Vulnerability Analysis and Risk Management for Water-Related Hazards

PART II: “Socio-economic valuation of risk perception”

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4. Stated preferences methods

A. Contingent valuation

B. Choice experiment

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A. Contingent valuation

- Contingent valuation (CV) is a survey approach designed to create the missing market for public goods by determining either:
  - what people **would be willing to pay (WTP) for specified increases** in the quantity/quality of the good
  - what they would be **willing to accept (WTA) in compensation for specified degradations** in the provision of these goods
- CV circumvents the absence of markets for public goods by presenting consumers with a hypothetical choice situation in which **they can buy or sell the goods in question**

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History of Contingent Valuation (1/3)

- Bowen (1943) and Ciriacy-Wantrup (1947): first to propose the use of specially structured public opinion surveys to value public goods
- Davis (1963): first economist to **empirically implement a CV survey** in his Harvard dissertation entitled "The value of outdoor recreation: an economic study of the Maine woods
- Over the following years several other economists followed Davis's lead and used the CV approach to **value various recreational amenities**
- Hanemann (1974): CV on how much people were willing to pay for improved water quality at beaches in the Boston area. Comparison with findings from a travel cost with reasonable correspondence

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History of Contingent Valuation (2/3)

- 1989: Exxon Valdez oil spill. The state of Alaska's claim for damages was largely based upon a claim for the loss of non-use values, estimated via CV studies.
- The oil industry mounted an aggressive public relations campaign intended to convince policy makers that CV was too unreliable to be used for any purpose
- In the face of tremendous industry lobbying, tin 1993 the NOAA convened a Blue Ribbon Panel co-chaired by two Nobel Prize winners to consider whether passive use values should be included in natural resource damage assessment.
- The Panel concluded that **passive use values should be included in natural resource damage assessment** and that "CV studies can produce estimates reliable enough to be the starting point for a judicial determination of natural resource damages"

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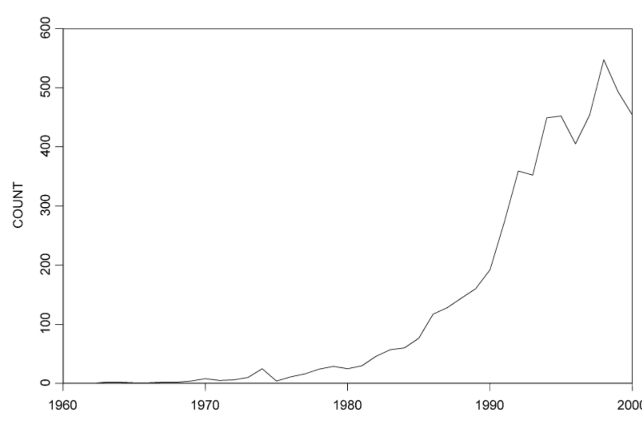
History of Contingent Valuation (3/3)

- The CV literature grew rapidly after the NOAA Panel Report
- The growth also reflected the increasing use of contingent valuation in other OECD countries as well as in developing countries
- It also reflected an ever-increasing variety of environmental amenities being valuated



(Source: Carson and Hanemann, 2005)

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Steps in a Contingent valuation study

1. Identify the change in quantity or quality to be valued
2. Identify whose values are to be estimated
3. Select data collection mode
4. Design the information component of the survey instrument
   - 4.1 Define item to be valued
   - 4.2 Explain the method of provision
   - 4.3 Select a payment vehicle
   - 4.4. Select a time frame of payment
5. Designing the contingent-valuation question
   - 5.1 Select response format
6. Data analysis and value estimation

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1. Identify the change in quantity or quality to be valued

- The first step in conducting a contingent-valuation study involves defining the value(s) to be estimated, which is based on the **difference between the baseline utility of the current** environmental condition and the **utility of the new environmental condition**
- The fundamental information transmitted in the survey is the description of the <u>change to be valued</u>
- For example, if a policy will protect groundwater from contamination, the survey will explain current conditions in the aquifer and what would happen to quality if the protection policy were (or not) implemented

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2. Identify whose values are to be estimated

- Once the change to be valued has been specified, the **affected population** needs to be identified. This information is important in **selecting a sample frame** so that the contingent-valuation survey will be administered to a **representative sample of affected individuals**

- It is necessary to know the size of the affected population to expand the per-unit values to a population value. The affected population and unit of measurement could indicate a desirable mode of data collection or modes of data collection that are acceptable for the particular application.

