Natural Disasters and Willingness to Pay for Reliable Electricity: The 2021 Winter Storm in Texas as a Natural Experiment

Gail J. Buttorff, Yuhsin Annie Hsu, Yewande Olapade, María P. Perez Arguelles, Pablo M. Pinto, Savannah L. Sipole, Agustín Vallejo and M. C. Sunny Wong[†]

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Abstract

Winter Storm Uri led to power outages in many Texas households in February 2021 and exposed crucial deficits in the state's electricity grid. We analyze how an individual's experience during a natural disaster, in this case Winter Storm Uri, affects their willingness to pay for a reliable supply of electricity. Given its public good properties, reliable electricity supply in times of natural disasters will tend to be undersupplied absent public policy interventions. Using a choice experiment embedded in a survey fielded after Winter Storm Uri, we estimate the price respondents would pay for such interventions to improve the reliability of the grid. We find that respondents who experienced longer-than-average outages were willing to pay 2 cents more per kWh to winterize electricity grids. This amount is significantly lower compared to 4 and 4.4 cents more, respectively, for those that experienced no or shorter-than-average outages. We argue that these results stem from how the experienced blackouts affected evaluations of the providers and government to deliver the public good, finding supportive for this conjecture.

[†] Hobby School of Public Affairs. University of Houston.

1 Introduction

The reliability of the Texas electricity system depends on the ability of electricity suppliers to meet demand, which is not a problem under normal circumstances. Winter Storm Uri in February 2021, however, exposed the vulnerability of the system to natural disasters and extreme weather events. Between February 14-20, 2021, Texas experienced an unprecedented collapse of its electrical generation and distribution system, causing more than 10 million Texans to lose power for multiple days amidst freezing and below-freezing temperatures. At its peak, Winter Storm Uri left 4.5 million homes and businesses without power, killed at least 151 people, and cost at least $195 billion in material losses. Given that extreme weather events are only expected to increase in frequency in the future, such events will continue to threaten the reliable supply of energy, resulting in disruptions and losses of human life and physical capital.

Addressing problems with the Texas grid to secure a more reliable energy supply demands massive investments and regulatory changes that will ultimately raise the cost of electricity. In a similar fashion to other public goods, individuals – including consumers and producers – face incentives to free ride on other market players' contributions to make the electric grid more reliable, resulting in underinvestment and underprovision of the service (Pigou, 1947; Brainard and Dolbear, 1967; Williams, 1966; Stiglitz and Rosengard, 2015). In this paper, we argue that individuals' experiences with extended power outages during Winter Storm Uri affects their willingness to pay (WTP) for policies aimed at bolstering the resilience of the Texas grid in different ways. All else equal, experiencing a natural disaster that affects the supply of electricity exposes the need to invest in the resiliency of the system to lower future disruptions. Yet, individuals will ultimately have different experiences during any one particular natural disaster, which, in turn, will also impact their WTP. We argue here that experiencing lengthy blackouts negatively affects individuals' assessment of the ability of government and electricity suppliers to deliver the public good, lowering their willingness to pay for investments in resiliency. Experiencing shorter blackouts, on the other hand, may increase individuals' valuation of the public good and willingness to pay for policies aimed at making the electric grid more resilient to natural disasters. To test this argument about the differential effect of natural disasters on the valuation of a resilient electricity supply, we use original data from a choice experiment embedded in a representative public opinion survey of Texas residents conducted after Winter Storm Uri.

Winter Storm Uri led to extended power outages of different lengths to different households. We leverage this natural experiment to explore two related questions. First, does experiencing a natural disaster, which affected the electricity supply, impact individuals' WTP for policy changes to Texas's electricity grid? Second, did the power outage duration make individuals more or less willing to pay to improve the reliability of their electricity supply? We find that households who experienced longer-than-average outages had significantly lower WTP for reliable energy than those who experienced shorter-than-average outages and those who did not experience any outages. In addition, those experiencing longer power outages were more likely to blame the government and electricity producers for the failure of the Texas power grid.

Our empirical strategy relies on exploiting the *as-if-random* assignment to exposure to blackouts of different durations during Winter Storm Uri. We are, thus, able to leverage this exogenous shock to assess the differential impact of outage duration and experience on WTP following a natural disaster. Our findings provide a basis for reconciling mixed results in the literature concerning the effect of prior experience on WTP for reliable electricity, and for public goods more generally Cohen et al. (2018); Baik et al. (2020); Taale and Kyeremeh (2016); Amador, González and Ramos-Real (2013). Importantly, while previous literature also utilizes choice experiments to assess how respondents value reliable electricity supply under hypothetical scenarios, our analysis relies on data collected shortly after the winter storm. Respondents did not have to "imagine" hypothetical unplanned outages allowing us to better evaluate how actual experiences with natural disasters affect individuals' WTP for the supply of a public good.

2 Related Literature: WTP for Reliable Electricity

An individual's WTP for public goods – whether national defense, clean air, or reliable electricity – depends on various factors, including gender López-Mosquera, 2016; Adebo and Ajewole, 2012; Alozie and McNamara, 2010, income Horowitz and McConnell, 2003; Flores and Carson, 1997; Baumgärtner et al., 2017, education Tianyu and Meng, 2020; Zorić and Hrovatin, 2012; Taale and Kyeremeh, 2016, parental status Olli, Grendstad and Wollebaek, 2001; Wolters, 2014, and risk perception Huang, 1993; Xu and Shan, 2018. The literature on electricity reliability, which possesses public goods properties, finds that customers are willing to pay to reduce the number and duration of power outages and to improve service quality Goett, Hudson and Train, 2000. The WTP of electricity customers to avoid power outages, especially sudden or unplanned ones, varies with their age, family size, season, location, housing type, and the day and time of the week Carlsson and Martinsson, 2008; Abdullah and Mariel, 2010; Taale and Kyeremeh, 2016; Kim, Kim and Yoo, 2019; Hensher, Shore and Train, 2014; Ozbafli and Jenkins, 2016; Cohen et al., 2018.

Yet, determining how various demographic and other factors influence WTP requires understanding how these factors interact with outage duration. Outages of different lengths can have adverse welfare effects depending on an individual's demographic profile, the season, time of the week, and housing type. For example, WTP to avoid power outages is expected to be higher on weekends or weeknights than on weekdays Carlsson and Martinsson, 2008. Moreover, factors related to reliance on and demand for electricity also account for some heterogeneity in WTP for reliable electricity, with higher electricity usage associated with greater disutility from power outages Ozbafli and Jenkins, 2016; Taale and Kyeremeh, 2016. People are likely to be home during the former and thus more negatively impacted by a power outage than if it happened during a weekday when they would be at work or school.

Previous studies on WTP for reliable electricity service have documented that certain demographic characteristics account for some heterogeneity in WTP, likely because of how these factors relate to reliance on and demand for electricity. Those with higher electricity usage are expected to experience greater disutility from power outages (Ozbafli and Jenkins, 2016, p. 448). Thus, any factors that might affect electricity usage or reliance might also affect individuals' WTP. Taale and Kyeremeh, 2016 suggested that education positively influenced WTP because more educated individuals are likely to rely on electricity more and own more electric appliances, which will result in greater welfare loss when the electricity goes out.

Individuals' reliance on electricity, and thus the welfare losses resulting from power outages, could also vary depending on whether the outage occurs in summer or winter. In their study on Cyprus, Ozbafli and Jenkins, 2016 argue that the finding that higher-income individuals were willing to pay more in the summer was due to their reliance on electricity in the summer, especially because of air conditioning at home and at work. Moreover, as Cohen et al., 2018 find, which season has a higher WTP will depend on local temperature, particularly whether the country or region has hotter summers or colder winters.

Other demographic factors are thought to capture respondents' ability to pay more and thus influence WTP. Taale and Kyeremeh, 2016, for example, show that in Ghana, household size was negatively associated with WTP. They argue that one reason for this finding is that larger households are likely to have tighter budget constraints, which does not leave much room for spending beyond basic needs. On the other hand, Abdullah and Mariel, 2010 study WTP for electricity in Kisumu, Kenya. The authors find that larger households were more willing to pay for reliable service, possibly because "larger families, unlike smaller ones, rely on electricity for housework and demand more electricity to accommodate the varied needs of the family members" (p. 4575).

Abdullah and Mariel, 2010 suggest that individuals' trust and confidence in service providers can also influence WTP. The same Kenyan study finds that older respondents were less likely to pay for reliability. They posited that this might result from a "decline in confidence in government policies in the area among older participants" (p. 4575). Taale and Kyeremeh, 2016 found that receiving prior notices of power outages associated positively with WTP, suggesting that increased communication increased trust in the electricity service providers, influencing their willingness to pay more. Anderson, 2017 found that trust in various levels of government (e.g., cabinet, executive, regional, etc.) was significantly related to WTP additional taxes for education, public health, and helping the needy. Oh and Hong, 2012 also find that trust in government affects WTP, especially when the government implements the public good project.

Beyond demographic factors, previous experience with power outages has also been found to impact individuals' WTP for reliable electricity. Cohen et al., 2018 find that the WTP to avoid future power outages is lower among individuals who have experienced power outages lasting more than four hours. They posit that this is likely due to "the readiness factor" making such individuals better equipped to endure future power outages (p. 39). Thus, those who have experienced power outages of long duration may be willing to pay less because they are better prepared to endure sustained power outages. Similarly, Ozbafli and Jenkins, 2016 argued that older respondents were not as negatively affected by power outages as younger respondents because older respondents had "experience coping with such inconveniences than do young individuals" (p. 448).

Individuals who have experienced extended power outages may be willing to pay more because of their familiarity with the consequences and thus desire to avoid large and long-duration power outages. Taale and Kyeremeh, 2016 find that households that had experienced a power outage lasting several hours in the week preceding their survey were willing to pay more for reliable electricity supply. By contrast, Baik et al., 2020 argue that those who have not experienced outages of long duration will be unfamiliar with the consequences and, given the uncertainty, may be willing to pay more to avoid such large, long outages; Baik et al., 2020, however, found that past experience did not affect WTP.

Amador, González and Ramos-Real, 2013 suggest that it is not only past experience but also *perceived experience* that affects WTP. In their study on supplier choice in the Canary Islands, they found that although all respondents preferred fewer and shorter duration outages, "an increase in outage frequency results in a greater disutility to the individuals who bestow a greater importance on the outages endured in the previous year" (p. 961). Thus, individuals' WTP might depend not only on whether they have experienced an outage, but also on the intensity of that experience.

In the next section, we provide a modified theoretical framework originally suggested by Oh and Hong, 2012, showing the differential effect of outage experiences on individuals' willingness to pay for reliable electricity supply. It helps reconcile the results in the previous literature finding either positive or negative associations between outage experience and willingness to pay for more reliable access to electricity. Our empirical strategy in the following sections exploits a quasi-natural experiment: the differential impact of the length of outages experienced by Texas residents during Winter Storm Uri, which brought freezing temperatures to the state impacting the production and distribution of electricity to households and businesses. We analyze how individuals' differential experiences with power outages affect their WTP for regulatory changes to the Texas electricity grid to lower outages and mitigate the impact of severe weather events on the supply of electricity.

3 A Theoretical Framework on WTP for Public Goods

The Texas electricity system was designed to promote competition among producers and limited government intervention. Producers are only paid when supplying electricity to the system. There are no requirements to keep backup capacity. To avoid federal regulation of the Texas electricity grid, the Texas interconnection of the Electric Reliability Council of Texas (ERCOT) is not linked to any of the other two neighboring grids. The reliability of the system thus depends on the ability of suppliers of electricity to meet demand, which under normal circumstances is not a problem. However, the system can be vulnerable to natural disasters and extreme weather events, as reflected in the massive impact of Winter Storm Uri. The problem is not only limited to the impact of freezing temperatures on the supply of natural gas, which accounts for roughly 50% of the fuel used for electricity production. Higher demand during heatwaves can also strain the ability of producers to supply electricity.

The reliability of the electric grid can be characterized as a public good that the current system does not necessarily supply at the optimal level for society. Access to a reliable supply of electricity is valuable to individuals. Yet, individuals are not likely to internalize the value of the reliability of the system. Just like in the case of other public goods well documented in the literature, individuals face incentives not to contribute to its provision, nor do private suppliers of the good, resulting in under-investment and under-supply (Pigou, 1947; Brainard and Dolbear, 1967; Williams, 1966; and Stiglitz and Rosengard, 2015).

Addressing problems in the Texas electricity grid, including reliable electricity supply, requires massive investments and regulatory changes that will affect the cost of electricity. This section presents a simple model of an individual's expenditure function for a basket of private goods and a public good, which depends on income, prices, and the marginal rate of substitution between private goods and the public good. After characterizing the expenditure function, we introduce a potential intervention aimed at increasing the level or the quality of the public good. Given the typical properties of public goods, individuals have no incentive to reveal their willingness to pay as they can free ride on the contributions by other actors with a higher valuation for the good. Importantly, an individual's willingness to pay for the proposed changes in the level (or quality) of the public is affected by her experience with the good and their perception of the public authority's ability to deliver the proposed level or quality of the public good. Hence, we would expect that past experiences affecting the supply of reliable power could affect individuals' willingness to pay for a more reliable electricity supply.

