Do numerical probabilities promote informed stated preference responses under inherent uncertainty?

Insight from a coastal adaptation choice experiment

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Stated preference methods

- Provide estimates of economic value of non-market goods (e.g., clean air)
- Help determine the value of a good to society
  - Estimates of benefits for benefit-cost analyses
  - The value of losses from environmental damages (e.g., loss of recreation opportunities after oil spill)
  - ...
- Wide range of applications: transportation, health, environment, culture, etc.
- Value estimates derived from preferences stated in surveys
  - Typically large survey studies on representative samples of respondents
  - Preferences are often elicited through discrete choice experiments

Stated preference choice experiments

Choice options: Policy scenarios

Attributes

Methods and Effects of Protection	Result in 2020s with NO NEW ACTION	Result in 2020s with PROTECTION OPTION A	Result in 2020s with PROTECTION OPTION B
Wetlands Lost	**12%** 60 of 497 wetland acres expected to be lost	**7 %** 25 of 497 wetland acres expected to be lost	**5%** 25 of 497 wetland acres expected to be lost
Beaches and Dunes Lost	**10%** 3 of 30 beach acres expected to be lost	**5%** 2 of 30 beach acres expected to be lost	**7 %** 5 of 30 beach acres expected to be lost
$ Cost to your Household per Year	**$0** Increase in annual taxes or fees	**$35** Increase in annual taxes or fees	**$65** Increase in annual taxes or fees
HOW WOULD YOU VOTE? (CHOOSE ONLY ONE) I vote for	☐ I vote for NO NEW ACTION	☐ I vote for PROTECTION OPTION A	☐ I vote for PROTECTION OPTION B

Stated preference choice experiments

Choice options: Policy scenarios

Methods and Effects of Protection	Result in 2020s with NO NEW ACTION	Result in 2020s with PROTECTION OPTION A	Result in 2020s with PROTECTION OPTION B
	12% 60 of 497 wetland acres expected to be lost	7 % 25 of 497 wetland acres expected to be lost	5% 25 of 497 wetland acres expected to be lost
(CHOOSE ONLY ONE) I vote for	I vote for NO NEW ACTION	I vote for PROTECTION OPTION A	I vote for PROTECTION OPTION B

Outcome uncertainty – Will the effects described in scenarios indeed occur?

(1) Uncertainty in scientific models and predictions

(2) Uncertainty in the effectiveness of policy interventions

(3) Inherent uncertainty in ecological systems

Inherent outcome uncertainty (tied to ecological systems)

- Uncertainty that is invariant across policy scenarios
- Example: The effect of installing new coastal flood defenses depends on a probability of severe storms that is fixed in the study area
- Very little attention in the stated preference literature
- Most surveys provide no formal communication of inherent uncertainty
- Often (unstated) assumptions that scenario outcomes are certain, that presented attribute levels reflect expected values, etc.
- These assumptions can have important implications for the interpretation and validity of value estimates
- To our knowledge, there have been no tests of **inherent** uncertainty communication formats for stated preference studies

Our research question:

Do numerical probabilities help respondents make more informed choices in stated preference surveys under inherent uncertainty?

Data – discrete choice experiment

- Policy scenario: coastal flood adaptation to protect homes and natural systems such as beaches and wetlands from flooding and erosion
- In Old Saybrook, Connecticut, USA
- The survey distributed via mail
- May – July 2014
- 282 complete surveys returned

PROTECTION OPTION A and **PROTECTION OPTION B** are possible protection options for Old Saybrook. **NO NEW ACTION** shows what is expected to occur with no additional protection.

