Report #04-001

DESIGNING BENEFIT-COST ANALYSIS FOR HOMELAND SECURITY POLICIES

Smith, V., & Hallstrom, D.

CREATE REPORT
Under FEMA Grant EMW-2004-GR-0112

August 11, 2004

Center for Risk and Economic Analysis of Terrorism Events
University of Southern California
Los Angeles, California

3710 McClintock Avenue, RTH 314 Los Angeles, CA 90089-2902 ~ (213) 740-5514 ~ www.usc.edu/create

This research was supported by the United States Department of Homeland Security through the Center for Risk and Economic Analysis of Terrorism Events (CREATE), grant number EMW-2004-GR-0112. However, any opinions, findings, and conclusions or recommendations in this document are those of the authors and do not necessarily reflect views of the U.S. Department of Homeland Security.

8/11/04

Designing Benefit-Cost Analyses for Homeland Security Policies

V. Kerry Smith and Daniel G. Hallstrom*

I. Introduction

The purpose of this paper is to outline the methodological and empirical issues associated with developing benefit-cost analyses for homeland security policies. The 9/11 attack on the United States transformed domestic and international perceptions of the ability of the public sector in developed economies to provide a secure environment for daily living. Security at this very general level affects nearly every aspect of life, including, of course, those individual behaviors that influence market outcomes. When one includes the scope of the impact on non-market behaviors that are motivated by fear and anxiety, it is difficult to imagine how current policy initiatives could restore earlier perceptions about our security.[1] For practical purposes, the change in the background environment for all private and public choices is probably best treated as irreversible. As a result, we argue that the task of measuring the net benefits provided by homeland security policies should not be treated as an effort to restore a pre-9/11 baseline. Rather, it should be described based on how each policy changes a specific set of "outputs".

* University Distinguished Professor, North Carolina State University and Resources for the Future University Fellow and Faculty Research Associate CEnREP respectively. This research was partially supported by the United States Department of Homeland Security through the Center for Risk and Economic Analysis of Terrorism Events (CREATE). Thanks are due to Alex Boutaud, Michael Darden, and Jaren Pope for research assistance and help in assembling the data used in this analysis and to Susan Hinton for preparing the manuscript. Any opinions, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the Department of Homeland Security.

[1] Adler [2003] and Sunstein [2003] discuss the dimension of fear and anxiety that are related to the loss of security. Sunstein's focus is on the potential for individuals to ignore low probabilities and focus on extreme outcomes. Fischhoff et al. [2003] and Viscusi and Zeckhauser [2003] are among the first studies of subjective risk perceptions following 9/11. As a result, additional research will be needed to identify how specific types of public mitigation relate to perceived risks.

These outputs need to be clearly delineated to avoid confusing ex ante objectives with ex post measures of performance of a policy initiative.

Homeland security policy can reduce risk and/or reduce consequences from terrorist activities. Because there is no single physical measure that allows the diverse possible terrorist events to be reduced to a single loss metric, the task of specifying the connection between policies and risk reductions is likely to be complex.[2] Equally important, risk reduction can arise through public protection, self-protection, or some combination of these two activities. The value of a public initiative to an individual depends on what is at risk; the ability to insure against bad outcomes; the ability to mitigate the risk on one's own (i.e. the level of self-protection and prospects for self-insurance); and the potential for adaptation to its consequences after a bad outcome may have taken place.

The current economic literature on terrorism and homeland security policies does not provide the basis for answering a small subset of the issues required to develop a practical set of strategies for evaluating the net benefits of policy alternatives.[3] As a result, after describing the basic ideas underlying revealed and stated preference methods for measuring the economic value of policies that reduce risk or enhance other goods and services available outside markets, we focus our attention on the potential for using "parallel" hazards as a source of some of the information. That is, we propose using behavioral responses to large-scale natural hazards to gauge how people would respond to changes in some dimensions of homeland security policy. This opportunity seems

[2] Economic benefit measures can describe the monetary compensation an individual would require in lieu of the suite of changes to risk, severity of outcomes, personal freedom, and so forth that are associated with a policy. As a result, they offer one consistent metric for this measurement. We return to this point below.

especially relevant for activities related to the risk of catastrophic events that affect an individual's living environment.[4]

Before outlining non-market valuation methods in Section III, the next section summarizes the rationale for using an efficiency criterion for security policy and discusses the particular complexities in defining it. Section IV summarizes the strategies that can be used to get started in developing benefit-cost assessments. Sections V through VI provide the background and results for using a natural event, Hurricane Andrew, in two counties in Florida (Lee and Dade) to evaluate the incremental compensation required to accept increased risk of extreme events. Two counties were selected because one (Lee) provides an example of a "near miss". The path of the hurricane missed the county. As a result, residents of coastal areas with significant risk of damage from future storms received new information about the severity of these storms but no actual damage.[5] The second county, Dade, experienced the brunt of the storm. Indeed, Andrew was the worst insurance event prior to 9/11 in U.S. history largely based on the damage in Dade County. For this county, we are able to combine geo-coded records of the storm's path and wind records with a NOAA inventory of damage to evaluate how the treatment of the location of damage influences estimates of the compensation homeowners would require to accept increases in the probability of catastrophic events (and thus measures of the benefits of reducing it). A comparison of

---

[3] See the special issue of the *Journal of Risk and Uncertainty* (March/May 2003) for examples of the available conceptual and empirical literature. Sandler and co-authors have an extensive set of contributions. See Sandler and Enders [2004] for a partial set of references to this work.

[4] Lakadawalla and Zanjani [2002] suggest the use of natural hazards is not as appropriate as decisions involving other types of risk. Their reason seems to stem from interest in insurance as a policy instrument. Our focus is on measuring the ex ante incremental value of reducing risk. Here, we argue the parallel is more direct.

the two case studies demonstrates the potential for using information about people's responses to parallel events to measure the benefits of policies that avoid risk increases. The last section of the paper will discuss implications of the example and next steps in developing the capacity to perform benefit analyses for homeland security policies.

II. Benefit Cost Analysis for Homeland Security Policies

A. Background

Benefit-cost analysis is usually described as a practical basis for judging whether a change in a benchmark resource allocation offers a potential Pareto improvement. In other words, the sum of the gains experienced as a result of a proposed change exceeds the sum of the costs due to the change. Thus, a Pareto improving change would allow, in principle, for those gaining to compensate the losers and retain some positive increment as a result of the change in how resources are used. The framework takes as given the conditions defining the baseline resource allocation, including assignments of property rights to those resources. It does not claim that the evaluation of net gains would be invariant to these initial conditions (see Bradford [1970] and Smith [2003]).

Measurement of the gains and costs to people is usually discussed in terms of Hicksian consumer surplus measures (see Freeman [2003] for background). When the analysis is assumed to take place for uncertain choices, the monetary measure of benefits and costs is usually defined within an expected utility framework. Most of the current

[5] Andrew took place after a long lull in hurricane activity in Florida. Thus, given the length of stay of most U.S. households in a given area (e.g. about seven years) it would be reasonable to assume that residents of this county had not experienced a severe storm.

literature on the definition of monetary measures for gains or losses uses the concept of an option price (see Graham [1981] and Freeman [2003]). Within a state contingent approach to describing behavior under uncertainty, an option price is the state independent payment an individual would pay (or have to be paid) to realize a beneficial change (or to compensate for an undesirable one). This concept has received wide acceptance in environmental economics. In these situations the analysis generally involves non-market services with limited opportunities to insure. As a result, consideration of market adjustment in response to uncertainty is not considered relevant.

For the case of policies involving homeland security this assumption may not be as readily acceptable. In these cases, an amended version of a state independent payment for benefits is needed. That is, the payment would be defined for a baseline set of assumptions including a description of adjustments that are possible with existing insurance markets.[6]

To discuss some of the complexities associated with the definition of benefit concepts for security related policy, we adapt a framework introduced by Ehrlich and Becker [1972] to describe how self protection and self insurance might be represented in a model of individual decision making under uncertainty. Lakdawalla and Zanjani [2002] have recently adapted it for considering economic analyses of terrorism. Our description further adapts their model so that it is more compatible with our empirical example discussed below.[7] A homeowner's expected utility (V), given opportunities to select a location, undertake some actions that involve self-protection (e.g. reduce risks of

[6] The logic for this strategy stems from Graham [1992], which extends his earlier work on the option price to define a criterion for judging when change in a contingent claims framework represents a Pareto improving resource reallocation.

[7] Our example is an extension of work reported in Carbone, Hallstrom and Smith [2004] .

an event that causes harm), and insure (with a given information set) is represented in equation (1).

$$V = p\left(p(r,I),s\right)\cdot U_H\left(r,h,m-s-R(r,h,i_0,p(r,I))-L(r,h,i_0)\right) + \left[1-p\left(p(r,I),s\right)\right]\cdot U_{NH}\left(r,h,m-s-R(r,h,i_0,p(r,I))\right) \quad (1)$$

m = income (or wealth) less any hazard insurance
h = housing characteristics
r = site attributes for home that can relate to hazard attributes, amenities, and local public good
R(.) = hedonic price function (measured as an annual rent if *m* is annual income)
i_0 = insurance rate per dollar of coverage
p(r,I) = household's subjective probability of hazard at a given location and information set, *I*, (factors that could be observed in a market)
p(p,s) = household subjective probability of hazard with self protection (*s*) *p(p,0)=p*; if locational attributes are average substitutes for self protection expenditures *p(p,s)=p(r,I)-g(s)*
L(.) = monetary loss due to hazard net of insurance coverage
$U_j(.)$ = utility in state *j* (*H*=harmful event, *NH*=no harmful event).

Within this setting we can define a number of policy alternatives based on how they affect the parameters influencing this representation of individual well-being.

B. Protection Policies

This structure allows distinctions to be made in ex ante protection that is privately undertaken as well as what arises through public protection activities. Private protection increases the value of *s*, which we assume reduces the probability of the harmful event $\frac{\partial p}{\partial s} < 0$. Public protection affects more than one individual simultaneously. If *s* is assumed to be due to public actions, we might hypothesize that individuals do not recognize they will ultimately have to pay for it. Alternatively, we could include a budget balancing condition where an individual's perceived share of the cost of public activities is removed from the income argument in the U_H and U_{NH}.

Publicness implies the effects of *s* are experienced by all individuals in the protected area. Policies that provide such increments would be treated as comparable to local public goods.

Private protection would lead to reduced income and presumably would reduce the risk experienced by the individual. These activities could involve avoiding public places thought to be threatening, developing independent water sources (to protect from contamination of public supplies), etc. Some forms of private (and public) protection create negative externalities. That is, assuming those engaged in terrorist activity allocate resources to achieve objectives efficiently, then it should be expected they will re-allocate efforts away from more secure targets to less secure. Thus, if public protection is done at the state level, then improvements in security in some states will increase the risks for others who live in less secure areas. At the individual level, for terrorist activities, high profile citizens who might be targets (e.g. politicians, significant public features, or even entertainers) who undertake averting behaviors become more difficult targets and may increase the risks for others in this category who do not. For ordinary citizens these external negative effects are harder to image, but they could entail other types of externalities (e.g. removing trees around a home to assure unobstructed views for protection reduces the neighborhood amenities provided by the trees).[8]

For analytical purposes three attributes of the protection policies are important: (a) they are assumed to affect probabilities of the harmful event and thus are <u>ex ante</u> (before an outcome); (b) they may influence positively or negatively other people (depending on whether they are public and whether they have external effects); and (c)

[8] It is also important to consider how security is produced. Arguments such as those developed by Hirshleifer [1983] for production of public goods could well apply in these cases as well.

they may or may not be "visible" to external observers (including terrorists). If they are visible, then terrorists are likely to take them into account and so might markets in judging the safety of a location (our specification in equation (1) assumes they are not noticeable or not relevant to the price of a location). All of these actions can also be included as forms of ex ante mitigation.

C. Insurance Policies

Equation (1) includes the effects of insurance in three ways – through the price term, i_0, implicitly through the loss net of insurance coverage (*L*), and similarly through income net of insurance premiums (*m*). Homeland security policy can take the form of subsidies to private insurance (or even establishing public insurance markets where private markets do not exist).[9] Lakdawalla and Zanjani [2002] discuss the interactions between insurance subsidies and self-protection, concluding it is reasonable to expect (given moral hazard together with the assumption that insurance and self protection can be treated as substitutes) that subsidized insurance reduces self-protection. There are a number of interesting alternative possibilities depending on what is assumed, but this discussion is outside the scope of our analysis. We take the insurance framework as a given in our benchmark. It therefore affects benefit measures and could be considered a part of a policy. In this case it would then be the modifications to an existing set of insurance opportunities that would be defined as part of a policy. The task we analyze involves measuring the benefits due to the proposed change.

[9] We have structured the problem in this way because we do not consider insurance directly – only its affects as reflected in housing prices.

D. Other Types of Policy

Public protection and insurance are not the only types of policy options. Equation (1) specifically identifies state of information as a factor that influences subjective risk perceptions. Public warning systems (or programs to describe private protection options independent of a specific threat) could be modeled as changing the information regime. As several authors have noted, these approaches must take account of the important and separate influence of the media in influencing the perceived value of any public information program.[10] Woo [2002], for example, notes that Margaret Thatcher specifically identified the important role of the media as an "oxygen of publicity" for terrorists. Thus, models must consider the role of information for the receptors of terrorist actions and the terrorists to evaluate its overall effectiveness.

Other possibilities involve ex post (e.g. after an event) mitigation programs, say a reduction in L or $-?L$, that may serve to reduce the losses due to an event (e.g. the $L(.)$ term in (1) and (2)). These activities have different implications than the others discussed to this point because they are state dependent. That is, they take place only if the harmful event actually takes place. The expressions we developed for all the other policies specify modifications that impact utility in both states of the world.

E. Defining the Option Price for a Differentiated Policy

For our purposes what is important is the recognition that pre-existing insurance markets or any policy changes in insurance markets as part of homeland security policy will affect benefit measures developed for policies primarily directed at protection. We can see the logic underlying this conclusion by simply subtracting a term, OP, from m in

[10] See Lofstedt [2004] for an interesting discussion of changes in the effectiveness of risk communication in Europe.

both U_H and U_{NH} and adjusting the other arguments to reflect the dimensions we wish to use in characterizing a specific policy (e.g. public expenditures for protection, s; subsidies to insurance rates, t; an information program providing warnings, $?I$; $m*$ to reflect new net income, etc.) as in equation (2). OP is implicitly defined as the value that would assure, given a specific policy, that the resulting expected utility is exactly equal to the expected utility attained under the baseline condition (e.g. without the policy; this is designated here as V^o).

$$\begin{aligned} &p\left(p(r, I+\Delta I), s+s\right) \cdot U_H\left(r, h, m^* - s - R(r, h, i_0 - t, p(r, I+\Delta I)) - L(r, h, i_0) + \Delta L - OP\right) \\ &+ \left(1 - p\left(p(r, I+\Delta I), s+s\right)\right) \cdot U_{NH}\left(r, h, m^* - s - R(r, h, i_0 - t, p(r, I+\Delta I))\right) - OP\Big) = V^0 \end{aligned} \quad (2)$$

As a result, OP is a function of all the parameters describing the policy as well as the baseline condition.[11]

A full benefit analysis would require that we are able to identify the contribution of each of the arguments considered relevant to the option price function and estimate (based on actual or stated choices) the relative importance of each. This ideal is probably out of reach for the foreseeable future. Thus, a more practical question is whether we can gauge the importance of these individual effects on option price measures using uncertain events that are comparable to those associated with homeland security. Where threats involve spatially delineated assets, such as private homes or commercial buildings, Smith [1985] has demonstrated that hedonic property models can provide measures of how the option price changes with the attributes of the uncertain events, including the probability of the harmful outcome. This result requires that these attributes are recognized by the agents who participate in this market as being associated with the location of the

[11] This assumes we wish an ex ante money metric interpretation. That is, the baseline parameters are what determine the V^0.

property. This simple relationship underlies all of the hedonic analysis of natural hazards.[12]

Three implications follow from this simplified description of how homeland policies might be included within a model of individual choice. First, the evaluation of a policy must recognize the baseline conditions defining the choice being considered, as well as all the opportunities available for individual adjustment independent of the policy. Second, security related outcomes are the result of both public action and the composite of all private actions. Our focus has been on one individual. To the extent there are positive or negative effects of one agent on others, the nature of the information available about others' actions in response to that action and the concept of the equilibrium (e.g. Nash equilibrium) needs to be considered to evaluate the overall effect of the policy.[13] These judgments will influence how we define the benefit measure as well. Finally, the externalities generated by public and private actions implicitly assume a model of terrorist behavior and with it terrorists' responses to new policies.

