alluvial Valley (LMAV) and Upper East Gulf Coastal Plain and comprises approximately 6,736 square km (USDA 1986), 55,848 ha of which is bottomland hardwood (BLH) forest (16 percent of all BLH in TN) (Schweitzer 2000). A principal river draining the HRW is the Hatchie River, which has been designated one of 13 State Scenic Rivers and one of the 75 "Last Great Places" by the Nature Conservancy. The Hatchie River is the longest unchannelized river remaining in the LMAV, however many of its tributaries have been channelized. Primary physical characteristics of the study area include flat topography, seasonal and permanent flooding, soils dominated by fine wind-blown soil (loess), and an oak-hickory forest cover type.

2.2. Issue Identification

Soil erosion and excessive sedimentation are the critical issues for forested wetland ecosystems in the HRW. Erosion typically can lead to loss of upland areas, unstable channel bank conditions, incised stream channels, and loss of vegetation along stream banks, all having negative impacts on forested wetlands. Sedimentation is a normal process in wetland ecosystems that provides several benefits including replenished nutrients and fertile soil. Human interactions have accelerated this process, however, negatively altering functional processes of forested wetlands, such as nutrient cycling and flood abatement. Moreover, when excessive sedimentation is combined with changes in channel slope or debris jams, valley plugs and alluvial fans are created. These geomorphic structures cause increased overbank flooding and excessive sand deposition in the floodplain. As a result, the floodplain system is damaged in several ways including: degraded aquatic habitats, reduced flood capacity, increased water table level, creation of natural levees, increased flooding and ponding of water that affects the survival, growth and regeneration of bottomland hardwood tree species, burying fertile soils with infertile sand and gravel, and increased lateral erosion (Happ et al. 1940). Diehl (2000) has recorded over 35 valley plugs across the Hatchie River Watershed, with two-thirds located in our study area.

Past and present land use practices, namely agricultural development and forest harvesting, in combination with channelization, have and continue to be the driving factors behind soil erosion and excessive sedimentation. These factors have led to erosion of the thin loess layer of the region, exposing and eroding the coarse alluvium sands beneath, thereby resulting in massive gully erosion. An estimated 580 million kilograms of sediment accumulates in the Hatchie River every year (USDA 1986). One of the most significant contributors is channelization, which refers to the straightening and dredging of a stream channel for flood control or navigational purposes. Such alterations cause a degradation of the stream channel and lead to channel erosion (Robbins and Simon 1983, Simon and Hupp 1987, Simon 1994). Several studies on sediment dynamics in West Tennessee suggest that channelization results in bed-level lowering and stream degradation (Hupp and Simon 1986, Darby and Simon 1999, Diehl 2000). Additionally, channel alterations caused by channelization combine to increase stream velocity and power, which enables the stream to transport and deposit increased quantities of sediment downstream and into the floodplain (Gilvear and Bravard 1996). In the HRW, 92 percent of the major tributaries have been channelized and since channelization of these tributaries, the main channel of the Hatchie River has become shallower and flooding has increased (USDA 1986). The emphasis of this paper and corresponding valuation model is on monetizing the impacts (or negative externalities) of channelization on forested wetlands in the HRW.

2.3 Field Plots

In order to apply a spatial, hedonic-type model to value factors affecting forested wetlands, a large number of field plots located across the continuum of ecological site conditions was necessary. Accordingly, 357 fixed-radius, circular plots were established along the Hatchie River and 5 different tributaries of the Hatchie River during Summer 2002 (Figure 3). The tributaries were selected by degree of hydrologic impairment and access, with the latter being the most limiting factor. Thirty three percent of the field plots were located on Federal lands (Hatchie National Wildlife Refugee) with the residual established on private, nonindustrial lands.

At each site, field plots were established at 50m increments along transects located 200m apart and perpendicular to the selected tributary, with the first plot at the stream bank. Approximately 40 site measurements were recorded per field plot, with each plot containing three sub-plots defined by different radii. Within the $1m^2$ inner circular plot (1m radius), groundflora data were collected including species, average herbaceous height, and litter depth. Species and diameter at breast height (DBH) of saplings, defined by DBH between 4 and

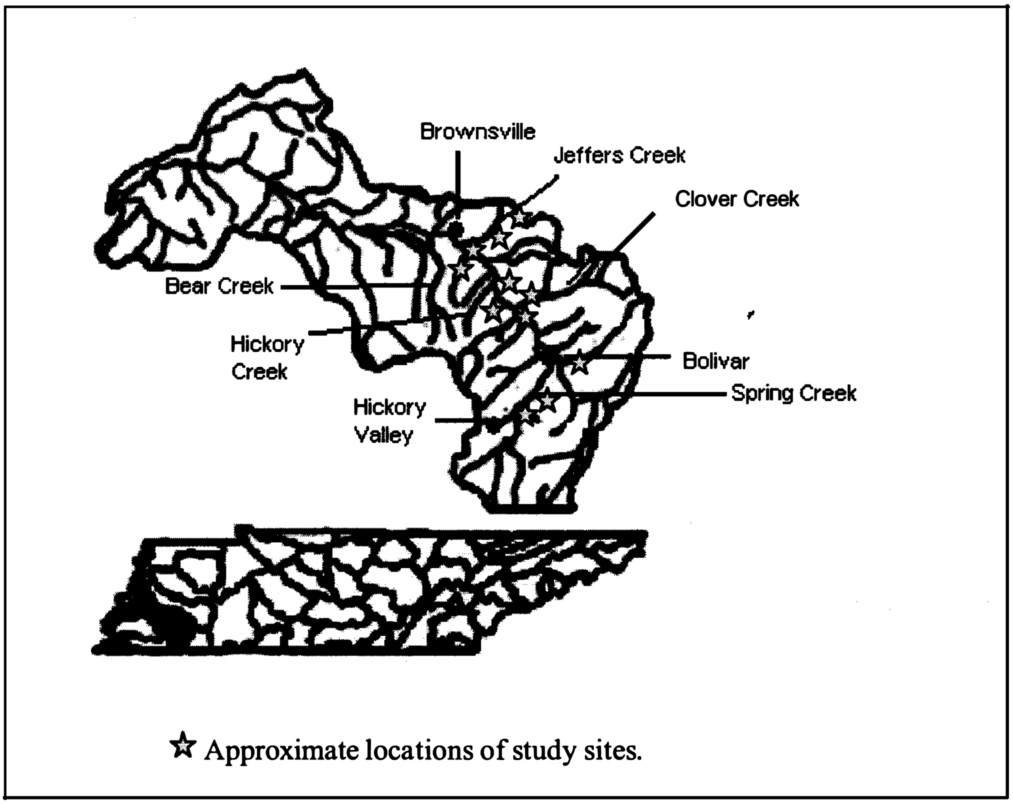
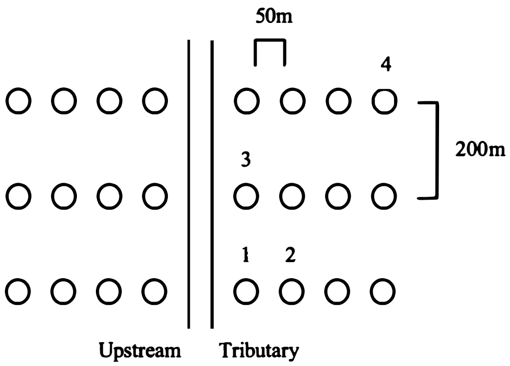


Figure 3
Map of Hatchie River Watershed and location of study streams.

and 10 cm, species and number of both seedlings (greater than 1m in height) and shrubs, and average sapling and shrub height measurements were recorded in the 0.004ha circular plot (5.6m radius). Information for all tree species greater than 10cm DBH, including canopy position, total height, sawtimber height, and stem quality were collected in the 0.04 ha outer circular plot (11.3m radius). See Figure 4 for an example design applied in field data collection. Additional measurements within each plot included ocular estimates of the stand structure (even or uneven aged), stand development stage (initiation, stem exclusion, transition or old growth), past disturbance (logging, fire, flooding, and combinations thereof), Field plot design for a representative site



Binary contiguity form of spatial weights matrix *Z* (d_{ij}* = 50m).

Field Plots	1	2	3	4
1	0	1	0	0
2	1	0	0	0
3	0	0	0	0
4	0	0	0	0

Inverse distance form of spatial weights matrix *Z*.

Field Plots	1	2	3	4
1	0	0.0200	0.0050	0.0023
2	0.0200	0	0.0049	0.0024
3	0.0050	0.0049	0	0.004
4	0.0023	0.0024	0.004	0

Figure 4
Example binary contiguity and inverse distance weight specifications for the spatial weights matrix *Z*, based on the field plot design applied in the data collection phase of this study.

disturbance severity (light, moderate or severe) and time since disturbance (0-5, 5-25 or >25 yrs). Finally, site information such as presence of water within the plot, percent canopy cover (determined with a site tube at plot center and from four points on the edge of the $1m^2$ plot), and the number and species of logs, snags, and stumps were collected at each plot. Collectively, all of the measured site attributes constitute microlevel data on the ecological condition and state of forest productivity at each plot.