Consider individual i's utility function over a basket of two types of goods, X and Y, as follows:

$$U_i = U\left(X_i, Y\right),$$

where $X_i = [x_{i1}, ..., x_{iJ}]$ is a vector of J private goods for individual i, and Y is a public good. The utility function U has regular properties, where $U_z = \partial U/\partial z > 0$ and $U_{zz} = \partial^2 U/\partial z^2 < 0$, for $z \in \{X, Y\}$, and $\partial^2 U/\partial X \partial Y = \partial^2 U/\partial Y \partial X > 0$. Following Oh and Hong (2012), the public good is not produced by private producers, but by a collective entity, a public good provider or public authority, such as the government.[1]

Let P be a vector of prices for private goods X, and I_i be the level of disposable income for individual i. The individual chooses the optimal level of X to maximize her utility function given the levels of price P, income I_i, and public good Y.[2] As a result, the indirect utility function can be written as:

$$V\left(P, Y, I_i\right) = \max_{X_i}\left\{U_i | P X_i \leq I_i\right\} \tag{1}$$

We can derive the expenditure function from the indirect utility function (1). The expenditure E can be represented as the minimum amount that individual i must spend on private goods in order to achieve a certain level of utility U_i, given P and Y. The private good expenditure function is presented as follows:

$$E\left(P, Y, U_i\right) = \min_{X_i}\left\{P X_i | U\left(X_i, Y\right) \geq U_i\right\}. \tag{2}$$

Suppose the public authority proposes a policy to raise the level (quality) of the public good from Y^0 to Y^1, such that $Y^1 > Y^0$. We define the change in the level of the public good as $y = Y^1 - Y^0 > 0$. Assuming that the additional level of public good will be paid by individuals and that society prefers more of the public good, we can derive the willingness to pay for the extra level of the public good for individual i:

$$WTP\left(y_i^e\right) = E\left(P, Y^0, U_i^0\right) - E\left(P, \left(Y_i^1\right)^e, U_i^0\right) > 0, \tag{3}$$

where $y_i^e = \left(Y_i^1\right)^e - Y_0$, U_i^0 represents the initial utility level, and $\left(Y_i^1\right)^e$ the expected level of the public good for individual i after the policy implementation, which is *not* necessarily identical across individuals in society. Equation (3) suggests that individual i is willing to spend less on private goods if she expects to obtain more (better) public good $\left(Y_i^1\right)^e$, given the same level of utility. Hence, the difference between the private-good expenditure with the original level of public good $E\left(P, Y^0, U_i^0\right)$ and the expenditure with a higher expected level of public good $E\left(P, \left(Y_i^1\right)^e, U_i^0\right)$ is interpreted as the willingness to pay for the additional level of public good for individual i, *ceteris paribus*.

From Equation (3), if individual i's expected level of public good $\left(Y_i^1\right)^e$ equals the level that the public authority proposes (i.e., Y^1), then $WTP\left(y_i^e\right) = WTP\left(y\right)$. In other words, society is willing to contribute the amount to the public authority for providing the proposed level of public good if they valuate the public authority that is able to supply that good. However, an

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[1] We will use public good provider, public authority, and government interchangeably to describe an entity providing public goods in society.

[2] In this model, we assume that individuals in the society do not pay to obtain the initial level of public good Y^0, which has been paid by the public authority.

individual would be less willing to pay if she expects that the public authority will not be able to deliver the proposed level or quality of the public good.

To develop the relationship between the subjective valuation of public good providers and willingness to pay for public goods, we first linearize the private good expenditure function of $E_i\left(P, \left(Y_i^1\right)^e, U_i^0\right)$ around the initial level of the public good Y^0 based on the first-order Taylor approximation:

$$E\left(P, \left(Y_i^1\right)^e, U_i^0\right) \approx E\left(P, Y^0, U_i^0\right) + E_Y\left(P, Y^0, U_i^0\right) \cdot \left(\left(Y_i^1\right)^e - Y^0\right), \tag{4}$$

where $E_Y(\cdot) = \partial E(\cdot)/\partial Y < 0$. Substituting (4) into (3), the linearized function of willingness to pay for the public good can be presented as:

$$WTP\left(y_i^e\right) = -E_Y\left(P, Y^0, U_i^0\right) \cdot y_i^e > 0. \tag{5}$$

Equation (5) shows that individual i's willingness to pay for the public good depends on the negative value of the marginal expenditure on public good $(-E_Y)$ multiplied by the expected change in the level of public good $\left(y_i^e\right)$ for individual i. Following Oh and Hong (2012), we assume that the expected change in the level of public good is formed based on probability density function (pdf) for *a posteriori* completion of the public good perceived by individual i, $f\left(\hat{\gamma}_i, y^*\right)$, where $\hat{\gamma}_i$ is an individual-specific determinant of the pdf, such as the past *undesirable* experiences or knowledge γ_i, relative to the average level of experiences in the community $\bar{\gamma}$, such that $\hat{\gamma}_i = \gamma_i - \bar{\gamma}$. We have:

$$y_i^e = \int_0^y y^* f\left(\hat{\gamma}_i, y^*\right) dy^* = \Gamma\left(\hat{\gamma}_i\right) y, \tag{6}$$

where $\Gamma\left(\hat{\gamma}_i\right) \in [0,1]$ represents the subjective valuation of the public good provider's ability to produce the public as a function of the individual's past relative experience $\hat{\gamma}_i$ for individual i. We assume that $\hat{\gamma}_i$ represents the relative undesirable experiences of the public goods, such that $d\Gamma/d\hat{\gamma}_i < 0$, for $\hat{\gamma}_i > 0$. This condition implies that, if individual i previously experienced *more undesirable state* with the public good relative to the community (i.e., $\hat{\gamma}_i > 0$), the individual will have a lower expected level of of public good after policy implementation such that $y_i^e < y$. On the other hand, if individual i's past experience was relatively *better* than the average in the community (i.e., $\hat{\gamma}_i \leq 0$), the individual-specific pdf $f\left(\hat{\gamma}_i, y^*\right)$ is normalized as $1/y^*$, such that $y_i^e = \int_0^y y^* f\left(\hat{\gamma}_i, y^*\right) dy^* = y$, for $\hat{\gamma}_i \leq 0$. In other words, the individual is confident that the level of of public good after policy implementation will meet the individual's expected standard as he/she had better-than-average experiences in the past. Finally, we obtain the following linear willingness to pay function for individual i by substituting (6) into (5):

$$WTP\left(y_i^e\right) = -E_Y\left(P, Y^0, U_i^0\right) \Gamma\left(\hat{\gamma}_i\right) y. \tag{7}$$

According to Equation (7), we see that $\partial WTP\left(y_i^e\right)/\partial\hat{\gamma}_i < 0$ for $\hat{\gamma}_i > 0$. In other words, given better than average level of past relative experience, individuals will be willing to pay the amount that is equal to the proposed amount by the public authority, i.e. $WTP\left(y_i^e\right) = WTP(y)$. However, if an individual encountered more undesirable experiences relatively in the past, she will have a lower valuation on the public authority (i.e. $\Gamma\left(\hat{\gamma}_i\right)$ decreases). As a result, she would be less willing to fund the public good project (i.e., $WTP\left(y_i^e\right)$ decreases.)

4 Empirical Strategy

To assess individuals' willingness to pay for reliable electricity, we fielded an online survey between May 13-24, 2021 – a month after the beginning of the winter storm. The survey included a sample of 1,500 respondents representative of residents from across the state of Texas. The survey asked Texans about their experiences during Winter Storm Uri, their confidence in state leaders and existing laws and regulations to address the vulnerabilities in Texas' electric system, their tolerance for power outages and higher prices, the importance of a secure and reliable electricity supply, as well as their willingness to pay for the required policy interventions to make the grid more resilient to the effects of severe weather events. Table 1 presents the descriptive statistics of the relevant elements of the survey used in our analyses below.

[**Table 1: Descriptive Statistics for Full Sample**]

As discussed earlier, the subfreezing temperatures brought by Winter Storm Uri created major disruptions to the Texas electricity grid. The cold weather froze natural gas pipelines, which were not weatherized to endure exceptionally low temperatures, reducing the supply of fuel a large proportion of electricity producers. The cold weather also forced some power plants out of the system when demand was expected to peak as consumers braced for the extreme temperatures. This resulted in major power outages across Texas.

Winter Storm Uri revealed crucial deficits in the state's electricity grid, making apparent the low reliability of the system. As we document below, the *as-if-random* assignment of blackout times across households in Texas presents itself as a *quasi*-natural experiment. We designed a public opinion survey of a representative sample of Texas residents fielded soon after Winter Storm Uri, and rely on this quasi-natural experiment to assess how individuals' differential experiences with power outages affect their WTP for policies aimed at increasing the reliability of the supply of electricity.

4.1 Choice Experiment

To analyze respondents' preferences for different policies to mitigate future outages and their willingness to pay to enact these policies we use a choice experiment embedded in the survey. Choice experiments (CE), also called conjoint experiments, are often used because they allow respondents to give feedback on multiple attributes at one time. CE have increased in popularity because of its market realism and use in various valuation areas, including health, environment, and infrastructure (Ozbafli and Jenkins, 2016). Additionally, this type of experiments allows for a more in-depth form to study the phenomenon of choice in various applications and has been a widely used method used for the purposes of studying residential customers' electricity supplier preferences (Amador, González and Ramos-Real, 2013; Cai, Deilami and Train, 1998; Goett, 1998; Louviere, Hensher and Swait, 2000; Revelt and Train, 1998). Another important advantage of this method for eliciting respondents' valuations over alternative choices is that it offers a way to obtain the values of the attributes involving characteristics that pertain to resources or services rather than the overall values of the resource or service (Hanley et al., 1998).

To design the conjoint experiment, we rely on the empirical literature on willingness to pay for public goods: *attributes of electricity services*, *cost of power outages for electrical services*, and *the policies of the Texas state government when it comes to the electric grid.* Table 2 shows attributes and corresponding levels for the conjoint analysis. Each respondent was asked to make four sequential choices between two different policy profiles (Policy A or Policy B) at a time (see example in Figure A1 in the appendix). Each profile had three attributes: policy, cost, and outage length. For each of the four decisions, respondents had to choose between two profiles where the levels of the three different attributes were randomly assigned.

For the policy attributes, we presented respondents with five different options, which included the *status quo* - doing nothing or no new investment. The four policy proposals that respondents were presented with were based on the policies discussed in policy circles in the aftermath of Winter Storm Uri to protect the Texas interconnection from the effects of future severe weather. The proposals, which were widely covered in the media and discussed, included: (1) merging the Texas electrical grid with one of the two national grids; (2) requiring the winterization of the electricity system, including at gas wellheads and processing plants; (3) maintaining a minimum reserve capacity; and (4) increasing the renewable energy supply.

Following previous studies (e.g., Abdullah and Mariel, 2010; Carlsson and Martinsson, 2008; Morrison and Nalder, 2009; Ozbafli and Jenkins, 2016), we characterized reliability as outage duration. For the outage length, there were four attribute levels: (1) full service (no interruptions); (2) rolling blackouts or intermittent service on and off for up to 2 hours; (3) rolling blackouts or intermittent service on and off from 2 up to 12 hours; and (4) power outage for more than 12 hours.

Finally, we chose attribute levels based on the average cost of electricity in the state of Texas in 2019. The levels for the increase in cost per kWh were: (1) no increase in cost per kWh; (2) 1 cent more per kWh (12% increase over the 2019 average household electricity bill); (3) 2 cents more per kWh (23% increase); (4) 4 cents more per kWh (47% increase); and (5) 6 cents more per kWh (70% increase). Figure A1 in the appendix presents an example choice set from the conjoint choice experiment included in this study. Each respondent was asked to choose between different policy alternatives of randomly generated attribute levels like the one shown in Figure A1. The full factorial for this study yields 100 profiles (i.e., 5 × 4 × 5), which includes 4,950 pairs (i.e., 100 × 99/2).

[TABLE 2: Descriptive Statistics for Conjoint Experiment]

4.2 Winter Storm Uri as a Natural Experiment

We use a quasi-natural experiment design based on the distribution of the length of power outages in Texas. Blackouts left more than 4.5 million customers without power during winter storm Uri. According to the Electricity Reliability Council of Texas (ERCOT), power outages occurred for several reasons, but mainly because power generators and other equipment could not withstand the cold weather, fuel limitations, and to a minor extent, forced outages by transmission line disconnections. The blackouts exposed the inability of the electricity supply to meet the extreme demand, which brought the electric grid within minutes of complete collapse.

While the most impacted counties in terms of an average number of customers without power were Throckmorton (93%), Brazoria (92%), and Wharton (90%), power outages occurred statewide. In addition, power outages varied in length hour by hour from February 10 to February 19, being February 16, the day with most customers affected. The map below (Figure 1) shows the survey respondents' average hours without power by ZIP codes in Texas. The distribution of hours does not appear to follow a spatial pattern or be clustered in specific regions.

