Natural Disasters and Willingness to Pay for Reliable Electricity†

Pablo M. Pinto
Professor of Public Policy
Director of the Center for Public Policy

Hobby School of Public Affairs
UNIVERSITY OF HOUSTON

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† Based on joint research with UH Energy and CPP research team: Gail Buttorff, Annie Hsu, Yewande Olapade, Maria Paula Perez Arguelles, Pablo M. Pinto, Savannah Sipole, Agustin Vallejo and Sunny Wong

The problem of climate change

"The 12 hottest years on record have all come in the last 15 years. One third of people living in America experienced 10 days or more of 100-degree heat. The number of cases has doubled in the last 30 years. Increasing floods, heats waves, and droughts have put farmers out of business, which is raising food prices; there were 11 climate disasters events resulting in $110 billions estimated damages"

Barack Obama, June of 2013

- Carbon emissions, generated by factories, electricity production, passenger vehicles, heating, etc. contribute to climate change
  - Each consumer of fossil fuels bears a tiny fraction of the cost of personal emissions, but at the aggregate level everyone loses
  - Individuals have incentives to continue emitting, and disincentives to spend more in switching to sustainable energy sources
  - Decentralized solutions unlikely to address the problem

What is the energy transition?

- “A pathway toward transformation of the global energy sector from fossil-based to zero-carbon by the second half of this century...” (IRENA 2018)
- The energy transition will require changes in:
  - Technology
  - Markets
  - Actors’ behaviors and preferences
  - Regulations and policies
- Ultimately the effectiveness and sustainability of the adoption of new technological processes will depend on costs and policies

“Policy is the main difference between the current and past energy transitions” (Blazquez et al. 2020, p. 2)

Winter Storm Uri and the Texas Electric Grid

- Challenges in transitioning to a sustainable energy future are reflected in the problems facing the Texas electricity grid
- Addressing problems with the Texas electricity system, including reliable supply of electricity, requires massive investments and regulatory changes

Winter Storm Uri as a case study

- Winter Storm Uri hit Texas February 2021
  - Texas experienced unprecedented collapse of its electrical generation and distribution system
  - Over 10 million Texans lost power; many went without power for days resulting in losses of life and large economic costs
  - The storm exposed persistent vulnerabilities in Texas' electricity system

Willingness to Pay for Reliable Electricity

- The Hobby School and UH Energy fielded a survey soon after Winter Storm Uri, to study the following questions:
  - Do natural disasters affect individuals' support for renewable sources of electricity production?
  - Did the experience with Winter Storm Uri–the length of the power outage experienced– affect individuals' willingness to pay for policy interventions aimed at make the electricity system more reliable?
- Using a conjoint survey experiment assess support and willingness to pay for the proposed policy interventions to improve the Texas grid under consideration in the Legislature
- Leverage a natural experiment immediately after a natural disaster: the as if random assignment of outage lengths

Winter Storm Uri and the Texas Electric Grid

menu

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69 deaths, 44 hours of freezing, $18 billion in damage: This week's winter storm, by the numbers

