Estimating Contingent Values for Protection from Wildland Fire Using a Two-Stage Decision Framework

Gregory J. Winter and Jeremy S. Fried

ABSTRACT. The ongoing expansion of human populations into wildland areas dominated by flammable vegetation, and the concomitant increased frequency of uncontrolled wildfires that result in losses of property and human lives, has raised new questions about the optimal level of fire protection. The morphing of the problem conception from minimizing costs plus losses of natural resources to responding to the concerns of people whose homes are at risk has stimulated fire protection planners to account for potential changes in people's well-being beyond what is reflected by insured value. Knowing the perceived value of an increase in collective (agency-provided) fire protection that achieves a risk reduction target can contribute much to policy debates on the restructuring and funding of fire protection infrastructure and fuel management.

To evaluate the utility of contingent valuation for assessing such risk reduction value, the value of collective fire protection at the wildland-urban interface was assessed for residents of a Michigan jack pine forest. Seventy-five percent of the 265 residents interviewed chose to participate in a hypothetical market for a 50% reduction in risk and, on average, were willing to pay over $57 a year for such risk reduction. Results were consistent with a two-stage decision model: (1) participation in the hypothetical market for risk reduction, and (2) how much the risk reduction is worth. Homeowner risk perception and objectively assessed risk both influenced the probability of market participation. For market participants, willingness to pay was related to property value and household income, suggesting that value at risk and ability to pay weigh heavily in this decision. For. Sci. 47(3):349–360.

Key Words: Risk reduction, wildfire, willingness to pay.

THE EMERGENCE AND EXTENSION OF THE wildland-urban interface (WUI) phenomenon[1] has greatly complicated the management of wildland fires. The traditional tactic of constructing a containment line around a fire as rapidly as possible is infeasible when homes and lives are immediately threatened. During a typical incident, firefighting resources are diverted to protect structures, thereby reducing containment effectiveness.

The WUI phenomenon also affects fire planning and efficiency analysis. Cost-plus-loss minimization is widely regarded as the principal criterion by which fire protection efficiency should be judged (Gorte and Gorte 1979). However, fire planning models which implement this criterion (e.g., USDA Forest Service 1985) rely on vegetation-based, zonal treatments of the landscape and assign a single, per-acre damage value for every burned acre within a zone. Calculating per-acre damage values under this framework is relatively straightforward when the primary value-at-risk is timber; it is far more difficult when the primary values-at-risk (buildings) are not evenly distributed over the landscape.

1 Where homes are built adjacent to and within areas of flammable vegetation.

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Although wildland fire protection organizations are compelled to protect property, little is known about the end-user demand for such protection. Individual homeowners can reduce their exposure to welfare impacts through insurance markets; yet insurance payouts rarely offset all losses. Investments in self-protection (physical modifications to a homesite or changes in behavior) can reduce risk, but most homeowners fail to take such precautions [Rural Fire Protection in America Steering Committee (RFPA) 1994]. The efficiency of government-sponsored programs designed to counteract imperfections in risk-reduction markets and misperception of risk by individuals can be enhanced by a better understanding of the processes by which individuals select risk-reduction alternatives (Shrogen and Crocker 1991). A valid efficiency analysis of fire protection at the WUI requires valid estimates of the value of protecting developed areas. Such estimates are difficult to generate because of both the dispersed nature of WUI development and the significant nonmarket components of wildfire damages (e.g., pets, photographs, keepsakes, and the time, inconvenience, and potentially unreimbursed expenses associated with post-fire relocation).

The contingent valuation method (CVM) is a promising and novel approach to obtaining estimates of the value of fire protection at the WUI (Fried et al. 1995). Residents can be asked to state their willingness to pay (WTP) for state-sponsored programs designed to reduce the risk of their home being destroyed by a wildland fire. Examples of such programs include improved firefighter training, acquisition of specialized equipment, and fire safety education programs aimed at homeowners and visitors to WUI areas.

The absence of prior applications using CVM to assess the value of fire risk reduction and the potential for bias when CVM is improperly designed or administered (Mitchell and Carson 1989, p. 321–359) motivated the construction of hypotheses to test the appropriate framework for analyzing CVM responses. Most agree that CVM study results will only be useful to policy makers if the validity of the approach can be demonstrated (Mitchell and Carson 1989, p. 207, Whitehead et al. 1997). This article describes the testing of a conceptual model of the homeowner decision to purchase collective protection in a Michigan jack pine forest.

Modeling the Decision to Reduce Risk

Expected utility theory suggests that in the face of an uncertain future (e.g., whether or not fire destroys their home), utility-maximizing individuals will place value on avoiding an unpleasant outcome or reducing the likelihood of its occurrence. This value can be expressed as a willingness to pay for risk reduction (Freeman 1993, p. 223). However, decision-makers are also assumed to behave as though they know the probabilities of future states and the value of potential losses and can accurately estimate their utility for each prospective state of the world. In practice, expected utility maximization frequently fails to explain the observed behavior of individuals facing uncertainty, possibly due to the failure of one or more underlying assumptions (Schulze 1993, Viscusi 1989, Slovic 1987, Kahneman and Tversky 1979).

Kunreuther (1978, p. 8) proposed an alternative, "bounded rationality" choice model for valuing insurance in which simple heuristics rather than abstract utility functions form the basis of individuals' decisions. Decisions concerning hazard insurance can be represented as a two-stage sequence: (1) "Do I consider the hazard a problem?" and (2) if so, "How much should I invest to reduce the risk posed by this hazard?" Individuals will ignore even a catastrophically consequential hazard if they regard its likelihood as below their threshold of concern (Kleindorfer and Kunreuther 1988).

Literature addressing the WUI problem suggests that residents possessing different information concerning fire hazard are likely to provide different WTP responses when confronted with a contingent market for risk reduction (Gardner et al. 1987, McKay 1985). For example, those who have lived in a fire-prone setting long enough to witness fires in nearby communities and be exposed to media coverage of such events are likely to have a greater awareness of the fire problem and to perceive a greater risk. Ultimately, willingness to take protective measures depends on risk preference and risk perception, which, in turn, likely depends on fire experience and proximity to recent fires. Based on a study comparing fire risk perceptions in two fire-prone communities, only one of which had experienced recent, damaging fires, Gardner et al. (1987) proposed that the occurrence of a wildfire introduces a dampening effect on hazard awareness, risk perceptions and propensity to take actions to reduce risk among fire-affected residents who subscribe to the notion that "lightning won't strike twice in the same place"; however, residents living outside the immediate vicinity may exhibit opposite reactions. The latter result is consistent with the high, positive correlation between hazard experience and assessment of the likelihood of future hazard events observed in prior studies of responses to fires and other hazards (e.g., Cortner and Gale 1990, Gardner et al. 1987, McKay 1985, Tversky and Kahneman 1973).