3. Spatial Theoretic Model

3.1 Spatial Ecological Econometrics: Basic Principles

The interaction of ecological and anthropogenic factors influencing forested wetland productivity and market value across the watershed motivates the use of spatial econometric models. To model productivity otherwise would require the restrictive and unrealistic assumption that ecological units, defined either by research requirements (e.g., field plot) or by the ecosystem (e.g., watershed), are unconnected or islands across the landscape. Under the island framework, only site specific factors affect productivity at the site and cross-site nutrient, climate, and related ecological interactions are ignored. Ecological research has shown that this assumption does not hold (Robbins and Simon 1983, Rossi et al. 1992, Legendre 1993), thus a framework that explicitly incorporates spatial interaction can be designed based on both theoretical and data-driven reasons.

A basic spatial theoretic model of ecological interaction states that the productivity at plot i is implicitly determined by on-site *and* neighboring plot attributes:

$$q_i = q(r_i, s_i; q_{-i}) \qquad \forall\, i \in J \qquad [1]$$

where q_i is a scalar measure of ecological productivity (e.g., number of understory plant species), r_i is a $1 \times k$ row vector of measured plot attributes, s_i is a $1 \times k^*$ row vector of unmeasured plot attributes (where $k \cup k^* = K$), q_{-i} is a $1 \times k$ row vector of attributes defining productivity at all plots other than i, and J indexes plots. The separation of q_i into measured and unmeasured components is necessary for ecological research since it is never practical or feasible to collect data on all attributes affecting site productivity. The inclusion of q_{-i} is also a necessary addition to the spatial implicit model of site productivity and implies spatial interaction between/among neighboring sites. This formulation (i.e., q_{-i}) is similar to the model of interacting agents in the public economics literature (see Brueckner 2003).

The implicit spatial interaction specified in equation [40] can be explicitly modeled through a spatial lag or a spatial error model (Anselin 1988).[30] The spatial lag model includes a spatially lagged dependent variable ($Z\boldsymbol{Q}$), computed as the weighted sum of values of q at all neighboring locations, as a separate term in the set of explanatory variables. Accordingly, the spatial lag model for equation [1] is

$$Q = \phi Z\boldsymbol{Q} + X\beta + \mu \qquad [2]$$

where Q is a $J \times 1$ vector of site productivity, Z is the $J \times J$ spatial weights matrix, $\boldsymbol{Q}$ is a $J \times 1$ vector of spatially lagged dependent values, ϕ is the spatial autoregressive coefficient, X is a $J \times k$ matrix of measurements on R (where R denotes measured attributes across all plots), β is a $k \times 1$ matrix of coefficients and μ is assumed to be a $J \times 1$ vector of independent and identically distributed (i.i.d.) error terms with mean zero and constant variance $I\sigma^2$. A spatial

[30] Equation [1] can also be modeled with higher order models such as spatial lag with spatial error components or models that incorporate spatial heterogeneity through spatial regimes.

lag model might be specified for equation [1] if theory suggested that productivity across sites was functionally dependent on the productivity at each neighboring site.

In contrast to the spatial lag model, the spatial error specification models the spatial interaction among sites through the error term:

$$Q = X\beta + \mu$$

$$\mu = \lambda Z\mu + \varepsilon \qquad [3]$$

where λ is the spatial autoregressive parameter that is jointly estimated with the other model parameters β, $Z\mu$ is the spatially lagged error term, and ε is a $J \times 1$ vector of i.i.d. error terms with zero mean and constant variance Ω (and all other terms are explained above). The error component for Q will equal ε if Z is nonzero for some elements and there is insignificant correlation of unobserved site attributes across neighboring plots. In the case of a significant spatial autoregressive parameter, the spatial error model captures the influence of both the measured attributes R and the omitted attributes S (where S is an aggregate index of unmeasured attributes across all plots) on the productivity at site i. Thus, in this formulation, unobserved or unmeasured on-site and neighboring attributes play a significant role in explaining differences in site productivity across space.

Spatial econometric estimation of equation [1] with either the spatial lag or spatial error model depends critically on the specification of the spatial weights matrix Z. Generally, zero elements of Z indicate islands and nonzero elements measure the weight of association between neighbors. Formally, Z is a $J \times J$ matrix with elements z_{ij} corresponding to the

Euclidean distance between two points i and j (denoted d_{ij}).[31] The diagonal elements of Z (z_{ii}) are set equal to zero indicating that an observation is not a neighbor to itself (Anselin 2004). If some element z_{ij} has $d_{ij} > 0$, then the researcher can specify a particular weight (or functional form) to the element. Commonly used forms include binary weights (based on either first or second order contiguity), inverse distance weights (such as the "gravity index"), and k-nearest neighbors (used primarily in real estate analyses). For binary weights, $z_{ij} = 1$ if i and j share a common border (first order binary contiguity) and zero otherwise; alternatively, $z_{ij} = 1$ if i and j are not adjacent, but through a common border with l, are contiguous (second order binary contiguity). Binary weights based on contiguity can also be computed for points, such as polygon centroids, using a distance criterion. For example, two points i and j are neighbors ($z_{ij} = 1$) if the distance between them is less than some cut-off distance (i.e., $d_{ij}^{*} \geq d_{ij}$). Inverse distance weights for z_{ij} are computed as $1/d_{ij}^{\tau}$ ($\tau \geq 1$) and imply decreasing association between two sites with increasing separation. This form of spatial weight seems appropriate in ecological research since attribute interaction will tend to be stronger with increasing proximity. The k-nearest neighbors specification requires each z_{ij} to have the same number of neighbors, thus eliminating islands and reducing variability in Z. Figure 4 presents two 4×4 spatial weights matrices Z using binary and inverse distance weights for the field plot design employed in this study.

3.2. Spatial Ecological Econometrics in Site Attribute Pricing

Since ecological relationships and negative externalities associated with channelization are by definition unpriced and hypothesized to vary by geographical location, we employ a spatial

[31] Computation of spatial weights matrix Z (and hence d_{ij}) requires georeferenced coordinates for each site. For this study, global positioning system units were used to collect the latitude and longitude of each plot center.

implicit econometric model to monetize site attributes. The theoretical development of the model is based on the hedonic price method (Freeman 1993, Rosen 1974), whereby the effects of ecological and anthropogenic factors are assumed to be capitalized into the market value of merchantable pulpwood and sawtimber. Monetary values for individual site attributes are then econometrically estimated through an indirect relationship between the market value of merchantable wood and the attributes. A principal assumption underlying our model is that as the quality of site attributes increases (for example, more productive soils), both forest productivity (measured by volume ha^{-1}) and percentage of preferred tree species increase, and overall, the market value of merchantable wood increases because a buyer would be willing to pay a premium for these higher quality forests. The ecological component of this assumption is supported by decades of research in bottomland hardwood forests (e.g., Hodges 1997) and the willingness to pay component follows from economic theory, thus lending credibility to the model. Additional model assumptions are provided over the course of the next several equations.

Given the theoretical structure presented in equation [1], spatial econometric models are necessary in order to explicitly incorporate spatial interaction in the data. Ignoring this interaction in model estimation affects the significance and magnitudes of the coefficients (Anselin 1988, Anselin et al. 1996), which in our case are the basis for determining the economic value of unpriced site attributes (namely, externalities of channelization). Thus, we are motivated to use spatial econometric models on both theoretical and empirical considerations.

The dependent variable in the spatial implicit valuation model is the aggregate market value of all measured trees greater than 10 cm diameter at breast height (DBH), in each field plot:

$$W_i = \sum_{m=1}^{M} \delta^P_m V^P_{mi} + \sum_{n=1}^{N} \delta^T_n V^T_{ni} \quad [4]$$

where W is the market price of wood volume, V denotes cords (ft^3) of pulpwood (P) and thousand board feet (ft^2) of sawtimber (T), δ denotes the delivered price per unit of V, i indexes field plots, m indexes pulpwood species groups, and n indexes sawtimber species and groups.[32] The total market value W varies across plots due to different species compositions,

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[32] Market prices for pulpwood (DBH < 30.5cm) and sawtimber (DBH ≥ 30.5cm) were derived from the July–September 2002 Tennessee Department of Agriculture, Division of Forestry's Wood Products Bulletin (WPB) (Tennessee Department of Agriculture, 2002). The WPB lists delivered timber prices per thousand board feet (mbf), Doyle Rule, for specific species (e.g., tulip poplar), species groups (e.g., red oak), and a miscellaneous category, which includes boxelder and elm species. Pulpwood prices are reported as delivered prices per cord (90 ft^3 of solid wood and bark per cord) and based on the general product class "hardwood". Delivered prices are presently the only viable market data available for merchantable wood in our study area. The alternative of stumpage prices is not feasible given limited species-specific price information. A concern with delivered prices in our model is that we must assume buyers implicitly value the site attributes that contributed to the growth of the purchased wood. This relationship can be shown mathematically using a series of implicit functions. First, express V in equation [4] as a function of q_i:

$$V_i = v(q_i) \qquad \forall\, i \in J \quad [5]$$

so that the total quantity of merchantable wood at each site (i.e., field plot) i is a function of the quality at the site. Next, decompose the measurable component of equation [1], r_i, so that it is equal to:

$$r_i = r(t_i, y_i) \quad [6]$$

where t comprises the measurable components at the site that the buyer is most concerned with, e.g., species, DBH, height, and overall tree quality, and y comprises all other measurable site attributes, e.g., canopy closure and whether or not the site is located near a channelized stream. Substituting equation [6] into equation [1] and then the resulting expression into equation [5], we have:

$$V_i = v\{q[r(t_i, y_i), s_i; q_{-i}]\} \quad [7]$$

Equation [7] now states that the quantity of wood at a site is a function of measurable attributes taken directly and indirectly into account by a buyer, unmeasured attributes, and neighboring site conditions. Finally, if we express the price a buyer pays for delivered timber and pulpwood ($\delta^{T,P}$) as a function of V_i and x, a vector of non-ecological, exogenous factors that affect the individual's decision making process, e.g., time of year (where a subscript on x denoting buyers is dropped for convenience without changing the outcome):

stem densities, and product mixes, which in turn is directly influenced by differences in site conditions. Accordingly, W can be written as an implicit function of growing site attributes:

$$W_i = w(q_i) \qquad \forall\, i \in J \qquad [10]$$

where q_i is a $1 \times K$ vector of all on-site attributes defining quality at plot i. We hypothesize that W is increasing at a decreasing rate with increases in q ($\partial W/\partial q > 0$, $\partial^2 W/\partial q^2 < 0$). Substituting equation [1] into equation [10] gives W_i as an implicit function of measured and unmeasured attributes at plot i and all neighboring plots $-i$:

$$W_i = w\{q(r_i, s_i); q_{-i}\} \qquad \forall\, i \in J \qquad [11]$$

Based on the spatial implicit function given by equation [11], we can derive the marginal implicit price of the k^{th} measured attribute in R by partially differentiating with respect to the element and setting the solution equal to zero. In the case of a linear functional form for equation [11], $W = R\beta + \mu$, the marginal implicit price is simply the coefficient from the estimated regression equation:

$$\partial W / \partial R_k = \gamma_k \qquad [12]$$

$$\delta^{T,P} = \delta(V_i, x) \qquad [8]$$

then the following relationship can be shown:

$$\delta^{T,P} = \delta\{v[q(r(t_i, y_i), s_i; q_{-i})], x\} \qquad \forall\, i \in J \qquad [9]$$

Equation [9] shows that the price an individual pays for delivered wood can be used to price t_i and y_i, but at the same time delivered prices are an imperfect measure because they are more than a function of just these two variables.

3.3. Model Specification

The explicit form of the spatial implicit valuation model for the microlevel data on attributes influencing forested wetland productivity and condition, and correspondingly, market value, is written as:

$$LNPLOT\_TOTAL_i = f\{[CHANNELIZED_i\ CLOSURE_i\ STREAM\_DIST_i\ DISTRUB_i\ CHAN*STREAM_i\ ROAD\_DIST_i\ OAK_i\ CYPRESS_i]' * * [\beta_1\ \beta_2\ \beta_3\ \beta_4\ \beta_5\ \beta_6\ \beta_7]\} + \mu_i \qquad [13]$$

where the relationship between the dependent variable and explanatory variables may be nonlinear, μ may or may not be normal, i.i.d, and i indexes field plots (see Table 7 for explanation and descriptive statistics of each variable). Diagnostic tests for misspecification of equation [13] are carried out based on ordinary least squares (OLS) estimation with resultant statistics measuring strength against null hypotheses of homoskedastic, normally distributed, and spatially independent error terms μ_i. Additionally, informal tests for potential model misspecification are conducted using several different functional forms of equation [13]. Homoskedasticity is checked with the Breusch-Pagan test (Breusch and Pagan, 1979), if normality holds, and with the Koenker-Bassett test (Koenker 1981, Koenker and Bassett 1982) if not. In either case, robust estimation procedures, such as the groupwise heteroskedasticity specification (Anselin 1992, p. 220) can be used to explicitly incorporate nonconstant error variance in model estimation. The assumption of a normally distributed error term is tested with the Jarque-Bera test (Jarque and Bera 1987) and if violated, maximum likelihood (ML) and OLS estimation techniques cannot be used to estimate equation [13] because these methods are based on normality. If the assumption of normality does not hold, the more

Table 7

Explanation and descriptive statistics for field plot attributes by stream channel condition

Variable (Plot attribute)	Description	Channelized Streams (n = 133)[a] Mean	Channelized Streams (n = 133)[a] Std. Dev.	Natural Streams[b] (n = 224) Mean	Natural Streams[b] (n = 224) Std. Dev.
PLOT_TOTAL	Market value of woody stems (> 10 cm) ($)	155.79	113.80	515.00	471.94
CHANNELIZED	= 1 if the plot is located on a transect originating from a stream that had been channelized; 0 otherwise (–)	–	–	–	–
CLOSURE	Percent closure of overstory canopy; computed as the average of 5 measurements taken at each plot (%) (+)	70.57	24.98	78.98	21.70
STREAM_DIST	Distance from stream channel to plot center (m) (+)	114.66	89.78	192.41	160.95
DISTURB	Multicategory variable measuring effect of time since last significant disturbance on site productivity and plot market values; time is measured in discrete categories, 0-5, 5-25, and >25 yrs, which are interacted with severity of disturbance (levels 1 through 3 with severity greatest at level 3); base category is 0-5 years with "minimal" (level 1) disturbance; time and severity measures visually determined at each plot (?)	2.10	0.91	2.50	0.69
CHAN*STREAM	Interaction term measuring effect of channelization on plot market values across different distances from stream channel (–)	142.96	76.73	–	–
ROAD_DIST	Euclidean distance from nearest road to plot center (m) (–)	2935.94	13984.76	760.18	475.77
OAK	Number of sawtimber size oak stems (> 25.4 cm) (+)	0.52	1.32	2.09	2.40
CYPRESS	Number of sawtimber size cypress stems (> 25.4 cm) (+)	0.21	1.04	0.50	1.28

Notes: Signs in parentheses indicate expected relationship with the dependent variable PLOT_TOTAL.

[a] Number of field plots.

[b] Natural streams are defined as streams that have not been channelized.

flexible generalized moments (Kelejian and Prucha 1999) procedure, which does not rely on parametric assumptions for μ, must be applied to the estimation of equation [13].

Robust Lagrange Multiplier (LM) tests (if μ_i are normal) (Anselin et al. 1996) or the Kelejian-Robinson (KR) test (if μ_i are not normal) (Kelejian and Robinson 1992), where both are asymptotic and χ^2 distributed tests, provide statistical evidence for the most appropriate econometric representation of the underlying spatial dependence (i.e., lag vs. error). As a review, if the dependence is across neighboring values of the dependent variable, i.e., $\text{cov}[W_i W_j] \neq 0$, then the spatial lag model is the appropriate representation. If the spatial dependence is between error terms, $\text{cov}[\mu_i \mu_j] \neq 0$, the spatial error model should be applied. We believe, a priori, the spatial dependence to be of the spatial error type. Spatial dependence in the error term can be modeled with OLS and yield unbiased coefficients, but these estimates will be inefficient. In order to derive unbiased and efficient estimates, the spatial error model is estimated by maximum likelihood, instrumental variables or generalized moments procedures.

Tests for spatial dependence as well as significance and magnitude of estimated model parameters are dependent on the specified weight matrix. In a hedonic price study of property values in Maryland, Bell and Bockstael (2000) report empirical evidence on the sensitivity of coefficients to different specifications of *Z*. In order to explicitly address this potential problem, we estimate equation [13] with an inverse distance weight functional form of the weight matrix with multiple cut-off or critical distances (d_{ij}*).

4. Results

The results of generalized moments estimation of equation [13] are reported in Table 8. A variety of model diagnostic tests were conducted based on OLS estimation of the model and

Table 8
Results of robust, generalized moments estimation of the spatial error model representation of the implicit valuation model

	Semi-Log Model		Double-Log Model		Square-Root Model	
Plot Attribute	Robust GM ($d_{ij}^* = 800$)	Robust GM ($d_{ij}^* = 1500$)	Robust GM ($d_{ij}^* = 800$)	Robust GM ($d_{ij}^* = 1500$)	Robust GM ($d_{ij}^* = 800$)	Robust GM ($d_{ij}^* = 1500$)
CONSTANT	4.613* (0.22329)	4.609* (0.22438)	6.429* (0.56977)	6.427* (0.57471)	4.132* (0.29556)	4.129* (0.29648)
CHANNELIZED (1=Yes)	−0.933* (0.22439)	−0.927* (0.22578)	−1.08* (0.37941)	−0.953* (0.38751)	−1.004* (0.23349)	−0.986* (0.23447)
CLOSURE (%)	0.014* (0.00213)	0.014* (0.00214)	–	–	–	–
LNCANOPY_ CLOSURE	–	–	0.682* (0.07038)	0.678* (0.07038)	–	–
SQRTCANOPY_ CLOSURE	–	–	–	–	0.228* (0.02681)	0.228* (0.02681)
STREAM_DIST (m)	−0.001 (0.00045)	−0.001 (0.00045)	–	–	–	–
LNSTREAM_ DISTANCE	–	–	−0.030 (0.02846)	−0.030 (0.02843)	–	–
SQRTSTREAM_ DISTANCE	–	–	–	–	−0.012 (0.00958)	−0.012 (0.00957)
DISTURB	−0.105 (0.07548)	−0.106 (0.07584)	−0.073 (0.07910)	−0.076 (0.07947)	−0.102 (0.07381)	−0.103 (0.07413)
CHAN*STREAM	0.001 (0.00101)	0.001 (0.00101)	0.001 (0.00107)	0.001 (0.00106)	0.001 (0.00104)	0.002 (0.00104)
ROAD_DIST (m)	−5.90E-5* (0.00001)	−5.91E-5* (0.00001)	–	–	–	–
LNROAD_DIST	–	–	−0.585* (0.06032)	−0.589* (0.06058)	–	–
SQRTROAD_DIST	–	–	–	–	−0.018* (0.00160)	−0.018* (0.00161)
OAK (> 25.4 cm)	0.118* (0.02228)	0.118* (0.02227)	0.107* (0.02136)	0.107* (0.02135)	0.112* (0.02137)	0.111* (0.02137)
CYPRESS (> 25.4 cm)	0.173* (0.04124)	0.173* (0.04119)	0.175* (0.03985)	0.178* (0.03981)	0.182* (0.03975)	0.182* (0.03971)
λ	0.454[a]	0.469	0.743	0.760	0.505	0.518
R^2	0.528	0.522	0.639	0.600	0.565	0.557
OLS diagnostics[b]						
Jarque-Bera	107.889*		24.240*		31.711*	
Koenker-Bassett[c]	0.053		0.498		0.386	
Kelejian-Robinson	25.532*	26.737*	68.379*	58.396*	27.830*	23.946*
Multicollinearity condition number	10.866		26.993		16.710	

Notes: Dependent variable is the log of the market value of all standing pulpwood and sawtimber stems in each field plot; * indicates significance at the 99% confidence level; 357 observations for each model; R^2 values are computed as the ratio of the variance of the predicted values over the variance of the observed values for market value (Anselin 1995).