By Alex Meier

Sunday, February 21, 2021

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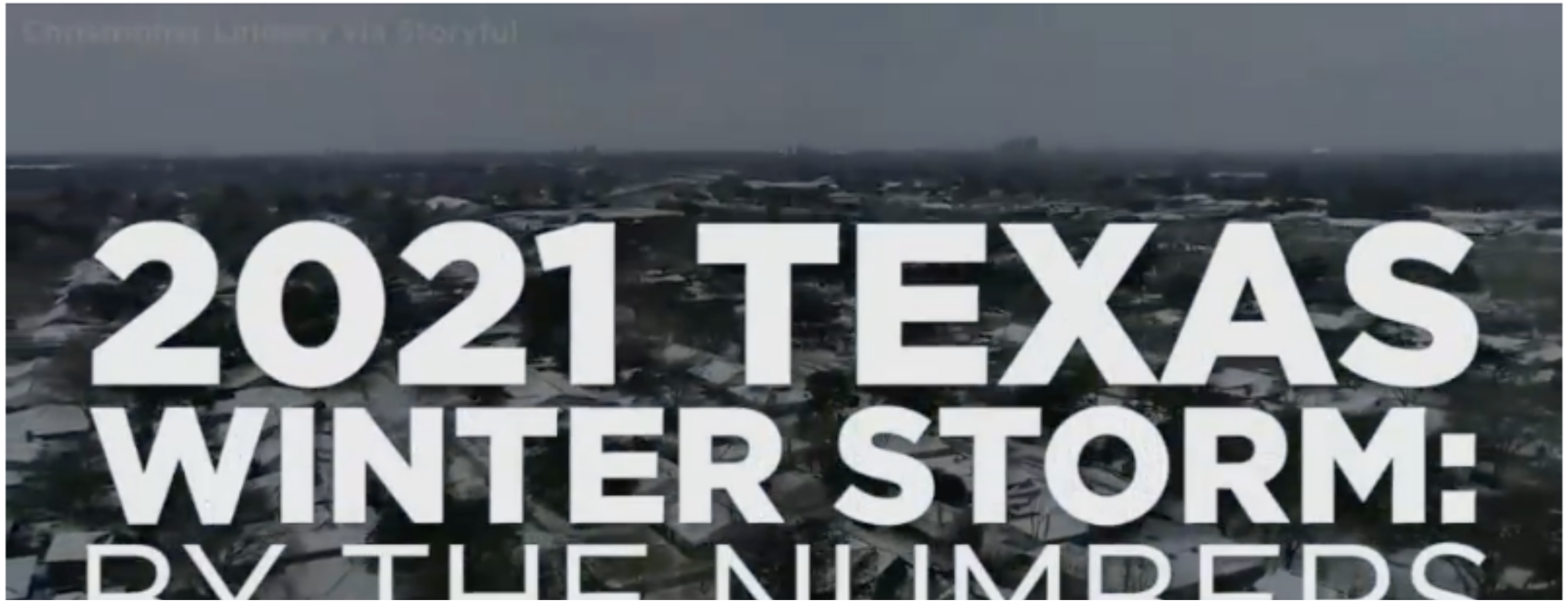
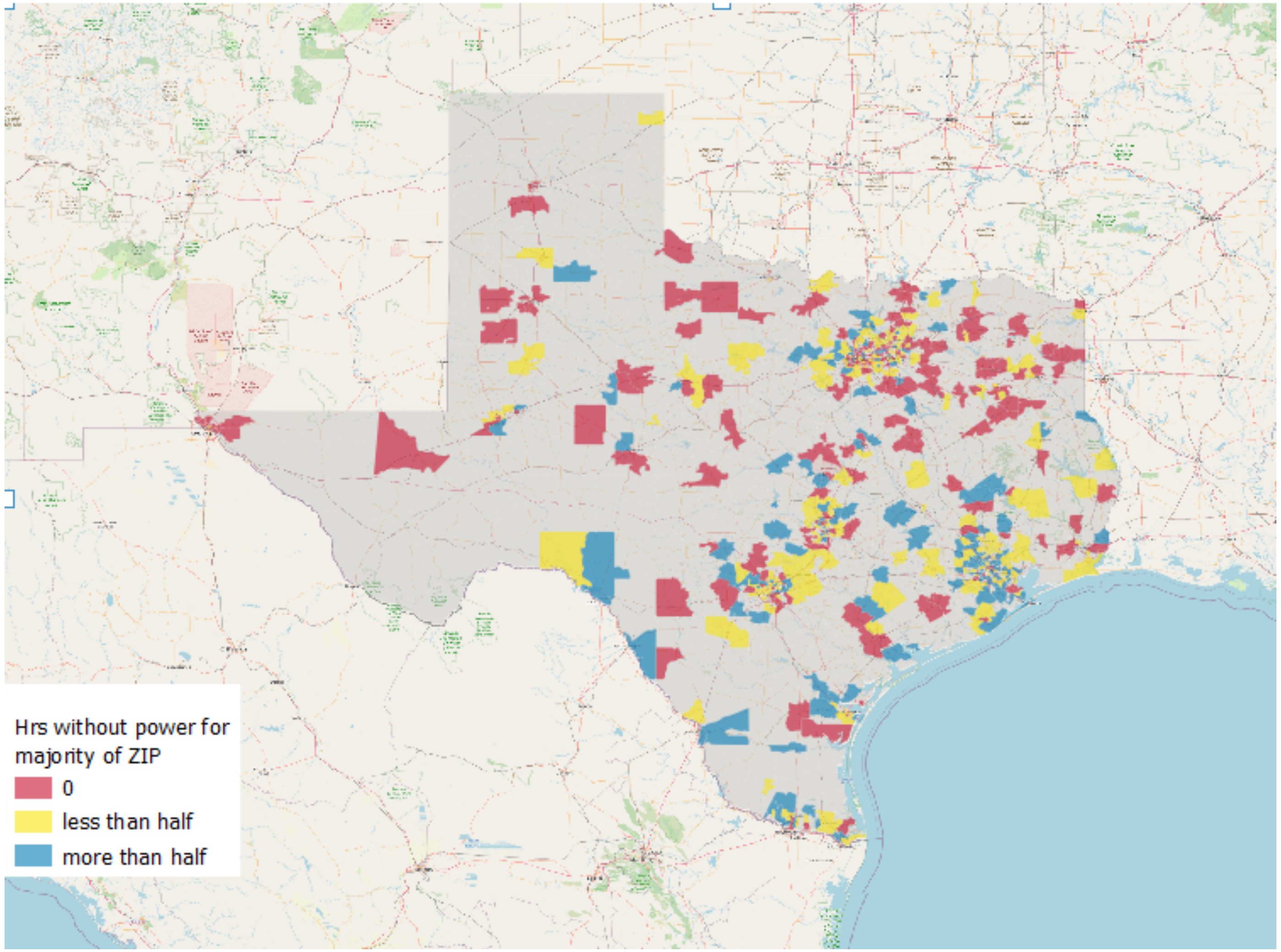


Winter Storm Uri as a Natural Experiment

- Although Winter Storm impacted the entire state, not everyone had the same experience:
  - Some didn’t lose power, others faced multiple day-long outages
  - Among survey respondents the average number of hours of power outage was 46.2 hours
- We divided respondents into three groups based on outage length (i.e., based on exposure/experience)
  - No outage (did not experience power outage)
  - Shorter outages (less than average)
  - Longer outages (greater or equal than average)