An individual's perception of his or her role in society has been identified as an important psychological factor in decisions about taking precautions against a hazard (Burton et al. 1993, p. 119). This may be especially relevant in the case of wildland fire where multiple opportunities for hazard precautions are available, some open to individuals and others requiring collective action (i.e., typically under the auspices of a government agency). The mix of hazard precautions ultimately undertaken will likely depend on perceptions of who is responsible for wildfire protection. Individuals can reduce their exposure to risk through *collective action*; for example, by opting to pay additional taxes earmarked for improving government-sponsored fire prevention and suppression programs. They can also engage in *self-protection*, as when they manage vegetation and/or retrofit their homes to reduce vulnerability to wildfire damage. Purchasing fire *insurance* offers yet a third option for hazard precaution.

The availability of multiple modes of hazard precaution complicates the analysis of risk-reduction benefits. Because each strategy can reduce the probability and/or severity of wildfire damage, an absence of insurance or self-protection opportunities could be expected to increase the value of collective risk reduction. Conversely, when multiple strate-

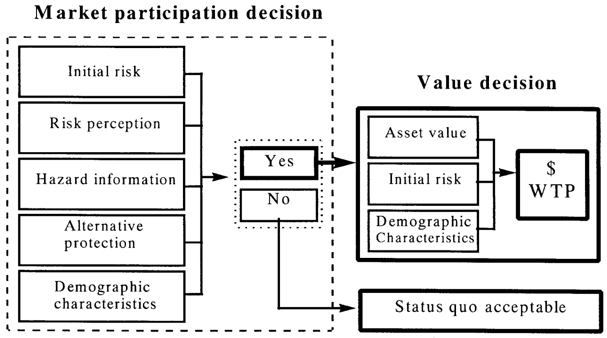

Figure 1. Conceptual model of a staged decision process for purchasing collective wildfire protection.

gies are known to be available, the reported value of any one of them may underestimate the full benefits received. In a series of controlled experiments designed to assess the influence of alternative hazard precaution strategies on the value of risk reduction, self-protection was more highly valued than collective action, and some individuals provided with opportunities for self-protection or insurance exhibited negative willingness to pay for collective action (Shrogen and Crocker 1991).

Conceptual Model

These theoretical relationships and empirical findings give rise to a testable, conceptual model of the homeowner's decision to purchase collective protection from wildfire home destruction (Figure 1). Consistent with a sequential choice model, the decision can be considered as a two-stage process: first, homeowners decide whether or not to participate in the market for collective protection; then, those who choose to participate decide how much the risk reduction is worth. If a homeowner is unconcerned about fire risk, she is unlikely to participate in a market for risk reduction. Risk perception, hazard information, alternative protection behavior (fire insurance and self-protection), and initial risk influence the likelihood that homeowners will purchase collective protection. Value of assets at risk and household income affect the amount that homeowners are willing to pay for a given amount of protection. Demographic variables including age, household income, education, and gender are also included as potential explanatory variables for both stages of the decision. We also consider an alternative model where market participation and value decisions are simultaneous.

Methods

Survey Design

Data for this study were generated via an in-person, CVM survey administered in Crawford County, Michigan, the site of several recent wildfires including the devastating 1990 Stephan Bridge Road (SBR) fire in which over 70 homes were destroyed (Figure 2). The survey instrument was designed to elicit estimates of the value of incremental reductions in the risk of home destruction by wildland fire via a hypothetical market in which a supplemental tax funds additional government investments in fire protection (Batts 1993). Additional questions measured demographic variables and other elements of the conceptual model. The conceptual

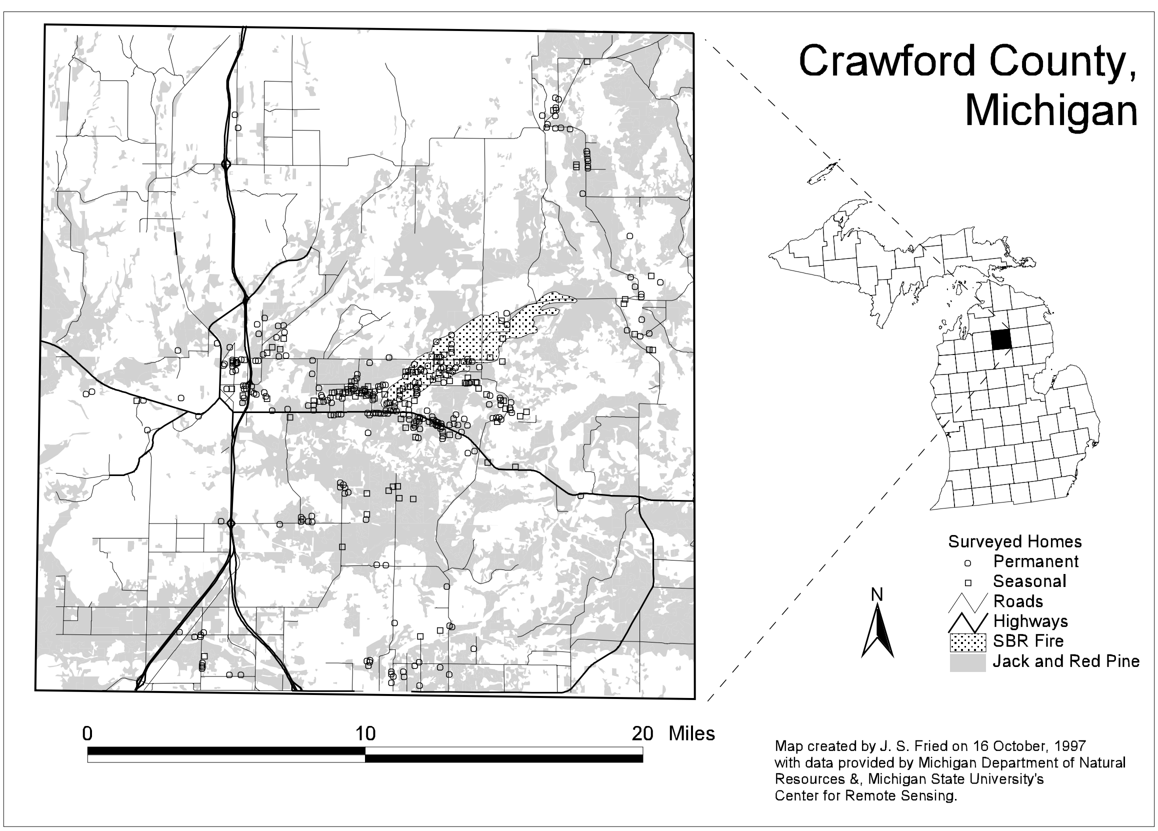

Figure 2. Map of the Crawford County, Michigan, study area showing the locations of households sampled, main roads and highways, the perimeter of the 1990 Stephan Bridge Road (SBR) fire, and the locations of pine forests.

Table 1. Definitions of variables used in the contingent value models.