All of these complexities make the task of policy evaluation seem hopeless. It is not. There are different, but equally daunting, issues that are present with the evaluation of any large, complex policy. We raise them here to establish background for our discussion of strategies for measuring how homeland security policies could affect behavior and to motivate our arguments for using "parallel outcomes" to measure incremental benefits for specific aspects of a policy (e.g. a risk reduction). Practical compromises may well offer the best starting point rather than an effort to pursue

[12] See Carbone, Hallstrom, and Smith [2004] for a discussion of this literature.
[13] Nash equilibrium concepts could be accommodated within Graham's [1992] general description of the criteria for defining movements toward efficient resource allocations in the presence of uncertainty.

research that seeks an ideal measure of benefits such as the option price function for all dimensions of potential homeland security policies.

III. Information and Methods of Evaluation

Homeland security policies share the evaluation challenge faced by any policy that impacts non-market services. That is, the outcomes relate to goods and services available outside markets. There is no routine basis for observing how people would acquire them in the absence of public provision. Moreover, the institutions overseeing these activities usually do not collect information that can be used to understand how the policy affects people's choices. By contrast, for goods provided on markets the process of exchange itself provides information. Markets are simply rules governing exchanges between agents. The participants involved decide to buy or sell goods and services. If these decisions are the behaviors of interest, then the results (e.g. prices and quantities) of trades are "revealed" as an outcome of the exchange process.[14]

As we discussed in the previous section, a benefit cost framework seeks to provide information that can be used to judge whether a policy would improve an existing allocation of resources. Improvement in this context means enhancing the economic efficiency. It relies on the assumption that there are pre-existing factors that prevent private individuals from achieving an efficient allocation. This condition can be due to the features of the goods and services affected by the policy. Reducing externalities or increasing public goods are outcomes that individuals acting on their own

[14] Of course, they may not be recorded in publicly available format. However, they have been increasing opportunities to purchase data describing private market exchanges.

are unlikely to be able to accomplish at a level consistent with a Pareto efficient allocation.

The primary focus of this section is describing methods for measuring the economic benefits associated with policies that provide increments to non-market goods or lead to risk reductions for events that would reduce well-being. After a brief discussion of the distinctions between revealed and stated preference methods we consider each type of approach to non-market valuation. The section closes with a discussion of how these methods compare to economic impact analysis. These methods are sometimes discussed as if they were frameworks for evaluating resource allocations. They are not. Impact analyses evaluate the implications of a proposed change in one or more resources that affects the other goods and services used to produce the resources of interest in the analysis. It is a consistent accounting scheme to describe consequences of a re-allocation rather than to measure the tradeoffs people would make to bring about (or to avoid) a change in resources.

A. Background for Revealed versus Stated Preference Methods

All measures for the economic value of a change in "something" are derived from tradeoffs that an individual's choices imply. Thus, if a person purchases a home, the analyst knows that everything conveyed to the individual (e.g. the attributes of the structure, the associated land, and the characteristics associated with its location) was worth *at least* as much as the purchase price. Otherwise, the individual would not have agreed to the purchase. All of these features could be worth much more. The single choice does not answer this issue. It reveals only a lower bound on what a person would pay.

Similarly, when a person is offered a house and chooses not to purchase it, the analyst knows all the characteristics of that house are not worth the price. In this case, price is an upper bound. Several conditions are important to how these choices are interpreted: the definition of the object of choice; the specification of the circumstances of choice; and the assumed decision making unit. All three are relevant to revealed and stated preference methods. In the first class of techniques (i.e. revealed preference methods), the analyst has available or collects information about choices that have taken place. The challenge is to provide answers to these three sets of issues. These answers *reconstruct* the implicit decision process that led to the choice. By contrast, with stated preference methods the analyst is designing a potential choice and the challenge is to present it in a way that the individual states a decision in exactly the same way she would if the choice could actually be made and have the consequences be binding. Before turning to the specific techniques in each class, some background on each of the constituents of an informative choice will help in understanding the decisions that must be made in implementing each method.

The object of choice simply represents what the individual believes she receives from a decision to do whatever is involved in the choice. In the example of the house, it may well be an array of services provided by the home and its location. If the analyst specifies that access to high quality public schools, neighborhood safety, or specific amenities are provided by a location, then these features must be understood in these terms by the person making the choice. Similarly, the analyst needs to understand what the individual's situation is for these same features if the choice is rejected. The circumstances of choice relate to the terms (e.g. what must be given up and when); the property rights to the object of choice; the degree of certainty; any limitations on the individual's ability to make the choice (e.g. information, time, resources, etc); and the full consequences of the choice. The last component relates to how such choices are made – by an individual, a household, or a group of unrelated individuals (e.g. voting). Clearly this last feature has implications for whose behavior is described by choice.

B. Revealed Preference Methods

Most applications of revealed preference methods to estimate the demand for or economic value of (changes in) a non-market good assume the good cannot be directly selected. Each person alters the amount consumed through the choices that are made for some other observable private good that has an identifiable (e.g. explicit or implicit) price. Using this logic requires an analyst to specify how the private good conveys different amounts of the non-market good to each person. Some examples may help to make the logic more tangible.

1. Hedonic Models

Hedonic models rely on the existence of a set of differentiated objects of choice with identifiable attributes and prices – houses, jobs, automobiles, and so forth. Often people are assumed to buy one type of the good in the time frame hypothesized to capture the important elements in people's choices. The model assumes that knowledge of the alternatives and access to a wide array of types will lead to an equilibrium schedule of prices – where buyers and sellers would have no incentive to change their decisions. This schedule can be represented with a function that describes how the prices of the types relate to each alternative's attributes.[15] This formulation implies that the house's price

[15] Tinbergen [1956] demonstrated analytically this relationship. Rosen [1974] is perhaps the most widely cited discussion of the economic relationship between what is observed and the underlying behavioral

should differ by the important (to people) features of the location. Moreover, the marginal price "reveals" the incremental value to buyers (and sellers) of a small change in each attribute. It does not isolate (or allow identification of) the schedule of marginal values, but does provide a measure of the specific marginal value implied by the schedule at specified values of the goods' attributes.[16]

To the extent an attribute cannot simply be purchased in another way, the framework offers an estimate for an incremental value of the non-market object of choice conveyed through the purchase. In housing this could be air quality, some dimension of neighborhood amenities, noise, local public schools (if access is defined through one's housing location), and so forth.[17] Hedonic models applied to jobs and wage rates have been used to estimate the compensation for accepting increased risks of death and serious injury on the job. These attributes are assumed conveyed to workers when they agree to work for a specific firm.

2. Demand Models

In environmental applications, the most common application in this area is a recreation demand model for trips to one or more recreation sites (e.g. parks, lakes, beaches, etc).[18] To the extent features of these sites vary over location (or time) then it is often possible to measure the effects of these characteristics on the demands. Better water quality at rivers and lakes increases the demand for these locations in comparison to those with lower quality levels. Recovering a measure of the demand for one or more

---

model. Ekeland, Heckman, and Neishem [2004] offer a more modern description of the logic. Palmquist [forthcoming] provides the most comprehensive overview of the literature.

[16] Different marginal values at different locations do not comprise the schedule because these are the values of different people (who selected those locations) and without more information the model does not explain all the reasons for the differences.

[17] See Smith and Huang [1995] for a meta-analysis of studies involving air pollution and Palmquist and Smith [2002] for a review of the applications.

aspects of these quality attributes (or values of changes in one of them) requires additional assumptions about how that quality feature contributes to individual well-being. These preference restrictions limit the way the attribute is hypothesized to affect each individual. That is, the maintained assumptions allow a change in that attribute to be described as equivalent to a price change. For example, weak complementarity maintains one is only interested in the linked attributes if the private good involved is consumed. A person does not care about water quality at sites he does not visit.

In the context of homeland security policy, suppose the policy reduces risk of terrorist events at amusement parks or large sporting events (e.g. football games). A weak complementarity restriction would require that this risk reduction would only be valued if a person went to the parks or the games. This condition seems unlikely to hold.[19]

Other strategies that may well be closely related to homeland security could entail demands for averting goods. Private households might, for example, stockpile food and water as a precaution against terrorist contamination of typical sources. Changes in these demands with varying levels of threats would, under another set of assumptions (e.g. perfect substitution of the stockpile for a reduction in the probability of harm due to contamination, see Smith [1991]), provide the information required to estimate the economic value of the threat reduction.

The distinction between demand and hedonic models arises from the information provided by the related good. In the hedonic case analysts are usually assuming the home

---

[18] See Phaneuf and Smith [forthcoming] for a review of these studies.

[19] As noted at the outset, successful terrorist attacks increase the perception of fear an anxiety even if the targets are not areas ever used by an individual. In addition, concern about others would also lead to a violation of this assumption.

location (or the job) is the only source of the attribute relevant to the person. Marginal values are derived from the estimated price equations. Efforts to recover the marginal willingness to pay schedule (i.e. an inverse demand for the attribute) require additional assumptions. By contrast, the demand relationship can only reveal whether an attribute is important to a person's choices. Demand and/or valuation (even marginal values) measures require the added restrictions on preferences.

3. Random Utility Models

The hedonic model can be considered as a strategy to avoid the conceptual issues raised by corner solutions. That is, when an individual selects one type of good from a diverse array of goods (i.e. in the housing case, one type of house and not any of the other alternatives available), that decision implies she has zero consumption of all other types. Conventional analysis underlying the demand functions just discussed assumes people select mixes of goods that imply positive levels of consumption for all goods. With more extensive micro data and greater resolution in the definitions of goods, this maintained assumption is less likely to hold. McFadden [1974] developed random utility models (i.e. economic descriptions for a choice of one item from a set of *k* alternatives) to respond to these conditions. Hanemann [1978] provided the first welfare theoretic interpretation of these models. Today they are applied in a wide array of applications. For non-market applications they can involve alternative approaches to describing recreation site choice or housing choice that allow the development of welfare measures for changes in the attributes.[20]

[20] See Phaneuf and Smith [forthcoming] for a summary in recreation and Banzhaf [2002] for an application involving valuation of air quality.

Basically, these models describe the possibility a choice would be made, assuming it is motivated by preference functions with observable (indirect utility functions conditional on the specific choice) and unobservable (random) components. Given assumptions about the unobserved heterogeneity (e.g. the error), it is possible to recover a measure of the economic value of changes in the attributes of the choice alternatives.

It is important to acknowledge that there are a wide array of these models and the conditions required for consistent welfare measures are significant.[21] Moreover, the measures relate to the specific circumstance of choice assumed by the model – a choice occasion. In applications to recreation sites this would be a trip. When random utility models are alternatives to hedonic models, the time frame relevant for a housing choice is probably best considered as annual (see Banzhaf and Smith [2004]).

Recently, generalized corner solution models (Phaneuf [1999], Herriges and Phaneuf [2004], and Von Haefen, Phaneuf, and Parsons [2004]) have been developed to consider the challenge posed by considering the choice of a type among a finite set of alternatives and an amount of consumption for the selected type of the good (i.e. a specific recreation site and then a number of trips during a season). To date, most of the recent applications have been to recreation choices, but these could also serve as an alternative to averting behavior models (e.g. purchasing some types of supplies, but not all, for emergencies along with varying the amounts of the types selected).

4. Natural Experiments

[21] These structures also implicitly restrict the way attributes are assumed to contribute to preferences. See Morey [1999], Haab and McConnell [2002] and Phaneuf and Smith [forthcoming] for discussion

Revealed preference methods require that the analyst specify how the features of the object of choice are measured. For example, in the case of the hedonic model, the analyst must enumerate the characteristics of (and services provided by) a location that matter to people; develop measures of these attributes or services; and select applications with sufficient variation in them to estimate their effects on housing prices. The models rely on the consumers recognizing differences that are approximated by what is measured. Equally important, the variation in variables hypothesized to be determinants of prices (for the hedonic case) should not be correlated with sources of unobserved heterogeneity that may also influence prices. Households with limited information or with less sensitivity to undesirable attributes may locate in areas with high levels of that attribute – implying these observed factors are correlated with both the price and the attribute they select. These types of problems are difficult to overcome with cross-sectional records and with reduced form models.[22]

As a result, a natural experiment is another strategy that is proposed for cases where information may change and there are special difficulties in isolating exogenous sources of variation in explanatory variables. A natural experiment exploits an event outside the individual decision maker's control to provide a "transparent exogenous source of variation" in the explanatory variable of interest. Repeat sales analyses are examples of this approach for housing markets. These studies examine price changes for the same set of homes before and after an event that is assumed to provide the variation in the relevant explanatory variables.

[22] Sometimes these are described under the heading of endogeneity or social interaction effects or "reflection effects" (Manski [1993]).

In applications involving non-market goods and services, one of the most common examples involves risk and information. Gayer et al. [2002], for example, considered how information from EPA's Remedial Investigation and Feasibility Studies (RI/FS) for superfund sites influenced the effect of risk on housing sale prices. The information was hypothesized to change subjective risk beliefs. Their findings for applications in the area of Grand Rapids, Michigan, confirmed the basic logic – those houses near sites whose risks were lowered appreciated while those where it was raised declined. The effects these authors estimated were related to computed risks as well as to features of the sites associated with the risk. Comparable analyses for other sources of information that varied over time offered offer qualitatively similar findings.[23]

This strategy is especially important to homeland security, where most policy alternatives seem likely to have important information and risk reduction attributes. It is unlikely that our pre-existing sources of information about people's private choices would have recognizable variation in both these dimensions. Time, policy change, and unanticipated natural events offer opportunities to isolate separate effects of information and risk. The framework of natural experiments focuses attention on careful delineation of the sources of variation in variables of interest.

C. Stated Preference Methods

All stated preference methods request hypothetical decisions from individuals. They vary in how the information is presented and what type of response is requested. To recover measures for economic tradeoffs, the attributes of what is presented must be varied (either for a single individual or across different people). Before describing the

[23] See Mendelson et al. [1992], McCluskey and Rausser [2003], and Dale et al. [1999] as further examples.

two classes of methods commonly used it is important to highlight a fundamental controversy about whether these responses should be taken as economic choices.

Ten years ago, Diamond and Hausman [1994] offered the most dogmatic rejection of the methods for situations where changes to be evaluated do not involve tangible uses of resources, noting that:

> "We believe contingent valuation is a deeply flawed methodology for measuring nonuse values, one that does not estimate what its proponents claim to be estimating. … we conclude that current contingent valuation methods should not be used for damage assessment or for benefit-cost analysis" (p. 62-63).

This conclusion was stated after a distinguished panel of economists, including Nobel laureates, reached a different, but carefully qualified, verdict for results from contingent valuation surveys (see Arrow et al. [1993]). We suspect if the economists who supported the negative conclusion then were asked again today, they would likely state nothing has happened to change their judgment. Nonetheless, the Diamond and Hausman conclusion has not slowed research in this area. Moreover, as a result of this research, many skeptics have been convinced to take the results of contingent valuation surveys seriously. Boyle's [2003] summary draws a different conclusion from Diamond and Hausman, one more consistent with the Arrow panel's judgment and one that probably describes a large number of economists' views of the method's properties. He observed that:

> "The preponderance of evidence indicates that contingent valuation can provide estimates of Hicksian surplus that inform policy analyses and litigation, but…The 'but' is that contingent valuation appears to overestimate values" (p. 155).

Recent research has focused on two features of the format of CV questions that appear directly related to the appearance of overestimation of economic values in some studies.

We will discuss them in the context of our description of the logic of the two classes of methods.