The effects of Uri on the electric grid of Texas caused outages that varied by region and by time as if they were random. Because of these reasons, the quasi-experimental design is used as leverage to understand the willingness to pay. A balance test is proposed as evidence of the quasi-natural experiment, which shows, holding everything else constant, that the length of power outages seems to be the one factor affecting subjects' experiences. Due to the unique structure of the dataset, where the number of hours without power is a continuous variable, we are able to investigate three discrete levels to complete the empirical analysis: Those who experienced longer power outages (above the average), those who experienced shorter power outages (below the average) and those who did not experience power outages.

[**FIGURE 1: Geographical Distribution of Electricity Outages**]

For the identification strategy to be valid, individuals who experienced shorter or longer outages should not be systematically different in their characteristics from the group who experienced no outages. Figure 2 addresses systematic differences among these groups. Figure 2a shows whether a respondent who reported having experienced outages during the winter storm is not systematically associated with personal and demographic characteristics. Specifically, the figure reports *p-values* for the sharp null hypothesis that experiencing outages is not associated with the distribution of 16 covariates. The dashed vertical line denotes a statistically significant *p-value* smaller than 0.05. Consistent with the claim that assignment to either group was randomly assigned, the 16 covariates are not statistically significant.

Figure 2b presents in red *p-values* among the set of covariates between the group of respondents who did not experience outages with those who experienced shorter outages. Blue dots show the *p-values* on the covariates between those who did not experience outages and those who went through longer-than-average outages. Finally, yellow dots present the *p-values* between the shorter and the longer outage groups. Consistently, with Figure 2a, all the covariates are not statistically different between the no outage and the longer outage groups comparison or between the shorter and longer outage group comparison. Furthermore, all the 16 covariates show to be not statistically significant between the no outage and the shorter outage group.[3]

[**FIGURE 2: Balance checks for demographic variables between households with and without outages**]

5 Model Specification and Empirical Results

5.1 Mixed Logit Model

This section outlines the specification and estimation of the discrete choice models that have been adopted to examine respondents' choices among a fixed set of options, suggested by McFadden (1973) random utility theory (RUT).[4] In each conjoint experiment, respondent i

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[3] Table A1 in the appendix shows in detail the distribution of the covariates analyzed in this section by group.

[4] RUT is based on the assumption that individuals will make decisions based on the characteristics with a stochastic component (a certain level of randomness) that exists due to random preferences or the unavailability of information to control for respondent's decisions.

makes a decision based on $J = 2$ choices. Each respondent takes a series of $T = 4$ experiments. As a result, the utility U derived from respondent i's choice of alternative j in an experiment t can be written as follows:

$$U_{ijt} = x_{ijt}\beta_i + \epsilon_{ijt}, \tag{8}$$

where x_{ijt} is a vector of alternative-specific variables, and ϵ_{ijt} is assumed to be distributed as iid extreme value which is independent of β_i (McFadden and Train, 2000). We apply a mixed logit model, where the coefficient vector β_i in equation (8), called random coefficients, are different across respondents due to unobservable factors, such as tastes and preferences.[5]

The random parameters β_i in the utility function (8) are assumed to be distributed as $\beta_i \sim f(\beta, \theta)$, where θ is a vector of the parameters of the distribution of β. For example, if the random coefficients β_i is distributed as normal, i.e., $\beta_i \sim N(b, \Sigma)$, where Σ is the variance-covariance matrix, it implies that the random parameters β_i are assumed to be conditionally drawn from the density function $N(b, \Sigma)$ (see Mehndiratta, 1996; Bolduc and Ben-AkiWand, 1996; Revelt and Train, 1998; Greene, 2011). Intuitively, if β_i is specified to be non-random and identical for all respondents, then $\beta_i = b$ for all respondents. On the other hand, in the mixed logit model, β_i is treated as a random parameter and is specified to be normally distributed across respondents.

Given the error term ϵ_{ijt} is an iid extreme value and independent of $\beta_{i,}$ the conditional probability that respondent i chooses j from a set of J alternatives in experiment t, given β_i, is a standard logit model:

$$P_{ijt|\beta_i} = \exp(x_{ijt}\beta_i) / \sum_{k=1}^{J} \exp(x_{ikt}\beta_i). \tag{9}$$

As β_i is a random coefficient distributed as $f(\beta, \theta)$ across respondent i, the choice probabilities are the standard logistic probabilities integrated over the density $f(\beta, \theta)$:

$$P_{ijt} = \int P_{ijt|\beta_i} f(\beta, \theta)\, d\beta. \tag{10}$$

Equation (10) represents the mixed logit model, where P_{ijt} is defined as the probability of choosing alternative j for respondent i in experiment t. Due to not closed-form solution for the integral, equation (10) is approximated by maximum simulated likelihood where β_i are randomly drawn from the specified distribution.

5.2 Mixed Logit Results

Table A2 presents the results of the mixed logit model estimating respondents' choice on policy attributes related to costs, outage duration, and severe-weather-protecting policy options. Note that the baseline conditions for the choice attributes are in the status quo, as shown in Table 2.

The significant negative coefficients on the cost and outage attributes in the baseline model of Table A2 suggest that respondents dislike increases in costs and power outages of any duration from full service. Unsurprisingly, this suggests that respondents prefer lower costs and outages of shorter duration. Nevertheless, respondents are willing to pay more to see policies

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[5] See (Train, 2009) for the detailed discussion on the mixed logit model.

implemented to protect the grid from severe weather in the future. The significant positive coefficients for the policy attributes reveal that respondents prefer to have better policies implemented to protect the Texas electric grid if the cost and outage attributes remain unchanged.

We then divide the sample into three groups of respondents: (1) households that did not experience a power outage, (2) households that experienced power outages that lasted shorter than average, and (3) those who experienced power outages lasting longer than average. As expected, increases in the cost of electricity per kWh and duration of the outage decrease respondents' utility. By contrast, the positive sign of the coefficients for the policy options suggests the respondents valued (positively) these policies relative to doing nothing.

Our results also show that the households that did not experience any outages and those with shorter-than-average outages have similar preferences regarding the attributes on cost, outage duration, and electricity grid protection policies. However, among respondents experiencing longer than average power outages, the coefficients on cost attributes are more negative, suggesting a greater loss of utility than the other two groups.

[TABLE A2: Policy Preferences on Protecting the Texas Electrical Grid from Severe Weather]

Figure 3 shows a large variance in the relative importance of the three attributes across the three outage groups. Relative importance was calculated by subtracting the difference between the largest and smallest coefficients for each attribute in Table 4, divided by the sum of the ranges of the three attributes. Consistent with other studies in the literature, we find that duration of the outage proved to be the attribute with the highest relative importance in the profiles, followed by cost and the policy proposed.

[FIGURE 3: Relative Importance between Outages, Cost and Policy (No Outages, Shorter Outages, and Longer Outages)]

Table 3 reproduces the results for the mixed logit for respondents' choice. The models have been estimated as a function of respondents' change in annual electricity expenditure (in natural log) as a result of the price increases rather than the change in cost per kWh.

[6] Similar to results presented in Table A2, respondents, on average, dislike paying more for electricity, as evidenced by the negative and significant coefficients for *additional electricity expenditure*, regardless of their outage experience. However, those that experienced a longer than average outage viewed price increases more negatively than those that experienced a shorter than average outage and those that did not experience an outage.

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[6] Each respondent's additional electricity expenditure is calculated by multiplying the predicted annual consumption of electricity (ACE) (in kWh) by the cost per kWh required for the policy described in Table 2. The predicted ACE is estimated using the 2015 Residential Energy Consumption Survey (RECS) data obtained from the U.S. Energy Information Administration (EIA). We first run a regression model of the ACE with the following demographic factors: household income, age, employment status, education, number of household members age 17 or younger, and homeowner-renter status based on the EIA data. We then predict the annual electricity consumption with the same set of demographic factors in our sample. Figure A2 in the appendix reports the distribution of the reported *ACE* from the EIA data and the predicted distribution in our sample. The Kolmogorov-Smirnov equality-of-distributions test shows that the largest difference between the two distributions is 0.0316, with the approximate asymptotic p-value of 0.424. Both distributions are *not* significantly different from each other. Finally, we generate a variable called *additional electricity expenditure* by multiplying ACE by the corresponding cost attributes in the conjoint experiment (see Table 2).

The negative and significant coefficients for outage duration suggest again that respondents prefer shorter duration outages to longer ones.[7] Finally, the positive significant coefficients for the policy proposals indicate respondents value these proposals positively and would be willing to pay more to see any of these policies implemented over doing nothing (the status quo).

To investigate if the households experiencing and without experiencing power outages have different levels of willingness to pay, we perform the likelihood ratio (LR) tests. We report the chi-square statistics of the LR tests in the last row in Table 3. We first compare the models for the households experiencing power outages and those without power outages during the winter storm. The LR test shows that both types of households (with and without power outages) are significantly different (the chi-square statistic = 30.52 with the p-value less than 1%). We then test the models between the families with shorter and those with more extended outages, on average, in the last two columns of Table 3. The LR test also shows that both groups of households have significantly different levels of willingness to pay.

[TABLE 3: Mixed Logit Estimations on the Willingness to Pay]

5.3 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. According to equation (8), the marginal willingness to pay (MWTP) for attribute k can be presented as follows:

$$MWTP_k = \frac{\partial U/\partial x_k}{-\partial U/\partial p} = \frac{\beta_k}{-\beta_p}, \tag{11}$$

where p is the price attribute, which in this case is the change in the amount customers pay on electricity per year (in log). Equation (11) suggests that the MWTP for a change in a specific attribute k can be calculated as the marginal rate of substitution (MRS) between the additional electricity payments (i.e., p) and the amount expressed by the specific attribute (i.e., x_k), holding the utility level constant.

The results from Table 3 are used to compute the amount more or less than respondents are willing to pay to reduce outages and for policies aimed at protecting the grid from the effects of severe weather in the future.

Figures 4 and 5 plot the estimated MWTP coefficients. Negative signs for the coefficients in the first row of the figures indicate that respondents - regardless of whether they experienced an outage or its duration - are willing to pay to *reduce* outage duration. However, the MWTP among households that experienced a longer than average outage is lower than for the two other groups. For the four policy proposals, the MWTP coefficients imply that individuals are willing to pay more on their annual electricity bills to see these proposals implemented. The estimated MWTP coefficients also reveal the important influence of respondents' experience during Winter Storm Uri, namely whether and for how long they lost power. Individuals who

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[7] The variable of outage duration is specified in natural logarithmic form. As the outage length in the conjoint analysis has four attribute levels: full service (no interruptions), rolling blackouts or intermittent service on-and-off for up to 2 hours, rolling blackouts or intermittent service on and off from 2 up to 12 hours, and power outage for more than 12 hours. We restrict the maximum length of the outage to 48 hours. The outage variable is defined as ln(outage length+1) in this study.

reported experiencing a longer than average power outage consistently revealed lower MWTP than the other two groups.

The left panel of Figure 5 shows that the MWTP for those that did not experience an outage and those that experience a shorter than average power outage are similar for three of the policies. For the policy of increasing renewable energy supply, the MWTP is slightly lower, but this difference is not statistically significant. From the right panel, we can see that the MWTP for merging the Texas electrical grid with one of the nation's two other grids is the same for those that did not experience an outage and those that experienced a longer than an average outage. The right panel of Figure 5 also shows the significant effect of the outage experience. The estimated MWTP coefficients of those who experienced a longer than average outage are significantly lower for increasing renewable energy supply and maintaining a minimum reserve capacity than those who did not experience any power outages.

[FIGURE 4: Estimated Marginal Willingness to Pay between Households With and Without Outages]

[FIGURE 5: Estimated Marginal Willingness to Pay (No Outages, Shorter Outages, and Longer Outages)]

The estimated MWTP for three of the policies for those that experienced shorter than the average power outages is higher than for the two other groups. The exception is increasing the renewable energy supply, for which the MWTP is the highest among individuals who did not experience an outage of any length. The MWTP of those that experienced shorter than the average outage is almost three times that of those that experienced longer than the average outage when considering the policy of maintaining a minimum reserve capacity.

To interpret the results, we multiply the estimated MWTP for each of the four policy areas by the average total cost of \$106.69, which allows us to see the change in the amount respondents would be willing to pay on their electricity bills annually.[8] For example, an individual who experienced a longer than average outage is willing to pay \$242.86 more annually to increase the renewable energy supply, compared to \$617.35 more for those that did not experience an outage during Winter Storm Uri. To increase the renewable energy supply, those that experienced a shorter than average outage are willing to pay \$404.66 more annually.