[a] Standard errors are not computed for the spatial autoregressive parameter λ in generalized moments estimation.

[b] The Jarque-Bera and Koenker-Basset (KB) tests and the multicollinearity condition number are calculated for the same OLS model, regardless of the specified form of the spatial weights matrix. Accordingly, only one value for each diagnostic is reported per set of models.

[c] The KB test is conducted against a model that has already been corrected for heteroskedasticity, thus we should expect to fail to reject H_o: constant error variance.

include the following. Tests for normally distributed, homoskedastic error terms were strongly rejected at the 99 percent confidence level (see Table 8 for Jarque-Bera and Koenker-Basset statistics), thus robust, nonparametric estimation methods were applied. Robust estimation included an additive, groupwise heteroskedasticity specification, with CHANNELIZED as the grouping variable. Spatial lag and spatial error models were estimated but due to nonnormality, only the null hypothesis of spatial independence could be tested in the spatial error model.[33] Results of the Kelejian-Robinson test for all spatial error models indicate significant spatial dependence across the error terms of neighboring plots. Thus, a spatial error representation of the spatial dependence inherent in the data is an appropriate econometric specification of the valuation model.

Informal tests of potential model misspecification were conducted by specifying several functional forms for both the spatial error model and the spatial weights matrix. Semi-logarithmic, double-logarithmic, and square root functional forms of the spatial error model were each estimated with two critical distances, 800m and 1500m, defining the maximum distance for two neighboring plots in the spatial weights matrix. The critical distances pertain to the average (800m) and maximum (1500m) distance between any two plots in a common site. The qualitative results of these different model specifications are surprisingly similar, indicating model validity and relevance of included explanatory variables. Each model explained more than half of the variability in plot market values, which is a promising finding given the considerable spatial variability in plot locations and the complex ecological relationships between site attributes and productivity. This result indicates there is a common set of measurable ecological factors that significantly influence forest productivity and market values across the watershed. The core set of attributes (variables) significant in all models

[33] Model estimation was conducted in SpaceStat (Anselin 1995), which currently does not provide the Kelejian-Robinson test of spatial dependence for the spatial lag model. Accordingly, only the results of the spatial error model are presented in Table 8.

includes whether or not the plot is located along a stream that has been channelized, percent canopy closure, distance (m) from the nearest road, and number of sawtimber size (> 25.4cm) oak and cypress stems. The sign of each variable was consistent with our expectations. Distance (m) from the stream channel, time elapsed since the last significant disturbance, and an interaction term between stream channelization and distance from stream channel were not significant in any model. These later terms may be insignificant due to the wide range of ecological conditions present across the watershed, which confound the relationship between each attribute and plot value.

An inverse distance weights (IDW) specification of the relationship between two neighboring plots was used to define the spatial weights matrix in the spatial error models. We experimented with multiple cut-off distances to test the extent of spatial interaction and found significant spatial dependence up to 20km, after which the software was unable to compute the model. In ecological research, it is reasonable to expect site attributes to be spatially correlated across large expanses, or in the present case, an entire watershed, because of shared abiotic and biotic processes endemic to the system. As discussed in Bell and Bockstael (2000), though, row standardization of the spatial weights matrix, which is necessary for the generalized moments estimation procedure, results in greater weight given to plots that are more distant.[34] Consequently, while a significantly large cut-off distance (or simply, no cut-off) may seem sensible from an ecological modeling standpoint, it is computationally intractable and improperly weights the strength of spatial dependence. To avoid this problem and still incorporate the inverse relationship between distance and spatial dependence, we choose to use the overall average and maximum distance between plots at a common site.

[34] Row standardization refers to the recalculation of each cell of the spatial weights matrix by dividing cell values by their respective row total such that the row sum of all new cell values equals 1. In the case of more distant plots with fewer neighbors and smaller weights, the row total is less than that of plots in the opposite case. Accordingly, a smaller denominator will result in a larger row standardized cell value (spatial weight), relative to non-standardization.

Under this framework, the unmeasured components of plots are spatially dependent (neighbors) if they are located in the same site and independent otherwise. As stated earlier, model estimation results are qualitatively similar for the two cut-off distances, with coefficient magnitudes only slightly lower for the greater cut-off distance.

In addition to testing the sensitivity of model estimates to different specifications of the spatial weights matrix, we estimated equation [13] with three nonlinear functional forms. Nonlinear models were specified because imposing linearity between the dependent and independent variables requires the restrictive assumption of perfect substitutability between each attribute. As an example, two oak trees cannot be substituted for one cypress tree. For all three forms, the contribution of each continuous attribute (variable) to the economic value of the plot increases at a decreasing rate, which is in accordance with the theoretical specification in equation [10]. In the semi-log model, attribute contribution, measured by the parameter estimate, is interpreted as the percentage change in plot value with a unit change in the attribute (i.e., partial elasticity). For the double-log model, coefficients are interpreted as elasticities; interpretation is not as straightforward for the square root model. Estimation results for all three models are very similar, but the double-log model explains the most variability in plot values for both specifications of the spatial weights matrix (R^2 = 64 and 60 percent for d_{ij}* = 800m and 1500m, respectively).

Given that all six model specifications are qualitatively similar, choice of a particular model for attribute interpretation and calculation of implicit prices will not lead to inconsistent conclusions. We chose the double-log model evaluated at a cut-off distance of 1500m for three reasons, foremost of which is our belief that the cut-off distance should be as great as possible without compromising the integrity of the spatial weights. Second, of the three models evaluated at 1500m, the double-log model explains the most variability in plot values. Finally, this model specification provides a parameter estimate for the key policy variable CHANNELIZED that is approximately the average of the values reported in the semi-log and square root models. Thus, based on generalized moments estimation of a double-log, spatial autoregressive error representation of the implicit valuation model equation [13], the impact of stream channelization on forested wetland market values is such that 95 percent of the average economic value of the nearby forest is lost. Since channelization has been restricted for over thirty years by the Federal Water Pollution Control Act Amendments of 1972 (Section 404), this significant reduction in forest value reflects the cumulative damages to local forested wetland productivity and condition caused by the negative externalities associated with channelization, which include excessive sedimentation and channel bank and bed erosion. Regarding the remaining variables, the coefficients for percent of overstory canopy closure and number of sawtimber size oak and cypress stems were highly significant and positive. Based on the estimates in Table 8, a one percent increase in canopy closure and a one unit increase in oak and cypress stems results in a 68, 11, and 18 percent increase in average plot value, respectively. The variable capturing the relationship between distance from the nearest road and plot values had the expected negative sign, indicating an inverse relationship between plot value and distance, but reported an estimate greater in magnitude than we expected. The average market value of a plot decreases by 59 percent for each one percent increase in distance (m) between the plot and the nearest road.

5. Implicit values

The economic values derived from the valuation framework are implicit since a direct relationship does not exist between ecological attributes and channelization and the market value of a forested wetland; value for these nonmarket site attributes arises from an indirect relationship with the aggregate economic value of merchantable wood in the wetland. Similar to hedonic pricing, implicit prices are calculated from model first order conditions. For the continuous variables, implicit prices are simply calculated by partially differentiating equation [13] with respect to each variable and setting the solution equal to zero, holding all other attributes constant (refer to Table 9). Prices for continuous variables are often referred to as marginal implicit prices because they measure the monetary change in the dependent variable as the result of a marginal, or one unit change, in a right hand side variable. Due to the discrete nature of the variable CHANNELIZED, the implicit price for channelization is a measure of the partial and not marginal effect on plot values. The implicit price (denoted IP) of damages (negative externalities) associated with channelization is thus computed as the difference in expected values of equation [13] when CHANNELIZED is set equal to one and zero, ceterus paribus:

$$\begin{aligned} IP_{CHANNELIZED} &= E[\text{LNPLOT\_TOTAL} \mid X_k, \text{CHANNELIZED} = 1] - \\ &- E[\text{LNPLOT\_TOTAL} \mid X_k, \text{CHANNELIZED} = 0] \end{aligned} \tag{14}$$

where k indexes remaining regressors (Long 1997, p. 14). Table 9 provides the equations and resultant implicit prices for the significant attributes from the double-log, spatial autoregressive model (evaluated at 1500m).