1. Contingent Valuation[24]

Contingent valuation questions ask for choices. Thus, the framework we used to describe economic choices can be used to outline how the methods work. They require collection of primary data. This process necessarily requires selection of a population to be sampled, method for sampling, and for interviewing (see Champ et al. [2003] for a detailed discussion of these issues). The object of choice is a change in something from a well-defined baseline condition to a new level. Following the Arrow panel's recommendations, most CV surveys describe how the change would take place. As a result, respondents are actually evaluating the "how" of the proposal change or the plan used to indicate actions leading to the change. The goal of the description is to convince those interviewed that it will work. Nonetheless, in the end, the choice they are making is about the plan (see Smith [1997]). In addition, the question must elicit the resources each respondent will be required to give up; describe how a decision is made; and how the resources will be collected.[25] For example, in a discrete response (yes/no) question a price or cost to the individual is stated and the individual is asked what she would do. In most cases, the object of choice is sufficiently different from a private good that a

[24] See Smith [2004] for a more detailed review of the literature.
[25] There are a variety of ways contingent valuation questions are asked, including:

a. discrete choice – a person is asked a yes/no question after the object of choice and a stated payment required to have the object of choice is described.
b. open-ended – a person is asked to state a maximum payment he or she would be willing to make for the object of choice.
c. payment– a person is asked to select a maximum amount from a list of amounts for an object of choice card.

There are also repeated discrete choice questions with varying amounts that adjust (or do not adjust) in response to amounts and other variations on the questions asked. For example, if more than one unit could be purchased (e.g. vaccines to prevent disease for family members) this type of question leads to another type of response.

purchase decision is not feasible. As a result, the statement is often a vote. This must be accompanied with a description of how everyone else's statements will affect provision. Usually labeled the provision point, this aspect of the questions describes how decisions are made and what happens to any excess of the sum of the resources collected over total costs (if there is uncertainty associated with cost).

Variation in the stated cost across individuals allows analysts to use stated choices for different costs, with an assumption that the decisions follow conventional economic models (akin to equations (1) and (2)), to estimate respondent's willingness to pay. The interpretation of these tradeoffs must be consistent with the way the model used to estimate willingness to pay explains the decision process. Second, and related to the tendency toward upward bias in estimates of values, the questions should convince respondents that their answers will influence an outcome related to the object of choice (e.g. supporting responses will increase the chances of the "thing" being provided; rejections the opposite). These efforts are described as assuring the answer given by respondents is interpreted as *consequential.*[26]

There are econometric issues in how this is done; challenges in designing the set of dollar costs proposed as "prices" to the survey respondents; and issues concerning how to vary the "amount" of the object of choice. Each topic could involve more space than can be provided in this overview.

Three lessons emerge from this research. First, questions must be designed and evaluated to assure respondents understand them and appear *consequential*. Potentially as important, respondents need to be convinced that they would ultimately pay the

[26] Carson, Groves, and Machina [2000] have demonstrated this property is important to conclusions that these questions are incentive compatible.

amount proposed. The efforts to encourage treating answers as financial commitments have been labeled as adding "*cheap talk*" scripts or short descriptions encouraging each respondent to focus on the choice as a genuine financial commitment. Alternatives to scripts to encourage "budget discipline" have been what are sometimes labeled as certainty questions -- asking how certain, on a scale of 0 to 10, a respondent is that she would actually make the stated choice (see Boyle [2003]). Finally, the results will be affected by the models and estimators used to represent the decisions so the estimates need to be interpreted as reflecting both types of information.

At first, this method might seem the most viable for homeland security policies. However, describing the object of choice provided by these policies and convincing respondents their answers would be consequential seem especially important constraints. The experience to date in describing choices involving low probability events has not been as successful with other non-market goods. Many of the issues identified in the risk assessment literature concerning people's subjective probabilities for unfamiliar, dreaded, and involuntary outcomes are certainly relevant. In short, a number of pilot studies would be needed before one could evaluate the feasibility of using contingent valuation for homeland security policy.[27]

2. Conjoint Surveys

The primary difference between conjoint and contingent valuation methods is that the object of choice is assumed to be capable of being decomposed into changes in a set of attributes. This assumption allows a variety of different types of questions – choice of one among several alternatives, ranking of a set of alternatives, adjustment in one attribute to define equivalent options, and scoring of alternatives using Likert scales. Not all of these alternatives are directly compatible with an economic model that allows measurement of economic values.

To illustrate the logic, Figure 1 provides the type of attribute-based design Johnson, Smith, and Sloan [2003] used to evaluate a hypothetical filter intended to reduce the harmful effects of smoking. Two filters that varied in effectiveness and price along with a baseline or "no choice" alternative were offered to a sample of older smokers. One filter was used as a method to gauge respondents' willingness to tradeoff health consequence of smoking – extension to life expectancy and quality of life. For the most part, conjoint methods rely on being able to quantify (or to describe in consistent, understandable terms that reflect differences in amounts or severity of a condition) the attributes that distinguish the objects of choice being compared. This figure represents a "choice based" conjoint design. One that focused on tradeoffs might leave an attribute unspecified and ask each respondent to select a value that would make the alternatives equally desirable (see Viscusi, Magat, and Huber [1987] [1991] for an example of risk-risk tradeoffs).

Designing the variation in combinations of values of each attribute across individuals as well as the variations elicited from a single respondent is also another source of complexity that increases with the number of attributes and the extent of variation in each one (see Louviere, Hensher, and Swait [2000] and Kanninen [2002]). It is an issue best discussed with specific examples.

At this general level, several overall observations can be made about conjoint methods. They have been popular for applied research because they collect more information from each respondent. To accomplish this task and use the results, they

[27] Results reported by Fischhoff et al. [2003] and Viscusi and Zeckhauser [2003] in limited surveys.

largely assume responses are independent across the questions asked.[28] As with contingent valuation, they rely on a formal model of the decision process to interpret the responses. Finally, to develop valuation measures there must be a well-defined baseline for the situation where respondents do not select any of the alternatives presented.

3. Joint Estimation

Revealed and stated preference information can describe choices motivated by changes in the same non-market good. Cameron [1992] first proposed joint estimation.[29] That is, collect information from a common set of individuals about the actual use of goods linked to non-market resources and about the hypothesized choices they would make if changes were made in the resource. This process allows the use of both sources of information to estimate individual preferences. It requires a consistent description of the relationship between what is observed and the model describing individual behavior. As a rule, it assumes actual and hypothetical behavior stem from the same behavioral process.[30] Cameron [2002a] has suggested that joint estimation serves to impose a "budget discipline" on the stated preference responses. In principle, it is also possible to extend this logic to combine RP and SP data for different individuals, following the logic of matching (see Heckman and Navarro-Lozano [2004]) and use the cross model restrictions to link the responses.[31]

---

[28] This is an issue that has been questioned with CV applications.

[29] Even when they relate to different aspects of the same resource there are advantages in using the two data sources in joint estimation.

[30] There are a wide array of different types of applications. Those most associated with conjoint sources of the SP data tend to use a random utility framework and assume the RP and SP data arise from a common preference function with different errors that reflect unobserved heterogeneity. The errors are allowed to have different variances so the ration of their scale factors is often interpreted as a calibration factor. See Louviere, Hensher and Swait[2000] for discussion.

[31] See Smith [2004] for a simple example.

These strategies are most effective where the object of choice has well defined attributes and the analysts can be confident how to introduce them into a behavioral model. The reason is direct. The analysis relies on a priori restrictions to link the models. To the extent an application relates to an object of choice that is difficult to define in quantitative units or the circumstances of choice that are imperfectly specified, then it is unlikely that joint estimation will be feasible.

D. Impact Analysis

Impact analyses have no direct role when the objective is an evaluation of policy alternatives based on efficiency criteria. These assessments consider what their name implies – the re-allocation in resources that would be associated with an *exogenous* change in demands for a specific set of goods and services. Many of these types of analyses rely on a description of the input requirements per unit of output (e.g. an input/output matrix). These changes in demand are then translated into their implications for the other goods and services required to meet the specified demands. Since the change that is evaluated must be specified outside the framework it can be assumed to arise from any source. For example, Mansfield and Smith [2002] compared the output and employment multipliers for growth in animal agriculture in North Carolina versus coastal tourism, implicitly suggesting that an increase in one might reduce the other. All the analysis required was conducting using an input-output model for North Carolina. Separate research is required to establish an increase in one activity (e.g. animal agriculture) would necessarily reduce the other (e.g. coastal tourism).

Comparisons of impact multipliers have also been used to identify the potential for bottlenecks in meeting increased production. For example, one might envision comparing the multiplier for the input requirements per unit of output to evaluate the "needs" for strategic inputs and indirectly evaluate vulnerabilities. One significant issue with this strategy stems from the model itself. The input requirement coefficients are treated as constants, which implies the model does not allow for substitution. For very short run assessments, the results are more likely to be relevant than for those where adaptation and adjustment is possible.

Other approaches for evaluating impacts involve using market models. These approaches are usually more aggregate than the preferred scope for impact analysis based on input-output models. They tend to focus on price and output effects rather than a detailed accounting of input responses. The two most commonly used are equilibrium displacement and computable general equilibrium models. While both could permit measures of welfare effects, their focus is usually on price effects and not non-market influences.[32] The equilibrium displacement model for one or more industries into a set of comparative static equations describing responses to exogenous shocks (see Alston, Norton, and Pardy [1995]). These equations are usually expressed in terms of elasticities. Exogenous shifts – expressed as proportional changes in price or quantity – are specified and the model solved to describe a consistent overall response.

Computable general equilibrium models can be used in a similar format. However, they include important distinctions. First, these models describe community demands, commodity and factor supplies, and link each to income. As a result, expenditures must balance with payments. Second, the models are comprehensive, representing a complete (often aggregated) description of goods and services. They tend

[32] Recently non-market considerations have been considered in CGE models (see Espinosa and Smith [1995,2004] and Carbone and Smith [2004] for examples).

to rely on simple competitive market conditions and use single specifications of preference and production relationships to describe all households and all firms in a sector.

Neither approach includes spatial detail (except as it might be linked to a reason for a demand or supply difference in the first case or a price wedge in the second). Equilibrium and smooth adjustment (or simple departures from these conditions) are important simplifying assumptions. Finally, all of these approaches require complete information on all the parameters to calibrate the models. This requirement has been a direct limitation on their ability to reflect non-market effects.

IV. Getting Started – Homeland Security and Benefit Transfer

Most benefit-cost analyses used for environmental policy follow what might be termed the damage function logic as outlined in Table 1. In the example, a policy is translated into a change in the ambient concentrations of one or more pollutants. The analysis estimates how people are exposed to these pollutants.[33] Physical effect relationships translate the changes in ambient conditions experienced into changes in outcomes. These are the physical damages. Finally, these changed outcomes are monetized and the result is the set of benefits attributed to the policy. The table is a simple characterization of the situation for health effects associated with air pollutants. Table 2 provides a more specific example for the changes estimated due to the 1990 Clean Air Act Amendments in 2010. It is taken from EPA's [1999] Prospective Analysis. The last column of Table 2 lists the monetary values, V_j, (per unit) used for

[33] To the extent there are other physical effects on plants or materials, these exposures would also be computed.

each health effect. These estimates were not derived for the particular analysis. They were adapted from measures in the literature. Most uses of benefit-cost analysis involve some adaptation of existing economic measures of the benefits provided by non-market goods and services. In fact, these adaptations are not unique to the applications involving non-market goods. If we sought to measure the benefits of a public investment that controlled floods and generated electricity (e.g. a dam with capacity for hydroelectric power) the analyst would need to address the question of what price to use in evaluating the net gains from the hydro component of the project.

The process of adapting estimates of the willingness to pay for changes in non-market goods and services (or risk) to meet the needs of specific policy analyses is often labeled *benefits transfer*. Understanding these approaches (and their limitations) is especially relevant to the design of benefit-cost analysis for homeland security policies. Nearly all of the analyses conducted over the short term will need to adapt estimates of economic values for specific outcomes (e.g. reducing risks of fatal accidents on the job) to fit the circumstances associated with the "outputs" of a homeland security policy. As a result, an overview of methods used helps to confirm that there are not necessarily huge information demands. Of course, the ability to inform policy judgments does depend on the quality of the match between the benefit measure for an incremental change in something and the actual "thing" that changed as a result of policy. Concerns about this correspondence as well as for differences in people represented in the prior research and those affected by a policy being evaluated are also important. Nonetheless, both issues are not unique to homeland security policies. We simply have less experience with resolving them in this context.

The remainder of this section will provide a brief overview of the techniques used in benefits transfer and then outline a strategy for developing analyses of policies or events that parallel some of the attributes of homeland security policies. In sections V and VII we illustrate one of these with a summary of results from an analysis that uses responses of housing prices to new information about hurricane risks to coastal areas to estimate the incremental option price of avoiding increase in the risk of severe storms.

A. Benefit Transfer

Navrud [2004] describes two main approaches to benefit transfer.

1. Unit value transfer
   - Simple
   - Adjusting for income
2. Function transfer
   - Benefit function from an individual study
   - Meta analysis of benefits across studies

The first approach parallels the use of a value of a statistical life (VSL) in the EPA analysis cited above. The VSL is measured from the hedonic wage equations describing the incremental compensation paid to people to accept higher risks of fatal accidents on the job. Translating these incremental values into a VSL[34] and applying them to the

[34] A VSL is another way of representing the economic value for a risk change. It is based on the rhetorical question – how much in the aggregate would have to be paid to save one life as a result of a hypothesized small risk reduction? If the risk reduction (in absolute magnitude) is *?p*, then we can ask for what value of *N*, the number of people experiencing *?p*, would the following be true:

$$N \cdot \Delta p = 1$$

Solving for *N*, we have:

$$N = \frac{1}{\Delta p}$$

With an estimate of what each would pay for the *?p* reduction (say WTP), we have the VSL defined as:

$$VSL = WTP \cdot N = \frac{WTP}{\Delta p}$$

estimates of reductions in expected deaths due to reductions in particulate matter in EPA's analysis implies people would evaluate these risk reductions the same way (e.g. the reduction in risk of an accidental death is the same as a reduction in risk of the deaths due to air pollution related health conditions). It also assumes the people involved are "equivalent". Both assumptions have proved to be controversial.

Adjustments for income differences are sometimes undertaken because the unit benefit measure is recognized to be constrained by income. It has been considered particularly relevant for applications that use (or transfer) benefit measures estimated based on experiences and choices in a developed country to one that is less developed (or vice-versa) where there are dramatic differences in income. The typical strategy is simple (and not necessarily consistent with the theory underlying the definition of the benefit measures). It is represented in equation (3).

$$\hat{b}_P = \hat{b}_S \cdot \left({m_P}/{m_S} \right)^{h}$$

where $\hat{b}_j$ = unit benefit measure in either the study ($j=S$) or the policy ($j=P$) application
m_j = average household income in either study ($j=S$) or policy ($j=P$) application
? = income elasticity of willingness to pay for the environmental service yielding the unit benefit.[35]

Function transfers are distinguished from unit value transfers because the former rely on having a multivariate functional relationship in the original study that can be used to describe how unit benefits change with characteristics of the individuals (or

This process allows those estimating the effects of policy on risk to measure them as avoided deaths for a given population. Aggregate benefits are then computed as illustrated in Table 2.

[35] Navrud describes this parameter as the income elasticity of demand. It is not an income elasticity of demand, but rather an income elasticity for the marginal willingness to pay. Under some conditions, the income elasticity of marginal willingness to pay for a non-market service will equally the income elasticity

households) involved and/or with the characteristics of the non-market services involved. The function transfer would then use this estimated function along with the specific features of the affected individuals (as well as of the non-market good) to modify the unit value applied to the policy. This approach is distinguished from what he labels a meta-analysis in that the latter uses a function to describe estimates from multiple studies. Often it includes the features of the resources and the assumptions made in each study as potential determinants of estimates. Mrozek and Taylor's [2002] meta-analysis of VSL estimates proposed an adapted or "best practice" summary measure. It is important to acknowledge that methods are approximations and do not meet conditions to be consistent with the definition of the underlying benefit concepts.[36]

Navrud's suggestions for future areas where research could improve matters highlights the need for consistency in the object of choice between the studies available and the policies to be evaluated. They also note the composite nature of most policies and the need to separate components consistently.[37] This objective seems especially relevant for homeland security policy. As we discussed in our definition of the factors influencing the option price function for homeland security policies, there are many aspects that can interact in determining the value of policy change. Existing benefit transfer schemes do not have a good track record. When they are compared to separately estimated benefits from what are labeled as the study sites, all evaluations to date have found poor performance. Navrud, for example, concludes his overview noting that:

"…results from validity tests show that the uncertainty in

---

of demand for a private good if it is a weak complement to the service and preferences are consistent with the Willig [1978] condition (see Palmquist [2004]).