Model element	Variable	Definition
Market participation	WTP (Yes)	1 if homeowner bid positive amount for wildfire risk reduction, 0 otherwise
Collective risk reduction value	WTP Bid	Amount of final wildfire risk reduction bid
Alternative protection	Reducer	1 if homeowner has taken self-protection action(s) to reduce wildfire risk, 0 otherwise
Hazard information	Survey96	1 if homeowner was interviewed in 1996, 0 if 1994
Hazard information	Distance	Euclidean distance in miles to 1990 SBR fire perimeter
Hazard information	Damage	1 if homeowner has experienced damage to property from wildfire, 0 otherwise
Hazard information	Numyears	Number of yr respondent has occupied residence for all or part of the yr
Risk perception	WfireRank	Homeowner wildfire hazard rank, 1 if most likely…4 if unlikely
Risk perception	Firechance	Respondent assessment of percent chance wildfire occurs in neighborhood in next ten yr (as decimal)
Risk perception	Damchance	Respondent assessment of percent chance passing wildfire destroys home (as decimal)
Responsibility	Responsible	Responsibility for wildfire protection, 5 pt scale with 1= primarily homeowner, 5 = primarily government
Tax attitude	PropertyTax	Belief about current property tax spending, 1 = too much, 5 = too little
Demographic	Education	Education level, 1 if grade school…7 if graduate school
Demographic	Age	Age range, 1 if less than 25 yr old, 12 if over 76 yr old
Demographic	Income	Income range, 1 if less than $10,000/yr, 7 if over $45,000 per yr
Demographic	Seasonal	1 if seasonal resident, 0 if permanent resident
Demographic	Gender	1 if female, 0 if male
Initial risk	InitialRisk	Level of risk as percent chance that home would be destroyed by wildfire in next ten yr (on-site assessment)
Asset value at risk	PropertyValue	Respondent estimate of property value in $1,000's (or a township assessment of property value) including land and improvements

model was tested by evaluating the strengths and directions of the relationships between the dependent variables (market participation and collective risk reduction value) and the independent variables listed in Table 1.

Small population sizes (particularly for residents with loss experience, where $n = 47$) and the high cost per sample element motivated a direct, open-ended WTP question format with iterative bidding. Respondents were queried for their WTP for up to two levels of risk reduction via an increment in their annual property tax: (1) from an objectively estimated initial risk, π, conveyed to the respondent during the interview following elicitation of risk perception but before elicitation of WTP, to the next lower level in Table 2; and (2) for an additional reduction in π to the next lower level. Households already at the lowest level of risk ($\pi = 0.04$) were asked instead for their WTP for a single reduction in π to one-half of that level ($\pi = 0.02$).[2] Only the responses to the first risk reduction question are included in this analysis.

Risk Assessment

Initial risk was objectively assessed by interviewers based on decision rules established by a panel of local fire professionals and an on-site, property risk assessment by the interviewers immediately preceding the CVM interview at the respondent's home. Initial risk π, expressed as a percent chance, that a respondent's home would be destroyed by wildfire in the next 10 yr (assuming that no new individual or collective risk reduction efforts are undertaken), was calculated as the joint probability of occurrence of two events: (1) the unconditional probability, μ, that a wildland fire would occur in the respondent's neighborhood over a 10 yr period, and (2) the expert-assessed conditional probability, ρ, that the respondent's home would be destroyed if such a fire occurs (Table 2).[3] Analysis of Geographic Information System coverages containing land cover and historical fire ignitions produced a regional estimate of 0.15 for μ.[4] This estimate of initial risk ($\pi = \rho\mu$) was introduced, with a brief reference to its derivation, during the description of the hypothetical market for risk reduction at a point in the interview approximately 10–15 minutes following elicitation of perceptions of unconditional and conditional probability estimates (see below).

2 The operational definition of willingness to pay for risk reduction was defined by survey responses to the following question: *Earlier we determined that the probability of you losing your home to fire within the next ten years was ...(initial risk)... . Through a combination of public prevention and suppression programs this risk can be reduced to ...(refer to and show risk_card)... . Keeping in mind this action will only be taken if there is sufficient demand from the public, how much would you be willing to pay each year, in increased property taxes, for this risk reduction? (Q 23)*

3 Post-fire analysis has shown that landscaping and home construction characteristics are important predictors of wildfire home losses in areas where wildfires occur (Foote et al. 1992).

4 For any point in a stratum such as jack pine, the probability of fire during a 10 yr period can be estimated simply as the proportion of the stratum that has, on average, burned during historical 10 yr periods. The available, spatially referenced data on fire area spans only 12 yr, so a rough estimate of m suitable for the objectives of this study could be calculated as m = acres burned by fires igniting in jack pine between 1980 and 1992/ac of jack pine in 1980 × 10/12.

Table 2. Objectively assessed conditional and joint probabilities of home destruction by wildland fire, by hazard precaution taken.

Action taken	Conditional probability (ρ)	Joint probability (π)*
(1) None	0.93	0.14
(2) Trees cleared	0.67	0.10
(3) 2 + grass mowed in fall	0.47	0.07
(4) 3 + debris free	0.27	0.04

* based on $\mu = 0.15$

Risk Perception

Perception of π, the "intuitive judgment" of the risk posed by a hazard (Slovic 1987), was not elicited directly. Instead, respondents were asked to independently estimate the unconditional and conditional probabilities described in the risk assessment section above (these estimates are referred to as Firechance and Damchance in Table 1).[5] This separable risk elicitation approach was undertaken both to reduce the potential for conflict between the expressed perceptions of risk and the risk presented in the description of the hypothetical market (because they are not directly comparable), and to facilitate analysis of other questions addressed by the survey, such as the relationship between WTP for self-protection and perceived conditional risk. In a separate question pertaining to the perception of wildfire risk (referenced as Wfirerank in Table 1), respondents were asked to rank the chance of losing their home in a wildfire against three other risks (tornado damage to home, severe injury automobile accident, and being the victim of a nonviolent crime).

Hazard Precaution Alternatives

Some individuals may not take precautions against a hazard because they believe that government has an obligation to provide protection. If widely held, this belief could exert pressure on the community to provide protective services (Burton et al. 1993, p. 119–126). Examples of such collective protection include investments in new or upgraded fire suppression equipment, personnel training, improving roads to facilitate access by emergency vehicles, and fire prevention programs like homeowner education. Other individuals may view self-protection or fire insurance as the most appropriate responses. The survey assessed hazard precaution alternatives by asking homeowners whether they carry fire insurance[6] and whether they had invested in self-protection.

The joint probability model implies that individuals can reduce their exposure to the joint risk π, by engaging in self-protective actions that reduce the conditional risk, ρ. Individuals can create a defensible space by removing flammable vegetation, debris, fuel tanks, and firewood from a 30 ft zone around their homes. In some cases, they can retrofit their homes with fire-resistant building materials (e.g., by installing a fire-resistant roof or screening soffit vents). Survey participants received information about these self-protection options as well as information about collective protection alternatives.

Perceptions, Values at Risk, and Beliefs

Data thought to be related to hazard awareness and experience were collected, including length of residency, wildfire damage experience, years since the 1990 SBR fire (interview year), and proximity to the 1990 SBR fire perimeter (residents with homes inside the fire perimeter were assigned a distance value of 0).