Methods and Effects of Protection	Result in 2020s with NO NEW ACTION No Change in Existing Defenses	Result in 2020s with PROTECTION OPTION A More Emphasis on HARD Defenses	Result in 2020s with PROTECTION OPTION B More Emphasis on HARD Defenses
Homes Flooded in Category 2 Storm	**28%** 1,411 of 5,034 homes expected to flood in a Category 2 storm	**20%** 1,007 of 5,034 homes expected to flood in a Category 2 storm	**20%** 1,007 of 5,034 homes expected to flood in a Category 2 storm
Homes Flooded Only in Category 3+ Storm	**23%** 1,174 of 5,034 homes expected to flood only in a Category 3+ storm	**27%** 1,359 of 5,034 homes expected to flood only in a Category 3+ storm	**19%** 956 of 5,034 homes expected to flood only in a Category 3+ storm
Wetlands Lost	**5%** 25 of 497 wetland acres expected to be lost	**2%** 10 of 497 wetland acres expected to be lost	**2%** 10 of 497 wetland acres expected to be lost
Beaches and Dunes Lost	**10%** 3 of 30 beach acres expected to be lost	**16%** 5 of 30 beach acres expected to be lost	**10%** 3 of 30 beach acres expected to be lost
Seawalls and Coastal Armoring	**24%** 12 of 50 miles of coast armored	**24%** 12 of 50 miles of coast armored	**35%** 18 of 50 miles of coast armored
$ Cost to Your Household per Year	**$0** Increase in annual taxes or fees	**$35** Increase in annual taxes or fees	**$155** Increase in annual taxes or fees
HOW WOULD YOU VOTE? (CHOOSE ONLY ONE) I vote for	☐ I vote for NO NEW ACTION	☐ I vote for PROTECTION OPTION A	☐ I vote for PROTECTION OPTION B

- Three choice tasks per respondent
- We focus on the inherent uncertainty related to the protection of homes vulnerable to flooding during storms of different intensities (the Saffir-Simpson Hurricane Wind Scale)
- These storms have some inherent probabilities of occurrence
- The storm probabilities do not vary across the protection scenarios (not included as an attribute)
- The effect of flood adaptation measures depends on the inherent storm probabilities

Two survey versions

- Storm probabilities may be characterized by:
  - historical frequencies (common in media)
  - numerical percentage probabilities (common in stated preference surveys)
- Two versions of the survey that differ only in the uncertainty communication
- **(1) Without numerical probabilities**
  - describes only historical frequencies of Category 2 and 3 storms (and asks about respondents' subjective assessments of the probabilities)
- **(2) With numerical probabilities**
  - provides identical information on historical frequencies but also translates these frequencies into numerical percentage probabilities

Two survey versions

Over the last 75 years, Old Saybrook has been struck by **Category 2 storms in 1960, 1985 and 1991**, and by **Category 3 storms in 1938 and 1954**. There have been no Category 4 or 5 storms. Although hurricane Sandy was a Category 2 storm off the New Jersey coast, it weakened to below hurricane intensity before it reached Connecticut.

Without numerical probabilities

Based on past storm events, scientists estimate that there is approximately a **55% (or about one in two) chance that a Category 2 storm will strike Old Saybrook at least once by the mid 2020s** (0% would mean there is no chance and 100% would mean it is absolutely certain).

In contrast, scientists estimate that there is approximately a **20% (or one in five) chance that a Category 3 or higher storm will strike Old Saybrook at least once by the mid-2020s** (0% would mean there is no chance and 100% would mean it is absolutely certain).

With numerical probabilities

Econometric approach

- Each model is pooled—estimated on samples from the two survey versions
- In willingness-to-pay (WTP) space: Parameters represent willingness-to-pay values in dollars per year
- **Random parameters logit** – heterogeneous preferences described by continuous distributions of WTP parameters (all normal, except for the log-normal cost)

$$U_{ph}(\cdot) = \lambda_h(\boldsymbol{\omega}'_h \boldsymbol{X}_{ph} - C_{ph}) + \varepsilon_{ph}$$

  - An additional variable to capture systematic variation in preferences associated with the survey version (Num_h = 1 for numerical probabilities); $\boldsymbol{\omega}_h = \boldsymbol{\omega}_h^* + \boldsymbol{\rho} Num_h$
- **Latent class** – heterogeneous preferences described by discrete distributions
  - Three classes
  - Variable Num_h used to explain class membership probabilities