Following equation [14] and assuming natural stream conditions, the partial implicit price for CHANNELIZED is –\$217.54 per plot or –\$5,438 ha^{-1}.[35] Since natural streams are by definition unchannelized, the impact of channelization on the market value of forested

[35] We caution against aggregating the per plot damage value beyond a ha^{-1} basis since we do not know at present how far out these damages extend into the floodplain. The insignificant sign on the interaction term CHAN*STREAM provides some evidence that the negative effects of channelization

Table 9
Implicit prices for field plot attributes

Plot Attribute	Implicit Price Equation[a]	Implicit Price: Channelized Streams ($X_1 = 1$)	Implicit Price: Natural Streams ($X_1 = 0$)
CHANNELIZED[b]	$X_2^{\gamma_2} exp(\gamma_0 + \gamma_1 X_1 + \gamma_7 X_7 + \gamma_8 X_8) X_6^{\gamma_6} -$ $X_2^{\gamma_2} exp(\gamma_0 + \gamma_1 X_1 + \gamma_7 X_7 + \gamma_8 X_8) X_6^{\gamma_6}$	–$217.54 per plot [–$5438.44 ha^{-1}]	$217.54 per plot [$5438.44 ha^{-1}]
CLOSURE (%)	$\gamma_2 X_2^{(\gamma_2 - 1)} exp(\gamma_0 + \gamma_1 X_1 + \gamma_7 X_7 + \gamma_8 X_8) X_6^{\gamma_6}$	$1.31 per plot [$32.86 ha^{-1}]	$3.28 per plot [$81.92 ha^{-1}]
ROAD_DIST (m)	$\gamma_6 X_6^{(\gamma_6 - 1)} exp(\gamma_0 + \gamma_1 X_1 + \gamma_7 X_7 + \gamma_8 X_8) X_2^{\gamma_2}$	–$2.36 m^{-1} [–$236.00 km^{-1}]	–$6.10 m^{-1} [$610.00 km^{-1}]
OAK (> 25.4 cm)	$\gamma_7 X_2^{\gamma_2} exp(\gamma_0 + \gamma_1 X_1 + \gamma_7 X_7 + \gamma_8 X_8) X_6^{\gamma_6}$	$15.43 per plot [$385.78 ha^{-1}]	$38.71 per plot [$967.69 ha^{-1}]
CYPRESS (> 25.4 cm)	$\gamma_8 X_2^{\gamma_2} exp(\gamma_0 + \gamma_1 X_1 + \gamma_7 X_7 + \gamma_8 X_8) X_6^{\gamma_6}$	$25.67 per plot [$641.76 ha^{-1}]	$64.39 per plot [$1609.80 ha^{-1}]

Note: Calculated implicit prices are based on coefficients from the robust, generalized moments estimation of the spatial autoregressive error model listed in Column 5 of Table 8.

[a] Gamma notation identifies estimated parameters, with subscripts on each X denoting individual variables (corresponding to the order given in Eq. [13]). The implicit price equation is equivalent to the marginal (partial) effect of each continuous (discrete) variable on the dependent variable and is calculated for each data point and then averaged. The sample average is reported in the *Implicit Price* columns.

[b] The partial effect of channelization on plot values is computed as in the following manner: $\Delta E[Y|X] \,/\, \Delta X_1 = E[Y|X_k, X_1{=}0] - E[Y|X_k, X_1{=}1]$.

wetlands along natural streams represents the potential outcome if the stream were to be channelized. That is, a wood buyer would be willing to pay approximately $218 less for a site that changed from an unaltered to an altered state, given sufficient passage of time so that the full effects of the change are realized. Alternatively, the absolute value of these estimates reflects the monetary gain in forest worth if channelized streams and surrounding impacted forested wetlands were restored to their natural condition.

It is important to note that these values are based on delivered wood prices, which take into account transportation and harvesting costs. These costs should not be included in the valuation of on-site damages to forested wetlands. Accordingly, implicit prices reported in this paper do not represent the true net value lost to society as a result of channelization. An

on plot values vary too much across different distances from the stream channel to uncover any statistically significant relationship.

average value for the percent of delivered prices that can be allocated to these costs is 39 percent, based on Timber Mart South (2003) data for our study area.

These estimates represent the first published findings of the significant, long-term economic impacts channelization has had on forested wetlands, since earlier wetland valuation research focused on valuing individual wetland services or entire wetland ecosystems. In essence, our models show that channelization has had the unfortunate, unintended consequence of impacting forested wetlands to such an extent that they can no longer produce a viable supply of merchantable wood. Moreover, in terms of unmeasured, nonpriced site attributes, the capacity of impacted sites to provide wildlife habitat, scenic beauty, nutrient transformation, flood abatement, and water filtration has been severely diminished. By depositing and facilitating the movement of excessive quantities of sediment, which stifles plant, tree, and soil productivity and eventually reduces the site to an unproductive condition, channelization has virtually homogenized the vegetative structure and composition of sites along altered streams. Sites are now defined by a select number of understory and overstory species that can survive in harsh, impacted conditions. The tree species of this set are of such low market and ecological value that the economic worth of the wetland is reduced to mere dollars and sustainability of the system compromised.

While we believe the monetary estimates of damages associated with channelization are reasonable and defensible, a few caveats should be highlighted. First, the basis for the valuation component of the model is an indirect relationship between the economic values an individual places on merchantable wood and measurable on-site attributes. We acknowledged that the relationship was not a first best solution for valuing site attributes (see footnote 32), yet at the same time provided a means for linking productivity, ecological and anthropogenic factors, and overall forest market value for the ultimate purpose of monetizing damages to both the site and the system. Beyond the somewhat complicated theoretical linkages, the model relies on a quite simple concept that is consistent with economic theory in that attribute value is measured by the additional amount an individual (i.e., wood buyer) is willing to pay for a site with higher quality attributes. Conversely, an economic agent would be willing to pay less for undesirable sites due to degraded attributes, which in our study is credited to channelization and excessive sedimentation. Thus, while a direct relationship would be preferable for monetizing damages to forested wetlands, the implicit valuation framework presented here represents an initial pass that is consistent with economic, ecological, and spatial econometric theory.

The second caveat is a corollary to the first and identifies the values calculated with the valuation model as use values, or measures of the usefulness of the resource to the individual. Consequently, measures of nonuse values lost because of channelization cannot be captured in the model. Third, the real applicability of the model is in valuing cumulative damages to systems that are spatially and temporally dependent. For monetary assessment of damages from immediate disturbances, whether human or natural, standard accounting or real estate appraisal methods (e.g., replacement cost) should be applied. Last, since channelization is a discrete event restricted for the last 30 years, the opportunity to internalize the negative externalities is by definition limited. Thus, while the damage estimates may be used to evaluate future channelization projects the more likely application may be to provide information for restoring impacted sites, resource damage assessment, and ecosystem management.

For the most part, these caveats apply to the implicit prices calculated for the remaining significant site attributes. Based on the equation in Table 9, the marginal implicit price of a one percent increase in overstory canopy closure from the mean value of 79 percent is $3.28.[36] This estimate implies that a landowner interested in maximizing the economic value of pulpwood and sawtimber would pursue forest management strategies that lead to increases in the percent of closure. The landowner would do so only to a point as the curvature of the relationship between canopy closure and plot value indicates benefits increasing at a decreasing rate. From an ecological and economic standpoint, this result is reasonable since too much canopy closure would lead to increased competition and consequently reduced growth rates and value. The marginal implicit price for a one meter increase in distance between a plot and the nearest road is –$6.10 or –$61 for each 100m increase. The price of increasing separation is not trivial and indicates that there is a zone wherein a landowner should expend resources on forest management, since beyond the zone management costs exceed benefits. Lastly, the marginal contribution to average plot value from an increase of one oak and cypress tree species is $38.71 and $64.39, respectively. In terms of forest management, a profit maximizing landowner in our study area should pursue artificial and natural regeneration efforts until the marginal benefit of increased oak and cypress stems just equals marginal planting and maintenance costs.

6. Conclusions

This paper presents the application of a spatial theoretic, implicit valuation model to develop a set of implicit prices for factors affecting productivity and market value of forested wetlands in the Hatchie River Watershed in West Tennessee. In particular, prices were estimated for ecological relationships and negative externalities associated with

[36] For this and the following site attributes, only the implicit prices computed for natural streams are reported and discussed. The basis for the exclusion of prices for channelized streams in this discussion is that landowners would not expend resources on marginal changes in the forest structure when those resources would have greater value if expended toward overall site restoration.

channelization. The costs of channelization are significant, with 95 percent of the market value of a forest lost as a consequence of this anthropogenic activity. On a per hectare basis, a wood buyer is willing to pay $5,438 less for a forest located along a channelized stream than a similar forest located along a natural stream. These results indicate a role for forest management in terms of restoration and more importantly, a significant role for stream restoration projects that focus on returning the natural hydrological and sedimentation processes to channelized streams.