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3. Select data collection mode

- A CV study requires the collection of primary data.

- Survey modes: mail, telephone, personal interview, web-based, …

Survey Attributes	Mail Surveys	Telephone Surveys	Personal Interviews
Cost	Least Expensive	Moderate	Most Expensive
Geographical coverage	Very broad	Very broad	Unusually limited to a specific area
Respondent cooperation	Lower	Moderate	Higher
Ability to provide information in the survey	High	Low	Highest
Interviewer effects	None	Possible	Possible

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4. Design the Information Component of the Survey

- This step focuses on the information provided to respondents in the survey instrument.
- This includes **telling respondents what it is they are being asked to value**, how it will be provided, and how they will pay for it.
- Careful consideration must be given to these design features in the pretesting of the survey instrument. The design of the valuation scenario should be developed so that **respondents believe the change to be valued can be feasibly accomplished** and that the features selected do not unduly influence welfare estimates.
- The use of **focus groups and pilot surveys** is crucially important to understanding respondents' comprehension of the information presented and how they react to the information.

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4.1 Describe the Item to Be Valued

- The description of the item to be valued tells respondents what is being valued and presents the change in the quantity, quality, or probability to be valued. The information set should include a description of the item being valued, **baseline conditions**, and the **new conditions**.
- This does not require an extensive, detailed valuation scenario, but a **scenario that is clear** so that respondents understand the change they are being asked to value.
- The information is presented in written or verbal form and can be accompanied by graphs, pictures, and other visual stimuli to facilitate understanding. The information scenario is not a marketing or sales pitch but a **neutral and fair description of the change to be valued**.
- This information should also include an explanation of **why the change is being valued**.

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4.2 Select a Provision Mechanism

- In any contingent-valuation study, it is necessary to tell respondents how the change to be valued will be implemented
- Suppose a policy was protection of well water from contamination. One provision mechanism that has been used to provide such protection is to establish protection zones around wellheads, which preclude any activities that might contaminate the groundwater
- Without such information, respondents might not view the change as being credible or might implement a personal assumption that is not appropriate and could affect value estimates

4.3 Select a Payment Vehicle

- A payment vehicle is the mechanism by which respondents are told how payments would be made. For example, this might be a tax increase or a toll to be paid to collect funds to mitigate landslide risk in a road
- As realism increases the likelihood that the payment vehicle will results in inappropriate responses (e.g., protest values of $0) decreases.

Payment Vehicle Examples
Income taxes
General increase in prices and taxes
Admission fee
Recreation trip cost
Donations

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4.4 Select a Time Frame of Payment

- This step describes the number and frequency of payments respondents will make.
- For example, a valuation scenario might be posed where a new filtration system would be installed to remove contaminants from a public water supply. Values could be elicited as a one-time payment now or as annual payments over the lifetime of the system, say 20 years.
- The time frame of payment varies substantially across studies, from one-time payments to annual payments into perpetuity. The time frame is crucially important because this influences how value estimates are aggregated to compute benefits or costs. This is another design feature that must be carefully addressed in survey pretesting.

5. Design the Contingent-Valuation Question

- After the information regarding how the change to be valued will be provided, the respondents are asked to reveal information about the value they place on the change described in the valuation scenario.

5.1 Select a Response Format

- CV questions can be formulated in various ways. There are 5 response formats:
  1. open-ended questions
  2. dichotomous-choice questions
  3. iterative-bidding game
  4. payment-card

5.1 Select a Response Format

1) Open-ended question:

"If passage of the proposal would cost you some amount of money every year for the foreseeable future, what is the highest amount that you would pay annually and still vote for the program? (WRITE IN THE HIGHEST DOLLAR AMOUNT AT WHICH YOU WOULD STILL VOTE FOR THE PROGRAM)"

2) Dichotomous-choice question:

"Would you vote for this proposal if the proposal would cost you $_______ every year for the foreseeable future?"

Respondents can answer "yes" or "no". If yes, propose higher bid, if no lower. Total of two bids.