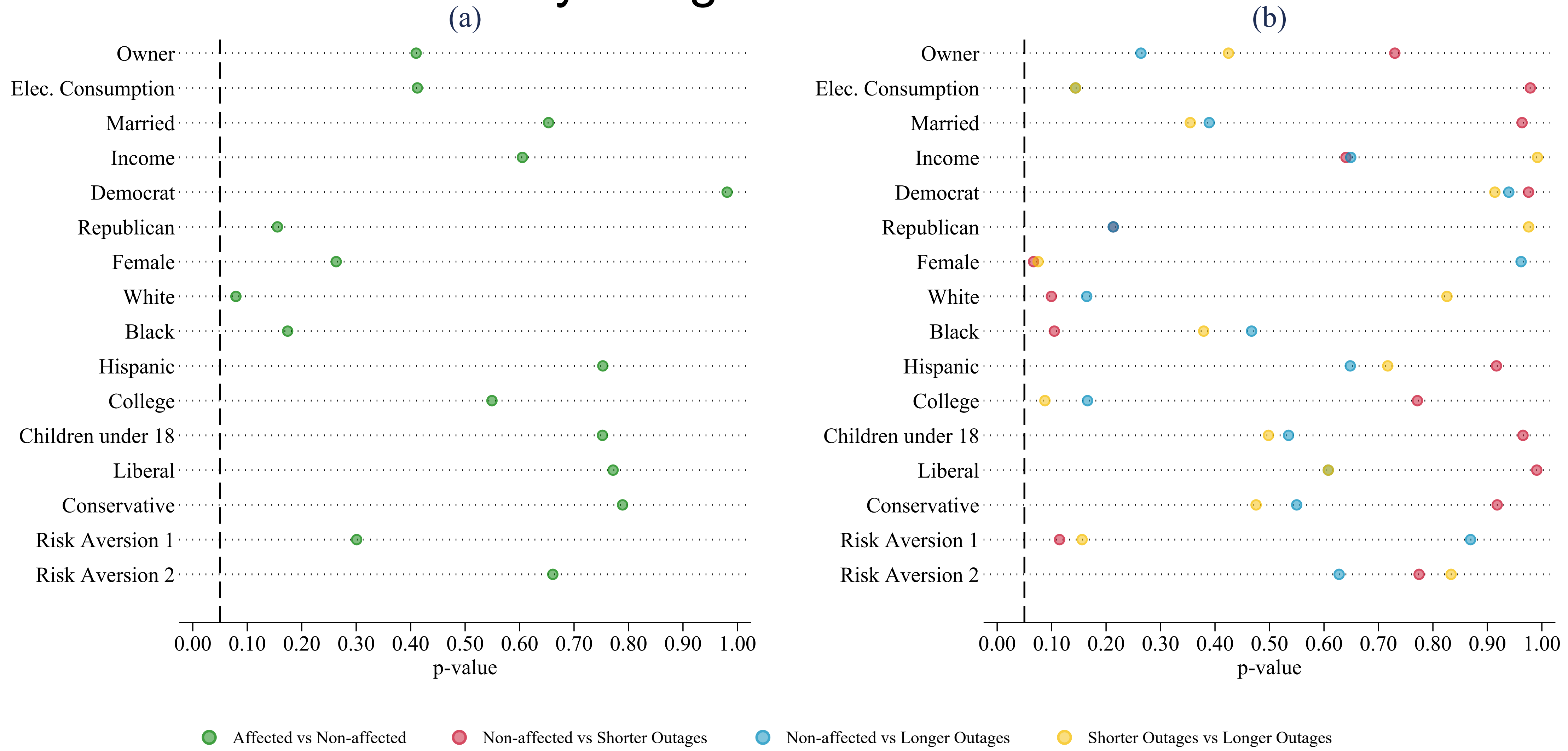
Winter Storm Uri as a Natural Experiment

Figure 1: Geographical Distribution of Electricity Outages



Winter Storm Uri as a Natural Experiment

Were blackouts randomly assigned?



Conjoint Experiment: Attributes and Setup

1. Cost

- Average Texan spent $103 per month on electricity 2019: (at 8.6 cents per kWh)
- Based on an average of 8.6¢, we decided on 1, 2, 4, and 6 cents, representing 12%, 23%, 47%, and 70% increases

2. Outage hours

- Full service (no interruptions)
- Rolling blackouts of up to 2, 12 or 12+ hours

3. Policy to improve reliability

- Status quo (do nothing)
- Winterizing grid
- Merging with one of the two national grids
- Maintaining a minimum reserve capacity
- Increase the renewable energy supply