The primary motivation for developing a model to value damages to forested wetlands arose from inadequate knowledge of the economic magnitude of cumulative impacts that negative anthropogenic factors have had on the integrity of forested wetlands. Previous research predominately focused on valuing the ecological functions and services provided by wetlands and valued by individuals, whereas this research addressed the valuation of individual attributes that affect site quality and overall system functioning. We applied spatial econometric procedures because of the inherent interconnectedness among ecological attributes across the watershed. Failing to recognize these relationships would have resulted in a misspecified model and possibly biased implicit prices. Nonparametric estimation procedures allowed us to address the nonnormal distribution of the unobserved component across plots and different functional forms of both the spatial weights matrix and the model were tested to assess the sensitivity of estimated parameters. The results of nonparametric, spatial autoregressive error estimation of the different specifications were surprisingly stable, thereby lending credibility to the valuation framework and resultant implicit prices. However, while the method applied in this study is simple and flexible it provides prices for only a small subset of the attributes of a forested wetland ecosystem. Accordingly, this method should be used in addition to other wetland valuation techniques and under different ecological conditions to determine the economic value of forested wetland attributes.

In a general sense, wetland valuation can provide useful information for cost benefit analysis, policy evaluation, resource damage assessment, ecosystem management, and increasing public awareness of the importance of wetlands. Specific to the case of valuing damages to forested wetlands, economic information in the form of implicit prices provides balanced information to stakeholders on the tradeoffs between discrete activities, such as draining and filling a wetland or leaving the resource in tact. Prior to the Clean Water Act Amendments, the potential consequences of channelization in terms of diminished ecosystem productivity and lost timber revenue were probably assumed negligible or discarded altogether. If the responsible party, i.e., the damager, were to have to access to the present information then decisions regarding channelization projects might have been at least delayed and possibly canceled. Of course, we will never know the outcome, but when evaluating present and future system altering projects, this type of information may play a critical role in balancing potential costs and benefits.

The greatest role for valuing damages to forested wetlands may be in the evaluation of alternative stream and wetland restoration projects. Since many of the benefits of restoration are nonmarket in nature there is a positive probability they will be under or over stated in a cost benefit analysis. Restoration efforts, then, can be made more efficient by including the implicit prices of damages to nonmarket attributes. Additionally, given budget and time constraints, agencies and individuals pursuing restoration can use this information to guide the selection process toward those sites that have endured the greatest nonmarket losses. However, for some forested wetlands located along channelized streams, especially in our study area, restoration may not be economically feasible as the sites are severely degraded. In these cases, the costs outweigh the benefits and the goals of the restoration project may be better served elsewhere.

Valuation, though, is just one step in the process toward restoring altered streams and degraded forested wetlands. The greatest challenge for future valuation research may lie in communicating the results of valuation studies to communities, policy makers, and resource specialists in a comprehendible format. Incorporating the interests of these stakeholders in the initial phases of the valuation process may help to ensure that efforts are directed toward the most important issues and result in lasting, tangible outcomes.

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Part 5

Summary and Conclusions

This dissertation approached the valuation of environmental quality in two Tennessee watersheds from both applied and theoretical perspectives. The theory underlying each application was presented to demonstrate the basis for selection of specific valuation methodologies, highlight weaknesses, and opportunities for extension to other problems. Two spatially and ecologically distinct watersheds were selected for the applied analyses because of a common lack of information regarding economic values of environmental quality. While each watershed has a specific set of factors responsible for present environmental conditions both watersheds could benefit from information on the costs of past damages and benefits of future improvements. Environmental valuation and advanced econometric models provide a framework for valuing such costs and benefits. This dissertation provides economic information for environmental quality that can help landowners, non-landowners, stakeholders, and policy makers collectively work together to improve the state of the environment and progress toward environmental sustainability within the context of further economic growth and development.

The three primary chapters in this dissertation are linked by a common objective of extending current environmental valuation techniques. The first chapter outlined necessary conditions for three separate economic agents to satisfy in order for a hypothetical forest amenity enhancement program to be realized. A representative contributor, third party non-profit organization, and profit maximizing forest landowner comprised the three agents. A random utility behavioral model was selected for the analysis of necessary contributor conditions, value maximization model with a budget balancing constraint for the third party, and a profit maximization model incorporating ecological capacity and environmental ethic for the landowner. The forest amenity enhancement program was described as a program administered by the third party and funded with individual contributions that supported private landowners who undertook forest amenity improvement activities. Theoretical and mathematical analysis of agent behavior within the enhancement program showed such a program was possible as long as agents choose factor levels that optimized their respective constrained objective (i.e., utility, value or profit). This is a standard microeconomic result but further analysis of agent behavior revealed that even if they behave optimally the presence of free-riders in the economy will undermine program success. Furthermore, abstracting from the efficiency reducing effects of free-riding behavior, I presented two cases where the program may succeed but not provide the optimal level of amenities and one case of an inconsistent outcome (see Figure 1, p. 47). This latter result derives from a disconnect (or information gap) between contributors representing demand and forest landowners that control the physical supply of forest amenities. It is this case that is of most interest for the success of the hypothetical forest amenity enhancement program and for evaluating the possibility of actually implementing a similar program in Tennessee.

The second chapter extended the theoretical analysis using data on individual choices and willingness to pay for improved forest amenities solicited in a choice modeling based survey. The results of econometric analysis of these data revealed that people are willing to pay approximately $25 per year for 5 years for improved forest amenities (see Table 6, p. 87). However, the majority of forest landowners (representing amenity supply) are not in favor of undertaking management activities to improve the supply (see Tables 3 and 5, p. 76 and p. 81). Thus, the theoretical disconnect presented in the first chapter is empirically verified in the results of the second chapter. Collectively, these results suggest significant extension efforts may be necessary in order for a forest amenity enhancement program to be realized in Tennessee (more specifically, the Emory-Obed Watershed). These efforts should be focused on informing landowners of not only the public benefits of forest amenities but also possible incentive-based schemes that would compensate landowners for amenity related management costs. Additionally, focused extension efforts would be able to inform forest managers and landowners of the types and levels of forest amenities the public prefers and how much they would be willing to pay to secure improvements from the current state. Given increasing urban development pressures in our study area and in the South in general, alternative compensation options that would enable forest landowners to maintain their land in its natural state must be explored. Environmental valuation offers a legitimate and promising means for valuing and evaluating such options.

In addition to complementing the theoretical analysis in the first chapter, data collected from the choice modeling survey were applied to an analysis of information effects in stated preference environmental valuation. A spatial information effect was defined to be the influence on survey respondent preferences of forest land cover (m^2) within a 100m radius of their residence. An aspatial information effect was defined to be the influence a researcher has on respondent preferences by simply altering the framing, or information content, of the survey. I altered the choice modeling survey by introducing an additional statement in one of the two survey versions informing respondents of the potential that 50 wooded acres in their area would be converted to a residential development. Results for the spatial information effects test reveal that spatial information affected choices but not stated willingness to pay (see Tables 4 and 6, p. 79 and p. 87; discussion on page 85). However, for the aspatial information effects test, differences in survey framing significantly affected both choices and stated willingness to pay (Tables 4 and 6). Thus, respondent preferences and ultimately choices were influenced by both types of information but only one type changed willingness to pay. The significance of the aspatial information test for stated preference environmental valuation is that researchers could achieve a desired result by simply including information they know will influence people to choose a certain way. The significance of the spatial information test is that to date no other published study has incorporated spatial land cover in a stated choice framework.

Finally, the third chapter presented an innovative approach for valuing damages to forested wetlands using an implicit pricing model adapted from hedonic price theory and spatial econometrics. The basis for this study was research conducted during Summer 2002 across 3 counties and 357 field plots in the Hatchie River Watershed, West Tennessee. Information from these field plots served as principal input in the implicit pricing model, which involved three stages. First, the aggregate market value of the forest at each field plot was determined by summing over the product of volume and market price by class (i.e., sawtimber or pulpwood). Next, site specific attributes known to affect the quantity of volume, species presence, and class distribution were measured at each plot and then incorporated in the econometric model. These attributes included both ecological, such as canopy closure, and anthropogenic factors, namely, channelization. In the third stage, the aggregate forest value was econometrically decomposed into the economic contribution of individual site attributes.

Several functional forms of the implicit pricing model and underlying spatial dependence among unmeasured cross-site attributes were estimated in order to assess the reliability of the model and sensitivity to different assumptions. For all functional forms, though, a common nonparametric, first-order spatial autoregressive error model was specified. The double logarithmic representation of this model was found to provide the best fit and most defensible interpretation of estimated parameters (see Table 8, p. 115). Generalized moments estimation of the double logarithmic, first-order spatial autoregressive error model revealed significant impacts channelization and excessive sedimentation have had on the ecological productivity and market value of local forested wetlands (Table 8). Through first order differentiation of the spatial econometric model, an economic value of –\$218 per plot or –\$5,438 ha^{-1} was imputed to these impacts (Table 9, p. 121). The significance of these results is three-fold. First, through the application of an environmental valuation technique economic values have been assigned to formerly unpriced negative externalities associated with channelization. Second, these values can be used to update present benefit cost analyses that involve channelization of streams in forest wetland systems or weight more appropriately the potential ecological damages associated with channelization in future analyses. Last, these results hold significance in justifying the economic benefits of restoring impacted streams and wetlands to their original condition (+\$218 per plot or +\$5,438 ha^{-1}).

Pooling the results of each study, the usefulness of environmental valuation for linking the economy and the environment through the development of prices is unambiguous. Moreover, these studies show the complicated theory and econometric analysis underlying environmental valuation and hopefully, legitimize further application of nonmarket methods for deriving market values.