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5.1 Select a Response Format

3) Iterative bidding-game:

"Would you pay X$" for the specified policy?

If respondents answer "yes" to the starting bid, then the bid is increased until they say "no," and decreased until they answer "yes" if the initial response was "no".

4) Payment-card:

"If the passage of the proposal would cost you these amounts every year for the foreseeable future, what is the highest amount you would pay and still vote for the program? (CIRCLE THE HIGHEST AMOUNT THAT YOU WOULD STILL VOTE FOR THE PROGRAM)"

10¢	50¢	$1	$5	$10	$20
$30	$40	$50	$75	$100	$150
$200	MORE THAN $200				

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6. Data Analysis and WTP estimates

- Responses to **open-ended** questions are analyzed with means:

$$\overline{\mathrm{WTP}} = \sum_{i=1}^{N} \frac{\mathrm{WTP}_i}{N}$$

WTP_i is the open-ended response for the i^{th} respondent and N is the number of observations.

- **Payment-card** and **dichotomous-choice data** require econometric analysis (binary logistic regressions) to derive estimates of WTP values:

$$P(Y) = \beta_{bid} bid + \beta_z Z$$

- Where $P(Y)$ is the probability of answering "yes" to the payment question, ***bid*** is the bid amount and ***Z*** is a vector of variables that may affect the magnitude of individual's WTP.
- The aim of the model is to estimate the β coefficients.

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6. Data Analysis and WTP estimates

- The average value for one individual is computed as:

$$V_{\hat{t}} = 1/-\hat{\beta}_{bid}$$

- Example (Chen et al., 2021, value of forest provisioning services in Taiwan):

Coefficients of logistic regression

Aspects of Ecosystem Services	Provision		
Variable	Coefficient		Prob.
C	−2.3566	**	0.0013
BID	−0.000372	***	0.0004
$AGREE_{EE}$	0.4985	***	0.0009
GENDER	−0.3321		0.1157
$OCCU_{D_{PUBLIC}}$	−1.1301	**	0.0017
$STAY_{HR}$	0.1631		0.0802
$AGE_{D60} \times INC_{D30}$	−1.0980	**	0.0025
INC_{10T}	0.0089	*	0.0109
DON_D	0.8491	**	0.0010

WTP computation

= 1/-(-0.000372) =

Provision
2688.17

Case study 1:
The Perceived Value of Improving Hurricane Forecast Accuracy
(Molina et al., 2021)

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Motivation

- Landfalling hurricanes in the continental United States are both common and devastating.
- Between 1900 and 2017, 197 hurricanes have resulted in about $18 trillion in economic losses (Weinkle et al. 2018). Some cost more than $100 billion per landfall, such as Hurricanes Andrew and Katrina.
- In an effort to reduce these impacts, the Hurricane Forecast Improvement Project (HFIP) was established in 2008 with the explicit goal of reducing track and wind speed forecast error over the following 10 years (Gall et al. 2013). By any measure, the project was a success. Storm track and wind speed forecast errors have been cut by more than 40% each, and the project is still in place striving to produce even better forecasts.
- But are these further improvements still valuable? Would the public benefit from an even more accurate hurricane forecasts?

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The case study

- The aim of the study is to evaluate how the public values further improvement of the forecast product.
- To do so, it constructs hypothetical scenarios using the historical forecast errors from the National Hurricane Center (NHC).
- Taking the error reduction trend from 2008 to 2018, it project hypothetical improvement scenarios for the next decade (2018–28). Three potential scenarios for the 2018–28 period:
  1. status quo, which assumes the rate of forecast improvement observed in 2008–18 will continue for another 10 years
  2. 20% acceleration with respect to the status quo
  3. 20% deceleration with respect to the status quo
- These projections for the error are valuated for three attributes of a typical forecast: storm track, wind speed, and precipitation