Finally, Figure 6 plots the marginal willingness to pay for each of the four policy proposals.[9] The figure graphs the amount on average respondents in each of the three groups would be willing to pay in kWh to implement the policies and reduce outage duration. For example, respondents who experienced a longer than average outage are willing to pay about 2 cents more per kWh to see a policy implemented that requires the winterization of the electricity

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[8] Recall the marginal willingness to pay (equation (11)) is presented as follows: $MWTP_k = [\partial U/\partial x_k] / [-\partial U/\partial p] = \beta_k (-\beta_p)^{-1}$, where p is defined as the additional electricity expenditure (in log) (see Footnote 6 for discussing the procedure of estimating the additional electricity expenditure in detail.) The estimated MWTP coefficients are presented in Table A5 in the appendix. Let's define p as $\ln P$, where P represents the additional electricity expenditure. We can compute the monetary value of willingness to pay for a specific proposed policy k *in a year* as $\partial P/\partial x_k = \beta_k (-\beta_p)^{-1} P$.

[9] To compute the additional payment for a specific policy per kWh instead of the total amount per year, we divide the annual additional payment by the average annual consumption of electricity ($\overline{ACE}$), that is, $\beta_k (-\beta_p)^{-1} P/\overline{ACE}$, where the amount of $P = \$106.69$ and $\overline{ACE} = 14979.44$kWh represent the average additional electricity expenditure according to the conjoint experiment and the annual average consumption of electricity, respectively. See Footnotes 8 for the further discussion on the MWTP calculation.

system, compared to 4 and 4.4 cents, respectively, for respondents that did not experience an outage and those that experienced a shorter than average outage.

[FIGURE 6: Marginal Willingness to Pay across Policy Investment (in dollars per kWh)]

The MWTP of those that experienced a longer than average outage is consistently lower than for the other two groups. The MWTP of respondents who experienced a shorter than average outage was greater than the MWTP for no outage respondents for three of the four policy options: maintaining a minimum reserve capacity, winterization, and merging the Texas grid with one of the nation's two other grids, though their estimated MWTP coefficients are similar for both minimum reserve capacity and winterization. Only for increasing the renewable energy supply is the MWTP of no outage respondents noticeably larger than for shorter outage respondents.

The MWTP to reduce outages by 12 hours axis shows how respondents' experiences influenced their willingness to pay to reduce the duration of outages. We find that the MWTP of those who experienced longer than average outages is lower than the other two groups. In terms of nominal value, respondents who did not experience any power outages were willing to pay extra 5.2 cents per kWh to reduce the duration of the downtime by 12 hours. This amount is higher than 3.9 cents for those that experienced a shorter than average outage and slightly more than 2 cents per kWh for respondents who experienced a longer than an average outage.

We also perform a battery of robustness checks to ensure that our results are not driven by specific locations or electricity utilities. We first estimate the WTP for different groups of households by removing one region from the sample one at a time. We consider the top-3 county with the largest GDP: Harris County, Dallas County, and Travis County.[10] Panel A in Table A3 in the appendix shows that results of the estimated WTP in the sample without the households living in Harris are generally similar to our baseline results. We find that families without experiencing power outages and those with outages shortages are willing to pay more for all different policy options than those experiencing longer-than-average power outages. These results are consistent in other sub-sample estimations where households in Dallas (Panel B) and those in Travis (Panel C) are removed from the sample.

We then explore any possible heterogeneity of the WTP for respondents subscribing to services from different transmission and distribution utilities (TDUs), which may not provide identical quality of services. In Texas, Oncor is the largest TDU, supplying electricity to over 10 million residential and commercial consumers. Its service covers over 400 regions, including Dallas, Fort Worth, Odessa, Killeen, Tyler, Wichita Falls, and Waco. The second-largest electric utility in Texas is CenterPoint Energy. It delivers electricity to the Greater Houston area and surrounding locations.

We perform a similar analysis by removing Oncor or CenterPoint Energy from the sample. The estimated results are presented in panels A and B of Table A4 in the appendix, respectively. We find that the results remain robust and similar to our previous results. In panel C, we also remove the municipal TDUs from the sample. We also see that households with outages more prolonged than average are less willing to pay extra to reduce the duration of future blackouts or other policy responses.

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[10] The county with the highest GDP in Texas is Harris County ($359.65 million), followed by Dallas County ($239,7 million), and Travis County ($115.79 million). See BEA (2021).

6 Explaining Differences in WTP

In section 3 we presented a theoretical framework aimed at explaining the relationship between outage experience and individuals' willingness to pay for improvements to the electric system. The framework is rooted in the public good features of having access to reliable electricity. We have also documented systematic differences in the willingness to pay for policies aimed at making the Texas grid more reliable and resilient to extreme weather events, natural disasters, and other potential shocks to the supply of electricity to Texas households. Our analysis suggests that those who have experienced longer outages were less willing to pay more for the menu of regulatory changes presented in the conjoint experiment.

The massive impact of the storm on the Texas grid is likely to make the vulnerabilities of the system more salient to all Texans, increasing the demand for policy interventions. Yet, those individuals who experienced no or shorter blackouts during Winter Storm Uri are more likely to hold a more positive perception about the electric system's reliability and resiliency to shocks. Those experiencing long outages, on the other hand, are more likely to lose faith in the electricity grid's reliability and less willing to contribute to the policies aimed at improving the system. Moreover, the past experience could impact respondents' perceptions about the ability of the government and the provider to deliver reliable access to electricity.

To further probe this mechanism, we analyze a series of responses to questions about who is responsible for the electric system's failure during the winter storm and who should pay for the investments needed to secure access to electricity during severe weather events and natural disasters. We find that, consistent with our expectations, those who experienced longer than average outages during Winter Storm Uri are more likely to blame electricity producers, the government, and lack of oversight as the culprits for the failures of the system than respondents who experienced shorter outages or no outages at all.[11] We also find that respondents across Texas who experienced longer outages would prefer others to pay for the extra costs from the proposed policies to the electric grid, particularly energy producers.[12]

[FIGURE 7: Perceived Responsibility of Power Outages]

Figures 7 shows whom the respondents blame for the power outage. Each figure presents on the x-axis the percentage of respondents who attribute blame for the electricity grid's failure to *Severe Weather*, the *Lack of Weatherization of Power Generators*, the *Lack of Weatherization of Natural Gas Equipment*, and the *Lack of Oversight over Power-Generation plants.* Figure 7a presents the comparison between the group that did not experience any outage and the group that experienced an outage shorter than the average. There is no statistical difference between these two groups. In contrast, Figure 7b shows that there are significant differences between the group with no outages and the group that experienced an outage longer than

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[11] The question in the survey read: *"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? Select all that apply."*. The answer options were: *Severe weather; the independence of Texas' electric grid from the nation's two other grids; lack of weatherization or winterization of power generators; lack of weatherization or winterization of natural gas industry equipment; reliance on renewable energy;* and *lack of oversight over power-generation plants.*

[12] The question about who should pay for the policy, the exact text was: *In your opinion, how do you think policies proposed to protect the Texas electric grid from effects of severe weather should be paid for?*. The answer options were: *Paid for by sales taxes; paid for by property taxes; paid for by consumers through their electricity bill; paid for by energy producers;* and *do not enact the policies to protect the Texas electric grid from severe weather.*

average. We can see that individuals who experienced longer outages are more likely to blame the companies (lack of weatherization of power generators and lack of weatherization of natural gas equipment) and the government (lack of oversight over power-generation plants) than those that did not experience any power outages during the storm.

[**FIGURE 8: Who should pay for the policy to protect the Texas Electric Grid**]

Finally, Figure 8 shows whom the respondents think should pay for the policies aimed at protecting the Texas electric grid from the effects of severe weather. We offered respondents five options, of which respondents were able to choose only one of the following: the policy should be paid with *Sales Taxes*, with *Property Taxes*, by *Consumers*, by the *Energy Providers*, and *Do not enact the policies to protect the Texas electric grid from severe weather.* Figure 8a compares the group with no outages and the group with shorter outages, while Figure 8b looks at the differences between the group with no outages and the group that experienced longer outages. We do not observe any statistical differences between these groups. We find, however, just one significant difference between the group with shorter and longer outages (not shown). Individuals who experienced longer outages are more likely to think that the energy producers should pay to implement the policies. While 51.6% of the respondents in the group that experienced longer than average outages responded that the energy producers should pay for the policy changes, just 45% of respondents in the group experiencing shorter outages agreed with that statement (p-value = 0.0377).

7 Conclusion

The intermittent and arbitrary outages caused by Winter Storm Uri in Texas motivated the study of the WTP of consumers for a higher provision and better quality of electricity (i.e., for reliable electricity). We develop a theoretical framework linking the past experience and willingness to pay for more reliant electricity services. We model the reliability of electricity services as a public good and likely to be provided at a level or quality which, for many, is unsatisfactory. In our framework, willingness to pay for interventions increasing the electricity supply is a function of individuals' past experiences with the service at times of natural disasters. We further assume that the differential experience with the blackouts affected by Winter Storm Uri had a differential impact on the underlying WTP for reliable electricity among Texans: some individuals may find access to electricity more valuable and be willing to pay more for reliable electricity service. Some individuals may realize the shortcomings of the system, and yet their evaluation of policies to improve the provision of the public good may result in a higher willingness to pay. On the other hand, those who were more affected may feel frustration and distrust with the government and the service providers, resulting in a lower willingness to pay than other individuals.

We use a choice experiment through which we proposed policy interventions aimed at improving the quality and quantity of the public good. We find that the heterogeneous experiences during the natural disaster affected individuals' willingness to pay or not to enhance reliable electricity service. In contrast to previous literature, we find that individuals who experienced a longer than average outage are willing to pay less for policies to improve the reliability of the grid. On the contrary, those with shorter outages and those who did not experience any outages are willing to pay more.

Our framework and findings have important implications for academic research on the willingness to pay for the provision of public goods and the role of past experiences. The differential impact of the length of outages helps reconcile contradictory results in earlier work on the effect of natural disasters on willingness to pay for reliable electricity and public goods in general.

Our results also highlight relevant public policy implications. Winter Storm Uri also exposed the mismatch between the electricity supply to meet the extreme demand. The current policy environment in Texas does not incentivize providers to maintain the public good reliably. During Winter Storm Uri, the government and service providers were not able to deliver a solution. This might have caused individuals to perceive a higher likelihood of the system failure in the summertime or other future scenarios where demand might surpass supply, which could, in turn, lead to lower WTP for such individuals. These findings call to reflect on how individuals, under different natural disaster experiences, decide who is to blame and how much they are WTP.

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Table 1: Descriptive Statistics for Full Sample

	Count	Mean	Std. Dev.
Married	1500	.52	.49
Family income ($1,000s)	1340	77.11	77.89
Democrat	1500	.37	.48
Republican	1500	.22	.41
Female	1500	.56	.49
White	1500	.46	.49
Black	1500	.09	.29
Hispanic	1500	.37	.48
College degree	1500	.36	.48
Full-time job	1500	.39	.48
Children under 18	1500	.27	.44
Liberal	1500	.31	.46
Conservative	1500	.30	.45

Table 2: Descriptive Statistics for 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%)	2,428	1,386	57.08
2 cents more per kWh (23%)	2,397	1,270	52.98
4 cents more per kWh (47%)	2,421	1,040	42.96
6 cents more per kWh (70%)	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 hrs	3,022	1,654	54.73
Rolling blackouts for up to 12 hrs	3,007	1,263	42.00
Power outage for more than 12 hrs	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

Table 3: Mixed Logit Estimations on the Willingness to Pay

	Baseline		Households without Power Outage		Households with a Shorter Outage on Average Power Outage		House Longe on Av Power
VARIABLE	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.
Additional electricity expenditure (log)	-0.438***	[0.075]	-0.387**	[0.109]	-0.298***	[0.082]	-0.897***
Derived standard deviations	0.576	[0.135]	0.409	[0.193]	0.426	[0.173]	1.306
Rolling blackouts/ intermittent service (log)	-1.297***	[0.173]	-1.550***	[0.361]	-0.910***	[0.177]	-1.509***
Derived standard deviations	1.698	[0.280]	2.015	[0.559]	1.173	[0.309]	1.816
Policy							
Merge the Texas electrical grid with one of the two national grids	1.390***	[0.153]	1.029***	[0.261]	1.154***	[0.205]	2.274***
Require the winterization/ weatherization of the electricity system	2.142***	[0.185]	2.173***	[0.345]	1.855***	[0.252]	2.612***
Maintain a minimum reserve capacity	1.506***	[0.161]	1.722***	[0.322]	1.414***	[0.223]	1.505***
Increase the renewable energy supply	1.682***	[0.167]	2.241***	[0.353]	1.132***	[0.206]	2.047***
Log simulated-likelihood	-3351.318		-1046.542		-1232.304		-1
Number of observations	12,000		3,888		4,264		
[1]LR test for the equality of two models (χ^2-statistics)					24.35 (p-value = 0.000)		31.41 (p-

Notes: * 10% significance level; ** 5% significance level; *** 1% significance level, two-tailed tests. [1]The baseline model for the LR tests is H
Power Outage.