Homeowner assessment of property value was used as a surrogate for value at risk. Ideally, *all* values at risk would be elicited from respondents, including monetary estimates of items with great sentimental value (e.g., photographs) and expenses associated with the inconvenience of losing one's home (e.g., temporary housing and commuting expense). However, pre-tests indicated that those not having had the experience of losing a home would find it exceedingly difficult to list these items, let alone generate value assignments for each in the course of a 30 minute interview.

Respondents were also asked about their beliefs concerning the division of fire protection responsibility between homeowners and government agencies and the amount of their property tax assessment. Those expressing high levels of dissatisfaction with their current property tax assessments were likely candidates for protest bidding.

Data Collection

Following a period of iterative pre-testing and revisions to the survey instrument, 407 WUI residents of Crawford County, Michigan, were interviewed (285 in 1994 and 122 in 1996). Surveys were administered at peoples' homes immediately following an on-site, property risk assessment. Seventy percent of this rural, forested county is under state or federal ownership, and jack pine *(Pinus banksiana*, Lamb.), a fire-adapted species that is native to the area, is the most common land cover type. Much of the public forest is managed as habitat for the Kirtland's warbler (*Dendronica kirtlandii*), an endangered songbird. The 1990 SBR fire destroyed 76 homes, burned nearly 6,000 ac of public and private forest [National Fire Protection Association (NFPA) undated], and left area residents with a legacy of direct and indirect wildfire experiences. Forty-seven survey participants had sustained damages during this fire.

The location of the population targeted for sampling was initially defined by an overlay of GIS coverages of roads and jack pine forest from the 1980 Michigan Resource Information System (MIRIS). However, the roads coverage contained only a fraction of the paved roads in the study area, and included no street names, and commercial maps of the study area were also woefully incomplete with respect to the road

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[5] Unconditional and conditional risk perception were elicited with the following questions: *Which percentage best represents your estimate of the probability of a wildfire moving through the block on which you live at some time in the next ten years? [respondent has card with 0–100% range printed on it for reference] (Q 13). If a fire were to pass through your neighborhood, which percentage best represents the probability of it destroying or severely damaging your home? (Q 14).*

[6] Nearly all homeowners (97%) responded "yes" to this question; therefore, insurance is not included as a variable in the model. The survey was also designed to elicit the degree of insurance as a variable, but many homeowners did not know the extent of their insurance coverage resulting in high item nonresponse for this question.

network. Further confusion with respect to the area's road network resulted from the ubiquitous local practice of using multiple names for the same road.

Telephone listings, tax records, and a "911" database summary were then consulted to identify as many of the households living in the study area as possible. A complete and correct list of names, addresses, and telephone numbers for all households living in the study area could not be developed due to deficiencies in these data sources. Telephone listings did not reflect unlisted numbers or households without telephones, making identification of seasonal residents particularly difficult. Commercial CD-ROM telephone listings included information on less than half of the households in the study area, so the more extensive listings in the 1993 Grayling telephone book had to be manually entered into a database, increasing the probability of data corruption. Addresses obtained from telephone listings were of limited utility for contacting households by mail, because the U.S. Postal Service recognizes only rural route and box numbers for a substantial number of the structures in the study area. An alternate address source, the Grayling Township property tax assessor's database, contained only legal property descriptions (i.e., referencing township, range and section rather than street address) and the mailing address to which property tax bills are sent. Over 40% of these tax bill addresses were outside the county, reflecting the study area's high proportion of seasonal residents. Even "local" tax addresses were not necessarily relevant, since many individuals held title to more than one property, and the records did not distinguish between properties with and without structures. Ultimately, address ranges along named roads had to be determined in the field utilizing maps and the telephone book database.

Starting from a list of households (with telephones) living on named roads in the study area, attempts to schedule interviews by telephone were problematic due to low at-home rates except in the evening hours, which were simultaneously the residents' preferred time to be interviewed. Interviewers therefore were directed to make door-to-door inquiries without prior telephone contact. Nevertheless, most households received a mailing informing them of study objectives and requesting their participation. Records were kept of all households who declined to participate regardless of contact method to allow calculation of an overall "decline-to-participate" rate, and to ensure against further contact.

Model Estimation

A feature of open-ended valuation responses complicates the data analysis: the distribution of willingness to pay is typically bimodal, containing a high frequency of zero bids, and a second bell-shaped part of the distribution covering positive willingness to pay values (Schulze 1993). Therefore the respondents can be divided into two groups, (1) those who bid positive amounts for risk reduction, and (2) those who chose not to participate in the hypothetical market (zero bidders). One option for data analysis is to estimate a binary response model (probit or logit) for the market participation decision and ordinary least squares (OLS) for the value decision. But for OLS regression, the resulting parameter estimates using this approach will be biased and inconsistent because if only market participants are considered, it cannot be assumed that the expected mean of the error term will be zero (Gujarti 1995, p. 573). Fortunately, several econometric techniques are available to analyze limited dependent variable data.

The tobit model is one example of a regression model widely used to estimate demand for consumer goods. In the context of this research, the tobit model takes the form

$$\begin{aligned} Y_i &= \beta X_i + u_i \quad \textit{if} \;\; \beta X_i + u_i > 0 \\ Y_i &= 0, \; \textit{otherwise} \end{aligned} \tag{1}$$

where Y is the payment for risk reduction by individual i, X is a vector of independent variables, β is a vector of unknown coefficients, and u is an independently distributed error term with mean of zero and constant variance (McDonald and Moffitt 1980).

An assumption underlying this application of the tobit model is that Y represents a latent variable (propensity to purchase risk reduction) so that if values for explanatory variables changed, say an increase in income, zero bids would turn positive (Blaylock and Blisard 1992). But in this study, changes in some explanatory variables may *not* affect willingness to pay. For example, residents who strictly prefer self-protection over collective protection, or who face an initial risk that falls below their threshold of concern, are unlikely to participate in the hypothetical market for public risk reduction. In the tobit model, variables that increase the probability of nonzero values also increase the mean of positive values, so both the decision to consume and the quantity to consume are based on a single set of estimated tobit coefficients. This can be seen by examining the mathematical relationship of parameters in the tobit analysis to the dichotomous participation decision and continuous value decision. The probability of observing a limit observation ($Y_i = 0$) is

$$P(Y_i = 0) = \Phi(-X_i\beta / \sigma) \tag{2}$$

where Φ is the standard normal distribution function. The likelihood function for Y_i is

$$L = \prod \Phi(-X_i\beta / \sigma)^{(1-I_i)} \cdot 1/\sigma\phi\left(\left[Y_i - X_i\beta\right]/\sigma\right)^{I_i} \tag{3}$$

where $I_i = 0$ for limit observations and $I_i = 1$ otherwise, and ϕ is the standard normal density function. Estimates of β and σ are obtained by maximizing the likelihood function. Because there is only one coefficient, β, in (3) that determines both the probability that Y is a nonlimit observation and the mean of Y for positive values (Haines et al., 1988), explanatory variables necessarily have the same directional effect on both stages of the consumer decision (market participation and value). Thus, while the tobit model can decompose the WTP observations into the participation and value decisions, its single coefficient set representation of two quite different decisions is inconsistent with a conceptual model that proposes differential effects of independent variables on the market participation and value decisions.