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The case study

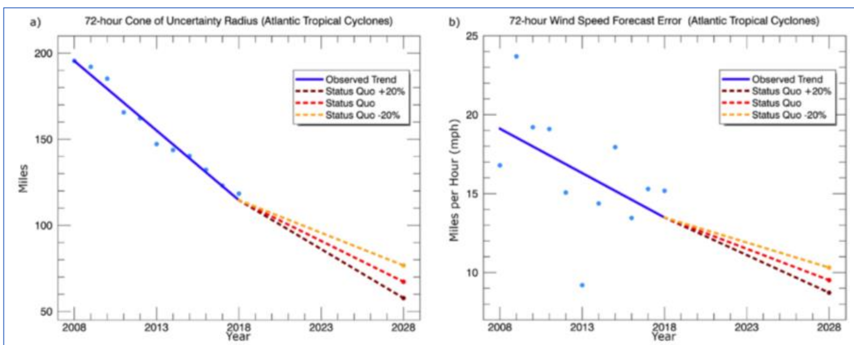

Fig. 1. Historical and hypothetical hurricane forecast errors. The figure shows the projections assumed for the construction of the hypothetical scenarios in the survey. (a) The trend in the size of the cone of uncertainty for 72-h track forecasts; (b) the trend in errors for wind speed. The same average percentage of improvement from 2008 to 2018 is extrapolated to 2028 using the same rate of improvement (Status Quo, red dashed line), a 20% increase in that rate (Status Quo + 20%, maroon dashed line), and a 20% decrease in that rate (Status Quo – 20%, orange dashed line).

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Data collection

- To elicit the value of improved hurricane forecasts a web-based survey questionnaire was implemented.
- The sample (N = 4,650) included individuals recently affected by one of two hurricanes, Michael and Florence, so participants could compare the forecast products familiar to them with those derived from an improved forecast's capability.
- In particular, the authors identified coastal counties that were under at least a tropical storm warning in the NHC advisories for Florence and Michael. To identify inland affected counties, the authors referred to the Federal Emergency Management Agency (FEMA) designations of counties eligible for assistance. Those designations include areas in Florida, Georgia, and North and South Carolina.

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Support material for the hypothetical scenarios

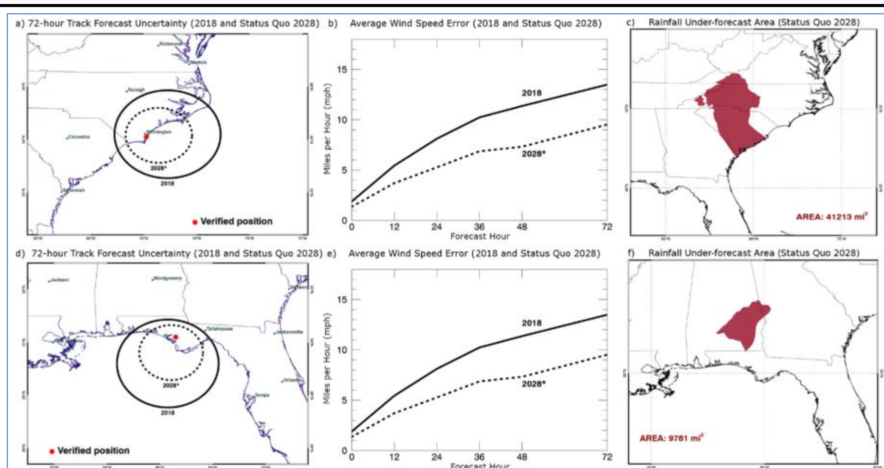

Fig. 3. Hypothetical forecast components. The figure shows the maps and charts shown to survey participants in (top) the Florence survey and (bottom) the Michael survey. Each of the three columns contains figures representing forecast improvements corresponding to the status quo improvement. (a),(d) The track uncertainty defined by the size of the cone for 72-h forecasts. (b),(e) The average wind speed error, and are the same because average wind speed forecast error is the same regardless of location. (c),(f) The rainfall underforecast area.