[36] See Smith and Pattanayak [2002] for a discussion of the importance of consistency in the concepts summarized in these meta-analyses.

[37] Preference calibration offers one way to impose this consistency. See Smith, Pattanayak, and Van Houtven [2002] for discussion of the methods and examples.

> value transfers both spatially and temporally could be quite large. Thus, benefit transfer should be applied to environmental valuation when the demand for accuracy is not too high" (p. 208).

Unfortunately, there is little prospect in available time or resources to conduct a new benefit analysis for each policy evaluation. Two qualifications are important the performance of transfer methods should be considered relative to the alternatives available and the resolution required for the policy judgment. Over forty years ago in discussing the rationale for benefit cost analysis, Krutilla noted the first of these qualifications observing that:

> "…The practicing economists in government, charged with the responsibility to act under constraints of time and information, will often be grateful for perhaps even a perforated rationale to justify recommendations in the public interest! Since the alternative is not to retire to inactivity but, rather, to reach decisions in the absence of analysis…" (p. 234).

Thus, the relevant question is how much error in the measures of benefits in relation to the costs would be enough to alter decisions?

Second, and equally important, all of these methods have used results without the benefit of restrictions from the models describing individual choice. Some additions of information as part of calibrating benefit functions, while datum that are not directly estimated, may nonetheless reduce the range of uncertainty without greatly increasing the prospects for bias in the transferred benefit measures (these are the calibration methods discussed in footnote #37).

B. Natural Hazards as Parallel Events

As Sandler and Enders [2004] note, there is an extensive time series database on transnational terrorism measures as counts by type of event and a considerably smaller database on the economic consequences of terrorist events. While two recent empirical studies confirm significant economic responses as well as changes in risk, neither offers information that could be used to assess the implications of policy for resource allocation. The first by Doherty et al. [2003] examines the changes in stock prices for 86 property-casualty insurance companies after 9/11. This study considers the effects of signaling and transparency in the firms' reports of losses as well as the effects of leverage and capacity constraints on performance as measured by the changes in stock prices after 9/11. The size of the loss, extent of leverage, and growth potential appear to influence the resiliency of insurance firms. Markets rewarded transparency in reporting losses. Long term effects or behavioral changes were not considered in the study. All of the changes considered were within about a two-month period after 9/11.

The study of risk perceptions by Fischhoff et al. [2003] was also an investigation of immediate responses conducted in November 2001. Risk judgments were asked on a zero (the event is impossible) to 100% (the event is certain to happen) scale for eight events occurring within the next twelve months. Five of these events were classified as terror related: being hurt in a terror attack; having trouble sleeping because of the situations with terror; traveling less than usual; screening mail carefully for suspicious items; and taking antibiotics for anthrax. Regression analysis of the average terror related risks indicated that risk judgments were higher for those outside 100 miles of the World Trade Center, decreased with age, and were higher for females, non-whites, and non-Republicans. As the authors acknowledge, it is difficult to interpret the sources of these differences or to evaluate their persistence over time.

These two studies illustrate the difficulties with ex post studies of terrorist events. We can examine changes in measures routinely recorded, but long term adjustment requires waiting for time to pass. In addition, there may not be sufficient variation in the elements that can compromise a policy initiative (e.g. insurance, ex ante mitigation, etc.).

While some authors (notably Lakdawalla and Zanjani [200]) have questioned the parallel between terrorist events and natural hazards, we believe these events offer the best prospects for recovering transferable measures of the incremental option prices (e.g. slopes of the option price function implicitly defined in equation (2)) with respect to policy relevant variables. Large natural hazards offer the potential to connect the record of ex ante policies (e.g. information, insurance, etc.) and ex post public responses to the behavior of economic agents. Moreover, our outline for the implicit definition of the option price as a benefit measure in equation (2) is compatible with using changes in property values as signals for these incremental values.

Natural disasters and "near miss natural disasters" offer the closest analogy to the scale of devastation in a terrorist attack, and the type of risk information on which decisions must be made. Nine of the world's ten largest catastrophes ranked by insured loss are natural disasters. As we noted, the largest is the terrorist attacks on September 11th. Robert Hartwig, Senior Vice President and Chief Economist of the Insurance Information Institute, used this characterization in comparing the impacts of Hurricane Andrew and September, 11th.

> "Hurricane Andrew, until September 11, 2001, was the global insurance industry's event of record. For nearly a decade it was the disaster against which all other disasters worldwide were compared.Andrew struck Florida in August 1992 with 140 mile-

> per-hour winds and produced insured losses of $15.5 billion – about $20 billion in current (2001) dollars…Andrew's reign as the most expensive insurance disaster in history ended, of course, with the terrorist attack of September 11, 2001" (Hartwig [2002] pp.1-2).

At a minimum the destruction of the World Trade Center cost more than three times Hurricane Andrew. The enormity of the losses on 9/11 has tended to overshadow the threat of natural disasters. However, catastrophe models predict that if an earthquake or mega hurricane hit a major city it would produce as much or more damage (Insurance Information Institute [2004]). The next two sections illustrate this strategy for the case of hurricane Andrew in Florida. This event is routinely cited as a parallel to 9/11.

V. Illustrating the Use of Natural Hazards as Natural Experiments – Hurricane Andrew in Florida

This section and the next outline the results from using a natural hazard as an opportunity to study the economic responses to a catastrophic risk. These events have at least two types of effects on property values.

First, properties will lose value because of physical damage to their structural attributes. Beyond the property owners themselves, damages of this type are of special interest to insurance companies as they represent potential insurance claims. Second, there is a pure information effect. This effect is the loss in value due to an increase in the subjective risk of the future coastal hazards at the home's location. Information can reduce asset values even when there is no physical damage in situations where there is a permanent shift in demand away from a given location. Much of the economics literature on hazard mitigation assumes that property owners will incorporate the risk of a hazard into their decision processes without explicitly testing this assumption (see Yohe et al.

[1997], Cordes and Yezer [1998] for coastal analyses and Shillings et al. [1989] for flood related hazards).

Hurricane Andrew offers a unique opportunity to study these types of effects of risk on asset values. This hurricane hit the Bahamas and south Dade County on August 23-24, 1992, and then moved across the Gulf of Mexico to strike Louisiana. Originally classified as a Class 4 storm, based on continuing study of the record Andrew has recently been upgraded to a Class 5. Peak wind gusts of almost 200 miles per hour destroyed entire communities. Total damages from Andrew were estimated at $20 billion, insurance claims $15.5 billion, with 25,000 homes destroyed, another 100,000 damaged, and approximately 14 percent of Dade County's economy was affected. All of the Homestead Air Force Base was destroyed.

Properties located near the eye of a Class 3 or higher hurricane will suffer structural damages. As we suggest, indirect effects on property values arise for properties that are not physically damaged when equilibrium housing prices respond to the new information on hurricane risk. In other words, if residents of a coastal community use hurricane events to learn and update their risk perceptions about the extent of risks of damage from coastal storms in specific locations, then there may be a shift in demand away from what are perceived to be high risk areas to safer locations in relative terms. This prospect is especially relevant to situations when there has been a recent history of few storms.[38]

[38] Hurricanes appear to run in cycles caused by factors such as the direction of equatorial stratosphere winds, Atlantic and Caribbean Sea pressure readings, and the amount of rainfall in the Sahel region of West Africa. The 20 years prior to Andrew were a period of below normal hurricane activity (Goldenberg [2001]).

We propose measuring the information treatment by selecting locations that are generally at risk, but not directly effected by a severe storm. This argument maintains that individuals suffering a "near miss" serve to identify a group who should have heightened awareness of the full effects of hurricanes. They may not, depending on past history in relation to their location choices, have accurate perceptions of the probabilities of storms. Under these circumstances, a storm that is "noticed" but that does not directly affect them provides information.

Our evaluation of homeowners' responses to Andrew using a composite of four sets of information for two counties in Florida. First we focus on the experience in Dade County. This area was directly hit by hurricane Andrew and as we noted above, experienced extensive damage from the hurricane. After discussing these results we also consider Lee County, a Gulf Coast County that was narrowly missed by the hurricane. This "near miss" situation serves two roles. First, it provides a means to evaluate the potential confounding effects of hurricane damage. In Lee County there was none. Homes in Dade experienced record setting damage. Our analysis seeks to isolate a pure information effect of the storm. Comparison of Dade and Lee results provides a basis for evaluating the plausibility of our controls for damage. This comparison is also an indirect means to gauge the transferability of estimated incremental value of hazard information.

Second, Lee County results may well be of independent interest precisely because they illustrate information effects through a "near miss". This situation is similar to a failed terrorist attack. Woo [2002] notes that the task of characterizing the tail of a terrorism loss distribution is assisted by using events that narrowly fail to be significant disasters. The same holds true for studying behavioral responses. That is, it seems reasonable to suggest the ex ante response to information about a hazard that could have taken place (except for the "near miss") provides an approximate lower bound measure for the incremental value of avoiding the event.

Our data include records of all residential home sales (including repeat sales) in Dade and Lee Counties between 1983 and 2000 purchased from a commercial vendor (First American Real Estate Solutions). These data include detailed records on the characteristics of properties at the time of sale, the date of each sale (year, month, and day), the sales price, the latitude and longitude coordinates, and a variety of other variables describing the properties.[39] The housing sales data for our analysis were cleaned to remove several types of transactions, including: properties that sold for less than $100; properties that were bought and sold within a period of several months and had a price difference exceeding $500,000; and properties where the first sale was for land only and the second sale included land and a structure. Finally, the National Flood Insurance Program includes special provisions for properties built before 1974, making them eligible for subsidized insurance. As a result, we limited our attention to properties built after 1982.

The precise identification of location for each property allowed each to be merged with a geo-coded record of what would be known to potential homebuyers about the flood and hazard risks for each county (i.e. the Federal Emergency Management Agency's G3 flood map). Information about the Special Flood Hazard Area (SFHA) is in

[39] The extent to which each record offers complete data varies by county because the data are derived from county tax records on housing sales. Different counties devote more or less resources to maintaining the full characteristics of the properties involved in the transactions, and the data provided by the commercial vendors vary with these differences. No effort is made to assure uniformity.

the public domain and a part of the considerations involved in setting hazard insurance rates. Thus, it is reasonable to assume that homebuyers are aware of their property's location in relation to these zones. Nonetheless our model does not require that they use the detailed delineation of the sub-areas with the SFHA. The definition of the flood zones are:

Zone A - Area inundated by 100-yr flooding, no Base Flood Elevations (BFE) have been determined.
Zone AH - Area inundated by 100-yr flooding (ponding), BFEs determined, depths 1 to 3 feet.
Zone AE - Area inundated by 100-yr flooding, BFEs have been determined.
Zone X - Area outside the 100 and 500-yr flood plain.
Zone X500 - Area inundated by 500-yr flooding, 100-yr flooding with average depths less than 1 foot or drainage areas less than 1 mile, or protected by levees from 100-yr flooding.
Zone VE - Area inundated by 100-yr flooding with velocity hazard (wave action), BFEs have been determined.

The highest risk zone is Zone VE. As noted, our analysis assumes that homebuyers do not take account of these detailed distinctions. Rather, we hypothesize that they recognize whether their home is inside or outside the SFHA zone.[40] As our formal model, outlined below implies, the "inside" and "outside" distinction is hypothesized to convey different subjective risk beliefs. When new information becomes available, these perceptions are assumed to be updated.

An important challenge in using the response of housing prices to the hurricane arises in distinguishing the effects of damage from that of new information. To meet this objective we developed two sets of information. The first is based on a report developed by NOAA of an assessment of damage by subdivision in the areas of Dade County

[40] We tested this hypothesis and could not reject a null hypothesis implying equal effects for the zones with adequate data on sales transactions that overlap the zones. Not all zones had transactions that were before and after the hurricane. For example we had no transaction in the highest risk zone.

affected by the hurricane. These details were published in the *Miami Herald* on December 20, 1992.[41] We geo-coded these records using the map presented in the *Herald's* articles on the aftermath of the storm. Our matching aligns the roadways and subdivisions with an Arcview map of the primary roads within the county. A set of 306 grids was defined to match the subdivision records to the latitude and longitude records for each record of a repeat sale in our data for the county. Figure 2 reproduces this map with the grid system overlaid on the subdivisions in the county. The color coding identifies areas with different percentages of uninhabitable properties . Figure 3 has two parts. The first , labeled "a" indicates the homes in our data bas that are in the damage area based on using *Miami Herald*/NOAA records and a threshold of more than one-third of the properties inhabitable. The background color coding also identifies the SFHA zones. Pane "b" includes the transactions involving homes outside the damage are based on this criterion

The second strategy uses the location of each property in relation to the path of Andrew's eye across Dade County. We had the record for the latitude and longitude for the path of Andrew as well as the area with the highest wind bursts using the wind maps prepared by Wakimoto and Black [1994].

Based on AIR [2002] estimates and the Wakimoto and Black [1994] data, we estimated that the damage zone corresponds to a band approximately 18 miles wide centered at the path of the eye of the storm. Figure 4 provides an expanded view of the

[41] These data were also used by Franstin and Holtmann [1994] to evaluate the determinants of damage due to Andrew.

path.[42] Most of the damage to residential properties was north of the path of the eye. As a result, we identify two further spatial details for Dade County. A zone that would include properties likely to experience structural damage (i.e. with distance from the hurricane's eye $\leq$ 9 miles) and a zone outside the 9 miles but less than 27 miles where we expect that the storm heightened residents' awareness of storms. Figure 5, panel "a" identifies the transactions in our sample in the damage zone based on this criterion and "b" those outside the wind based zone. Notice that the Miami Herald/NOAA criterion includes repeat sales transactions that would be in the expanded path with wind effects but lying in the south western portion of the county, above the path for the eye of the storm.

Our analysis treats Andrew as the source of a natural experiment in Dade and Lee Counties. By using all the houses that sold at least twice between 1983 and 2000 it is possible to use the timing of these sales in relation to the hurricane and the location of each of these homes to isolate properties experiencing the information treatment we attribute to Andrew as a catastrophic event for the local area. If there were no properties damaged by the hurricane (i.e. the situation in Lee County) a property would fall in one of four cells defined by these two dimensions.

TIMING OF SALES	LOCATION	
	IN SPECIAL FLOOD HAZARD AREA	OUTSIDE SPECIAL FLOOD HAZARD AREA
Bracket Andrew	**Hypothesized to Receive Information Treatment**	*Spatial Control* experience event but no differential hazard

[42] Wakimoto and Black provided us the original worksheets for their damage map. This worksheet provides a somewhat more detailed description of the zones of most significant damage, based on wind patterns. We are in the process of introducing these features into the analysis.

Does Not Bracket Andrew	*Temporal Control* no different information regime for the two sales	*Joint Spatial Temporal Control* no difference in information and no differential risk

A repeat sales model uses the logic of a hedonic property value model framework described above but in this case considers how the spatial and temporally defined event influences the price changes for the same properties. The hedonic price equation that we begin with is given in equation (3).

$$\ln R_{it} = \sum_k c_k z_{ik} + F_i(b_t + bp_t + h_i + e_{it}) + (1 + F_i)(g_t + b f_t + h_i + e_{it}) \quad (3)$$

where subscript *i* identifies the property and *t* the date of the sale. In equation (1), R_{it} is the sales price. The first term, $\sum_k c_k z_{ik}$, captures the effect of the housing characteristics. These attributes describe the features of the home and its lot. They would generally include its size, the lot size, age, the number of baths, presence of pool, carport, etc. $?_i$ is an idiosyncratic, time invariant effect due to unobserved heterogeneity. F_i is a qualitative variable identifying the location of properties inside (=1) and outside (=0) a Special Flood Hazard Area (SFHA). As we suggested, we assume there are different subjective probabilities of a hurricane strike causing major structural damage within an SFHA versus outside this area. They are p_t and f_t, respectively. b_t and g_t are the time effects for properties inside and outside an SFHA, respectively. e_{it} is assumed to be a well-behaved error (i.e. independent and identically distributed). .