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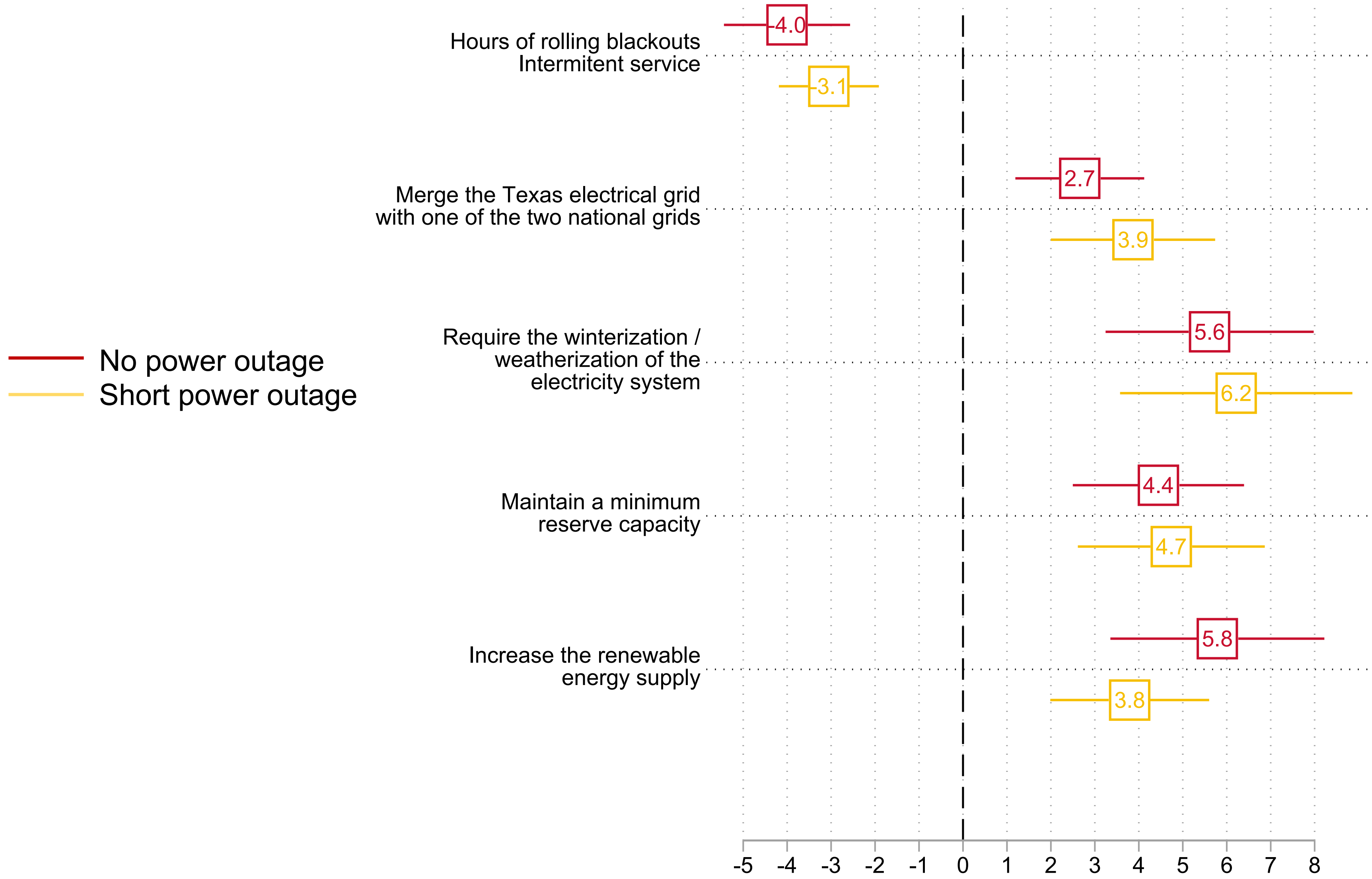
A number of policies have been proposed to protect the state of Texas from the effects of severe weather affecting its energy supply and delivery. Each proposal will need to be paid for in order to guarantee power outages are kept to the stated levels. In 2019, Texans spent an average of $103 per month on electricity (at 8.6 cents per kWh) and experienced power outages for about 4 hours per year. In the following screens you will be presented profiles of two hypothetical alternatives for protecting the Texas electrical grid from the effects of severe weather and their expected costs. Which of the two alternatives, A or B, would you be more likely to choose? Please consider each pair independently.

Attribute	Policy A	Policy B
Policy	Require the winterization / weatherization of the electricity system	Merge the Texas electrical grid with ono of the two national grids
Cost	2 cents more per kWh - 23% Increase	6 cents more per kWh - 70% increase
Outage Hours	Rolling blackouts/ intermittent service (on and off for up to 2 hours)	Rolling blackouts/ intermittent service (on and off for up to 12 hours)