Figures

Figure 1: Geographical Distribution of Electricity Outages

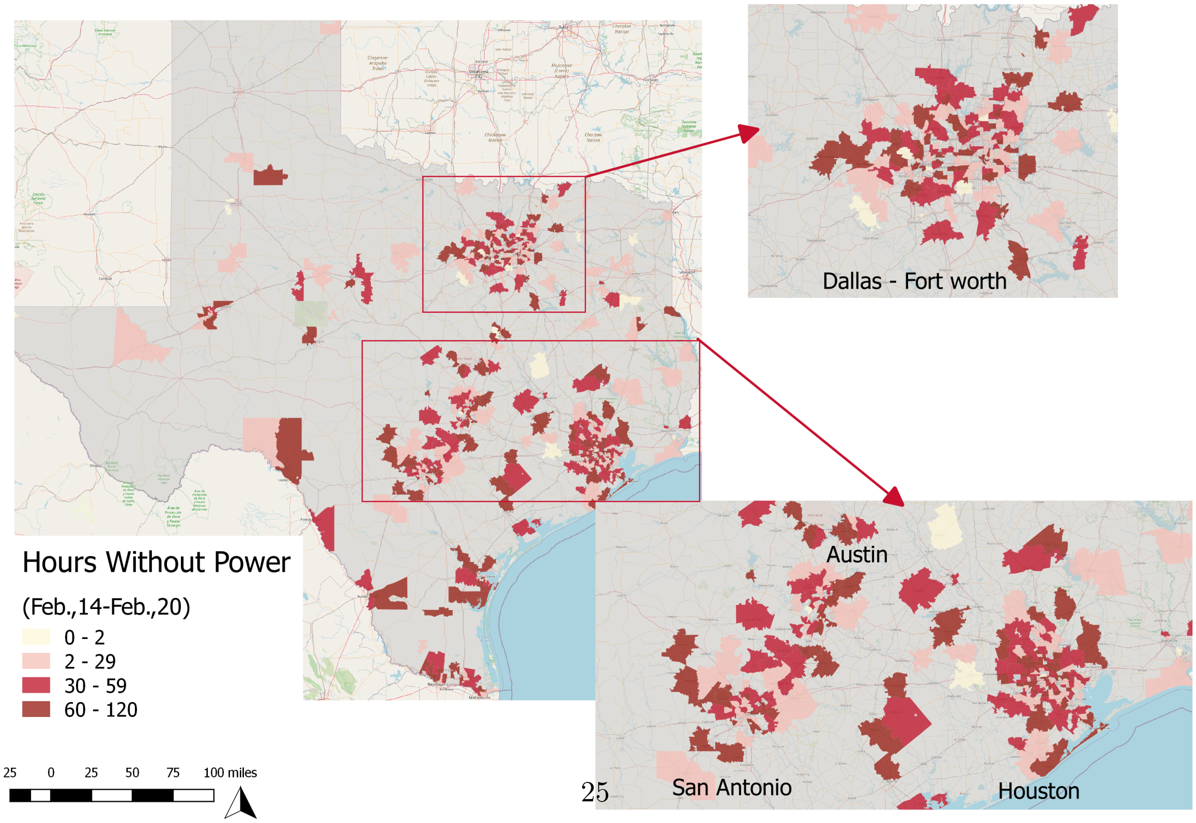
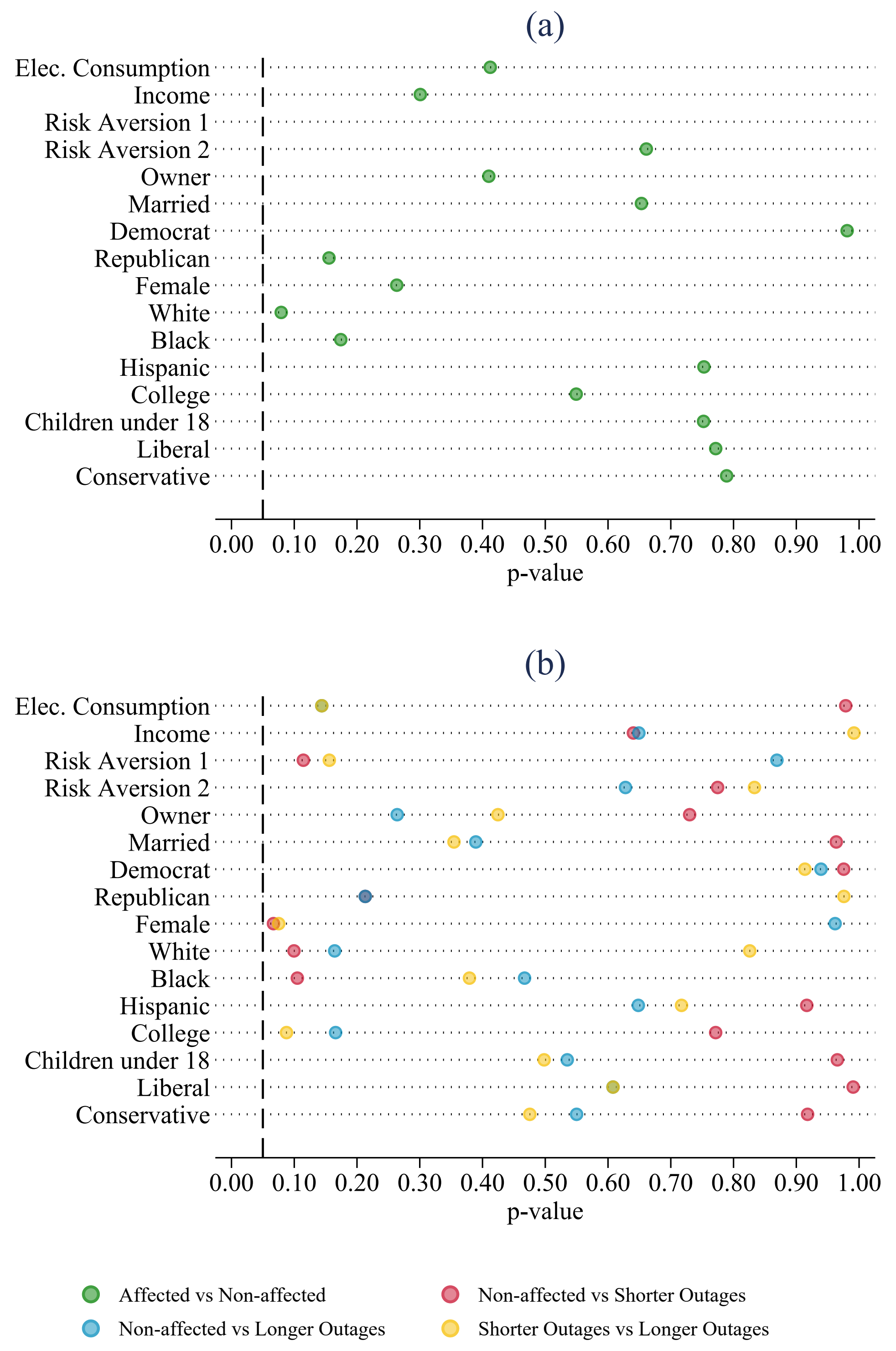


Figure 2: Balance Checks for Demographic Variables between Households With and Without Outages



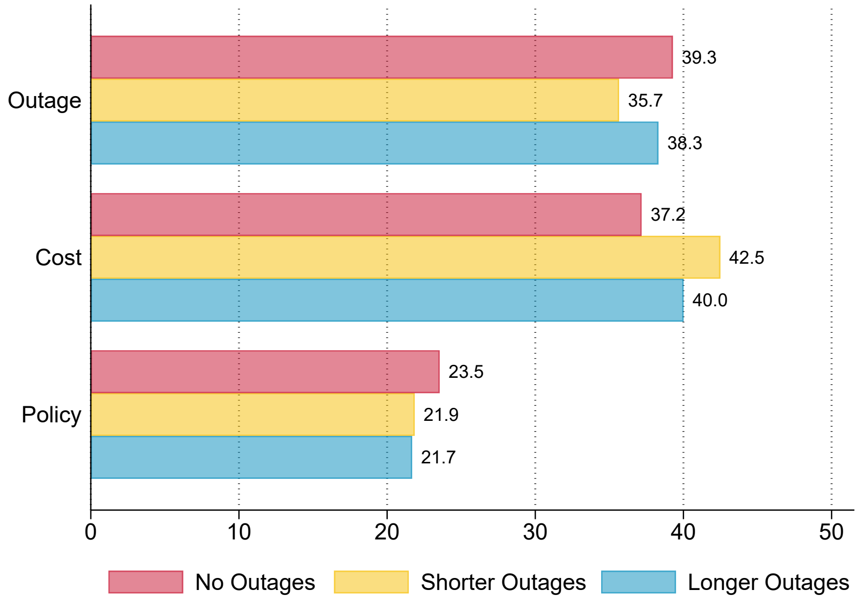


Figure 3: Relative Importance between Outages, Cost and Policy (No Outages, Shorter Outages, and Longer Outages)

Figure 4: Estimated Marginal Willingness to Pay between Households With and Without Outages

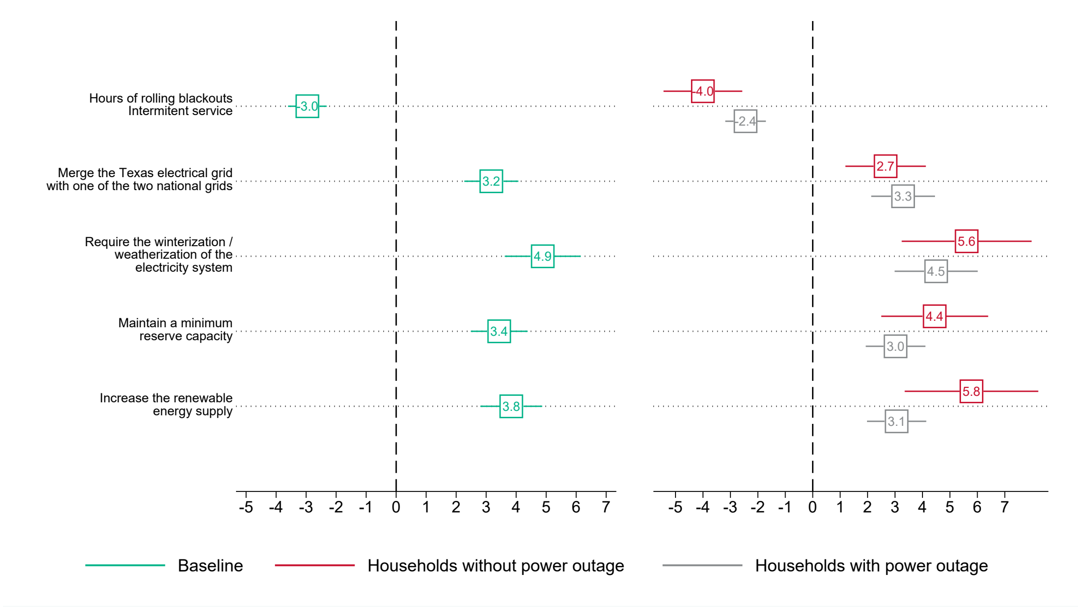
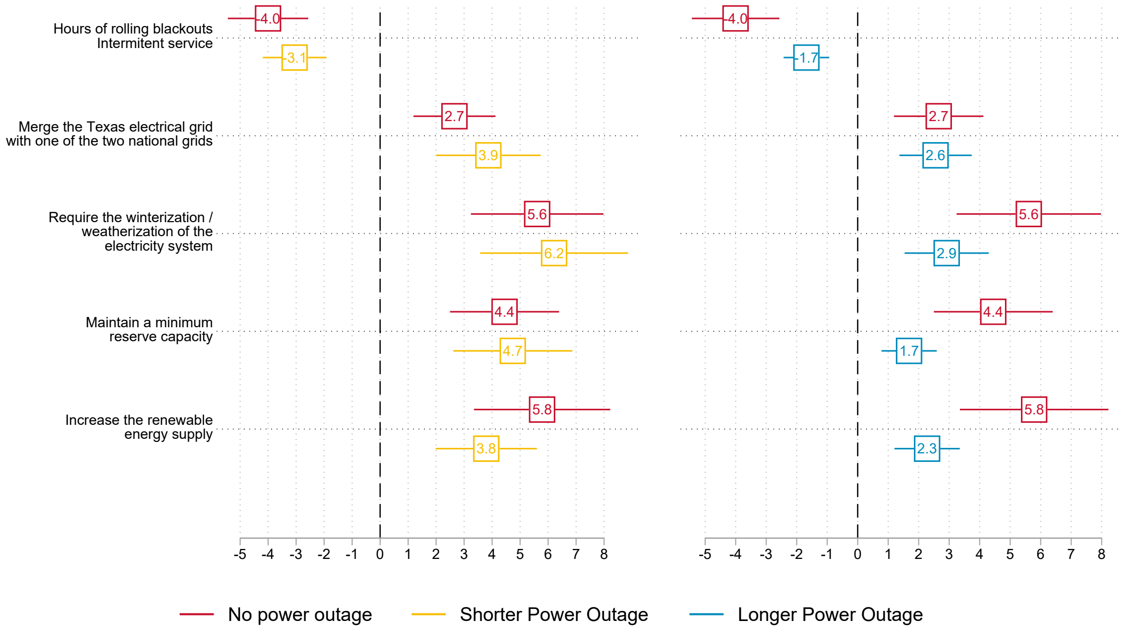