Table 3. Univariate summary statistics for dependent and independent variables assessed for the model.

Variable[a]	Mean	SD	Minimum	Maximum
WTP (Yes)	0.75	0.43	0	1
WTP Bid	$ 57.26	$ 74.60	0	$500.00
Reducer	0.74	0.43	0	1
Survey96	0.35	0.47	0	1
Distance	3.13	3.04	0	65
Damage	0.09	0.28	0	1
Numyears	15.75	12.40	0	1
WfireRank	2.75	0.97	1	4
Firechance (μ)	0.41	0.24	0	1
Damchance (ρ)	0.54	0.30	0	1
Responsible	2.72	0.96	1	5
PropertyTax	2.40	0.95	1	5
Education	4.27	1.51	1	7
Age	7.54	2.79	1	12
Income	4.96	1.94	1	7
Seasonal	0.42	0.49	0	1
Gender	0.25	0.44	0	1
InitialRisk	8.28	4.05	4	14
PropertyValue ($1,000)	50.58	43.44	0.12	450
N		265		

[a] Variables defined in Table 1.

A generalization of the tobit model developed by Cragg permits separation of the consumer decision into two stages. The probability of a limit observation is

$$P(Y_i = 0) = \Phi(-X_i\beta_1) \qquad (4)$$

The density function of Y_i conditional on being positive is normal with mean $X_i\beta$ and variance σ^2:

$$f(Y_i|/Y_i > 0) = \frac{\{1/\sigma\ \phi\ ([Y_i - X_i\beta_2]/\sigma)\}}{\phi\ (X_i\beta_2/\sigma)} \qquad (5)$$

The likelihood function for the observed sample is

$$L = \prod \Phi(-X_i\beta_1/\sigma)^{(1-I_i)} \cdot \left\{\frac{\Phi(X_1\beta_1)[1/\sigma\phi([Y_i - X_i\beta_2]/\sigma)]}{\Phi(X_i\beta_2/\sigma)}\right\}^{I_i} \qquad (6)$$

The function can be maximized for β_1 and β_2; therefore, the explanatory variables X_i can have different effects in determining the probability of a nonzero value for Y_i and in determining the mean of Y_i. The tobit estimator is a special case of the Cragg estimator where $\beta_1 = \beta_2/\sigma$. Generating Cragg model estimators β_1 and β_2 consists of estimating a probit model for the probability that $Y_i > 0$ and a truncated regression model for the nonlimit observations (Greene 1993, p. 700). If tobit is the correct specification, the tobit estimators are equal to the sum of the Cragg estimators (probit coefficients plus truncated regression coefficients). A likelihood ratio test is used to test this null hypothesis. The likelihood ratio test statistic, $-2 \ln \lambda$ is chi-squared, with degrees of freedom equal to the number of variables specified. For this case, the test statistic is given by

$$\chi^2 = -2\ \ln\left(\frac{L_{probit} + L_{trunc.}}{L_{tobit}}\right) \qquad (7)$$

If the null hypothesis is rejected, the estimators for the alternative models are not equal, and it is assumed that the independent variables do not have equal effects on (1) the probability that Y_i is a nonlimit observation, and (2) the variance of nonlimit observations (Greene 1993, p. 701).

Results

The population of interest consisted of homeowners living in or adjacent to jack pine forest in Crawford County Michigan, mostly in or near Grayling Township. Of 344 households contacted in 1994 (by phone or in person), 83% agreed to be interviewed. In 1996, 81% of the 151 households contacted agreed to be interviewed. Altogether, 407 interviews were conducted in 1994 and 1996. Item nonresponse and removal of five WTP outliers[7] reduced the useable data set for multivariate analysis to 265 responses.[8]

At 0.41 for the sample (Table 3), perception of unconditional risk of wildland fire occurrence, μ, exceeded the

7 Before estimating the model, five outliers greater than $500 (1000, 1000, 1000, 750, and 720) were removed because the algorithm used for maximum likelihood computations failed to converge when these values were included. The software program we employed (LIMDEP) uses Newton's method for maximum likelihood estimation. This algorithm is sensitive to clusters of data far from the truncation point, which might explain the convergence problem. Scaling the data—a technique commonly used to solve this problem—failed to eliminate the problem in this case. Outlying values are a common problem in CV studies, in part, because there is no upper bound to a person's WTP response. Researchers sometimes employ an alpha-trimmed mean or decision rules on how reasonable certain high value responses are—a percentage of pre-tax income, for example (Mitchell and Carson 1989, p. 226). However, we find these five outlying values reasonable and have eliminated them solely for the purpose of achieving convergence. Unfortunately, this may produce biased estimators if any of these outlying observations are influential in the truncated regression model.

8 Respondents in the usable survey group tended to report higher household income, suggesting anupward bias for risk-reduction values obtained from the usable surveys because income is positively related to risk-reduction value.

objective estimate of 0.15. The mean estimate of conditional risk, ρ, in the sample (0.54) is remarkably close to the objective estimate for the sample (0.55). The respondents' perceived conditional risk and our estimates of ρ based on the on-site risk assessments are moderately correlated ($r = 0.35$, $P < 0.001$). Only 25% of the sample respondents were women. Median household income was in the range $25,000–35,000. Mean property value was $50,580.

Seventy-five percent of respondents were willing to participate in the hypothetical market. For market participants, the mean annual WTP for collective risk reduction is $57.26 (median = $40.00). Independent sample *t* tests found no significant ($P = 0.1$) differences in mean WTP between 1994 and 1996 respondents. The distribution of WTP values is characteristic of those obtained from other open-ended CVM elicitation formats; it is bimodal with one mode at zero and another within a bell-shaped distribution with a thick upper tail (Schulze 1993).

Comparisons between tobit and Cragg specifications for this data set refute the notion of a simultaneous decision structure underlying the conceptual model. Using the likelihood ratio test, the null hypothesis that the tobit and Cragg models are statistically equivalent, is rejected ($\chi^2_{df=18} = 109$, $P < 0.1$), suggesting that the underlying decision process is, in fact, sequential and that the variables have different effects at each stage in the sequential decision. For example, the tobit coefficient for property value is positive and statistically significant (Table 4); however, only the truncated regression coefficient of the Cragg model is significant for property value, indicating that this variable affects the value decision but not market participation. Initial risk, conditional risk perception (Damchance), and property tax spending belief affect only the participation decision.

The probit (participation) and truncated regression (value) equations, which comprise the Cragg model, are summarized in Table 4. The probit model correctly classified 78% of the respondents (i.e., probability of participation > 0.5 for individuals with positive bids; probability of participation < 0.5 for respondents with zero bids).