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Data collection framework

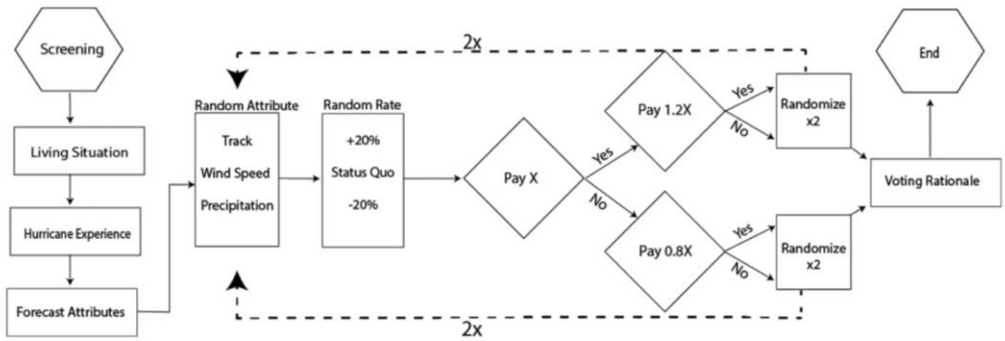

Fig. 2. Survey flowchart. The figure describes the structure of the survey. The rectangular sections represent questions pertaining to participant background. The middle of the diagram displays our dichotomous choice design. A random attribute is matched with a random improvement rate. Each attribute and each rate are only used once. The participants must vote in favor or against an annual tax between $1 and $50. The tax is then adjusted based on the previous answer, and the respondents are presented with another yes/no vote. This preocess is repeated two times. Both hexagons represent the beginning and end of the survey.

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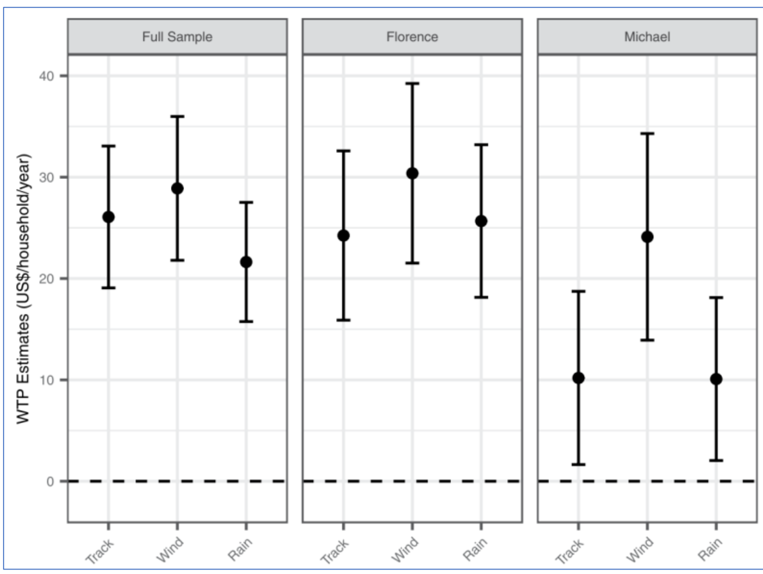
Results: WTP estimates



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Results: WTP projections

	Sampled	>50 mph	>40 mph	>30 mph	>20 mph
Total WTP (USD × 10^6 yr^{-1})					
Storm track	\$60 ± 16	\$376 ± 98	\$566 ± 149	\$946 ± 248	\$1,443 ± 378
Wind speed	\$67 ± 17	\$428 ± 101	\$645 ± 152	\$1,078 ± 254	\$1,637 ± 386
Precipitation	\$50 ± 14	\$327 ± 89	\$493 ± 135	\$824 ± 225	\$1,253 ± 342
Per capita WTP (USD per year per person)					
Storm track	\$12.56 ± 3.37	\$11.31 ± 2.07	\$11.47 ± 3.01	\$11.57 ± 3.04	\$11.72 ± 3.07
Wind speed	\$13.92 ± 3.42	\$12.89 ± 3.04	\$13.07 ± 3.09	\$13.18 ± 3.10	\$13.30 ± 3.13
Precipitation	\$ 10.42 ± 2.83	\$9.85 ± 2.69	\$9.99 ± 2.73	\$10.07 ± 2.75	\$10.17 ± 2.78
PV (USD per person)					
Storm track	\$115.08 ± 30.89	\$103.62 ± 27.22	\$105.09 ± 27.61	\$106.01 ± 27.84	\$107.38 ± 28.08
Wind speed	\$127.54 ± 31.32	\$118.10 ± 27.81	\$119.75 ± 28.30	\$120.76 ± 28.44	\$121.86 ± 28.70
Precipitation	\$95.47 ± 25.96	\$90.25 ± 24.68	\$91.53 ± 25.03	\$92.26 ± 25.23	\$93.18 ± 25.46