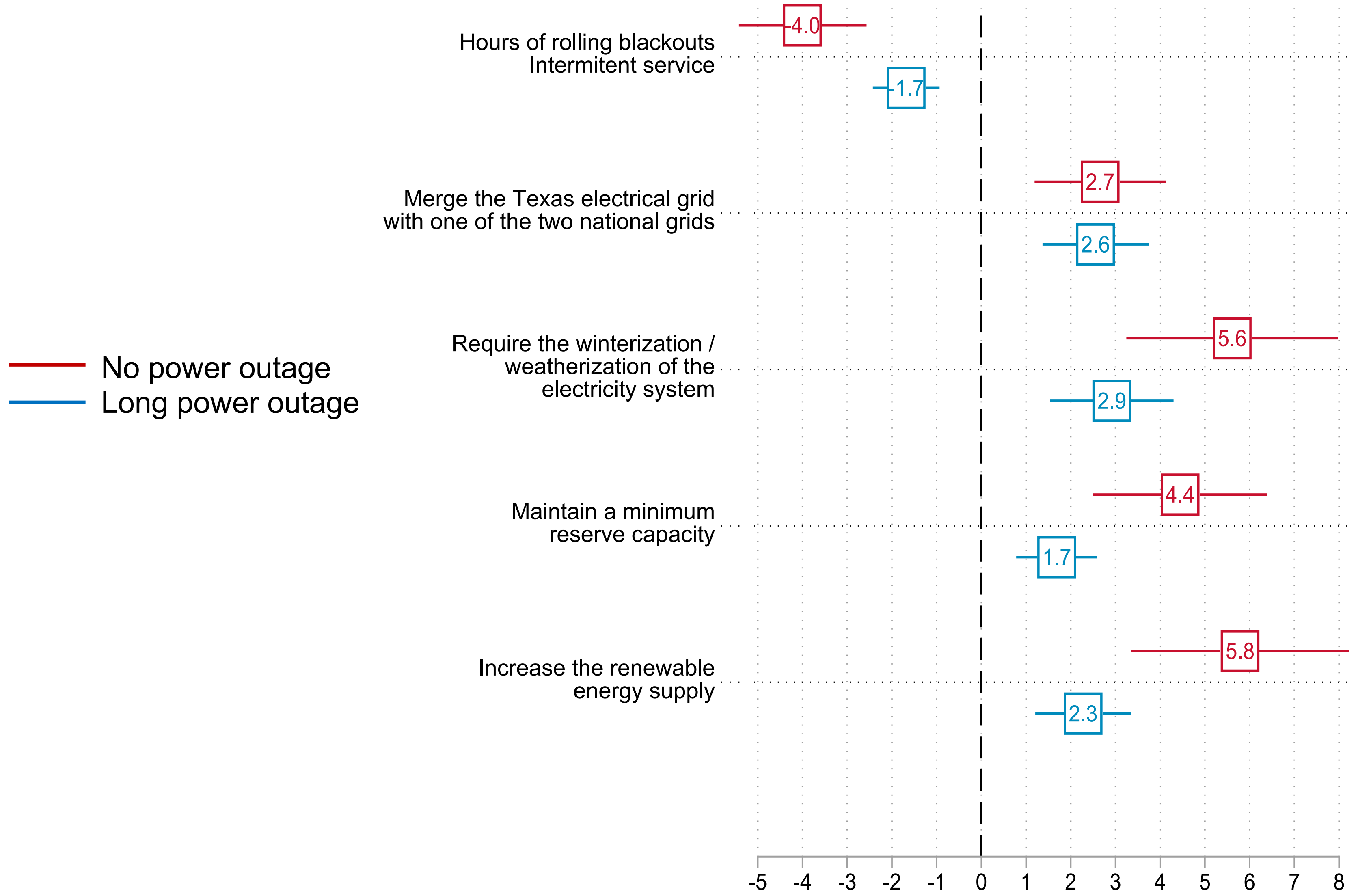
○ Policy A

○ Policy B

Marginal Willingness to Pay by Outage Length



Marginal Willingness to Pay by Outage Length