Figure 5: Estimated Marginal Willingness to Pay (No Outages, Shorter Outages, and Longer Outages)



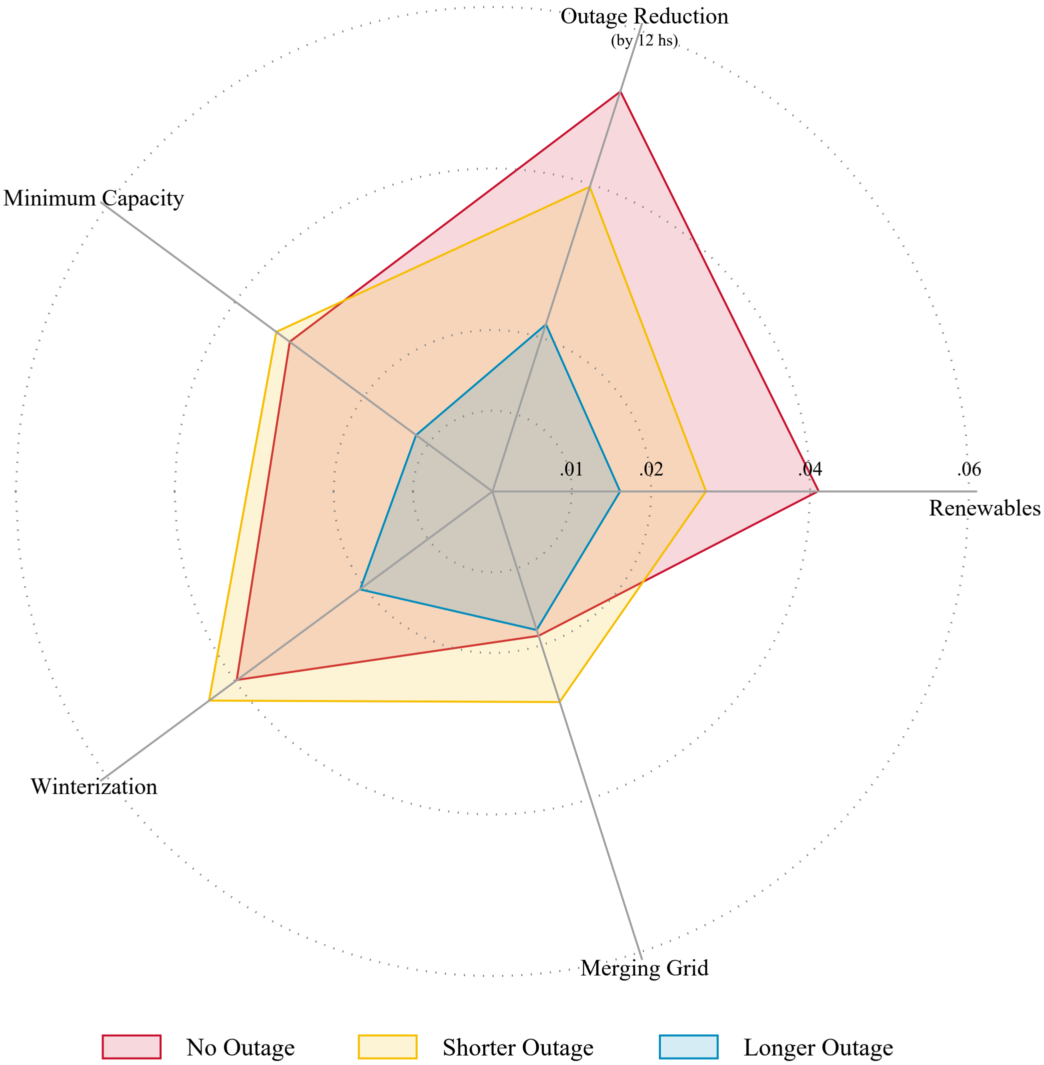


Figure 6: Marginal willingness to pay across policy investment (in dollars per kWh)

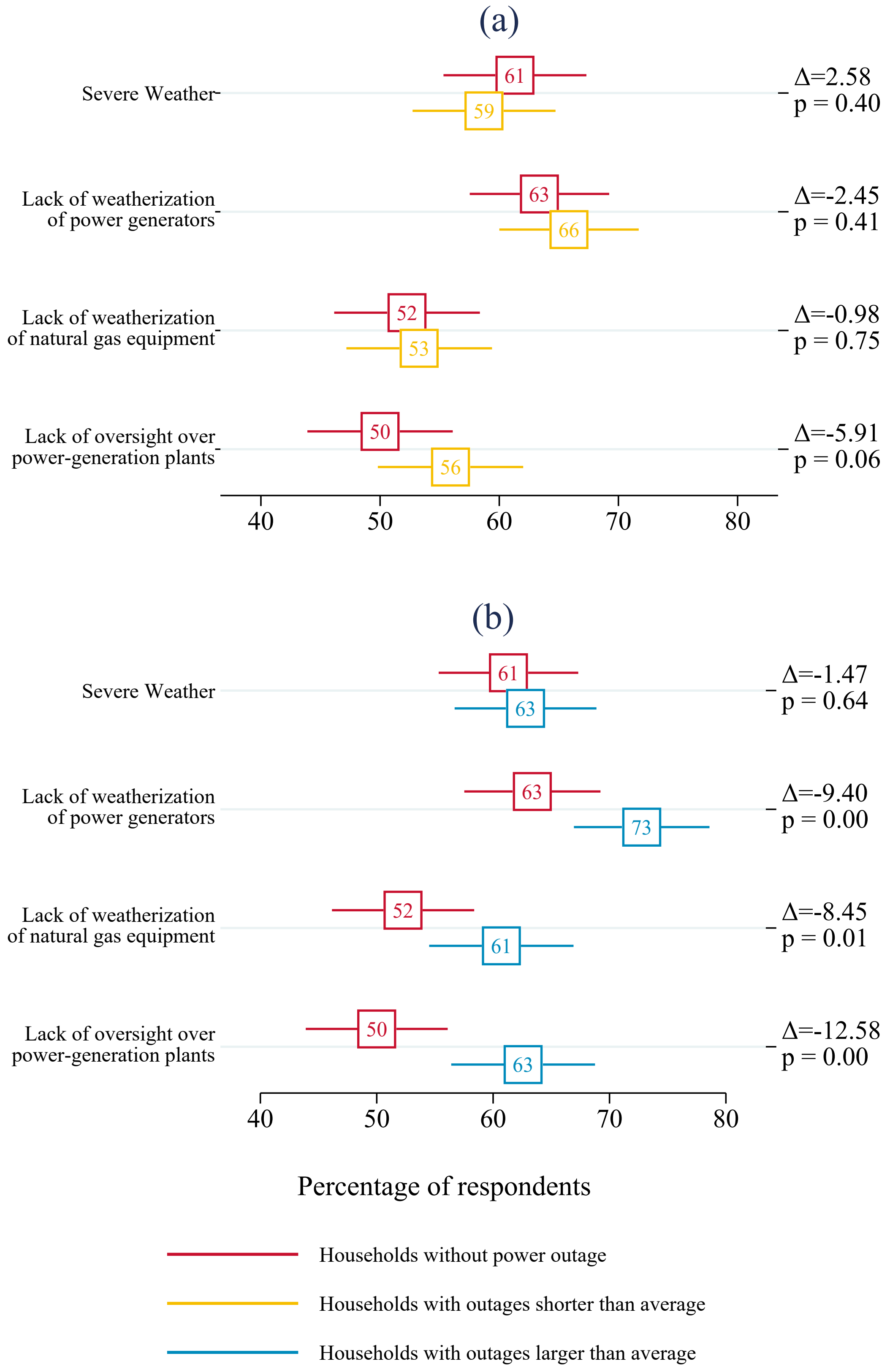
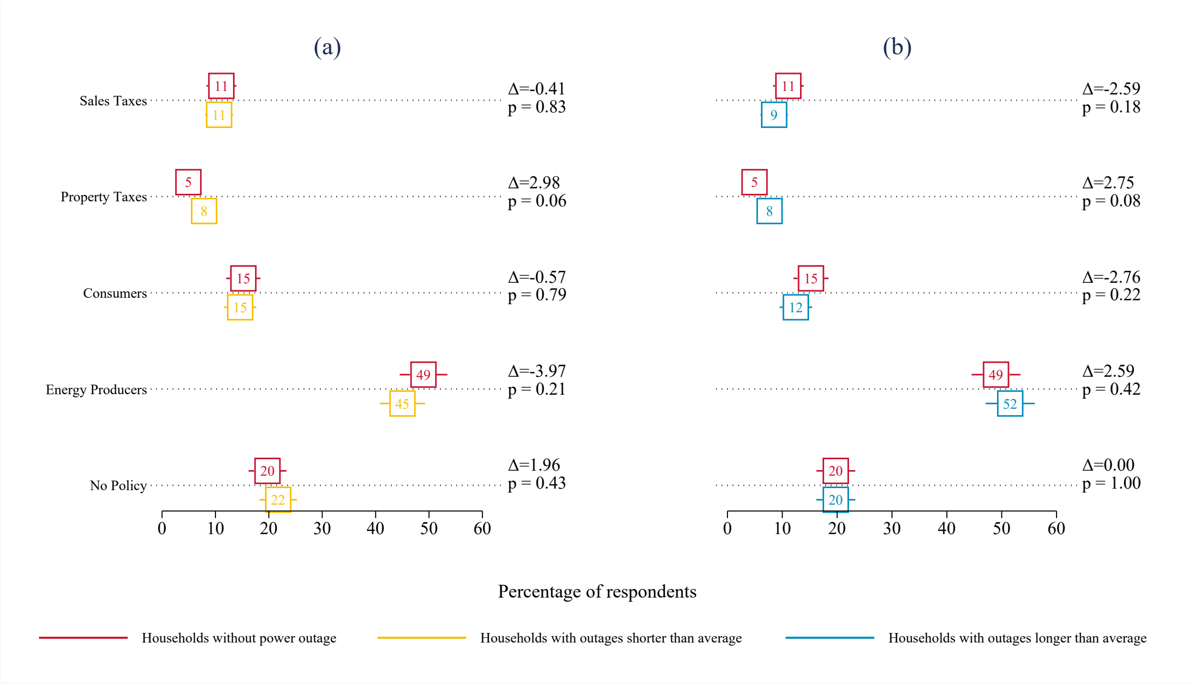


Figure 7: Perceived responsibility of power outages

Figure 8: Who should pay for the policy to protect the Texas Electric Grid



8 Appendix

Data and Choice Experiment

Data come from a survey fielded online between May 13-24, 2021 by YouGov. The survey included a sample of 1,500 respondents representative of residents in the state of Texas. The survey asked Texans about their experiences during Winter Storm Uri, their confidence in state leaders and existing laws and regulations to address the vulnerabilities in Texas' electric system, their tolerance for power outages and higher prices, the importance of a secure and reliable electricity supply, as well as their willingness to pay for the required policy interventions to make the grid more resilient to the effects of severe weather events.

To design the choice experiment, we relied on the empirical literature on willingness to pay (WTP) for public goods. Within the electricity WTP literature, common attributes were outage length, cost, source of energy, timing of outage, notifications, and policies. For the policy attributes, we presented respondents with five different options, which included the *status quo* - doing nothing or no new investment. The four policy proposals that respondents were presented with were based on the policies discussed in policy circles in the aftermath of Winter Storm Uri to protect the Texas interconnection from the effects of future severe weather. The proposals, which were widely covered in the media included: (1) merging the Texas electrical grid with one of the two national grids; (2) requiring the winterization of the electricity system, including at gas wellheads and processing plants; (3) maintaining a minimum reserve capacity; and (4) increasing the renewable energy supply.

Following previous studies Abdullah and Mariel (2010); Carlsson and Martinsson (2008);

Morrison and Nalder (2009); Ozbafli and Jenkins (2016), we characterized reliability as outage duration with four attribute levels: (1) full service (no interruptions); (2) rolling blackouts or intermittent service on and off for up to 2 hours; (3) rolling blackouts or intermittent service on and off from 2 up to 12 hours; and (4) power outage for more than 12 hours.

Finally, we chose cost attribute levels based on the average cost of electricity in the state of Texas in 2019. According to the US Energy Information Administration (EIA), Texans paid about 8.36 cents per kWh or about $103 per month on electricity. Based on an average of 8.36¢, the levels for the increase in cost per kWh were: (1) no increase in cost per kWh; (2) one cent more per kWh (12% increase over the 2019 average household electricity bill); (3) two cents more per kWh (23% increase); (4) four cents more per kWh (47% increase); and (5) six cents more per kWh (70% increase). Figure A1 presents an example choice set from the conjoint choice experiment as shown to respondents. Each respondent was asked to choose between different policy alternatives of randomly generated attribute levels. The full factorial for this study yielded 100 profiles (i.e., $5 \times 4 \times 5$), which includes 4,950 pairs (i.e., $100 \times 99/2$).