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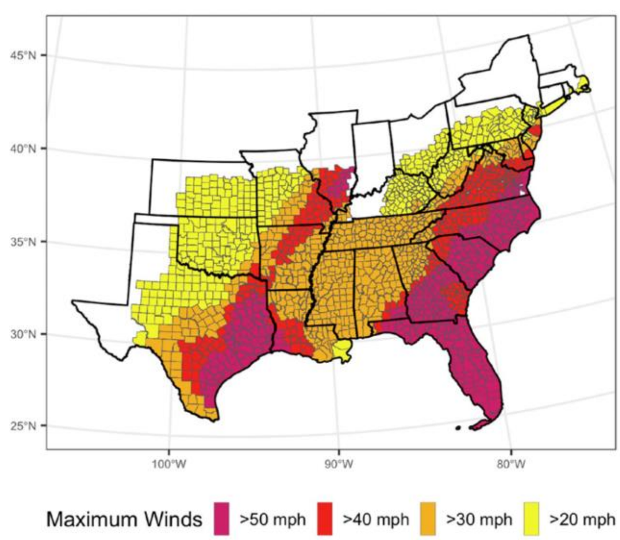
Past hurricane exposure. The map displays the maximum wind speed experienced, due to hurricanes, in the United States between 2006 and 2018. Wind speed is in miles per hour (mph) and the unit of observation is a county



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Implications

- To better interpret the practical significance of these results, it is useful to contrast them with the current tax load devoted to fund meteorological products. Using 2018 as a baseline, the federal weather enterprise report estimates the total meteorological funding to be $5.3 billion, which is about 0.081% of the $6.6 trillion total federal obligations in fiscal year (FY) 2018 (OFCM 2020).
- Given that the median income household ($63,179) paid about $4,320 in taxes for FY 2018, about $3.49 of that amount can be attributed to meteorological services and research. Out of this total, however, only a fraction is specifically allocated toward hurricane forecasting.
- Therefore, and when compared to this fiscal allocation, the results highlight that (i) hurricane forecast is perceived to be valuable, (ii) the perceived value greatly exceeds the operational cost of running the current programs, and (iii) further improvements are also valuable and present the regulator with a potentially sizable upside when it comes to funding research efforts

Case study 2:

Floodplain Inundation Analysis Combined with Contingent Valuation: Implications for Sustainable Flood Risk Management (Ghanbarpour et al., 2014)

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Motivation

- There is increasing attention in promoting sustainable floodplain management. Flood risks and economic damages are rising in many parts of the world due to increasing populations, urban development, deforestation, and climate change variability.
- Comprehensive planning for flood risk management is a necessity, as flood disasters produce socioeconomic and environmental consequences within the affected floodplain. Community involvement in the early stages of the planning process enables policy makers to facilitate sustainable flood risk management.
- In fact, effective flood risk mitigation needs collaboration between government, residents, and private sectors.

Motivation

- Flood hazard mitigation plans could be implemented as either structural or nonstructural measures, depending on the physical and socioeconomic settings of the floodplain.
- Structural measures such as levees, high flow diversion, and channel modification could be implemented to mitigate flood risk by reducing the water level or extent of the area of flooding.
- However, nonstructural methods such as flood insurance, land use regulation, and flood forecasting serve as flood hazard preventive measures. These measures do not involve physical construction, but their main function is to minimize vulnerability in the floodplain.
- Flood insurance program, for instance, could discourage residents from living in flood prone areas by increasing the rate of premiums. Flood insurance redistributes the cost of flood damage across the population and through time.

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Motivation

- The occurrence of the 1999 flood event in the Neka River Basin in Northern Iran has raised serious concerns about future flood hazards and the uncertain consequences of developments in the Neka floodplain. Furthermore, intensive urban development and deforestation increase flood vulnerability in the area.
- Funds for flood control projects are mainly provided from a limited government budget in the area. The other possible sources of support could be received from residents, or other involved stakeholders in the river basin. While governmental budget allocation may be limited, funds raised from other stakeholders may contribute substantially to the implementation of sustainable flood control measures.
- The Neka River Basin is being managed mostly on government funding and a top-down decision-making process in which professionals in the government develop flood control plans. In fact, there is no record of effective community-based flood control efforts in the Neka floodplain.