The probit and truncated regression coefficients indicate the direction of the relationship between the independent and dependent variables; however, since both models are nonlinear, the coefficients do not fully describe these relationships. To obtain indications of the extent to which changes in independent variables affect the predicted probability of market participation, we examine (1) the range of predicted probability when we allow one variable to vary from its minimum to its maximum, holding all other variables at their means (modes for dichotomous variables), and (2) the change in the predicted probabilities for a discrete change in the independent variables (Long 1997, p. 64). The predicted change in probability as independent variable x_k changes from its minimum to its maximum equals

$$\Pr\left(y = 1 \middle| \bar{x}, \max x_k\right) - \Pr\left(y = 1 \middle| \bar{x}, \min x_k\right) \quad (8)$$

Table 4. Coefficients (and standard errors, in parentheses), -log likelihood, and χ^2 statistic for Tobit and Cragg Models for the purchase decision component of the contingent valuation of collective wildland fire risk reduction.

Variable	Tobit Model	Cragg Model Probit	Cragg Model Truncated
Constant	*–102.940	*–2.098	*–460.580
	(42.922)	(0.816)	(219.320)
Reducer	9.562	*0.724	–23.685
	(12.333)	(0.240)	(40.510)
Survey96	6.424	*0.786	–66.934
	(14.207)	(0.287)	(47.173)
Distance	2.755	0.027	9.582
	(1.830)	(0.033)	(6.686)
Damage	–4.464	–0.351	59.468
	(19.735)	(0.351)	(62.391)
Numyears	0.077	0.001	0.393
	(0.468)	(0.009)	(1.475)
WfireRank	*–9.559	–.090	–6.459
	(5.548)	(0.106)	(18.149)
Firechance	13.046	0.310	17.459
	(24.261)	(0.472)	(80.392)
Damchance	27.541	*0.986	–10.331
	(20.485)	(0.393)	(69.719)
Responsible	4.112	–0.036	32.588
	(5.712)	(0.105)	(22.606)
PropertyTax	5.980	*0.253	–10.135
	(5.581)	(0.109)	(18.589)
Education	–0.009	–0.035	1.827
	(4.347)	(0.082)	(14.130)
Age	–0.558	–0.013	3.107
	(2.214)	(0.040)	(7.819)
Income	*9.812	*0.153	*35.372
	(3.798)	(0.071)	(16.250)
Seasonal	–20.479	–0.373	–17.001
	(14.363)	(0.265)	(46.107)
Gender	7.299	*0.606	–19.735
	(12.603)	(0.268)	(44.454)
InitialRisk	*4.068	*0.098	4.532
	(1.393)	(0.029)	(4.788)
PropertyValue	*0.711	–0.002	*1.566
	(0.130)	(0.002)	(0.352)
–Log likelihood	1,203.97	113.90	1,035.50
$\chi^2_{df=18}$		109.14*	

* Significant $P < 0.1$.

where

$$\Pr\left(y_i = 1 \middle| x_i\right) = \Phi\left(x_i \beta\right). \quad (9)$$

The change in the predicted probability of market participation for a discrete unit increase in x_k that is centered around $\bar{x}$ is

$$\frac{\Delta \Pr(y = 1|\bar{x})}{\Delta x_t} = \Pr\left(y = 1 \middle| \bar{x}, \bar{x}_k + \frac{1}{2}\right) - \Pr\left(y = 1 \middle| \bar{x}, \bar{x}_k - \frac{1}{2}\right). \quad (10)$$

A summary measure of the effect of the continuous independent variables on risk reduction value for market participants is obtained by taking the partial derivative of the truncated regression model with respect to x_k with all other variables held at their means (Greene 1993, p. 688); for dichotomous variables, the

Table 5. Discrete change in the probability of market participation for the probit model

Variable	Probabilities of market participation over the range of each independent variable for the probit model: At minimum	At maximum	Range of probability	Discrete change in the probability of market participation for the probit model: Centered unit change*	Change from 0 to 1
Reducer	0.536	0.705	0.168		0.168
Survey96	0.705	0.840	0.135		0.135
Distance	0.687	0.927	0.240	0.006	
Damage	0.705	0.627	0.078		–0.078
Numyears	0.701	0.702	0.000	0.000	
WfireRank	0.736	0.681	0.056	–0.019	
Firechance	0.677	0.741	0.064	0.006	
Damchance	0.583	0.790	0.206	0.021	
Responsible	0.717	0.687	0.030	–0.007	
PropertyTax	0.626	0.822	0.196	0.053	
Education	0.728	0.684	0.044	–0.007	
Age	0.722	0.692	0.030	–0.003	
Income	0.565	0.765	0.200	0.032	
Seasonal	0.705	0.622	0.083		–0.083
Gender	0.705	0.814	0.109		0.109
InitialRisk	0.611	0.807	0.196	0.020	
PropertyValue	0.725	0.518	0.208	0.000	

* The unit change for Firechance and Damchance = 0.1, all other unit changes =1.0

discrete change in risk reduction value as the variable moves from 0 to 1 is used (Long 1997, p. 209).

***Market Participation*.—**Of those variables that have a statistically significant effect on market participation, perception of conditional risk (Damchance) has the largest range of predicted probability (0.206) from 0.583 when Damchance equals its minimum value (0.00) to 0.790 when Damchance is at its maximum value (1.00), holding all other variables at their means (Table 5). For a man who was a permanent resident, was interviewed in 1996, had taken self-protection measures, had not experienced wildfire damages, and is average on all other characteristics, a 0.10 increase in his estimate of the conditional risk that he will lose his home to wildfire increases the probability of market participation by 0.02. For a woman with exactly the same attribute values, the probability of participation in the market for risk reduction increases by 0.11.

***Risk Reduction Value*.—**Marginal effects for the value decision are evaluated at the independent variable means (Table 6). Annual wildfire risk reduction value increased by \$7.51 per property value unit (\$1,000). Income also affected risk reduction value. An additional unit increase in household income (measured as ranges on a 7-point ordinal scale) increased the value by \$169.77.

The effect of property tax spending beliefs suggests that protest bidding may have been more pervasive than the three zero bids identified by interviewers would indicate. Respondent explanations for zero bids can be divided into two categories: (1) they preferred private risk reduction mechanisms, and (2) they assessed risk as acceptably low. While researchers accepted these explanations at face value, an underlying payment vehicle bias is evident for some bidders. Overall, 29% of respondents returned zero bids, but 48% of the respondents who believed they pay "too much" in property taxes ($n = 89$) bid zero. Despite our belief that a payment vehicle bias exists, none of the sample cases exhibiting this characteristic were removed from the usable data set.

Interviewer bias may explain the positive coefficient for 1996 respondents (Survey96). One of four 1994 interviewers returned surveys with a significantly higher proportion of zero bidders than those returned by other interviewers (whose proportion of zero-bidding respondents equaled that of the 1996 interviewer).