The information provided by Andrew for the potential of major hurricane damage in the market area is hypothesized to cause households to update risk assessments from their baseline levels in each area. If we assume that sales before

Andrew are based on an initial set of risk perceptions, for example, $p_t = p_0$ and $f_t = f_0$, then after Andrew, households have received the new information and adjust their risk assessments to $p_t = p_1$ and $f_t = f_1$. Defining A_t=1 if Andrew occurred and A_t=0 otherwise, p_t and ϕ_t can be defined recognizing this hypothesized discrete change in risks for the two locations by equations (4) and (5), respectively.

$$p_t = A_t p_1 + (1 - A_t) p_0 \tag{4}$$

$$f_t = A_t f_1 + (1 - A_t) f_0 \tag{5}$$

Substituting (4) and (5) into equation (3) yields equation (6).

$$\begin{aligned} \ln R_{it} = \sum_k c_k z_{ik} + F_i \left(b_t + b\left(A_t p_1 + (1 - A_t) p_0\right) + h_i + e_{it} \right) + \\ (1 - F_i)\left(g_t + b\left(A_t f_1 + (1 - A_t) f_0\right) + h_i + e_{it} \right) \end{aligned} \tag{6}$$

In Dade County the damage caused by the storm requires that we consider how this might influence the model. Perhaps the simplest strategy would be to exclude properties that experience significant damage from the storm. This strategy implicitly assumes that the changes in their prices reflect whether and how repairs are completed (i.e. the structural features change in ways that are not recorded in our data). As noted above, we have two sets of information available to meet this objective. The first is the *Miami Herald*/NOAA records. Here we aggregate experience in the subdivisions in each map grid and assume this average damage (measured by the percentage of the homes uninhabitable) applies to all homes in the relevant grid. By selecting a threshold level of damage (i.e. 33%), we can omit homes in areas with greater damage from the sample. As noted the distance criteria simply eliminated homes based on band north of the path of the eye of the storm and the timing of the repeat sales.

Table 3 compares the implications of these two criteria for the repeat sales in our sample that bracket the timing of Andrew. The top panel groups sales by the assigned percentage uninhabitable based on the *Miami Herald* special series describing the results from the NOAA survey. The estimates for the average percentage uninhabitable are grouped into cells with ten percentage point intervals. This description identifies sales using the two criteria identified in the experimental panel. To have the hypothesized effect of the hurricane's information and exhibit an observable response, properties must be located in an area designated as SFHA and have sales that bracket Andrew. These sales are designated as the "yes" column. Otherwise, they fall in the "no" column. By selecting a percentage as the minimum allowed without changes in the structural attributes we identify the observations that would be deleted under the first criteria. The second panel repeats this comparison using the nine miles north of the eye of the storm as the damage zone and the timing of the sales. In this case about 800 observations would be eliminated.

Using the distance based criteria there are other possible confounding effects due to the location of homes in relation to the central business district for Miami. That is, most of the damage from Andrew was wind-related and not the result of flooding (Wakimoto and Black [1994] and Rappaport [1993]). We assume that damages are inversely related to the distance from the path of the storm's eye (especially north of the path). However, monocentric city models would predict a declining rent gradient as the distance from the central business district increases. As we select a band north of the path of the storm's eye we are moving closer to Miami. Thus, for this reason alone (independent of the hypothesized damage gradient) we expect property values to increase, even if the storm had not occurred. Fortunately, the timing of sales with respect to Andrew helps (as our panel on controls indicates) to isolate a shift in property values with distance away from the path.

It is also important to note that risks due to proximity of a property to the coast cannot be identified. The effect of living in these locations is confounded with environmental amenities provided by coastal sites. A repeat sales model allows difference in differences estimation framework to investigate how the spatial location of properties and the timing of the storm in relation to the timing of housing sales to be used to isolate the effect of the risk information on housing prices. More specifically, this framework measures the homeowner's responses to the change in the perceived risk of hurricanes through the changes in housing values due to the information treatment group. It identifies this effect through the other controls provided by using the price changes for the same homes and by controlling for homes' locations and the timing of their sales.

Differencing equation (6) for the same property *i*, we have equation (7).

$$\ln\left(R_{it} / R_{is} \right) = (g_t - g_s) + F_i((b_t - b_s) - (g_t - g_s)) + b(f_1 - f_0)(A_t - A_s) + b \cdot ((p_1 - p_0) - (f_1 - f_s))F_i \cdot (A_t - A_s) + (e_{it} - e_{is}) \qquad (7)$$

In equation (7) the structural characteristics are assumed to remain constant and these terms will cancel. For this result to be plausible we must exclude the homes damaged by the storm. An alternative to this strategy, discussed below, would include a measure of damage interacted with the variable indicating the sales bracketed Andrew to attempt to take account of changes in structural attributes from the storm's damage. The interaction term indicating the sales bracketed Andrew and that a property is in a SFHA measures $b[(p_1 - p_0) - (f_1 - f_0)]$, the incremental option price scaled by the differential risk, for the areas with significant hazard compared to those without. The identifying restrictions required to estimate this pure information effect are that: (a) there are no significant changes in housing attributes between the two time periods (e.g. the z_j's remain the same); (b) the partial effects of structural attributes on the log of the sale prices are constant (i.e. the c_j's do not change); and (c) the unobserved heterogeneity is not differentially influenced by the event or the group.

This model is estimated in three ways for the various Dade County samples. The first distinction involves whether we allow the effect of the information to "decay" with the item from the storm. One model assumes the information effect is constant and the other allows it to vary with time from the storm. The second distinction concerns the treatment of properties damaged by the storm. We apply each of these two "time and effect" models to two sub-samples. One deletes observations that are estimated to have one third of the properties in a sub-division as uninhabitable and the second deletes observations that are within a band nine miles north of the path of the eye for the storm.

The third distinction considers the somewhat arbitrary nature of our selection of a damage threshold for the properties based on the *Miami Herald* account. This strategy re-estimates both the "time and effect" models on the full sample. However, it includes a control for the estimated percentage uninhabitable properties due to storm damage that was assigned to the property. This effect is interacted with a variable that identifies observations based on whether their sales bracket the timing of hurricane Andrew (i.e. the A_t determine identified earlier).

Finally, a concern raised with the repeat sales logic that underlies our estimation strategy arises from the potential for selection effects. That is, under this view homes that sell multiple times could be different in their responses to the information effect we wish to measure. These differences may arise because of the factors leading to their multiple sales. This argument implies the error for our difference in differences model (i.e. $(e_{it} - e_{is})$ in equation (7)) has a non-null expectation.

We account for the selection effect associated with Heckman's [1979] two-step logic. Our probit selection equation assumes the probability of being a repeat sales as a function of sixteen fixed effects (e.g. 1984-1999) identifying the year in which a home was built. This approach avoids the issues that can arise in identifying the selection effect as distinctive from the factors that would enter a hedonic model. A non-parametric treatment of the year built distinguishes selection from age and other attributes of a conventional hedonic price function (the estimates are reported in Appendix A).

Our analysis for Lee County follows the same basic structure using the repeat sales logic and the "time and effect" strategy for isolating the role of the hurricane as an information treatment. Because the storm did not cause damage, there is no need to control for these effects. Figure 6 provides a map of the repeat sales transactions for Lee county , identifying the distribution inside and outside the SFHA area for this county. As noted earlier, we present these results to help in confirming the Dade County results, gauge their transferability, and to parallel suggestions that they could serve as indications of behavior that responds to information derived from events that narrowly fail to be disasters.

VI. Results for the Case Study

Table 4 provides a summary of our estimates for the repeat sales model in equation (6) by county, subsample, and treatment of time. Our primary interest is in the estimated effect of the risk information conveyed to homeowners living in publicly announced high risk areas as a result of the hurricane. In all cases, these effects are significantly estimated. They confirm our a priori hypothesis in that they risk information conveyed by Hurricane Andrew clearly reduces the property values for homes in the area prone to coastal hazards. For Dade County, these estimated reductions range 34 to 44 percent (when the model allows for the effects to change over time), depending on how the areas with damaged properties are defined. Larger estimates of the effect (in absolute magnitude) are associated with the models using the threshold of one-third uninhabited. When we use a threshold of no properties designated as uninhabited in the subdivisions, the estimated effects remain highly significant and slightly larger in absolute magnitude. Forty-six percent declines (in absolute magnitude) in property values due the hurricane's information were found for models that allow the effects to adapt over time and 49 percent when they do not. Using the average value of the sale prices for homes in each sample, these estimates can be used to develop illustrative estimates for the incremental option price to avoid increased risk of severe coastal storms. As the table indicates, the models include controls for changes in the National Flood Insurance program, the time between sales, as well as the time between the most recent sale, and the date for Andrew (labeled in the table as time).

There are several assumptions required to establish these connections. Table 5 reports the primary elements used in the analysis for the two approaches for controlling for hurricane damage. The first column reports the estimated effect of the information due to Hurricane Andrew for property values as a percentage reduction in price. The second column is the average value of the sales prices for the most recent sale in 2002 dollars (using the housing component of the Consumer Price Index). The different controls for damage lead (as Table 4 indicated) to different samples and thus different means. Applying an annualization adjustment (i.e. capital recovery factor) assuming a five percent discount rate and thirty years to the absolute value of the product of the first two columns, yields the annual incremental value of the risk information conveyed by the storm. The last step uses our definition of the benefits due to risk reductions (and Smith's [1985] interpretation of the hedonic model) to establish that the incremental option price can be measured with the incremental housing value. For a change that involves an information induced risk change the expression is given by equation (8).[43]

$$R_I = \frac{p_I \cdot (U_{NH} - U_H)}{pU_{Nm} + (1-p)U_{NHm}} \tag{8}$$

Thus, the last step in the process involves computing p_I, the incremental change in the subjective probability of severe coastal hazards due to the information provided by Andrew. To develop one measure of this change we used NOAA's records of hurricanes making landfall from 1851 to 2002 to compute the relative frequency of storms within a 50 mile nautical scan of Dade County. The storms are categorized by wind speed (in knots per hour). Our results for Dade and Lee Counties are given in Figure 7.

Ideally, an assessment of the increment due to the information would be based on a carefully designed survey of homeowners' altered subjective perceptions of these hazards. We do not have this information. As a result, for the last step of the analysis we treated p_I as the difference between the likelihood of the strongest storm (i.e. 115 knots

[43] For notational simplicity we deleted the arguments of these individual functions and assumed p=p.

per hour) and the weakest. This approach assumes that before the storm homeowners equated their subjective beliefs about coastal hazards with the actual risks of the most severe hurricanes and the after Andrew updated to consider them as risky as the least severe storms.[44] This adjustment is about a 0.079 increase in probability. Dividing the third column by this estimate, as equation (8) implies, yields our last column – an estimate of the annual incremental option price for reducing the risk of severe storms. This estimate is the annualized value of homeowners' willingness to pay to reduce the risk of storms comparable to Andrew. The computation is illustrative (as noted earlier, we do not have information on how the subjective beliefs were actually updated in response to the information provided by Andrew). They are presented here to confirm the feasibility of linking market observed outcomes with surveys of how laypersons' subjective risk perceptions adapt ot information.

Two other sets of results are reported in Table 4. The first of these includes the estimate for the percentage uninhabitable that was assigned to each home as an argument in the two repeat sales models with different treatments of time. It would be introduced in our original model (in equation (6)) as an interaction term involving A_t and an unobserved measure of the repair/modifications effects on housing values. By allowing for this effect to be present with the sales bracketing the storm, we attempt to assure the controls in each subdivision reflect hurricane related impact on the homes involved in the repeat sales transaction. Because we do not know with certainty that the individual homes actually experienced the damage, it is a proxy measure. Thus, this variable will relate only to sales that bracket Andrew and fell in areas with a non-zero percentage of

[44] The literature has considerable evidence of this type of over-adjustment (for examples see Adler [2003] and Sunstein [2003]). The exact size is of course arbitrary in the absence of a survey on risk perceptions.

uninhabitable homes. The estimates for the model with time varying effects are quite close to the model that deletes properties in areas with one-third or more of the homes uninhabitable. Overall, these results suggest that impacts in the range of 35 to 45 percent of the value of the property offer quite robust measures of the impact of the risk information conveyed by Hurricane Andrew.

Finally, using a completely parallel model and methodology, we repeated the analysis for Lee County (see Hallstrom and Smith [2004] for details). The overall results are remarkably consistent for this "near miss" county with consistently significant negative effects on property values. The measured effects of the information conveyed by Andrew are slightly less than half the absolute magnitude of the effect in Dade. This outcome is what we would have expected for areas serving a role comparable to what Woo described as a narrow miss for estimating probabilities of events in the tails of the distribution. Moreover, the Dade County results no doubt reflect much greater awareness of the disruptions to daily life (independent of damage to one's home) that were experienced by residents of Dade County and would not be a part of the conditions in Lee County.

Overall then, these examples suggest repeat sales models used with past hazards can offer one means for estimating the types of benefit measures required for homeland security policies associated with these types of risks of property damage and disruption to living conditions. As we discuss below, they may well be more relevant than treating homeland security policies exclusively in terms of *ex ante* values of risks to life and *ex post* damages to structures. The incremental option price measure reflects the full consequences of avoiding large-scale disasters. Estimating how it behaves for different types of hazards, information, and local conditions would allow greater insight into the effects of other dimensions of policy such as insurance markets and ex post damage mitigation.

VII. Summary and Implications

Earlier this year (March 21, 2004) *Time* magazine published an article on the allocation of resources for homeland security. They reported:

> "If all the federal homeland-security grants from last year are added together, Wyoming received $61 a person while California got just $41, …, Alaska received an impressive $58 a resident while New York got less than $25. *On and on goes the upside-down math of the new homeland security funding*" (source: www.time.com/time/covers/1101040329/nhomland.html, emphasis added).

Of course, there is no reason equal security is achieved with equal allocation of resources per resident. In fact, there is no reason to believe security should be related to the number of people in a state. In a separate analysis, Canada [2003] finds the *average* of the per capita allocations would not greatly change between the largest and medium sized states if the decisions on homeland security funds were made based on a criterion that focused on population versus one that considered both population and infrastructure. Such choices make large differences for states with small populations. Both discussions are somewhat misleading. Evaluations of resource allocations require that there be a clear definition of each policy's objectives. We have argued that these objections need to be defined in terms of changes in specific dimensions of risk or ex post response.

Restoring earlier conditions of perceived security for daily activity in the U.S. is infeasible. Goals need to be risk based. Decisions among policy alternatives should be informed by economic analyses of the tradeoffs people would make to realize the conditions implied by the outputs of homeland security policies. Because all choices about how to allocate security resources inevitably imply values and statements comparable to the *Time* analysis, it is important to include measures of people's values for the policies in the decision process. This goal is precisely what benefit cost analysis is intended to do.

This paper has acknowledged the complexity of meeting these objectives and also of measuring these tradeoffs as net benefits of a policy (including the increased costs of everyone's activities due to public mitigation of risk). Nonetheless, the methods developed for evaluations of large-scale policies involving other non-market goods and services offer a starting point. Benefit transfer, using records of how people respond to risks, and new risk information for large natural hazards is, in our judgment, a preferable starting point to monetization of arbitrary measures of avoided demands with readily available VSL measures. Security related events involved bundle risk to life, property, and daily activities. Strategies relying on VSL measures require arbitrary decompositions of the full change in living conditions that fail to recognize the jointness in the events at risk. That is, they are not simply one more added risk to life. Instead, they alter the quality of life by many dimensions of the way people must live. One of these changes involves increasing the risks to life. While use of existing unit benefit measures provides convenient strategies for "quick" benefit cost analysis, they are not likely to be informative for many homeland security policies. It may be possible to use thm for some applications such as protecting the air travel system. However, efforts to secure large cities, events important to our national economy (e.g. reliable performance of security markets) or to our political system (e.g. political conventions), and to protect areas of national significance will not be adequately described in this context.