Appendices

Appendix A

Definitions for Non-Timber Forest Benefits and Quality Levels Included in Choice Modeling Survey

(1) *Recreational Opportunities*

LOW: The landowner does not allow the non-paying public to hike, camp, fish, hunt or birdwatch (or simply, to recreate) on any portion of his/her land.
MEDIUM: The landowner allows the public to recreate on some portion of his/her land. Additionally, only a certain type of recreation (for example, hunting or hiking) is allowed.
HIGH: The landowner allows the public to recreate on all of his/her land and all the types of recreation listed above are allowed.

(2) *Stream Quality*

LOW: The landowner disturbs (by harvesting or road building, for example) almost all of the forest and natural vegetation found along streams and on steep hillsides. As a result, soil erosion is increased and the quality of the water for drinking, swimming, and fishing declines.
MEDIUM: The landowner disturbs some of the forested and natural vegetation found along streams and on steep hillsides. Soil erosion still occurs, but not to the point found in LOW.
HIGH: The landowner does not disturb any of the forested and natural vegetation found along streams and on steep hillsides. Additionally, the landowner plants trees and native plants along stream banks and hillsides to help slow soil erosion.

(3) *Scenic Beauty*

LOW: Very little open space among the trees, trees are crowded and smaller in size, and there are few plants on the ground.
MEDIUM: Trees are more openly spaced and you can see into the forest. Trees are of moderate size and there are more plants on the ground than in the LOW level.
HIGH: Trees are openly spaced, trees are large in size and there are many plants (both in type and quantity) on the ground.

(4) *Wildlife Habitat*

LOW: The landowner does not actively manage his/her land for improved wildlife habitat.
MEDIUM: The landowner manages some of his/her land for native game or non-game animals. In order to do this, the landowner follows a management plan written by a wildlife resource professional.
HIGH: The landowner manages all of his/her land for either native game or non-game species, or both. The landowner manages the land according to a management plan written by a wildlife resource professional.

APPENDIX B

Definitions and Descriptive Statistics for All Components of the Choice Modeling Survey in Part 3

Status Quo Information	No Development (*n*=1045)		Development (*n*=815)	
	Mean (Std. dev.)	No. obs.	Mean (Std. dev.)	No. obs.
Demographic Variables				
Cumberland (*Cumberland*)	0.79 (0.4079)	1045	0.70 (0.4588)	815
Age	58.41 (14.2681)	1045	53.12 (15.3227)	815
Household size	2.33 (0.9553)	1040	2.56 (1.0752)	815
Length of residence	18.86 (18.9403)	1035	22.22 (20.7792)	810
Level of education	3.43 (1.1684)	1045	3.20 (1.1738)	815
Income	48903.01 (22778.8700)	1010	47194.52 (24536.6500)	795
Land Size (*Land Size*)	6.89 (16.0677)	1045	13.144 (23.0065)	815
Male	0.75 (0.4351)	1045	0.67 (0.4710)	815
Public and private forest participation	0.55 (0.4980)	1045	0.61 (0.4886)	815
Outdoor or environmental group or organization member	0.16 (0.3654)	1040	0.18 (0.3878)	815
Attitudinal Variables[b]				
"Forests should be utilized in such a manner that they are in the same condition or better for future generations"	0.94 (0.2327)	1045	0.95 (0.2162)	815
"Forests should not be managed and instead allowed to take the course of nature"	0.77 (0.4191)	1035	0.82 (0.3845)	805
"Forests are important for wildlife, water quality, and landscape appearance"	0.97 (0.1678)	1035	0.98 (0.1349)	810
"In your opinion, what is the primary threat to the future of Tennessee forests" [Urban and commercial development = 1; Otherwise = 0]	0.50 (0.5001)	1035	0.55 (0.4979)	810
"How would you rate, on a scale of 0 to 5, your knowledge of forests and trees" (*Knowledge*)	2.78 (1.1294)	1040	2.87 (1.0958)	810
GIS Variable				
Forest Cover within 100m buffer of respondent [*Forest Cover*: sum of (COV8, 9, 10) /1000)]	7.42 (6.8446)	1045	7.69 (7.2743)	815

Status Quo Information	No Development (*n*=1045)		Development (*n*=815)	
	Mean (Std. dev.)	No. obs.	Mean (Std. dev.)	No. obs.
Survey Design Variables				
"Please rate the difficulty that you may have had in filling out this survey" [No difficulty = 1; Some difficulty = 0]	0.311 (0.4631)	1045	0.37 (0.4838)	805
"Please rate the level of importance the Contribution Amount of each option played in your final decision" [Equal in importance to the nontimber forest benefits = 1; No role in my decision = 0]	0.68 (0.4669)	1030	0.56 (0.49681)	805
"Please rate the level of confidence you have in the answers you have provided us" [Full confidence = 1; Some confidence = 0]	0.69 (0.4624)	1035	0.71 (0.45409)	810
Plan Score	3.34 (1.8737)	1045	3.65 (1.8443)	815
Contribution Amount	22.69 (20.3687)	1045	26.67 (21.0370)	815

[a] Terms in parentheses denote variable names applied in econometric analysis of choices. Statistics based on actual choices made by participants.
[b] Survey respondents were asked to select one of five possible choices for the first three attitudinal questions: strongly disagree, disagree, neutral, agree, and strongly agree. The five response format was condensed to a dichotomous agree or disagree variable; neutral responses are grouped with the strongly disagree and disagree choices. The results with neutral responses grouped in the agree category are similar to those presented and are available from the author.

Appendix C

SAS Code for Designing Choice Modeling Questionnaire
(complements of Major Jeff Smith, Ph.D. Candidate in Econ., Univ. of Tenn., Knoxville)

```
*******************************************************************
*                                                                 *
*  This program:                                                  *
*  -Provides an orthogonal combination of attributes and          *
*   attribute quality levels for a choice modeling based          *
*   questionnaire                                                 *
*                                                                 *
*   (Figure 2)                                                    *
*******************************************************************

/*This follows Tech Note TS-677E, particularly the "Chair Example".*/

%mktex(4 3 3, n=3*3*4)

/*Create an efficient design from the full factorial.  This coding
means that I have three attributes, one with 4 levels, and two with 3
levels.  Here, n equals the full factorial.*/

data final(drop=i);
     set design end=eof;
   retain f1-f2 1 f3 0;
   output;
   if eof then do;
      array x[6] x1-x3 f1-f3;
     do i = 1 to 6; x[i] = i le 3 or i eq 6; end;
     output;
     end;
   run;

/*This step creates the full factorial candidate set with variables
x1 through x3, because I only have three attributes, and assigns a 1
in the flag column to levels of attributes that can be in any option
(columns f1-f2).  The final observation is the status quo, or base
option, and it is coded with a 1 in the f3 column.  The observations
with flag codes f1 and f2 can be used for any alternative of the
first two alternatives, while the f3 observation may only be the
third option (the status quo).*/

/*Options=noprint in choiceff and mktblk suppress the output.  The
final mktlab will print the output of interest.*/

%choiceff(data=final, model=class(x1-x3), nsets=18, maxiter=100,
          flags=f1-f3, beta=zero);

/*This set creates the most efficient design.  Nsets equals 18 choice
sets with the options that vary and it adds in the status quo option
to each choice set.*/
```

Appendix C (continued)

```
%mktblock(data=best, nalts=3, nblocks=2, factors=x1-x3)

*This option blocks the design into two blocks with 3 alternatives
and 9 choice sets.*/

data key;
input payment endangered $ readiness $;
format payment dollar5.0;
datalines;
0   Low    High
10  Medium Medium
25  High   Low
50  .      .
;
%mktlab(data=blocked, key=key)

/*This option assigns labels to each of my alternatives.*/

proc print; by block set; run;

/*This prints the final 18 choice sets, by block, by set.*/
```

Appendix D

SAS Code for Contingency Table Analysis of Choice Modeling Results

```
**********************************************************************
*                                                                    *
*  This program:                                                     *
*  -Conducts Cochran-Mantel-Haenszel Tests of conditional            *
*   independence for ixjxk tables of matched pairs                   *
*                                                                    *
*   (Table 3)                                                        *
**********************************************************************

/*code for information effects, controlling for county*/
data two_choices;
set choices;
if choice ge 1;
run;
options linesize=76 nodate nonumber;
proc freq data=two_choices;
tables cnty_c1*type_d1*option2_1 / chisq cmh nocol nopct agree;
run;



/*code for landowner effects: controlling for county*/
options linesize=76 nodate nonumber;
proc freq data=two_choices;
tables cnty_c1*land2_med*option2_1 / chisq cmh nocol nopct agree;
run;
```