Discussion

Estimates of collective risk-reduction value were consistent with theoretical expectations. Consistent with a threshold model of choice, risk perception influenced the probability of market participation but not WTP. Conformance with the expectations of the expected utility model was mixed: the relationship between asset value at risk and WTP was significant, as expected, but the proposition that, given an

Table 6. Marginal effects and discrete changes in risk reduction value for the truncated regression model

Variable	Effect of continuous and dichotomous independent variables on risk reduction value: Marginal effects	Discrete change from 0 to 1
Reducer	—	–23.685
Survey96	—	–66.934
Distance	45.990	—
Damage	—	59.468
Numyears	1.885	—
WfireRank	–31.000	—
Firechance	83.795	—
Damchance	–49.585	—
Responsible	156.400	—
PropertyTax	–48.641	—
Education	8.768	—
Age	14.910	—
Income	169.77	—
Seasonal	—	–17.001
Gender	—	–19.735
InitialRisk	21.753	—
PropertyValue (\$1,000)	7.514	—

equivalent percent reduction in risk, WTP values would increase with baseline risk, was not supported. Rather, initial risk appears, along with six other variables, to exert a threshold effect in that homeowners are more likely to participate in the market for collective risk reduction if initial risk is high. The value decision is driven by asset value at risk and household income, which also exerts a threshold effect. Comments by survey participants during WTP elicitation provided supporting evidence for this conclusion. Several individuals who were unwilling to participate in the hypothetical market regarded the specified initial risk as less than the risk of a house fire caused by arson or faulty wiring. One said: "At 7% you could get hit by lightning." The significant relationship between initial risk and market participation suggests that respondents adopted these expert opinion-based, objective estimates and incorporated them into their decisions. However, conditional risk perception (Damchance), prior to receipt of objective risk assessments, was also a significant factor. It is entirely plausible that those most concerned about risk, and thus most likely to be willing to pay for its reduction, have inherently pessimistic perceptions of the conditional risk they face.

The influence of past risk reduction behavior (Reducer) on market participation was the opposite of what we had hypothesized. Rather than treating alternative hazard precaution opportunities as substitutes, homeowners already practicing self-protection were more likely to purchase additional increments of protection, suggesting that past risk reduction is better viewed as an indicator of risk aversion. Although virtually all respondents carry fire insurance (97%), few could (or would) describe the kind and amount of coverage, so it was not possible to include insurance-related variables in the model.

Comments by many who bid zero indicated a preference for increased insurance or self-protection, or an acceptance of the risks that accompany "living in the woods." Some remarked on the ferocity of the 1990 SBR fire and averred that "nothing could have stopped it." Others doubted the efficacy of almost any initiative undertaken by the state's Department of Natural Resources. Insurance and self-protection are quite logical alternatives for those who regard collective protection as inherently futile.

Wildfire damage experience was not a significant predictor of market participation or WTP. Although perceived unconditional risk of wildfire occurrence was greater among respondents who had suffered wildfire damage, it was conditional, not unconditional, risk perception that significantly influenced market participation; neither perception was related to the value decision.

The lack of significance for proximity (straight-line distance) to the SBR fire perimeter may be explained by the complexity of the relationships that this variable was expected to capture. We expected that residents who experienced loss or direct threat from the 1990 fire (Distance = 0) would be the least willing to invest in collective protection because they would find a repetition of the disaster unlikely any time soon (i.e., it would take many years for vegetation-based fuels to reach a state of high hazard). However, for residents living outside the fire perimeter (Distance > 0), we expected WTP to decrease with increasing distance, as familiarity with hazard outcome diminished. Because the relationship appears to be nonmonotonic, it is not surprising that there is no statistically significant coefficient for this variable in the model as specified.

Commenting on the need for CVM validity tests, the NOAA Panel on Contingent Valuation wrote, "…some form of internal consistency is the least we would need to feel some confidence that the verbal answers correspond to some reality" (Arrow 1993, p. 4604). This study shows that a combination of continuous WTP data and an econometric model consistent with the consumer's decision framework is capable of yielding theoretically valid results. By dividing the decision into participation and valuation components, the two-stage approach permits testing theoretical validity free of assumptions that risk is exogenous or that initial risk affects a simultaneous valuation decision requiring perfect information.

Recommendations for Further Research

This study represents an important first step in assessing the feasibility of using CVM for wildfire risk valuation. However, additional work is needed to address potentially important predictors of market participation. Some individuals will reject even the most plausible hypothetical market for collective risk reduction because they view fire control efforts as a futile attempt to control an awesome natural force or because of their perceptions concerning their rights to the provision of adequate fire protection. Future valuation studies could measure and control for these responses by eliciting respondents' beliefs about the effectiveness of risk-reduction mechanisms presented in the hypothetical market to enhance the reliability of the survey instrument and provide greater insight into the relationship between wildland residents and their surroundings.

Many forest homeowners tend to reject private risk-reduction actions, especially the most effective private wildfire hazard precaution: clearing vegetation a safe distance from the home. In practice, the positive amenities offered by the vegetation outweighed the perceived danger (Fried et al. 1999). This may present an insurmountable obstacle to government-sponsored efforts aimed at encouraging fire-safe landscaping. Put succinctly by one resident, "People live in the woods to live in the woods." This thinking may be positively related to WTP for collective protection. While the design of this study did not permit incorporation of private risk reduction value into the collective risk reduction model, this would be a promising extension.

The wildland-urban interface is a challenging environment in which to conduct efficient, representative sampling because human populations at risk are dispersed, difficult to aggregate into a suitable sampling frame, and extremely difficult to contact. Researchers should not underestimate the difficulty of this vexing sampling problem.

This study shows that continuous WTP data and an econometric model that is consistent with the consumer's decision framework is capable of yielding theoretically valid results. However, our enthusiasm is tempered by the problems we encountered dealing with large WTP outlier values and the bias that outlier elimination may have introduced into the valuation equation (see footnote 7). Lacking a means to test the influence of these outlying observations, it is difficult to predict any particular bias that may have resulted.

Policy Implications

Understanding how people decide whether and how to respond to risk is vitally important to the success of government-sponsored initiatives to improve safety, such as special assessment districts to strengthen firefighting infrastructure. If, as we suspect from our results, individuals use a threshold choice model in response to this hazard, some homeowners (e.g., at least 25% of those we sampled) are unlikely to either support additional government expenditure on collective protection or respond to government programs to encourage self-protective behavior because they view the hazard as not worth worrying about (Kleindorfer and Kunreuther 1988). And, if the issue of funding for an increase in collective protection is put to a plebiscite or otherwise surfaced with details about *how* risk reduction will be accomplished, support will likely fall further; a randomly selected subset of residents interviewed for this study who later participated in focus group discussions were emphatic in their denunciation of fuel management by prescribed fire as intolerably risky and their conviction that no enhancement of fire protection infrastructure would make a difference to the outcomes of large, uncontrolled wildfires (Winter and Fried 2000). Even in situations where wildland urban interface residents will not, themselves, pay the costs of increments in fire safety, the threshold choice model provides useful guidance as to the proportion of the population likely to perceive benefits from increased safety. Willingness-to-pay estimates can be regarded as a lower bound on risk-reduction value in that they are, at least theoretically, subject to household budget constraints.