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Study area

- The Neka River is a major source of fresh water for drinking, agriculture, and industries in the region. The Neka River Floodplain is a densely populated area and subject to frequent flooding.
- Neka City had an estimated resident population of 46,152 at the 2006 census.
- According to previous studies, intense flash floods have occurred in this river, and the occurrence of floods has been accelerated by the conversion of rice paddies into residential areas, urbanization, and intense deforestation.
- The most intense flash flood ever recorded occurred in August 1999 with a peak flow of more than 1,300 m^3/s.

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Data collection

- A random survey of local residents (N = 91) at the Neka River Floodplain was conducted in summer 2009 using face-to-face interviews
- The first section of the survey provided an introduction to the current situation of flood hazard in the floodplain.
- In the second section, each respondent answered some questions about their demographic and socio-economic characteristics and past experience with flood events
- The third part included the CVM questions, aimed at investigating willingness to participate in the management and funding of proposed flood mitigation measures in the area.

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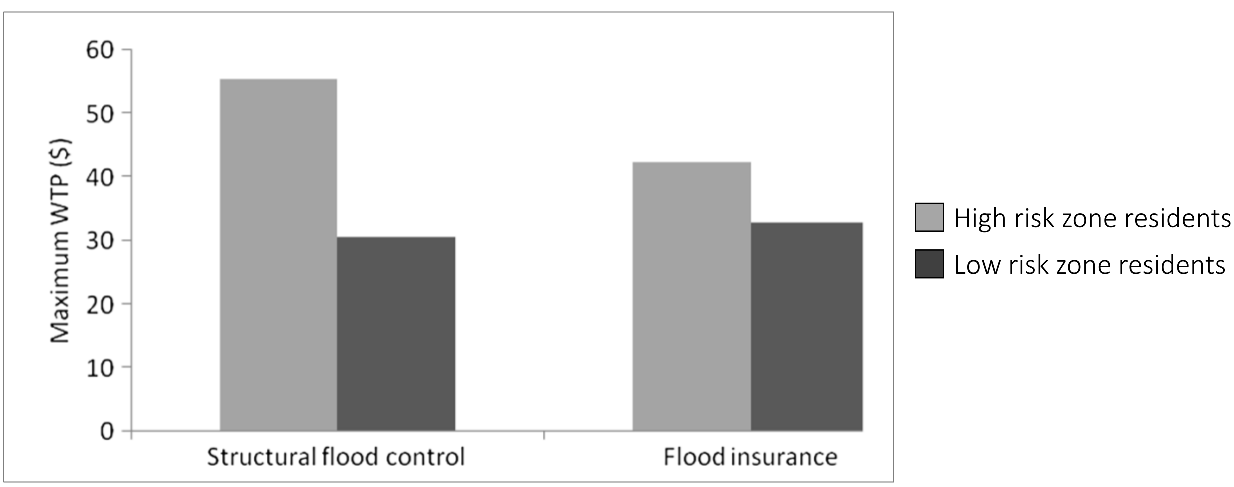
Results: WTP estimates



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Results: drivers of WTP

Variables	
Marital status	.319*
Family no.	−.340*
Types of land use	.242
Properties' ownership	−.319*
Properties' area	−.325*
Monthly income	.027
Distance to river	−.309*

** and * indicate significance levels at 1 % and 5 %, respectively

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Implications

- Floodplain development plans should be based on consideration of the natural features of the river basin (e.g., flood risk depth and frequency, river geomorphology) and the viewpoints of the residents, their willingness to participate, and their acceptance of mitigation plans.
- CVM and its associated insights could be used as important planning tools for use in sustainable flood risk management and policy-making. Estimated WTPs could be used as a basis for initiating participatory flood management strategies.
- Two different flood risk management options were discussed in this research with respect to the result of CVM combined with flood inundation analysis.
- It has shown that although the combination of these two options might provide more sustainable results, the construction of a levee as a structural flood control measure seems more practical and effective than the other option (insurance), given the higher rate of residents' WTPs. In fact, it is more physically effective to prevent future flood damage to residential areas.

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