This paper has also provided a brief summary of revealed and stated preference methods. It described the traditional partial equilibrium logic underlying benefit measure. There is an important issue that distinguishes security policy from other areas of non-market policy. The source of the externality (or risk) must be assumed to respond in ways that attempt to undo the policy. For environmental policy, coordination of private and public action has certainly been a large part of some policy discussions. Often this involves a "backing out" of private action (or charitable contributions) when public action to reduce an external effect increases. In climate policy it is usually the induced advantage to countries that are not part of the group or coalition seeking to coordinate their control objectives. However, in none of these cases do we experience efforts to purposefully increase the externality. Rather, they are usually efforts to reduce one's own costs of controlling sources of externalities. They may lead (as an unintended outcome) to results that do not meet initial objectives (see Carbone [2003] for further discussion). These feedback effects are not necessarily important to benefit measurement at the individual level. They are most certainly relevant to aggregate benefit-cost analysis where what is "delivered" by a policy must take account of these strategic feedbacks. As a result, the analysis of the aggregate benefits from policy needs to incorporate what is akin to a general equilibrium framework; the induced responses of the sources of the hazard in order to capture what might by termed the general equilibrium response to the policy. This feature is a significant difference from the context of all large scale benefit-cost analyses to date.

Figure 1: Example of a Choice Panel for Conjoint Study – Investigating Health Effects of Smoking

Sample Conjoint Screen

CATEGORY	FILTER A	FILTER B	NO FILTER
Life extension	You will have 26 months added to your life at age 77	You will have 45 months added to your life at age 77	You will have no time added to your life at age 77
Quality of live	• You are able to drive • You are able to walk a few blocks	• You are able to leave your home with assistance • You have trouble getting in and out of bed	• You are able to leave your home with assistance • You have trouble getting in and out of bed
Price of filters	$6.00 per pack of 20 filters in addition to the $3.00 per pack of 20 cigarettes	$2.00 per pack of 20 filters in addition to the $3.00 per pack of 20 cigarettes	No cost in addition to the $3.00 per pack of 20 cigarettes

Which do you prefer? **Filter A** ☐ **Filter B** ☐ **No filter** ☐

6

Figure 2: Dade County Grid for Matching Andrew Damage Estimates

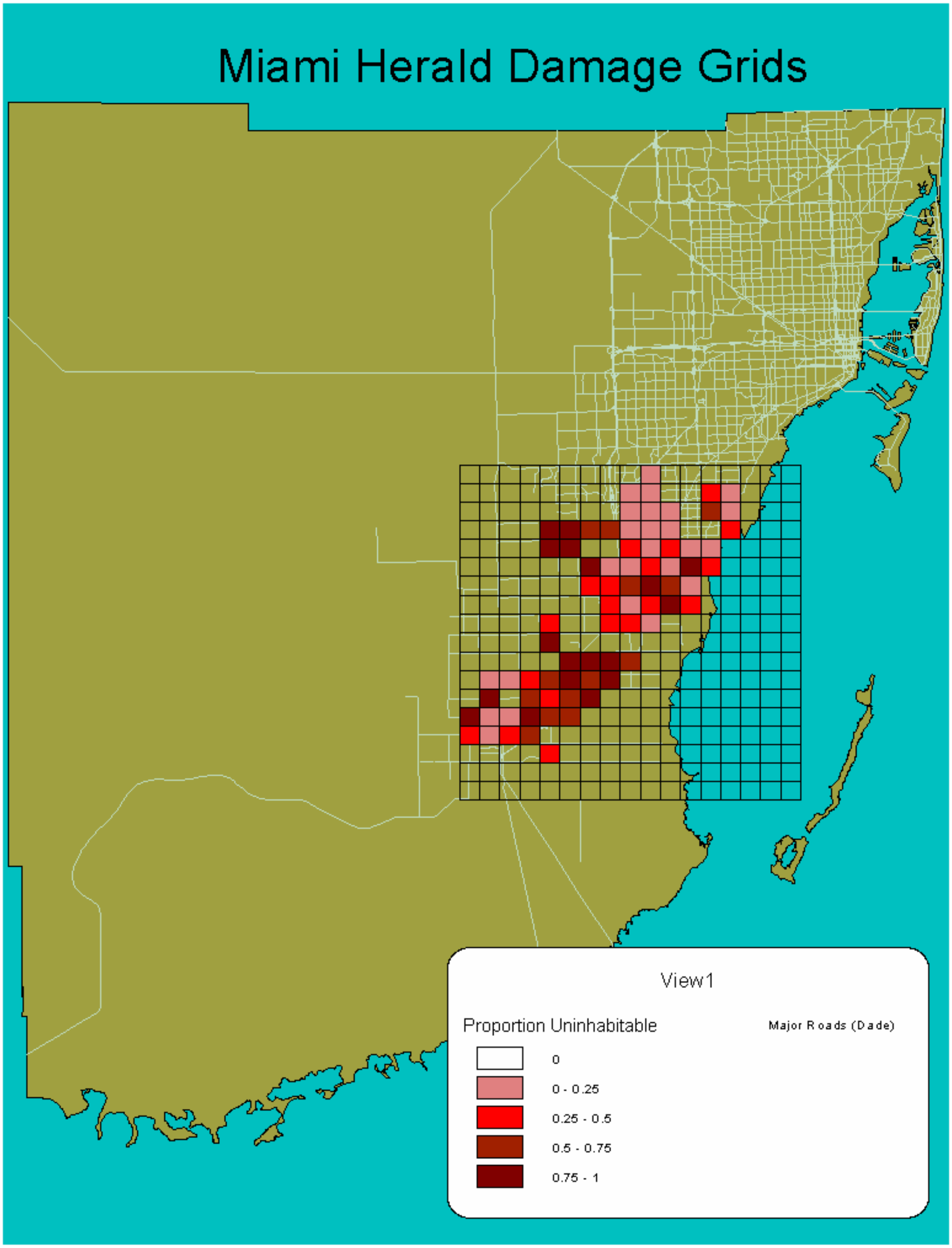


Figure 3: Dade County – Damage Estimates Using Miami Herald Report

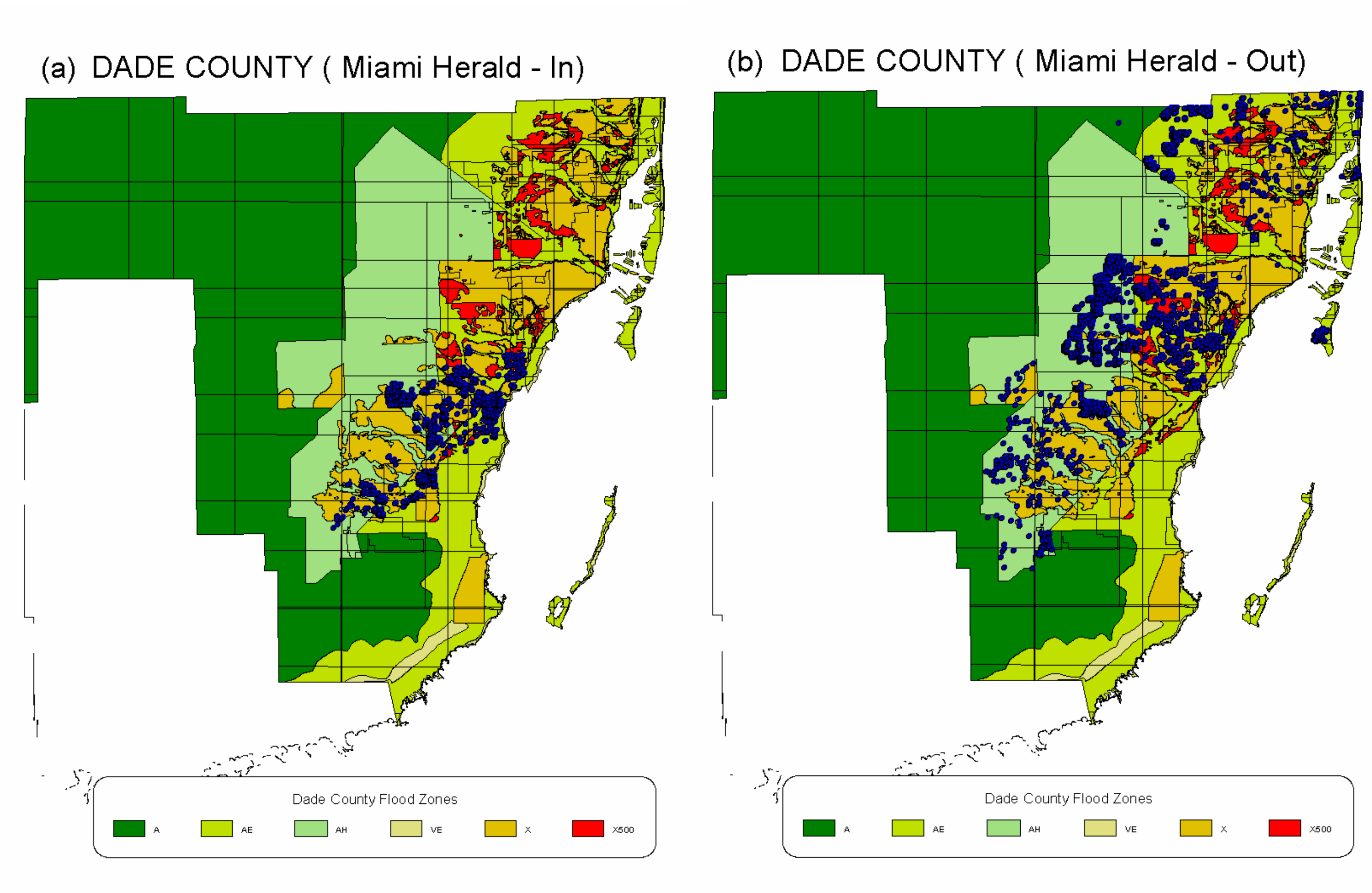
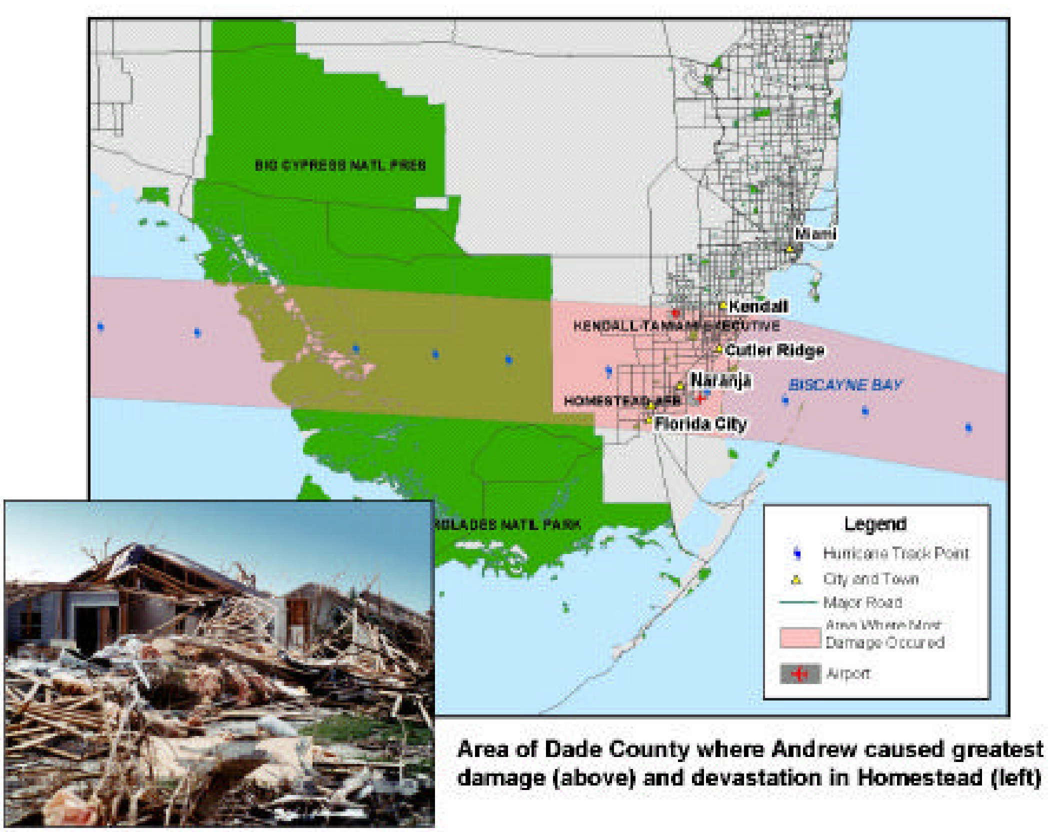


Figure 4: Hurricane Andrew Approximate Damage Zone



Area of Dade County where Andrew caused greatest damage (above) and devastation in Homestead (left)

Source: AIR Worldwide Corporation (2002), "Ten Years after Andrew: What Should We Be Preparing for Now?" AIR Special Report, Technical Document_HASR_0208, (August).