Appendix E

LimDep Code for Estimating Multinomial and Mixed Logit Models

```
**********************************************************************
*                                                                    *
*  This program:                                                     *
*  -Creates new variables                                            *
*  -Estimates mixed logit models with correlated coefficients        *
*  -Estimates marginal effects                                       *
*  -Estimates coefficient distributions                              *
*                                                                    *
*                                                                    *
*   (Tables 4 & 5)                                                   *
**********************************************************************

CREATE ; J = Trn(-3,0)
       ; ASC1 = (J=1) ; ASC2 = (J=2) ; ASC3 = (J=3)
       ; B_C = ASC1 + ASC2
       ; COV_A = (CODE8A + CODE9A + CODE10A) / 1000
       ; COV_B = (CODE8B + CODE9B + CODE10B) / 1000
       ; COVA_1 = COV_A + 1
       ; LNCOVA1 = LOG(COVA_1)
       ; BC_1COVA = B_C * LNCOVA1
       ; BC_TYPE = B_C * TYPE_D1 $
       ; BC_LAND = B_C * LAND_MED $
       ; BC_COVA = B_C * COV_A $
       ; BC_COVB = B_C * COV_B $
       ; BC_KNOWLEDG = B_C * KNOWLEDG $
       ; BC_CNTY = B_C * CNTY_C1 $
       ; BC_LO = B_C * LAND2_ME $


Reject; B_C=-999 | LN_ATTRS=-999 | BC_1COVA=-999 | BC_TYPE=-999 |
        BC_CNTY=-999 | BC_LAND=-999| BC_KNOWL=-999 $

CALC ;Ran(34569) $
NLOGIT     ; Lhs = CHOICE
           ; Rhs = PAYMENT,B_C,LN_ATTRS,BC_1COVA,BC_TYPE,BC_CNTY,
                   BC_LAND,BC_KNOWL
           ; Choices = C,B,A
               ; Tlg = 1.d-10
           ; RPL
          ; Fcn = PAYMENT(N),B_C(N),LN_ATTRS(N),BC_1COVA(N),
                  BC_TYPE(N),BC_CNTY(N),BC_LAND(N),BC_KNOWL(N)

          ; Effects: PAYMENT[C,B] / B_C[C,B] / LN_ATTRS[C,B] /
                     BC_1COVA[C,B]/ BC_TYPE[C,B] / BC_CNTY[C,B] /
                     BC_LAND[C,B] / BC_KNOWL[C,B]
          ; Cor
          ; Pds = 5
          ; Pts = 1000
          ; Halton $
```

```
?Coefficient Distributions

calc; cov_az = -0.25077/2.68552;
     list; x = phi(cov_az);
     list; z = 1-x $
calc; type = 0.71680/7.17740;
     list; x = phi(type);
     list; z = 1-x $
calc; score = 0.57317/0.91356;
     list; x = phi(score);
     list; z = 1-x $
calc; pay = -0.04490/0.00004;
     list; x = phi(pay);
     list; z = 1-x $
calc; asc = 4.25202/12.76366;
     list; x = phi(asc);
     list; z = 1-x $
calc; land = -0.00484/0.29212;
     list; x = phi(land);
     list; z = 1-x $
```

Appendix F

LimDep Code for Estimating WTP

```
*****************************************************************
*                                                               *
*  This program:                                                *
*  -Estimates willing to pay                                    *
*  -Estimates standard errors with the delta method             *
*  -Tests whether WTPs are different from each other            *
*  -Estimates 95% confidence intervals                          *
*                                                               *
*   (Table 6)                                                   *
*****************************************************************

Wald; Start   = bbp ;
      Var     = varbbp ;
      Fn1     = (-b3*2)/b1 ;             ?WTP Plan Score 0 to 2
      Fn2     = -(b3*2+b5)/b1 ;          ?WTP PS 0 to 2, DEVELP 0 to 1
      Fn3     = (b4*7.536-(b3*2+b4*7.159))/b1$ ?5% reduction in
                                              ?forest cover


calc; list; z_calc   = (41.49930899-25.53351507)/3.5849211 ;
     ? Testing null hypothesis that $41.50 is different from $25.53
            pvalue   = 1-Phi(z_calc,1) ;
            tablevlu = Ntb(.95,1) $

calc; list; z_calc   = (57.42463985-41.49930899)/6.7066264;
      ?Testing null hypothesis that $57.42 from MNL model is
      ?different from $41.50 ML model
            pvalue   = 1-Phi(z_calc,1) ;
            tablevlu = Ntb(.95,1) $


calc; list; z_calc   = (39.71189830-25.53351507)/4.6242656;
      ?Testing null hypothesis that $39.71 from MNL model is
      ?different from $25.53 ML model
            pvalue   = 1-Phi(z_calc,1) ;
            tablevlu = Ntb(.95,1) $


calc; list; confiu1 = 25.53351507+(2.6448536*2.6863059) ;
            confil1 = 25.53351507-(2.6448536*2.6863059) ;
            confiu2 = 41.49930899+(2.6448536*3.5849211) ;
            confil2 = 41.49930899-(2.6448536*3.5849211) ;
            confiu3 = 27.63929610+(2.6448536*2.6960093) ;
            confil3 = 27.63929610-(2.6448536*2.6960093) $
```

Appendix G

```
Procedures for Estimating Spatial Autoregressive Error Models in
SpaceStat
*********************************************************************
*                                                                   *
*  This program:                                                    *
*  -Provides procedures for the generalized moments                 *
*    estimator of first-order spatial autoregressive                *
*    econometric models                                             *
*                                                                   *
*   (Table 8)                                                       *
*********************************************************************

NOTE: SpaceStat is a menu driven software, thus the following is a
rudimentary outline (as opposed to specific coding) for estimating
spatial econometric models.


STEPS:

   (1)  In ArcView, use the "Data" option to convert the table
        component of the shapefile to a SpaceStat file

   (2)  In SpaceStat, select "Tools" then "Distance Weights" then
        "Create Matrix"

   (3)  Next, select "Tools" then "Distance Weights" then "Contiguity
        Weights" or "Inverse Distance Weights"

   (4)  Select "Regress" then "Classic Model" then either
        heteroskedasticity specification

   (5)  Repeat Step (4) for various spatial econometric models
```

Appendix H

ArcInfo AML for Buffering, Intersecting, and Condensing Land Cover Information

```
*******************************************************************
*                                                                 *
*  This program:                                                  *
*  -Buffers georeferenced points, intersects buffers and          *
*   underlying land cover coverage (polygon), and then sums       *
*   over all land cover classes                                   *
*                                                                 *
*   (Tables 2 through 6)                                          *
*******************************************************************


&args cross1_u-id

&if [null %cross1_u-id%] &then &return~
 Usage: &r do_it <cross1_u-id>

&if [length %cross1_u-id%] eq 1 &then &s housetext 00%cross1_u-id%
&else &if [length %cross1_u-id%] eq 2 &then &s housetext
0%cross1_u-id%
&else &s housetext %cross1_u-id%

&type %cross1_u-id% %housetext%

&s inpntcover cross1_u
&s inpntinfo cross1_u
&s inplycover class_uc
&s outpntcover pnt%housetext%
&s outbufcover buf%housetext%
&s outintcover int%housetext%

/*&goto SKIP

reselect %inpntcover% %outpntcover% point
reselect %inpntinfo%-id eq %cross1_u-id%
~
n
n

/* Below "borrowed" from buffer wizard
/* Begin: Buffer Wizard
/* Aml script created with ArcToolBox for tool: Buffer Wizard
/* Editing this file may make it unreadable to the ArcToolbox
 BUFFER %outpntcover% junk0 # # 105 # POINT
 BUFFER %outpntcover% xxxtemp0 # # 100 # POINT
  TABLES
  SEL xxxtemp0.PAT
  ALTER INSIDE
  INSIDE0 ,,,,,,,
  ~
```

```
QUIT

RENAME xxxtemp0 %outbufcover%
 ADDITEM %outbufcover%.PAT %outbufcover%.PAT INSIDE 5 5 I
 ADDITEM %outbufcover%.PAT %outbufcover%.PAT cross1_u-id 3 3 I
 TABLES
  SELECT %outbufcover%.PAT
  CALCULATE INSIDE =  0
  RESELECT INSIDE0  = 100
  CALCULATE INSIDE  =  100
  ASELECT
  DROPITEM  %outbufcover%.PAT INSIDE0
  DROPITEM  %outbufcover%.PAT xxxtemp0#
  DROPITEM  %outbufcover%.PAT xxxtemp0-ID
  RESELECT %outbufcover%-id ne 0
  calculate cross1_u-id = %cross1_u-id%
  QUIT

&if [exists xxxtemp0 -cover] &then KILL xxxtemp0 ALL

/* End: Buffer Wizard


clip %inplycover% junk0 junk1
intersect junk1 %outbufcover% %outintcover%

&if [exists junk0 -cover] &then kill junk0 all
&if [exists junk1 -cover] &then kill junk1 all

&label SKIP
frequency %outintcover%.PAT %outintcover%.FRQ
grid-code
inside
cross1_u-id
end
area
end


&return


&do i = 1 &to 372
  &r do_it %i%
&end
&return
```

Vita

Aaron R. Wells was born in Columbus, Ohio on April 9, 1977 to Charles R. Wells and Nancy L. Wells. In 1987 he moved to Germantown, Tennessee and attended St. Dominic Catholic school through grade eight. He graduated from Christian Brothers High School in 1995. Aaron graduated with a Bachelor of Science degree in Forest Resources Management in 1999 from The University of Tennessee, Knoxville. In August of 1999 he entered the Master's program at Northern Arizona University, Flagstaff. On August 5, 2000 Aaron married Jessica Lea Condrey in Medina, Tennessee. Aaron graduated with a Master of Science degree in Forestry from Northern Arizona University in 2001. Following graduate school, Aaron worked for the New Jersey Forest Service until he began the Doctoral program in Natural Resources at The University of Tennessee, Knoxville in January 2002. In August of 2002 Aaron also entered into the Master's program in Economics at UTK. Aaron graduated with a Master of Arts degree in Economics in May 2004 and a Ph.D. in Natural Resources in August, 2004.