Winter Storm Uri as a Natural Experiment

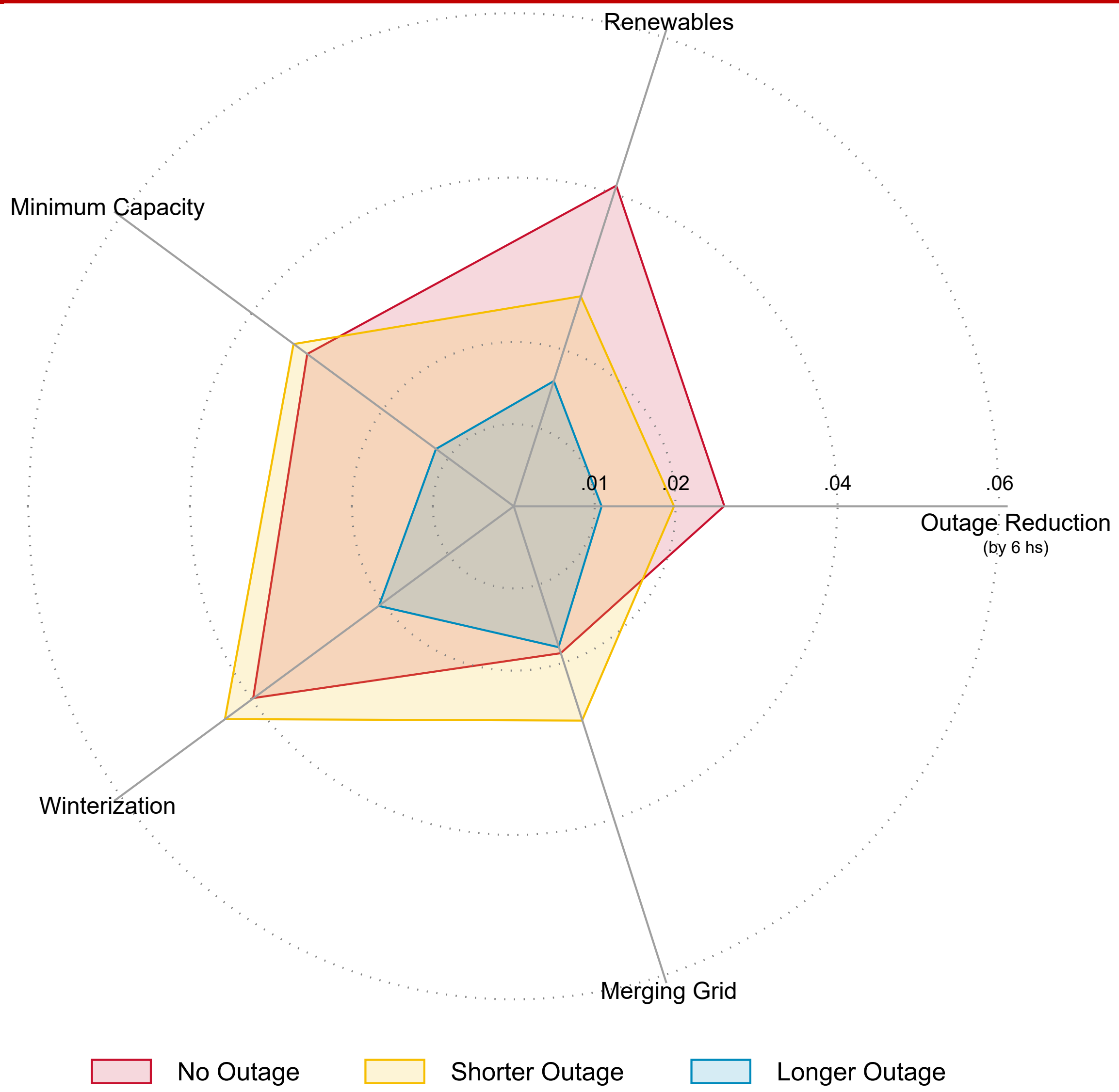
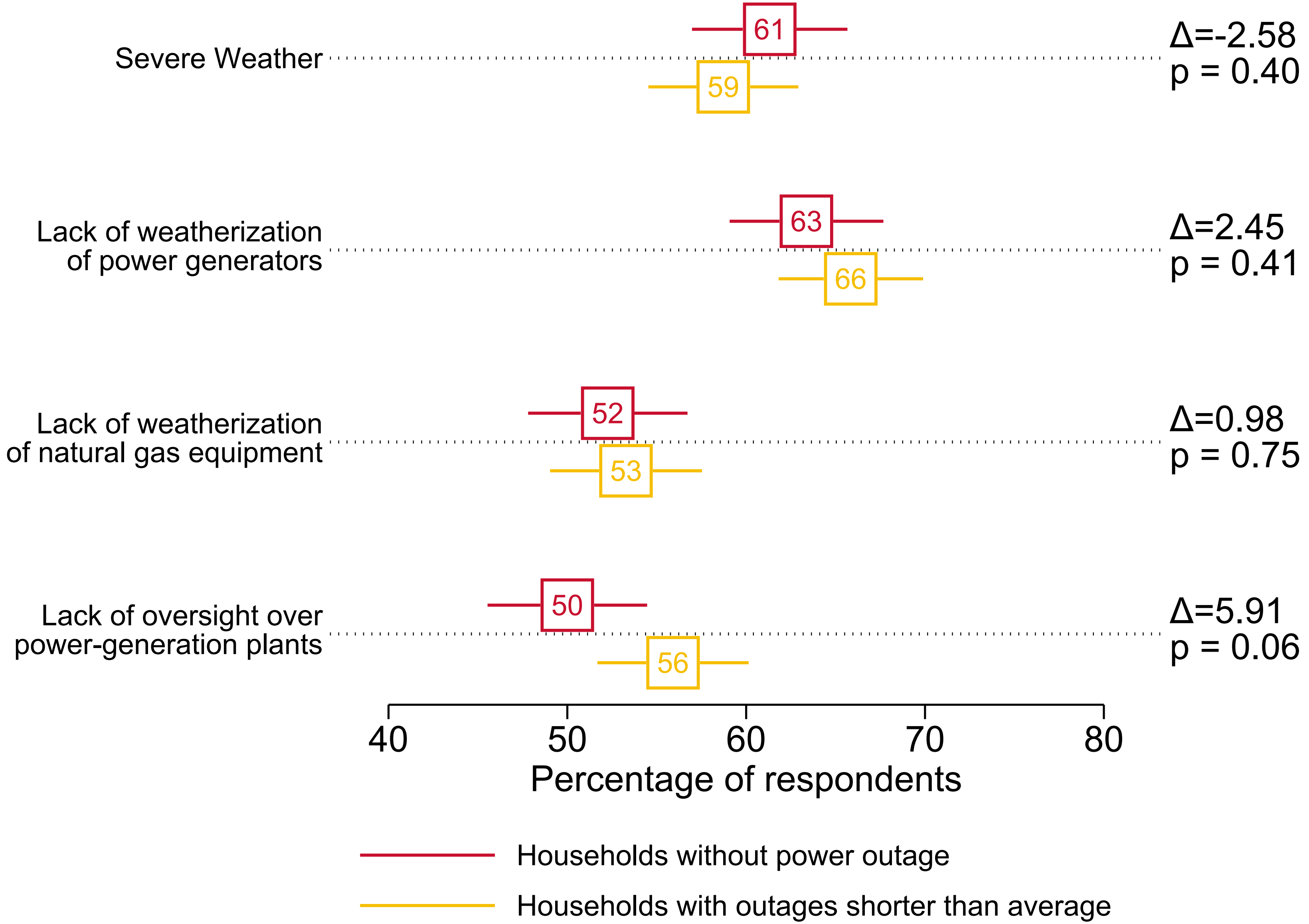