Mixed Logit Model

Table A2 presents the results of the mixed logit model estimating respondents' choice on policy attributes related to costs, outage duration, and severe-weather-protecting policy options. Note that the baseline conditions for the choice attributes are the status quo as shown in Table 1 of the main text. As expected, increases in the cost of electricity per kWh and duration of the outage decrease respondents' utility. By contrast, the significant positive coefficients for the policy attributes reveal that respondents prefer to have policies implemented to protect the Texas electric grid, if the cost and outage attributes remain unchanged, over doing nothing.

We also estimate mixed logit models for each of the three subsamples: (1) households that did not experience a power outage; (2) households that experienced power outages that lasted shorter than average; and (3) those who experienced power outages lasting longer than average. The results show that the households that did not experience any outages and those with shorter-than-average outages have similar preferences regarding the attributes for cost, outage duration, and electricity grid protection policies. However, among respondents experiencing longer than average power outages, the coefficients on cost attributes are more negative, suggesting a greater loss of utility compared to the other two groups.

Figure 3 shows a large variance in the relative importance of the three attributes across the three outage groups. Relative importance was calculated by subtracting the difference between the largest and smallest coefficients for each attribute in Table A2, divided by the sum of the ranges of the three attributes. Consistent with other studies in the literature, we find that duration of the outage proved to be the attribute with the highest relative importance in the profiles, followed by cost and the policy proposed.

Estimating Additional Electricity Expenditure

The mixed logit models in Table 3 in the main text are estimated as a function of respondents' change in annual electricity expenditure (in natural log) as a result of the price increases. Each respondent's additional electricity expenditure is calculated by multiplying the predicted annual consumption of electricity (ACE) (in kWh) by the cost per kWh required for the proposed policy. We estimated the predicted ACE using the 2015 Residential Energy Consumption Survey (RECS) data obtained from the US Energy Information Administration (EIA). To estimate, we first developed a regression model of the ACE with the following demographic factors: household income, age, employment status, education, number of household members age 17 or younger, and homeowner-renter status based on the EIA data. We then predicted the annual electricity consumption with the same set of demographic factors in our sample.

Finally, we compared the distribution of the reported ACE from the EIA data with the predicted distribution in our sample. Figure A2 shows the distribution of the reported ACE from the EIA data and the predicted distribution in our sample. The Kolmogorov-Smirnov equality-of-distributions test shows that the largest difference between the two distributions is 0.0316, with the approximate asymptotic p-value of 0.424, meaning that the two distributions are *not* significantly different from each other. Finally, we generated a variable called *additional electricity expenditure* by multiplying ACE by the corresponding cost attributes in the conjoint experiment which are shown Table 1 in main text. This new variable, *additional electricity expenditure* is then used to estimate the models in Table 3 of the main text.

Estimating Marginal Willingness To Pay

The marginal willingness to pay (MWTP) for attribute k can be calculated based on Eq. (1) in the main text as:

$$MWTP_k = \frac{\partial U/\partial x_k}{-\partial U/\partial p} = \frac{\beta_k}{-\beta_p}, \tag{4}$$

where β represents the estimated coefficients from the mixed logit model (Table 3 in main text), p is the price attribute, which in this case is the change in the amount customers pay on electricity per year (in log). (11) suggests that the MWTP for a change in a specific attribute k can be calculated as the marginal rate of substitution (MRS) between the additional electricity payments (i.e., p) and the amount expressed by the specific attribute (i.e., x_k), holding the utility level constant.

The estimated MWTP coefficients are presented in Table A5. We can compute the monetary value of willingness to pay for a specific proposed policy k *in a year* as $\partial P/\partial x_k = \beta_k \left(-\beta_p\right)^{-1} P$, where $p = \ln P$. To compute the additional payment for a specific policy per kWh instead of the total amount per year, we divide the annual additional payment by the average annual consumption of electricity ($\overline{ACE}$), that is, $\beta_k \left(-\beta_p\right)^{-1} P/\overline{ACE}$, where the amount of $P = \$106.69$ and $\overline{ACE} = 14979.44$ kWh represent the average additional electricity expenditure according to the conjoint experiment and the annual average consumption of electricity, respectively.

Figures 4 and 5 plot the estimated MWTP coefficients. The left panel of Figure 4 describes the MWTP based on all households in the sample, and the right panel presents the MWTP by separating the households without power outage (in red) from those with power outage (in gray). In Figure 5, we further compare the estimated MWTP in the three groups/subsamples: households without outages, households with shorter-than-average power outage, and households with longer-than-average power outage. Negative signs for the coefficients in the first row of the figures indicate that respondents - regardless of whether they experienced an outage or its duration - are willing to pay to *reduce* outage duration. We note that the variable of outage duration is specified in natural logarithmic form. The outage length in the conjoint analysis has four attribute levels: full service (no interruptions), rolling blackouts or intermittent service on-and-off for up to 2 hours, rolling blackouts or intermittent service on and off from 2 up to 12 hours, and power outage for more than 12 hours. We restrict the maximum length of the outage to 48 hours. The outage variable is here defined as ln(outage length+1). However, the MWTP among households that experienced a longer than average outage is lower than for the two other groups. For the four policy proposals, the MWTP coefficients imply that individuals are willing to pay more on their annual electricity bills to see these proposals implemented. The estimated MWTP coefficients also reveal the important influence of respondents' experience during Winter Storm Uri, namely, whether and for how long they lost power. Individuals who reported experiencing a longer-than-average power outage consistently revealed lower MWTP than the other two groups.

The left panel of Figure 5 shows that the MWTP for those that did not experience an outage and those that experienced a shorter-than-average power outage are similar for three of the policies. For the policy of increasing renewable energy supply, the MWTP is slightly lower, but this difference is not statistically significant. From the right panel, we can see that the MWTP for merging the Texas electrical grid with one of the nation's two other grids is the same for those that did not experience an outage and those that experienced a longer than an average outage. The right panel of Figure 5 also shows the significant effect of the outage experience. The estimated MWTP coefficients of those who experienced a longer-than-average outage are significantly lower for increasing renewable energy supply and maintaining a minimum reserve capacity than those who did not experience any power outages.

The estimated MWTP for three of the policies for those that experienced shorter-than-average power outages is higher than for the two other groups. The exception is increasing the renewable energy supply, for which the MWTP is the highest among individuals who did not experience an outage of any length. The MWTP of those that experienced shorter than the average outage is almost three times that of those that experienced longer than the average outage when considering the policy of maintaining a minimum reserve capacity.

Robustness Checks

Table A3 presents mixed logit results when we removed one of the top three counties in Texas (Harris, Dallas, Travis). Panel A in Table A3 shows that the results of the estimated WTP in the sample without households living in Harris are generally similar to our baseline results as shown in Table A2 and Table 3 in the main text. We find that those who did experience power outages and those with outages shorter-than-average are willing to pay more for all different policy options than those who experienced longer-than-average power outages. These results are consistent in other sub-sample estimations where households in Dallas County (Panel B) and those in Travis County (Panel C) are removed from the sample.

We also examine possible heterogeneity in respondents' WTP as a function of their subscriptions to different transmission and distribution utilities (TDUs), which likely do not provide identical quality of services. As noted in the main text, we examine the two biggest TDUs in Texas: (1) Oncor which is the largest and covers 400+ regions inlcuding Dallas and (2) CenterPoint Energy which covers Greater Houston and surrounding areas. We perform a similar analysis to Table A3 by removing Oncor and CenterPoint Energy respondents from the sample one at a time. The estimated results are presented in Panels A and B of Table A4. We find that the results remain robust and similar to our previous results. We see that households with outages longer-than-average are less willing to pay to reduce the duration of future blackouts compared to those who experienced shorter-than-average outages and those that did not experience any outages. Finally, in Panel C, we remove the municipal TDUs from the sample;

again, we find similar results to previous specifications.

Table A1: Descriptive Statistics by Treatment Group (Balance Check)

	Full Sample			**No Outage**		
	No.	Mean	S.D.	No.	Mean	S.D.
Owner	1500	0.61	0.49	486	0.63	0.48
E.C.	1500	14.97	8.49	486	15.23	8.51
Married	1500	0.52	0.49	486	0.54	0.50
Income	1340	77.11	77.88	436	75.52	68.95
Democrat	1500	0.37	0.48	486	0.37	0.48
Republican	1500	0.22	0.41	486	0.21	0.40
Female	1500	0.56	0.49	486	0.55	0.50
White	1500	0.46	0.49	486	0.50	0.50
Black	1500	0.09	0.29	486	0.08	0.28
Hispanic	1500	0.37	0.48	486	0.37	0.48
College	1500	0.36	0.48	486	0.35	0.48
Children	1500	0.27	0.44	486	0.28	0.45
Liberal	1500	0.31	0.46	486	0.32	0.47
Conservative	1500	0.30	0.45	486	0.31	0.46
Risk Aversion 1	1,141	0.27	0.45	363	0.25	0.44
Risk Aversion 2	1,499	0.24	0.43	486	0.23	0.42
Observations	1,500			486		

	Affected by Shorter outage			**Affected by Longer outage**		
	No.	Mean	S.D.	No.	Mean	S.D.
Owner	533	0.62	0.49	481	0.59	0.49
E.C.	533	15.22	8.58	481	14.44	8.38
Married	533	0.54	0.50	481	0.51	0.50
Income	472	77.90	82.91	432	77.84	80.80
Democrat	533	0.37	0.48	481	0.37	0.48
Republican	533	0.24	0.43	481	0.24	0.43
Female	533	0.60	0.49	481	0.55	0.50
White	533	0.45	0.50	481	0.46	0.50
Black	533	0.11	0.32	481	0.10	0.29
Hispanic	533	0.37	0.48	481	0.38	0.49
College	533	0.35	0.48	481	0.40	0.49
Children	533	0.29	0.45	481	0.27	0.44
Liberal	533	0.32	0.47	481	0.31	0.46
Conservative	533	0.31	0.46	481	0.29	0.45
Risk Aversion 1	407	0.30	0.46	371	0.26	0.44
Risk Aversion 2	533	0.24	0.43	480	0.25	0.43
Observations	533			481		

Notes: E.C. stands for electricity consumption (in 1,000 kWh), Income is measured in $1,000.

Table A2: Preferences for Protecting the Texas Electrical Grid from Severe Weather

	Baseline		Households without Power Outage		Households with a Shorter Outage on Average Power Outage		Households with a Longer Outage on Average Power Outage	
VARIABLE	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.
Cost								
1 cent more per kWh	-0.2363***	[0.067]	-0.2231*	[0.117]	-0.1620**	[0.081]	-0.3452***	[0.121]
2 cents more per kWh	-0.4511***	[0.069]	-0.4352***	[0.122]	-0.3983***	[0.083]	-0.5585***	[0.124]
4 cents more per kWh	-0.9139***	[0.071]	-0.9215***	[0.121]	-0.7481***	[0.084]	-1.1350***	[0.138]
6 cents more per kWh	-1.3240***	[0.078]	-1.3358***	[0.132]	-1.1640***	[0.092]	-1.5684***	[0.143]
Outage								
Rolling blackouts/ intermittent service:								
On and off for up to 2 hours	-0.7659***	[0.062]	-0.8181***	[0.115]	-0.8178***	[0.076]	-0.7033***	[0.112]
On and off for up to 12 hours	-1.3373***	[0.067]	-1.5219***	[0.122]	-1.3103***	[0.080]	-1.2637***	[0.124]
For more than 12 hours	-1.8117***	[0.079]	-1.9937***	[0.143]	-1.6587***	[0.096]	-1.8743***	[0.143]
Policy								
Merge the Texas electrical grid with one of the two national grids	0.7527***	[0.077]	0.5016***	[0.140]	0.7341***	[0.095]	1.0474***	[0.134]
Require the winterization/ weatherization of the electricity system	1.2141***	[0.075]	1.2061***	[0.137]	1.2206***	[0.094]	1.2499***	[0.127]
Maintain a minimum reserve capacity	0.7799***	[0.069]	0.8458***	[0.127]	0.8870***	[0.086]	0.5870***	[0.115]
Increase the renewable energy supply	0.9268***	[0.076]	1.2063***	[0.147]	0.7050***	[0.095]	0.9453***	[0.129]
Log simulated-likelihood	-3302.2572		-1033.2351		-1208.3864		-1030.0036	
Number of Observations	12,000		3,888		4,264		3,848	

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

Table A3: Robustness Check on Marginal Willingness to Pay - Subregion Regressions