Figure 5: Dade County – Distance Based Definition of Andrew Damage Zone

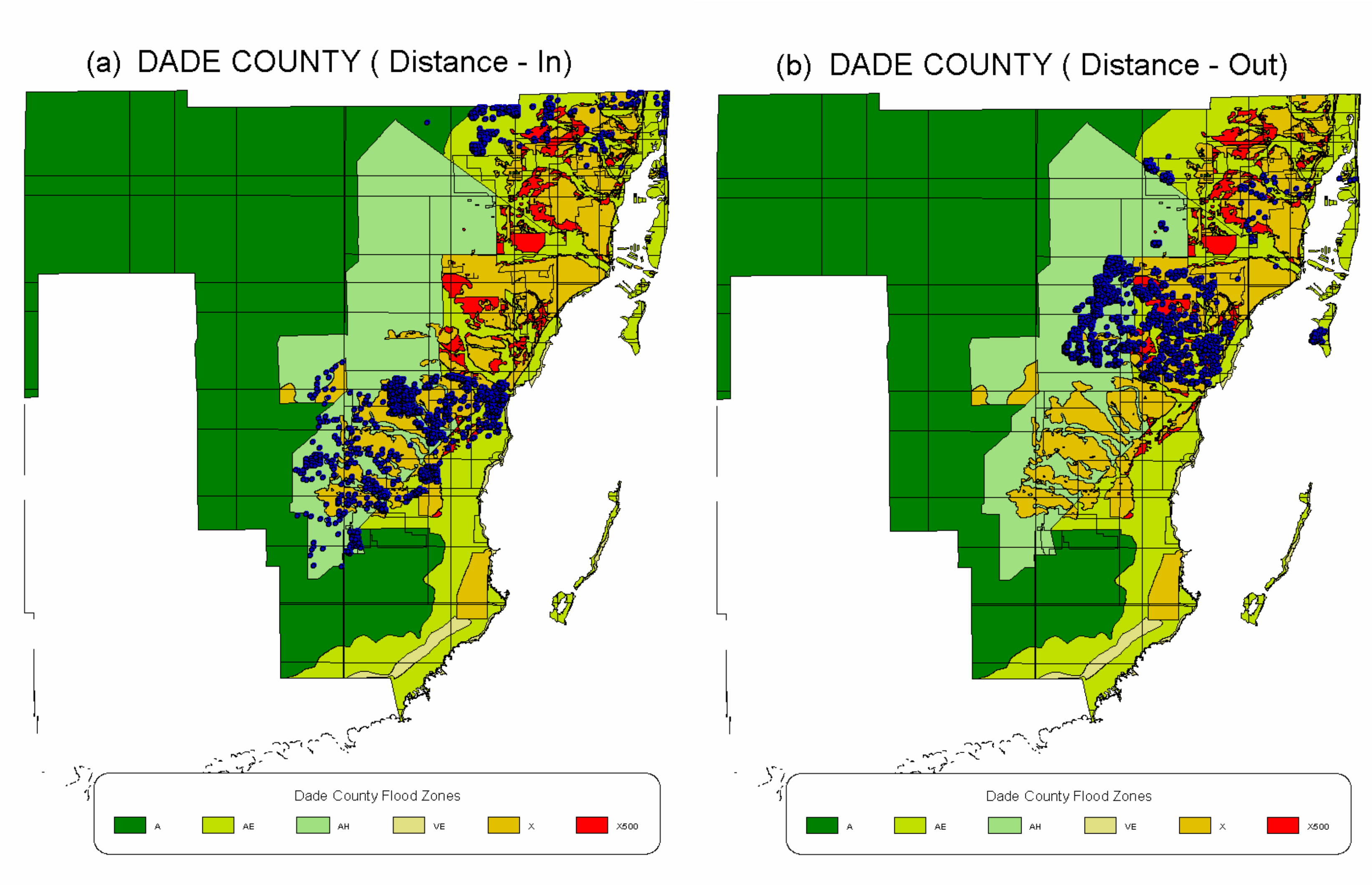


Figure 6: Spatial Distribution of Repeat Sales Transactions in Lee County

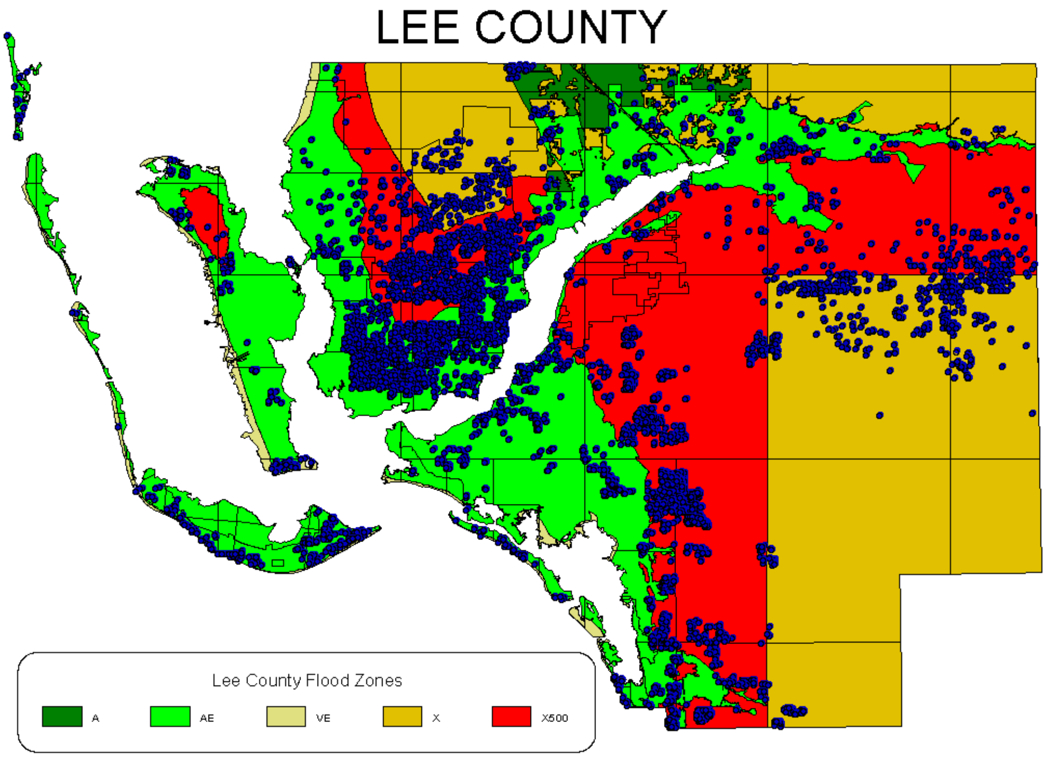


Figure 7: Hurricane Probabilities for Lee and Dade County (50 nautical mile scan circle)

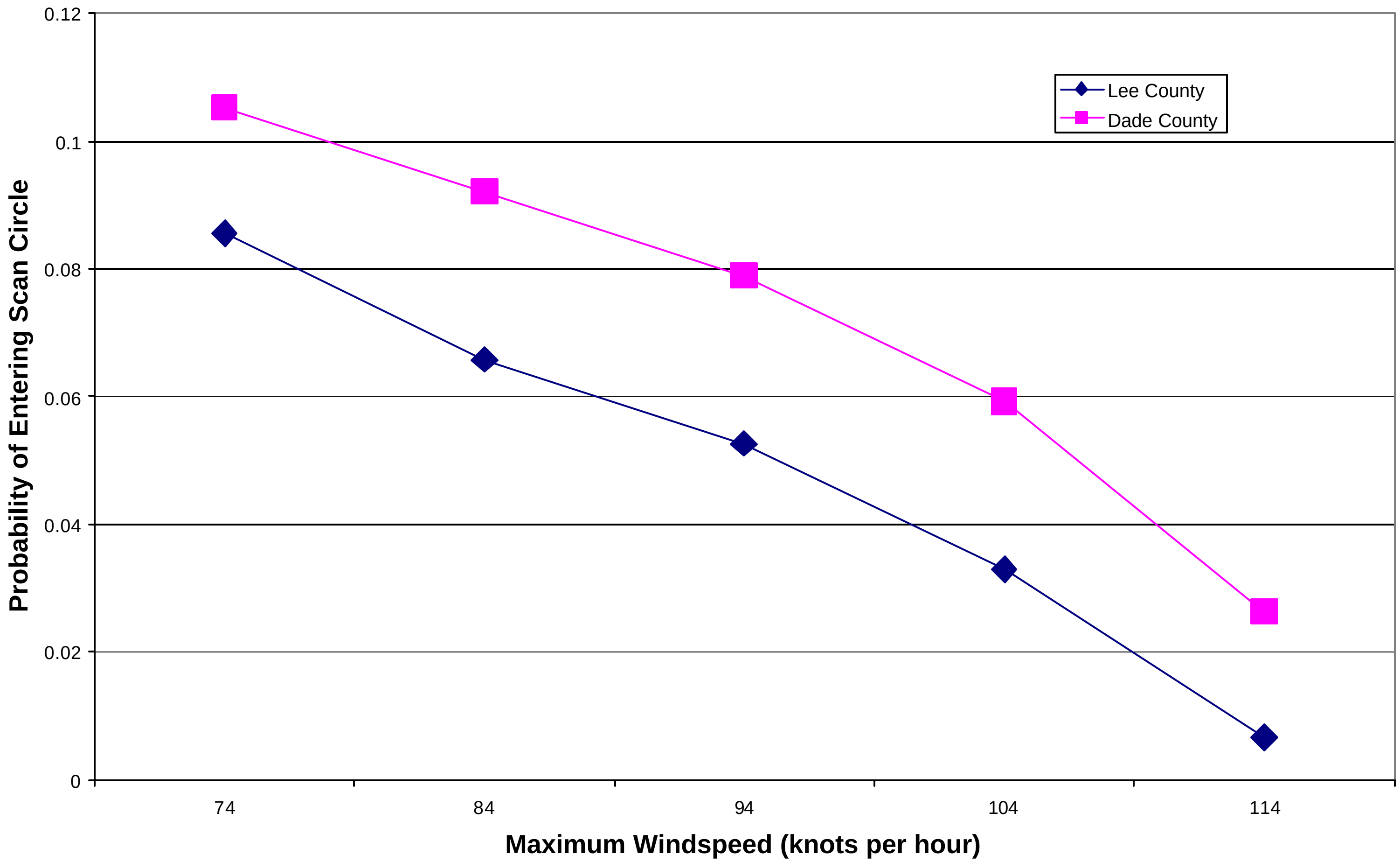


Table 1: An Outline of the Damage Function Strategy for Benefit Analysis

Logic	**Prospective Analysis**[a]
Change in Ambient Concentration of Pollutant	Air Pollution Emissions
Estimate Exposures	Spatially Delineated Air Diffusion Models
Estimate Change in Physical Effects (*E*)	Micro-Epidemiology Concentration Response Functions for Non-Accidental Mortality Rates
Unit Values (*V*) for Physical Effects	Compensation for Increased On-the-Job Risk (Value of Statistical Life)
$B = \sum_j V_j \Delta E_j$ [b]	

[a]Other health effects are measured using essentially the same logic.
[b]V_j = unit value for j^{th} health effect
ΔE_j = change in the j^{th} health effect due to change in concentration of pollutants
B = aggregate incremental benefits due to human health effects

Source: U.S. Environmental Protection Agency [1999].

Table 2: Adverse Health Effects Avoided Pre-CAAA minus Post-CAAA in 2010 Cases per Year

Selected Health Effect	Pollutant[a]	Mean	% of Baseline	Unit Value (1990 $)
A. Premature Death				
mortality 30 and over	particulate matter	23,000	1%	4.8 million
B. Chronic Illness				
chronic bronchitis	particulate matter	20,000	3.14%	260,000
chronic asthma	Ozone	7,200	3.83%	25,000
cardiovascular admissions	PM_{10}, CO, NO_2, SO_2, O_3	42,000	0.86%	9,500
C. Minor Illness				
acute bronchitis	PM_{10}	47,000	5.06%	45
asthma attacks	O_3, PM_{10}, SO_2	1,700,000	1.04%	32
minor restricted activity days / any of 19 respiratory symptoms	0_3, PM_{10}	31,000,000	2.15%	38

[a] PM_{10} corresponds to particulate matter smaller than 10 micros; CO designates carbon monoxide, NO_2 nitrogen oxide, SO_2 sulfur dioxide, and O_3 is ozone.

Table 3: A Comparison of Controls for Hurricane Andrew Damage – Dade County

Threshold for Significant Damage	Homes Affected By Storm Information		
	No	Yes	Total
A. Miami Herald/NOAA Survey			
% Uninhabitable			
None	4,927	2,352	7,279
0-10	274	146	420
10-20	59	17	76
20-30	152	11	163
30-40	143	45	188
40-50	187	123	310
50-60	66	19	85
60-70	90	30	120
70-80	59	1	60
80-90	83	12	95
90-100	851	282	1133
B. Storm Path Wind Record			
Outside Area	4,234	2,227	6,461
In Area	2,657	811	3,468
C. Total Sample of Repeat Sales			9,929

Table 4: Results for Dade and Lee Counties: Modeling Information Effects of Andrew[a]

	Dade County						Lee County	
	Outside Damage Miami Herald/NOAA Uninhabitable = 33%		Outside Damage Wind Criteria		Control for Damage With Miami Herald/NOAA			
	No Time	Time	No Time	Time	No Time	Time	No Time	Time
Effect of Risk Information	-0.481 (p-value=0.00)	-0.438 (p-value=0.00)	-0.321 (p-value=0.00)	-0.338 (p-value=0.00)	-0.558 (p-value=0.00)	-0.454 (p-value=0.00)	-0.198 (p-value=0.00)	-0.194 (p-value=0.001)
Andrew*SFHA	-0.009 (-0.11)	-0.062 (-0.70)	-0.280 (-3.20)	-0.256 (-8.29)	-0.086 (-1.33)	-0.214 (-3.02)	-0.187 (-2.69)	-0.196 (-2.09)
Andrew	-0.472 (-6.22)	-0.472 (-6.23)	-0.041 (-0.51)	-0.041 (-0.51)	-0.472 (-7.86)	-0.474 (-7.90)	-0.012 (-0.26)	-0.012 (-0.26)
SFHA	-0.062 (-1.06)	-0.039 (-0.66)	-0.566 (-8.39)	-0.566 (-8.29)	-0.102 (-2.18)	-0.46 (-0.95)	0.025 (0.50)	0.026 (0.52)
Time between Sales (t-s)	0.011 (10.11)	0.011 (10.10)	0.002 (1.83)	0.002 (1.83)	0.009 (11.96)	0.009 (11.95)	0.003 (4.87)	0.003 (4.87)
SFHA*(t-s)	0.009×10^{-1} (0.72)	0.004×10^{-1} (0.34)	0.008 (5.62)	0.008 (5.70)	0.002 (1.82)	0.006×10^{-1} (0.61)	0.005 (4.10)	0.005 (4.06)
National Flood Insurance Change*SFHA	-0.215 (-6.33)	-0.230 (-6.53)	-0.169 (-4.23)	-0.162 (-3.86)	-0.186 (-5.99)	-0.222 (-6.93)	-0.260 (-5.75)	-0.264 (-5.40)
Andrew*SFHA *time	– –	0.002 (2.10)	– –	-0.001 (-0.79)	– –	0.004 (5.65)	– –	0.002×10^{-1} (0.16)
Percent Uninhabitable* Andrew	– –	– –	– –	– –	-0.359 (-8.14)	-0.354 (-8.14)	– –	– –
Inverse Mills (Selection)	-1.011 (-26.40)	-1.013 (-26.51)	-0.774 (-16.84)	-0.772 (-16.77)	-1.145 (-33.43)	-1.149 (-33.75)	-0.763 (-8.87)	-0.763 (-8.86)
Intercept	0.499 (8.12)	0.501 (8.17)	0.775 (11.23)	0.773 (11.20)	0.708 (14.37)	0.713 (14.52)	0.962 (9.96)	0.962 (9.95)
Sample Size	7,938	7,938	5,118	5,118	9,929	9,929	5,212	5,212
R^2	0.176	0.176	0.150	0.151	0.200	0.202	0.052	0.052

[a] The numbers in parentheses refer to the ratio of the estimated parameter to the robust (Huber [1967]) estimate of the standard error. The estimated effect of the risk information for the "no time" model sums the coefficient for Andrew and Andrew*SFHA. For the "time" model it also includes Andrew*SFHA*time with time evaluated at the sample mean and treated as nonstochastic.

Table 5: Illustrative Estimates of Incremental Option Price for Avoiding Risk Increases for Coastal Hazards

Control of Storm Damage	Estimated Effect of Storm (%)	Sales Price (2002 $)	Incremental Option Price for Information[a]	Incremental Option Price for Risk[a]
Miami Herald / NOAA	-0.438	$217,762	$14,166	$179,449
Distance Based on Storm Path	-0.338	$235,299	$15,306	$193,901

[a]These estimates use a capital recovery factor, CRC, (or annuity storm factor) as follows:

$$CRC = \left(r \cdot (1+r)^n\right) / \left((1+r)^n - 1\right)$$

where r = discount rate (assumed to be 5%)
n = length of time (assumed to be 30 years)

Housing prices are converted to 2002 dollars using the housing component of the CPI.

References

Adler, Matthew D. (2003), "Fear Assessment: Cost-Benefit Analysis and the Pricing of Fear and Anxiety," AEI-Brookings Joint Center for Regulatory Studies, Working paper 03-12, (November).

AIR Worldwide Corporation (2002), "Ten Years after Andrew: What Should We Be Preparing for Now?" AIR Special Report, Technical Document_HASR_0208, (August).

Alston, Julian M., George W. Norton, and Philip G. Pardey (1995), *Science Under Scarcity*, (Ithaca: Cornell University Press).

Arrow, K., Solow, R., Portney, P., Leamer, R., Radner, R., and Schuman, H. (1993), "Natural Resource Damage Assessments under the Oil Pollution Act of 1990," *Federal Register* 58: 4601-4614.

Banzhaf, H. Spencer (2002), "Quality Adjustment for Spatially Delineated Public Goods: Theory and Application to Cost-of-Living Indices in Los Angeles," RFF Discussion Paper 02-10, (Washington, DC: Resources for the Future).

Beron, Kurt J., James C. Murdoch, Mark A. Thayer, and Wim P.M. Vijverberg (1997), "An Analysis of the Housing Market Before and After the 1989 Loma Prieta Earthquake," *Land Economics*, 73(1): 101-113.

Boyle, Kevin J. (2003), "Contingent Valuation in Practice," in *A Primer on Nonmarket Valuation*, edited by P. Champ, K. Boyle, and T. Brown, (Dordrecht: Kluwer Academic Publishers).

Bradford, David (1970), "Benefit-Cost Analysis and Demand Curves for Public Goods," *Kyklos*, 23 (December): 1145-1159.

Cameron, Trudy Ann (1992a), "Combining Contingent Valuation and Travel Cost Data for the Valuation of Nonmarket Goods," *Land Economics*, 68(3): 302-317.