Figure 5: Marginal willingness to pay by policy intervention (in dollars per kWH)

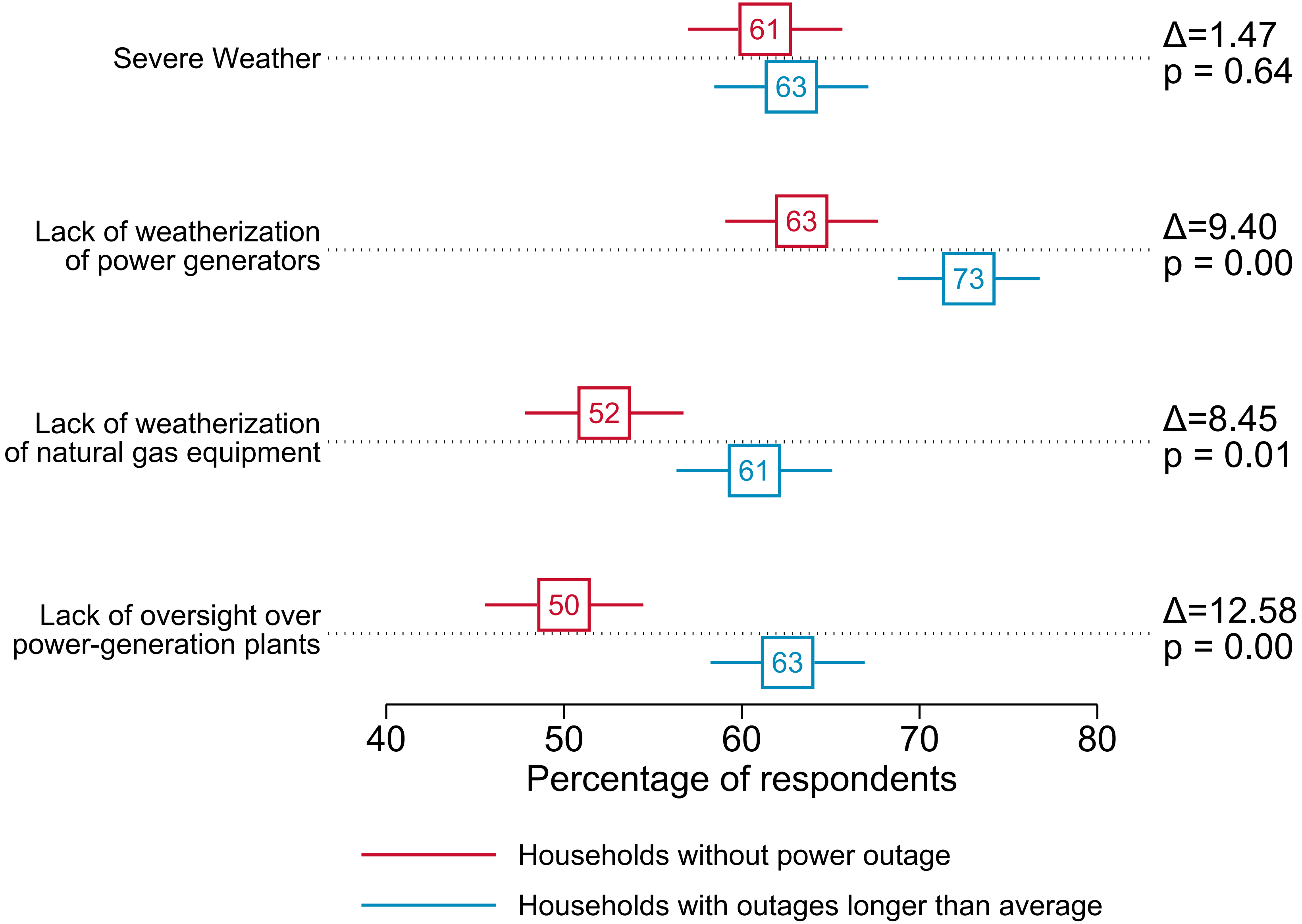
Perceived Responsibility for Power Outages

- Who should be responsible for the power outages?
  - Question: from what you've read or heard, which of the following do you believe are responsible for the electricity grid failure during the winter storm this past February?
    - Severe Weather (nature)
    - Lack of weatherization of power generators (producers)
    - Lack of weatherization of natural gas equipment (producers)
    - Lack of oversight over power-generation plants (government)
- Figures show the perceived responsibility for power outages by comparing the control group and treatment groups

Perceived Responsibility for Power Outages



Perceived Responsibility for Power Outages



Summary of findings

- The widespread electricity outages caused by Winter Storm Uri motivated the study of willingness to pay for improved, reliable electricity service among Texans
  - With unique survey data, we find that Texans are willing to pay more for increase the supply of electricity from renewable sources
  - Texans are also willingness to pay more for policy interventions aimed at making the electricity grid more reliable
  - We find individuals who experienced longer outages are less willing to pay for policy interventions compared to those who experienced shorter than average or those who did not experience any outage
- Implications for policymaking to address issues associated with climate change and the energy transition

Thank you

Pablo M. Pinto
Professor of Public Policy
Director of the Center for Public Policy
ppinto@central.uh.edu l www.uh.edu/hobby l pablopinto.com