Random parameters logit

in willingness-to-pay (WTP) space

Choice attributes	Mean WTP estimates	Standard deviations	Means interacted with "numerical probabilities"
Status quo	-4.83*** (1.24)	10.34*** (3.01)	0.04 (0.48)
Homes 2	-1.38** (0.63)	4.18*** (1.18)	0.35 (0.68)
Homes 3	-1.23* (0.64)	4.47*** (1.23)	-0.44 (0.73)
Wetlands	-1.32* (0.74)	3.64*** (0.99)	-0.17 (0.88)
Beaches	-0.24 (0.42)	3.07*** (0.83)	-0.95 (0.61)
Seawalls	-0.59 (0.38)	1.17*** (0.33)	0.50 (0.39)
Hard	-1.47** (0.66)	2.16*** (0.59)	0.66 (0.61)
Soft	-0.56 (0.52)	3.00*** (0.87)	0.47 (0.56)
– Cost	0.46 (0.53)	1.99*** (0.43)	0.33 (0.47)

LL at convergence	-678.50
LL at constant(s) only	-883.88
AIC/n	1.8422
BIC/n	2.2094
Number of observations	805
Number of Sobol draws	6,000

- Mean WTP estimates with expected signs
- Substantial preference heterogeneity and not strongly significant means for parameters
- No effect of presenting numerical probabilities
- Can a latent class model better capture this heterogeneity?

Latent class model

in willingness-to-pay (WTP) space

Attributes	**Class 1**	**Class 2**	**Class 3**
Status quo	0.44** (0.22)	-2.76*** (0.44)	1.55 (1.16)
Homes 2	1.38*** (0.35)	-0.50*** (0.17)	-0.34 (0.50)
Homes 3	0.75* (0.40)	-0.57*** (0.19)	-0.42 (0.67)
Wetlands	0.14 (0.43)	-0.60** (0.27)	-0.83 (0.68)
Beaches	1.07*** (0.31)	-0.28** (0.14)	-0.02 (0.38)
Seawalls	0.51*** (0.16)	-0.28* (0.16)	0.14 (0.28)
Hard	-0.51*** (0.09)	-0.54** (0.24)	-0.23 (0.71)
Soft	0.43*** (0.09)	-0.19 (0.19)	0.63 (0.58)
– Cost	-31.54 (51.54)	1.07*** (0.21)	1.51* (0.81)

LL at convergence	-681.09
LL at constant(s) only	-883.88
AIC/n	1.7692
BIC/n	1.9498
Number of observations	805

	Class 1	**Class 2**	**Class 3**
Class membership probability function			
Constant	-1.44*** (0.43)	0.68*** (0.19)	---
"Numerical probabilities"	1.03** (0.52)	-0.14 (0.29)	---
Average class probabilities			
	13%	57%	30%

- Standard neoclassical tradeoffs, in line with expectations
- "Numerical probabilities" do not influence the probability of being in this class

Latent class model

in willingness-to-pay (WTP) space

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- Pay attention only to cost
- A common pattern that some do not care about climate change adaptation measures and their environmental effects

Latent class model

in willingness-to-pay (WTP) space

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- Signs for many parameters are opposite to expectations;
  Highly random choices
- Choices inconsistent with standard neoclassical assumptions; These could be people who were confused, rejected scenarios, protested, etc.
- "Numerical probabilities" increase the probability of being in this class

Conclusions

Do numerical probabilities promote informed stated preference responses under inherent uncertainty?

- Not necessarily
- The use of numerical probabilities to communicate inherent uncertainty leads to more "randomness" in stated preferences
- This may suggest increased symptoms of scenario rejection, protest responses, confusion, among others
- Our findings contradict a common (perhaps naïve) expectation that the use of numerical probabilities necessarily enhances the validity of stated preferences
- Numerical probabilities may not always be an effective way to communicate inherent uncertainty in environmental stated preference questionnaires

THANK YOU!

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