If homeowner decisions and economic values are based on misperceptions of the wildfire risk, then policies based on these values may be misdirected (Kleindorfer and Kunreuther 1988). Our model and results suggest that this group of homeowners did not consider the unconditional risk of wildfire occurrence, but did rely on their perception of the conditional risk of home loss and on an expert assessment of the joint risk. In response to both risk perception and valuation questions, homeowners remarked about recent fire experiences indicating the dynamic nature of risk perception and, perhaps, valuation. These observations should be encouraging to public land management agencies such as the USDA Forest Service that are pursuing risk communication as a policy response to the wildland-urban interface fire problem (U. S. Department of the Interior and U. S. Department of Agriculture 1995).

Literature Cited

Arrow, K.R., R. Solow, P.R. Portney, E.E. Leamer, R.Radner, and H. Schuman. 1993. Report of the NOAA panel on contingent valuation. Fed. Reg. 58 (10):4601–4614.

Batts, D. 1993. Valuing incremental reductions in fire risk at the urban-wildland interface: Design and pretest of a contingent valuation survey instrument. M.Sc. thesis, Dep. of Resour. Dev., Michigan State Univ., East Lansing.

Blaylock, J.R., and W.N. Blisard. 1992. U.S. cigarette consumption: The case of low income women. Am. J. Agric. Econ. 74(3):698–705.

Burton, I., R.W. Kates, and G.F. White. 1993. The environment as hazard. Ed. 2. The Guilford Press, New York.

Cortner, H.J., and R.D. Gale. 1990. People, fire, and wildland environments. Pop. Environ. 11 (4):245–257.

Cragg, J.G. 1971. Some statistical models for limited dependent variables with application to the demand for durable goods. Econometrica 39 (5):829–45.

Foote, E.I.D., R.E. Martin, and J.K. Gilless. 1992. Defensible space factor study: A survey instrument for structure loss analysis. P. 66–73 *in* Proc. of the 11th Conf. on Fire and For. Meteorol., Andrews, P.L, and D.F. Potts (eds.). Soc. of Am. For., Bethesda, MD.

Freeman, A.M. 1993. The measurement of environmental and resource values: Theory and methods. Resources for the Future, Washington, DC.

Fried, J.S., S.I. Stewart, and J.K. Gilless. 1995. Objectives setting in the wildland fire system: What do the customers think? P. 150–160 *in* Proc. of the 1994 Symp. on Systems Analysis in Forest Resources, Sessions, J., and J.D. Brodie (eds.). Soc. of Am. For. Manage. Sci./Op. Res. Working Group, Bethesda, MD.

Fried, J.S., G. Winter, and J.K. Gilless. 1999. Assessing the benefits of reducing fire risk in the wildland-urban interface: A contingent valuation approach. Internat. J. Wildl. Fire 9(1):9–20.

Gardner, P.D., H.J. Cortner, and K. Widaman. 1987. The risk perceptions and policy response toward wildland fire hazards by urban home-owners. Landsc. Urban Plan. 14:163–172.

Gorte, J.K., and R.W. Gorte. 1979. Application of economic techniques to fire management—a status review and evaluation. USDA For. Serv. Gen. Tech. Rep. Int-53. 26 p.

Greene, W.H. 1995. LIMDEP Version 7.0 user's manual. Econometric Software, Inc., Bellport, NY.

Greene, W.H. 1993. Econometric analysis. Ed. 2. MacMillan, New York.

Gujarti, D.N. 1995. Basic econometrics, Ed. 3. McGraw Hill, New York.

Haines, P.S., D.K. Guilkey, and B.M. Popkin. 1988. Modeling food consumption decisions as a two-step process. Am. J. Agric. Econ. 70(3):543–552.

Heckman, J.J. 1976. The common structure of statistical models of truncation, sample selection and limited dependent variables and a simple estimator for such models. Annals Econ. Soc. Measure. 5 (4):475–492.

Kahneman, D., and A. Tversky. 1979. Prospect theory: An analysis of decision under risk. Econometrica 47 (2):263–291.

Kleindorfer, P.R., and H. Kunreuther. 1988. Ex ante and ex post valuation problems: Economic and psychological considerations. P. 77–86 *in* Amenity resource valuation: Integrating economics with other disciplines, Peterson, G.L., et al. (eds.). Venture Publishing, State College, PA.

Kunreuther, H. 1978. Disaster insurance protection: Public policy lessons. Wiley, New York.

Long, S.J. 1997. Regression models for categorical and limited dependent variables. Sage Publications, Thousand Oaks, CA.

McDonald, J., and R. Moffitt. 1980. The uses of Tobit analysis. Rev. Econ. Stat. 62:318–321.

McKay, J.M. 1985. Community adoption of bushfire mitigation measures in the Adelaide Hills *in* The economics of bushfires: The South Australian experience, Healey, D.T., et al. (eds.). Oxford University Press, Melbourne, Australia.

Mitchell, R.C., and R.T. Carson. 1989. Using surveys to value public goods: The contingent valuation method. Resources for the Future, Washington, DC.

National Fire Protection Association. (n.d.). Stephan Bridge Road fire: A case study. Fire Investigations Div., Nat. Fire Protect. Assoc., Quincy, MA.

Rural Fire Protection in America (RFPA) Steering Committee. 1994. Fire protection in rural America: A challenge for the future. Nat. Assoc. of State For., Washington, DC.

Schulze, W.D. 1993. Use of direct methods for valuing natural resource damages. P. 204–230 *in* Valuing natural assets: The economics of natural resource damage assessment, Kopp R.J. and V.K. Smith (eds.). Resources for the Future, Washington, DC.

Shrogen, J.F., and T.D. Crocker. 1991. Risk, self-protection, and ex ante economic value. J. Environ. Econ. Manage. 20:1–15.

Shrogen, J.F., and T.D. Crocker. 1994. Risk reduction mechanisms and risk valuation: An experimental study. Econ. Letters 44:241–248.

Slovic, P. 1987. Perception of risk. Science 236:280–285.

Tversky, A., and D. Kahneman. 1973. Availability: A heuristic for judging frequency and probability. Cog. Psych. 5:207–232.

USDA Forest Service. 1985. National fire management analysis sytem user's guide. Release of the initial action assessment model (FPL-IAA2). Aviation and Fire Manage., Washington, DC. 69 p.

U.S. Department of the Interior and U.S. Department of Agriculture. 1995. Federal wildland fire management policy and program review final report. Washington, DC.

Viscusi, W.K. 1989. Prospective reference theory: Toward an explanation of the paradoxes. J. Risk Uncertainty 2:235–264.

Whitehead, J.C., G.C. Blomquist, R.C. Ready, and J. Huang. 1997. Construct validity and polychotomous choice contingent valuation questions. (Work. Pap. #ECU9612). Dep. of Econ., East Carolina Univ., Greenville, NC.

Winter, G.J., and J.S. Fried. 2000. Homeowner perspectives on strategies for reducing fire damage at the wildland urban interface. Soc. Natur. Resour. 13:33–49.