Hobby School of Public Affairs
UNIVERSITY OF **HOUSTON**

Links:

Paper: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4141608

Reports on Winter Storm Uri and the Texas Electric grid: https://uh.edu/hobby/research/winterstorm/

Reports on ESG and employment choices: https://uh.edu/hobby/esgworkforce/

Reports on carbon management: https://uh.edu/hobby/carbonmanagement/

Survey Data - Conjoint Experiments

Table 1: Attributes and Attribute Levels for the Conjoint Experiment

	Occurrence No.	Chosen No.	Percent Chosen %
Cost: Increase in price per kWh required for policy			
No increase in price per kWh	2,358	1,448	61.41
1 cent more per kWh (12% increase)	2,428	1,386	57.08
2 cents more per kWh (23% increase)	2,397	1,270	52.98
4 cents more per kWh (47% increase)	2,421	1,040	42.96
6 cents more per kWh (70% increase)	2,396	856	35.73
Outage: Maximum length of outage in hours when electricity demand exceeds capacity			
Full service/no interruptions	3,013	2,077	68.93
Rolling blackouts for up to 2 hours	3,022	1,654	54.73
Rolling blackouts for up to 12 hours	3,007	1,263	42.00
Power outage for more than 12 hours	2,958	1,006	34.01
Policy: policy proposed to protect Texas from effects of severe weather			
Do Nothing/no new investment	2,359	843	35.74
Merge the Texas grid with one of the two national grids	2,378	1,193	50.17
Require winterization/weatherization of the electricity system	2,434	1,430	58.75
Maintain a minimum reserve capacity (backup power)	2,437	1,243	51.00
Increase the renewable energy supply	2,392	1,291	54.00

Marginal Willingness to Pay (MWTP)

- We quantify how much respondents are willing to pay to implement the various policies and reduce power outages
- We assume that each respondent has the following utility function: $U_{ijt} = x_{ijt}\beta_i + \epsilon_{ijt}$
  - where x_{ijt} is a vector of alternative-specific variables (in the set of attributes), and ϵ_{ijt} is an error term.
- To estimate the utility function, we estimate a mixed logit model

Mixed Logit Results

Table 4: Mixed Logit Estimations on the Willingness to Pay

	Baseline		Households without Power Outage		Households with Power Outage		Households with a Shorter Outage on Average Power Outage		Households with a Longer Outage on Average Power Outage	
VARIABLE	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err
Additional electricity expenditure (log)	-0.4385***	[0.075]	-0.3873**	[0.109]	-0.4778***	[0.104]	-0.2985***	[0.082]	-0.8974***	[0.292]
Derived standard deviations	0.5764	[0.135]	0.4094	[0.193]	0.6875	[0.196]	0.4260	[0.173]	1.3064	[0.505]
Rolling blackouts/ intermittent service (log)	-1.2975***	[0.173]	-1.5506***	[0.361]	-1.1695***	[0.170]	-0.9108***	[0.177]	-1.5090***	[0.331]
Derived standard deviations	1.6989	[0.280]	2.0156	[0.559]	1.5038	[0.275]	1.1739	[0.309]	1.8162	[0.475]
Policy										
Merge the Texas electrical grid with one of the two national grids	1.3907***	[0.153]	1.0291***	[0.261]	1.5740***	[0.187]	1.1546***	[0.205]	2.2741***	[0.408]
Require the winterization/ weatherization of the electricity system	2.1423***	[0.185]	2.1733***	[0.345]	2.1503***	[0.215]	1.8556***	[0.252]	2.6129***	[0.419]
Maintain a minimum reserve capacity	1.5061***	[0.161]	1.7222***	[0.322]	1.4429***	[0.183]	1.4149***	[0.223]	1.5058***	[0.332]
Increase the renewable energy supply	1.6823***	[0.167]	2.2414***	[0.353]	1.4614***	[0.186]	1.1322***	[0.206]	2.0478***	[0.391]
Log simulated-likelihood	-3351.3183		-1046.5429		-2287.26		-1232.3041		-1043.0159	
Number of observations	12,000		3,888		8,112		4,264		3,848	
LR test for the equality of two models (χ^2-statistics)			30.52 (p-value = 0.0000)				19.83 (p-value = 0.0030)			

Notes: * 10% significance level; ** 5% significance level; *** 1% significance level, two-tailed tests.

Estimating Marginal Willingness to Pay

- One of the advantages of conjoint analysis is that we can quantify how much respondents are willing to pay for different proposed policies based on the estimated coefficients in the mixed logit regressions.
- The marginal willingness to pay (MWTP) for attribute k can be presented as follows: $$MWTP_k = \frac{\partial U / \partial x_k}{-\partial U / \partial p} = \frac{\beta_k}{-\beta_p}$$
  - where p is the price attribute, which in this case is the change in the amount customers pay on electricity per year (in log).

Marginal Willingness to Pay (MWTP)

- The mixed logit model:

$$P_{ijt|\beta_i} = \exp\left(x_{ijt}\beta_i\right) / \sum_{k=1}^{J} \exp\left(x_{ikt}\beta_i\right)$$

  - and

$$P_{ijt} = \int P_{ijt|\beta_i} f\left(\beta, \theta\right) d\beta$$

  - where P_{ijt} is defined as the probability of choosing alternative *j* for respondent *i* in experiment *t*.