	Baseline	Households without power outage	Households with outages shorter than average	Households with outages longer than average
A. Removing Harris from the sample				
Hours of rolling blackouts/ intermittent service	-3.1325***	-3.9129***	-3.1479***	-2.0979***
	[0.359]	[0.709]	[0.642]	[0.721]
Policy response/ investment				
Merge the Texas electrical grid with one of the two national grids	3.2255***	2.4592***	3.9258***	3.1526***
	[0.494]	[0.715]	[1.030]	[1.079]
Require the winterization/ weatherization of the electricity system	5.3262***	5.2634***	7.1011***	3.7354***
	[0.721]	[1.150]	[1.593]	[1.328]
Maintain a minimum reserve capacity	3.7637***	4.402202	4.9385***	2.1208***
	[0.548]	[0.988]	[1.204]	[0.844]
Increase the renewable energy supply	4.2195***	5.567897	3.8653***	3.0351***
	[0.592]	[1.203]	[1.005]	[1.057]
Number of observations	10,024	3,768	3,440	2,816
B. Removing Dallas from the sample				
Hours of rolling blackouts/ intermittent service	-2.8881***	-3.6754***	-2.9278***	-1.8261***
	[0.323]	[0.693]	[0.572]	[0.422]
Policy response/ investment				
Merge the Texas electrical grid with one of the two national grids	3.2669***	2.5223***	4.0070***	2.8415***
	[0.470]	[0.714]	[1.008]	[0.659]
Require the winterization/weatherization of the electricity system	5.0353***	5.2811***	6.3353***	3.2176***
	[0.652]	[1.187]	[1.376]	[0.762]
Maintain a minimum reserve capacity	3.5348***	3.9108***	4.9011***	1.9906***
	[0.491]	[0.935]	[1.119]	[0.522]
Increase the renewable energy supply	3.8120***	4.9543***	3.8724***	2.5079***
	[0.523]	[1.183]	[0.954]	[0.590]
Number of observations	11,064	3,544	3,944	3,576
C. Removing Travis from the sample				
Hours of rolling blackouts/intermittent service	-3.0137***	-4.2176***	-3.2283***	-1.4729***
	[0.348]	[0.852]	[0.618]	[0.424]
Policy response/investment				
Merge the Texas electrical grid with one of the two national grids	2.9808***	2.2674***	4.0387***	2.1777***
	[0.465]	[0.736]	[1.005]	[0.622]
Require the winterization/weatherization of the electricity system	4.7490***	5.1713***	6.7272***	2.4954***
	[0.668]	[1.234]	[1.443]	[0.726]
Maintain a minimum reserve capacity	3.4420***	4.3492***	5.1831***	1.4055***
	[0.507]	[1.053]	[1.165]	[0.477]
Increase the renewable energy supply	3.6981***	5.4831***	4.0874***	1.8885***
	[0.538]	[1.291]	[1.001]	[0.545]
Number of observations	11,184	3,656	4,008	3,520

Notes: ∗ 10% significance level; ∗∗ 5% significance level; and ∗∗∗ 1% significance level, two-tailed tests. Standard errors are in parentheses.

Table A4: Robustness Check on Marginal Willingness to Pay - Subsamples of Electric Utilities

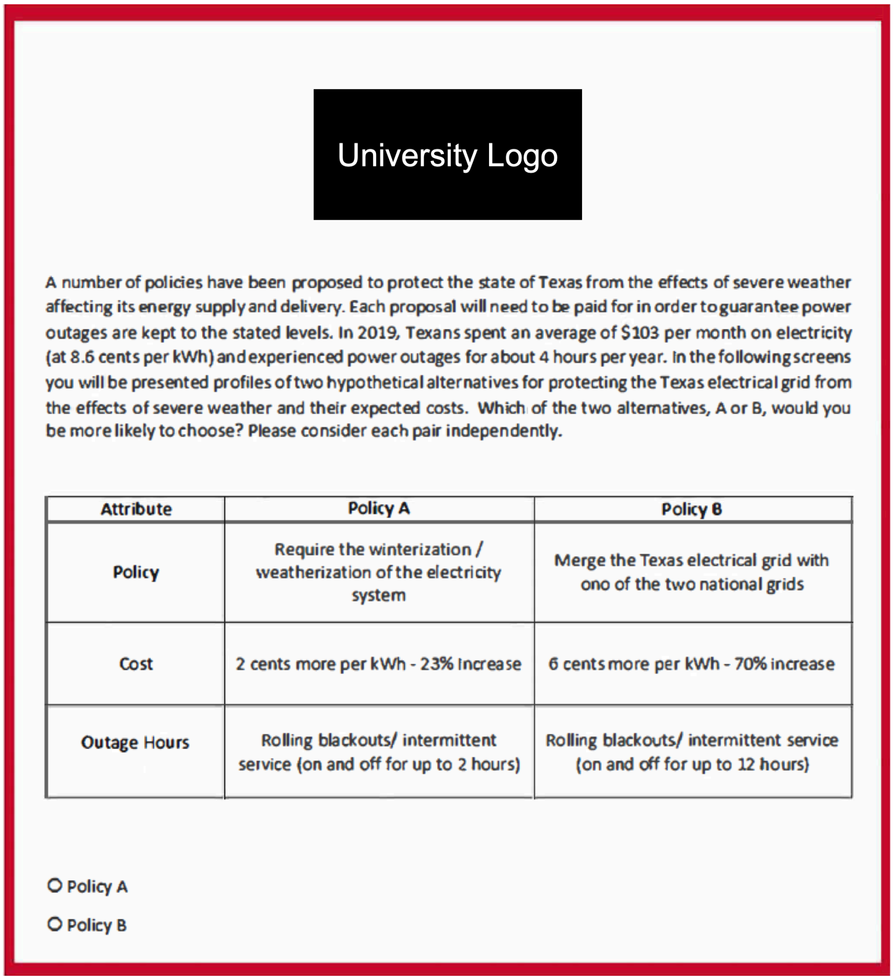
	Baseline	Households without power outage	Households with outages shorter than average	Households with outages longer than average
A. Removing Oncor from the sample				
Hours of rolling blackouts/ intermittent service	-3.0364***	-5.9695***	-3.1701***	-1.8018***
	[0.391]	[1.576]	[0.674]	[0.447]
Policy response/ investment				
Merge the Texas electrical grid with one of the two national grids	3.3368***	3.5363***	5.1329***	2.4528***
	[0.583]	[1.260]	[1.432]	[0.570]
Require the winterization/weatherization of the electricity system	4.9695***	8.1948***	7.2509***	2.5246***
	[0.777]	[2.094]	[1.771]	[0.615]
Maintain a minimum reserve capacity	3.7055***	6.4665***	6.0368***	1.7535***
	[0.621]	[1.869]	[1.530]	[0.459]
Increase the renewable energy supply	3.7489***	7.0267***	4.6524***	2.0532***
	[0.630]	[1.980]	[1.281]	[0.508]
Number of observations	7,832	2,168	2,872	2,792
B. Removing Centerpoint from the sample				
Hours of rolling blackouts/ intermittent service	-3.2086***	-4.1417***	-3.0726***	-2.0668***
	[0.377]	[0.771]	[0.664]	[0.657]
Policy response/investment				
Merge the Texas electrical grid with one of the two national grids	3.2507***	2.3710***	3.6622***	3.4434***
	[0.517]	[0.727]	[1.022]	[1.095]
Require the winterization/weatherization of the electricity system	5.3192***	5.1449***	6.7236***	3.8973***
	[0.759]	[1.197]	[1.619]	[1.293]
Maintain a minimum reserve capacity	3.7893***	4.2317***	4.7385***	2.3273***
	[0.575]	[0.994]	[1.242]	[0.853]
Increase the renewable energy supply	4.3353***	5.4420***	3.6277***	3.3506***
	[0.629]	[1.251]	[1.001]	[1.085]
Number of observations	9,424	3,648	3,128	2,648
C. Removing Muncipal from the sample				
Hours of rolling blackouts/ intermittent service	-2.7833***	-3.3729***	-3.2366***	-1.3341***
	[0.361]	[0.665]	[0.642]	[0.318]
Policy response/ investment				
Merge the Texas electrical grid with one of the two national grids	2.7194***	1.8916***	3.8818***	1.8314***
	[0.469]	[0.663]	[0.986]	[0.476]
Require the winterization/ weatherization of the electricity system	4.3094***	4.3165***	5.9156***	2.3342***
	[0.689]	[1.107]	[1.365]	[0.601]
Maintain a minimum reserve capacity	3.0389***	3.5474***	4.4120***	1.3254***
	[0.510]	[0.919]	[1.074]	[0.403]
Increase the renewable energy supply	3.4777***	4.8233***	3.8736***	1.7056***
	[0.570]	[1.203]	[1.011]	[0.451]
Number of observations	9,936	3,264	3,488	3,184

Notes: $*$ 10% significance level; $**$ 5% significance level; and $***$ 1% significance level, two-tailed tests. Standard errors are in parentheses.

Table A5: Marginal Willingness to Pay

	Baseline	Households without Power Outage	Households with a Shorter Outage on Average Power Outage	Households with a Longer Outage on Average Power Outage
Hours of rolling blackouts/ intermittent service	-2.9590***	-4.0030***	-3.0512***	-1.6814***
	[0.328]	[0.732]	[0.580]	[0.380]
Merge the Texas electrical grid with one of the two national grids	3.1715***	2.6569***	3.8678***	2.5529***
	[0.459]	[0.748]	[0.953]	[0.604]
Require the winterization/ weatherization of the electricity system	4.8853***	5.6106***	6.2161***	2.9183***
	[0.646]	[1.2070	[1.348]	[0.704]
Maintain a minimum reserve capacity	3.4346***	4.4461***	4.7396***	1.6857***
	[0.483]	[0.994]	[1.084]	[0.462]
Increase the renewable energy supply	3.8364***	5.7863***	3.7928***	2.2762***
	[0.526]	[01.241]	[0.921]	[0.546]
Number of observations	12,000	3,888	4,264	3,848

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



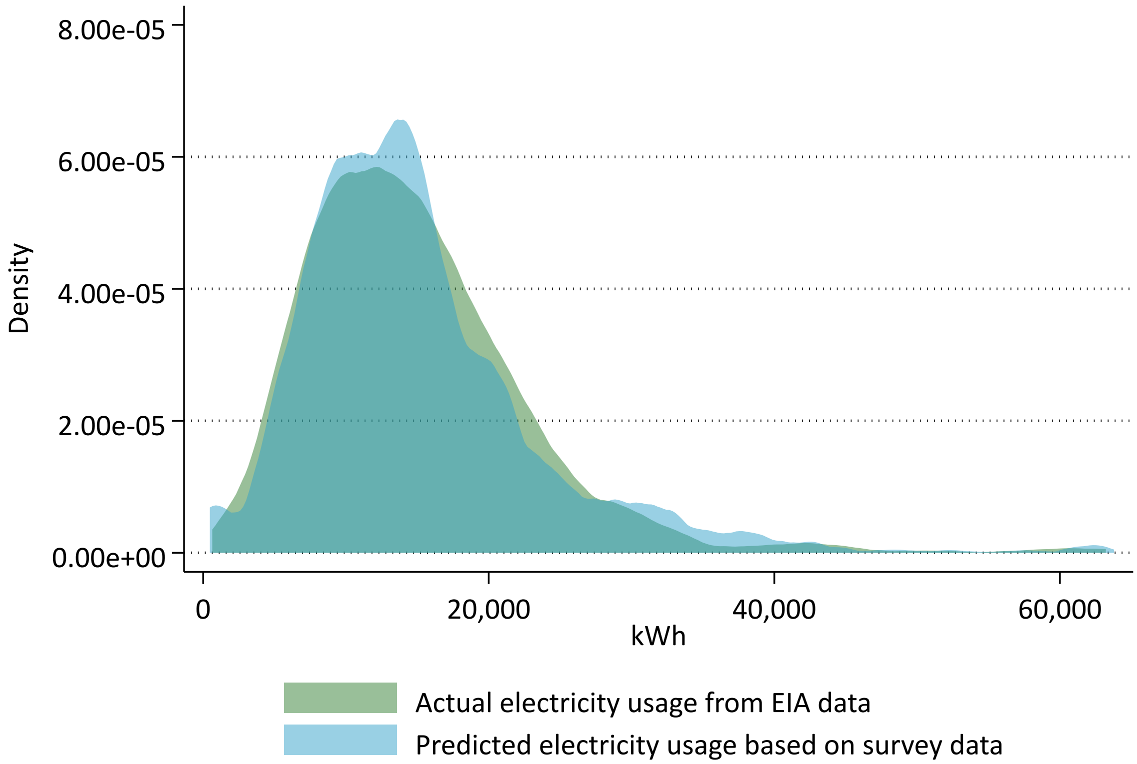
A number of policies have been proposed to protect the state of Texas from the effects of severe weather affecting its energy supply and delivery. Each proposal will need to be paid for in order to guarantee power outages are kept to the stated levels. In 2019, Texans spent an average of $103 per month 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

Figure A1: An Example of the Conjoint Experiment



Notes: Largest difference between distributions = 0.0316. Approximate asymptotic p-value = 0.424.

Figure A2: Distribution matching