Cameron, Trudy Ann (1992b), "Nonuser Resource Values," *American Journal of Agricultural Economics*, 74(5): 1133-1137.

Canada, Ben (2003), "State Homeland Security Grant Program: Hypothetical Distribution Patterns of a Risk-Based Formula," CRS Report for Congress, Order Code RL32101, (Library of Congress: Congressional Research Service).

Carbone, Jared C. (2003), "Strategy and Trade in International Climate Change Policy," Unpublished Ph.D. thesis, University of Colorado.

Carbone, Jared C., Daniel G. Hallstrom, and V. Kerry Smith (2004), "Can Natural Experiments Measure Behavioral Responses to Environmental Risks?" Unpublished Paper, CEnREP, North Carolina State University, (April 21).

Carbone, Jared C. and V. Kerry Smith (2004), "Average Substitution and Non-Market Effects in Second-Best Policies", Unpublished Paper, CEnREP, North Carolina State University, (July).

Champ, Patricia, Kevin J. Boyle, and Thomas C. Brown, editors (2003), *A Primer on Nonmarket Valuation*, (Boston: Kluwer Academic Publishers).

Chivers, James and Nicholas E. Flores (2002), "Market Failure in Information: The National Flood Insurance Program," *Land Economics*, 78(4): 515-521.

Cordes, Joseph J. and Anthony M.J. Yezer (1998), "In Harm's Way: Does Federal Spending on Beach Enhancement and Protection Induce Excessive Development in Coastal Areas?" *Land Economics*, 74(1): 128-145.

Cordes, Joseph J., Dean H. Gatzlaff, and Anthony M. Yezer (2001), "To the Water's Edge, and Beyond: Effects of Shore Protection Projects on Beach Development," *Journal of Real Estate Finance and Economics*, 22(2/3): 287-302.

Dale, Larry, James C. Murdoch, Mark G. Thayer, and Paul A. Waddell (1999), "Do Property Values Rebound from Environmental Stigmas? Evidence from Dallas," *Land Economics*, 75 (May): 311-326.

Diamond, Peter A. and Jerry A. Hausman (1994), "Contingent Valuation: Is Some Number Better Than No Number?" *Journal of Economic Properties*, 8 (Fall): 45-64.

Doherty, Neil A., Joan Lamm-Tennant, and Laura T. Starks (2003), "Insuring September 11th: Market Recovery and Transparency," *The Journal of Risk and Uncertainty*, 26(2/3): 179-199.

Ehrlich, Isaac and Gary Becker (1972), "Market insurance, Self-insurance and Self-protection," *Journal of Political Economy*, 80: 623-648.

Ekeland, Ivar, James J. Heckman, and Lars Nesheim (2002), "Identifying Hedonic Models," *American Economic Review*, Proceedings 92 (May): 304-309.

Ekeland, Ivar, James J. Heckman, and Lars Nesheim (2004), "Identification and Estimation of Hedonic Models," *Journal of Political Economy*, 112 (February): (Part 2) S60-S109.

Espinosa, J.A. and V. Kerry Smith (1995), "Measuring the Environmental Consequences of Trade Policy: A Nonmarket CGE Analysis," *American Journal of Agricultural Economics*, 77 (3): 772-777.

Espinosa, J.A., and V. Kerry Smith (2004), "Reconsidering Environmental Taxes with Non-Separable Damages," CEnREP Working paper, (July).

Fischhoff, Baruch, Roxana M. Gonzalez, Deborah A. Small, and Jennifer S. Lerner (2003), “Judged Terror Risk and Proximity to the World Trade Center,” *The Journal of Risk and Uncertainty*, 26(2/3): 137-151.

Fronstin, P. and Holtmann, A.G. (1994), "The Determinants of Residential Property Damage Caused by Hurricane Andrew," *Southern Economic Journal* 61(2): 387-97.

Fronstin, P. and Holtmann, A.G. (1994), "The Determinants of Residential Property Damage Caused by Hurricane Andrew," Southern Economic Journal, 61(2): 387-97.

Gayer, Ted, James T. Hamilton, and W. Kip Viscusi (2000), “Private Value of Risk Tradeoffs at Superfund Sites: Housing Market Evidence on Learning About Risk,” *The Review of Economics and Statistics*, 82(3): 439-451.

Gayer, Ted, James T. Hamilton, and W. Kip Viscusi (2002), “The Market Value of Reducing Cancer Risk: Hedonic Housing Prices With Changing Information,” *Southern Economic Journal*, 69 (October): 266-289.

Goldenberg, Stanley B., Christopher W. Landsea, Alberto M. Mestas-Nuñez, and William M. Gray (2001), “The Recent Increase in Atlantic Hurricane Activity: Causes and Implications,” *Science*, 293 (July): 475-479.

Goldenberg, Stanley B., Christopher W. Landsea, Alberto M. Mestas-Nuñez, and William M. Gray (2001), “The Recent Increase in Atlantic Hurricane Activity: Causes and Implications,” *Science*, 293 (July): 475-479.

Graham, Daniel A. (1981), “Cost-Benefit Analysis under Uncertainty,” *American Economic Review*, 71(4): 715-725.

Graham, Daniel A. (1992), “Public Expenditure under Uncertainty: The Net Benefit Criteria,” *American Economic Review*, 82 (September): 822-846.

Haab, Timothy C. and Kenneth E. McConnell (2002), *Valuing Environmental and Natural Resources: The Econometrics of Non-Market Valuation*, (Cheltenham, U. K.: Edward Elgar Publishing).

Hallstrom, Daniel G. and V. Kerry Smith (2004), “Market Responses to Hurricanes: Using Nature’s ‘Natural Experiments’ to Evaluate Risk Preferences,” Unpublished Paper, Department of Agricultural and Resource Economics, North Carolina State University, (March).

Hanemann, W. Michael (1978): *A Methodological and Empirical Study of the Recreation Benefits from Water Quality Improvement*, Ph.D. Dissertation, Harvard University (Economics).

Hartwig, Robert P. (2002), “Florida Case Study: Economic Impacts of Business Closures in Hurricane Prone Counties,” Working Paper, Insurance Information Institute, (June).

Heckman, J. (1979), "Sample Selection as a Specification Error," *Econometrica*, 47: 153-162.

Heckman, James J. and Salvador Navarro-Lozana (2004), “Using Matching Instrumental Variables and Control Functions to Estimate Economic Choice Models,” *Review of Economics and Statistics*, 86 (February): 30-57.

Hirshleifer, Jack (1953), “War Damage Insurance,” *The Review of Economics and Statistics*, 35(2): 144-153.

Hirshleifer, Jack (1983), “From Weakest-Link to Best-Shot: The Voluntary Provision of Public Goods,” *Public Choice*, 41: 371-386.

Huber, P.J. (1967), "The Behavior of Maximum Likelihood Estimates under Non-Standard Conditions," in *Proceedings of the Fifth Symposium on Mathematical Statistics and Probability*, (Berkeley, CA: University of California Press).

Insurance Information Institute (2004), Hot Topics and Insurance Issues. Available at www.iii.org/media/hottopics/insurance.

Johnson, F. Reed, V. Kerry Smith, Frank A. Sloan (2003), "Valuing Quality of Life Improvements at the End of Life for Smokers," Working paper, RTI International and CEnREP, NCSU, under revision.

Kanninen, Barbara (2002), "Optimal Design for Multinomial Choice Experiments," *Journal of Marketing Research*, 39 (March): 214-227.

Lakdawalla, Darius and Zanjani, George H. (2002), "Insurance, Self-Protection, and the Economics of Terrorism," NBER Working Paper No. W9215, (September).

Löfstedt, Ragnar (2004), "Risk Communication and Management in the 21st Century," Working paper, forthcoming in *International Public Management Journal*, (April).

Louviere, Jordan J., David A. Hensher, and Joffre D. Swait (2000), *Stated Choice Methods: Analysis and Applications*, (New York: Cambridge University Press).

Mansfield, Carol and V. Kerry Smith (2002), "Trade-off at the Trough: TMDLs and the Evolving Status of U. S. Water Quality Policy," in *Recent Advances in Environmental Economics*, edited by J. A. List and A. de Zeeuw (Cheltenham, U. K.: Edward Elgar Publishing).

Manski, Charles F. (1993),"Identification of Endogenous Social Effects: The Reflection Problem," *Review of Economic Studies*, 60 (July): 531-542.

McCluskey, Jill J. and Gordon C. Rausser (2001), "Estimation of Perceived Risk and Its Effect on Property Values," *Land Economics*, 77 (February): 42-55.

McCluskey, Jill J. and Gordon C. Rausser (2003), "Stigmatized Asset Values: Is it Temporary or Long Term?" *Review of Economics and Statistics*, 85 (May): 276-285.

McFadden, Daniel (1974), "Conditional Logit Analysis of Qualitative Choice Behavior," in Paul Zarembka, ed., *Frontiers in Econometrics* (New York: Academic Press).

Mendelsohn, Robert, Daniel Hellerstein, Michael Huguenin, Robert Unsworth, and Richard Brayee (1992), "Measuring Hazardous Waste Damages with Panel Models," *Journal of Environmental Economics and Management*, 22 (May): 259-271.

Meyer, Bruce D. (1995), "Natural and Quasi-Experiments in Economics," *Journal of Business and Economic Statistics*, 12 (April): 151-161.

Morey, Edward R. (1999), "TWO RUMS UNCLOAKED: A Nested Logit Model of Site Choice, and Nested Logit Models of Participation and Site Choice," in *Valuing Recreation and the Environment*, edited by Joseph A. Herriges and Catherine L. Kling, (Cheltenham, UK: Edward Elgar).

Mrozek, Janusz R. and Laura O. Taylor (2002), "What Determines the Value of Life? A Meta-Analysis," *Journal of Policy Analysis and Management*, 21(2): 253-270.

Navrud, Ståle (2004), "Value Transfer and Environmental Policy," in *International Yearbook of Environmental and Resource Economics*, edited by T. Tietenberg and H. Folmer (Cheltenham, U. K.: Edward Elgar Publishing).

Palmquist, Raymond (2002), "Weak Complementarity, Path Independence, and the Willig Condition," Working paper, Department of Economics, North Carolina State University, (January).

Palmquist, Raymond (2005), “Property Value Models,” in *Handbook of Environmental Economics*, edited by Karl G. Mäler and Jeffrey Vincent, (Amsterdam: North Holland, in press).

Phaneuf, Daniel (1999), “A Dual Approach to Modeling Corner Solutions in Recreation Demand,” *Journal of Environmental Economics and Management*, 37(1): 85-105.

Phaneuf, Daniel J. and V. Kerry Smith (forthcoming), "Recreation Demand Models," in *Handbook of Environmental Economics*, edited by K.G. Maler and J. Vincent, (Amsterdam: North-Holland).

Rappaport, Ed (1993), “Hurricane Andrew 16-28 August, 1992,” *Preliminary Report*, National Hurricane Center, (December).

Rosen, Sherwin (1974), “Hedonic Prices and Implicit Markets: Product Differentiation in Perfect Competition,” *Journal of Political Economy*, 82 (February): 34-55.

Sandler, Todd and Walter Enders (2004), “Transnational Terrorism: An Economic Analysis,” extension of “An Economics Perspective on Transnational Terrorism,” in *European Journal of Political Economy*, 20(2), 2004: (May 2004).

Smith, V. Kerry (1985), “Supply Uncertainty, Option Price, and Indirect Benefit Estimation,” *Land Economics*, 61 (August): 303-307.

Smith, V. Kerry (1991), “Household Production Functions and Environmental Benefit Estimation,” in *Measuring the Demand for Environmental Quality* edited by J. B. Braden and C. D. Kolstad (Amsterdam, North Holland).

Smith, V. Kerry (1997), “Pricing What is Priceless: A Status Report on Non-Market Valuation of Environmental Resources,” in *The International Yearbook of*

Environmental and Resource Economics 1997/1998, edited by Henk Folmer and Tom Tietenberg (Cheltenham, U.K.: Edward Elgar Publishing, Inc.).

Smith, V. Kerry (2004), "Fifty Years of Contingent Valuation," in *The International Yearbook of Environmental and Resource Economics 2004/2005*, edited by Tom Tietenberg and Henk Folmer (Cheltenham, U.K.: Edward Elgar Publishing, Inc.).

Smith, V. Kerry (2004), "Will Benefit-Cost Analysis Retain Its Place at the Policy Table?" in *Upjohn Institution's Benefit-Cost Symposium*, edited by Jon Neil (forthcoming).

Smith, V. Kerry, George Van Houtven, and Subhrendu K. Pattanayak (2002), "Benefit Transfer via Preference Calibration: 'Prudential Algebra' for Policy," *Land Economics*, 78 (1): 132-152.

Sunstein, Carl R. (2003), "Terrorism and Probability Neglect," *The Journal of Risk and Uncertainty*, 26(2/3): 121-136.

Tinbergen, J. (1956), "On the Theory of Income Distribution," *Weltwertshaftliches Archive*, 77: 489-505.

U.S. Environmental Protection Agency (1999), *The Benefits and Costs of the Clean Air Act 1990 to 2010*, Report to Congress, (November).

Viscusi, W. Kip and Richard J. Zeckhauser (2003), "Sacrificing Civil Liberties to Reduce Terrorism Risks," *The Journal of Risk and Uncertainty*, 26(2/3): 99-120.

Viscusi, W. Kip, Wesley A. Magat and Joel Huber (1987), "An Investigation of the Rationality of Consumer Valuations of Multiple Health Risks," *Rand Journal of Economics*, 18(4): 465-479.

Viscusi, W. Kip, Wesley A. Magat, and Joel Huber (1991), "Pricing Environmental Health Risks: Survey Assessments of Risk-Risk and Risk Dollar Tradeoffs," *Journal of Environmental Economics and Management*, 20(1): 32-57.

von Haefen, Roger, Daniel Phaneuf, and George Parsons (2004), "Estimation and Welfare Analysis With Large Demand Systems," *Journal of Business & Economic Statistics*, 22(2): 194-205.

Wakimoto, Roger M. and Peter G. Black (1994), "Damage Survey of Hurricane Andrew and Its Relationship to the Eyewall," *Bulletin of the American Meteorological Society*, 75 (February): 189-200.

Willig, R. D. (1978), "Incremental Consumer's Surplus and Hedonic Price Adjustment," *Journal of Economic Theory*, 17 (February): 227-253.

Woo, Gordon (2002), "Quantifying Insurance Terrorism Risk," Paper prepared for the National Bureau of Economic Research, Cambridge, MA, (February 1).

Zycher, Benjamin (2003), "A Preliminary Benefit/Cost Framework for Counterterrorism Public Expenditures," RAND Publication, (Santa Monica, CA: RAND).

Appendix A: Probit Selection Models for Housing Sales

Year Built Fixed Effect	Estimated Parameter	
	Lee County	Dade County
1983	-0.081	0.101
	(-0.73)	(0.87)
1984	-0.078	-0.010
	(-0.72)	(-0.09)
1985	-0.298	-0.078
	(-2.72)	(-0.70)
1986	-0.155	-0.055
	(-1.47)	(-0.50)
1987	-0.199	-0.186
	(-1.97)	(-1.73)
1988	-0.240	-0.179
	(-2.40)	(-1.68)
1989	-0.387	-0.303
	(-3.92)	(-2.91)
1990	-0.361	-0.236
	(-3.60)	(-2.27)
1991	-0.332	-0.290
	(-3.17)	(-2.71)
1992	-0.308	-0.450
	(-2.87)	(-4.01)
1993	-0.158	-0.864
	(-1.54)	(-8.26)
1994	0.165	-0.884
	(-1.68)	(-8.36)
1995	0.303	-0.916
	(-3.05)	(-8.42)
1996	0.388	-0.952
	(-3.83)	(-8.77)
1997	0.319	-1.237
	(-2.95)	(-10.78)
1998	0.079	-1.118
	(-0.72)	(-9.85)
1999	0.013	--
	(-0.08)	--
Intercept	-0.163	0.320
	(-1.90)	(3.36)
Number of Observations	8,320	10,534
Pseudo R^2	0.0300	0.0712