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Linking the value of energy reliability to the acceptance of energy infrastructure: Evidence from the EU

Jed J. Cohen[a], Klaus Moeltner[a,*], Johannes Reichl[b], Michael Schmidthaler[b]

[a] Department of Agricultural and Applied Economics, Virginia Tech, 208 Hutcheson Hall, Blacksburg, VA 24061, United States
[b] Energy Institute at the Johannes Kepler University, Altenberger Strasse 69, A-4040 Linz, Austria

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ABSTRACT

Existing studies on the acceptability of energy-related infrastructure have centered around how to overcome the Not-In-My-Backyard phenomenon amongst local stakeholders, focusing primarily on drivers such as community participation and direct economic benefits to impacted areas. To date, none of these contributions have related the acceptability question to the value of power reliability to the same stakeholders. We fill this gap by combining an analysis of outage vulnerability with an examination of infrastructure acceptability using a unique data set from 15 EU countries with household-level information on both aspects of power provision. We find only limited evidence of a positive relationship between local residents' sensitivity to outages and their acceptability of new energy infrastructure projects. This stresses the importance of creating awareness amongst stakeholders on how planned infrastructure expansions relate to energy security for their own household.

1. Introduction

The European Union (EU) has the ambitious goal of reducing greenhouse gas emissions by over 80% compared to 1990 levels by 2050 (European Commission, 2012). This has significant and wide-ranging implications for the energy sector. Most importantly, the EU aims for a share of total energy supply produced by renewable sources (RESs) of 25% by 2030, and 40–60% by 2050. Virtually all of electricity consumption is to be covered by RESs by 2050.

This requires rapid growth in RES installations, such as wind turbines and solar panel arrays, across the entire EU region. The decentralized nature of these facilities, and the corresponding need for inter-regional transfer and trade of electricity creates a new sense of urgency for the construction of transmission lines and pylons. The near-term goal is to increase interconnection capacity between regions by 40% by 2020 (European Commission, 2012). This is also consistent with the parallel objectives of enhancing the security of energy supply across all member nations and of working toward a completely unified energy market with a seamless exchange of electricity across all members (European Commission, 2012).

However, new energy projects are frequently met with opposition by local stakeholders. The EU "Roadmap 2050" report explicitly acknowledges this fact as one of the main barriers to implementation: "*The current trend, in which nearly every energy technology is disputed and its use or deployment delayed, raises serious problems for investors and puts energy system changes at risk*" (European Commission, 2012, p. 17).

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[*] Corresponding author.
E-mail addresses: jedcohen@vt.edu (J.J. Cohen), moeltner@vt.edu (K. Moeltner), reichl@energieinstitut-linz.at (J. Reichl), schmidthaler@energieinstitut-linz.at (M. Schmidthaler).

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In Europe and elsewhere, local opposition to public infrastructure is often referred to as the "Not-In-My-Backyard" (NIMBY) syndrome. There is a rich academic literature that has examined the drivers of NIMBY and possible remedies with respect to energy infrastructure for a variety of case studies and geographic regions (for a recent review see Cohen et al., 2014). Suggestions to facilitate acceptance include transparency of process, stakeholder involvement, and allowing locals to benefit economically from new installations (e.g. van der Horst, 2007; Soini et al., 2011; Cotton and Devine Wright, 2013; Devine-Wright and Batel, 2013).

There also exist economic contributions that have attempted to place a currency value on the disamenity effect of electricity infrastructure, either via stated preference methods (Navrud et al., 2008; Groothuis et al., 2008; Soini et al., 2011; Strazzera et al., 2012), or via property valuation methods (Colwell, 1990; Rosiers, 2002; Sims and Dent, 2005). A related branch of the literature has examined the cost of power outages, or, alternatively put, residents' willingness-to-pay (WTP) to avoid service interruptions (Layton and Moeltner, 2005; Carlsson and Martinsson, 2007, 2008; de Nooij et al., 2007; Baarsma and Hop, 2009; Reichl et al., 2013). Most of these contributions find that residents experience negative benefits from both the proximity to power infrastructure and from power interruptions.

However, and somewhat surprisingly, the two concepts of vulnerability to outages and acceptability of energy infrastructure have to date not been brought into direct comparison, let alone examined jointly. Yet there exist plausible reasons why local residents *should* associate new infrastructure with enhanced reliability. For example, for the case of high-voltage transmission lines, which are the focus of this study, recent history has shown that failures in interconnected transmission grids can have widespread and cascading effects, leading to prolonged outages over large areas (UCTE, 2007; Buldyrev et al., 2010). The European Network of Transmission System Operators (ENTSOE) has long advocated the "$N-1$" criteria for transmission grid reliability, calling for backup infrastructure for any single element in the system in case of failure. It lists supply security as a major reason for the proposed grid expansion in its recent network development plan (ENTSO-E, 2012).[1] Therefore, it is important to understand if customers are aware of this linkage between a reinforced grid and the reliability of supply, and to what extent this awareness affects their stance on new energy projects.

This study fills this gap by eliciting the WTP to avoid interruptions and the propensity to oppose new energy infrastructure from the *same* sample of stakeholders. We apply our estimation framework to a large sample of European households from 15 EU nations. Our data set is unprecedented in geographic scope, as existing valuation studies related to energy provision have exclusively focused on specific regions within a single country. While it probably falls short of capturing all relevant household-level details related to power provision at the local level, it does allow for a first comparison of values for power reliability and attitudes toward new transmission lines for the "typical residential customer" across multiple nations.

Our results indicate strong heterogeneity across countries with respect to both their WTP to avoid *specific* outage scenarios, and their acceptance of new infrastructure. In addition, we find only limited evidence of a positive linkage between a typical household's WTP to avoid interruptions and their propensity to have a positive disposition toward new power lines. We take this as a signal that an information campaign enhancing stakeholders' awareness of the implications of new large-scale infrastructure improvements on power reliability at the local level may be needed to overcome the NIMBY phenomenon.

Econometrically, our study presents an extension of the "recursive" bivariate probit model with a single endogenous regressor (Greene, 2012, Chapter 17) along multiple dimensions. Specifically, we consider a system of five correlated binary equations, the last of which includes the observed responses for the other four as endogenous covariates. Since variances are identified in our case for all but the last equation, we can also incorporate equation-specific heteroskedasticity into our framework. To our knowledge this is the first such high-dimensional recursive binary response model considered in the applied economics literature.

The following section provides an outline of the conceptual and econometric estimation framework. Section 3 introduces the data and presents estimation results. This is followed by concluding remarks in Section 4.

2. Estimation framework

In the outage cost part of our survey each respondent $i=1\ldots N$ is presented with $s=1\ldots S$ choice menus. Each menu contains two choice options – to tolerate the stipulated outage scenario s or to pay the offered bid P_{si} and prevent the interruption.

The corresponding indirect utilities are given as

$$\begin{aligned}\tilde{U}^*_{si} &= -d_s * \mathbf{x}_i'\boldsymbol{\beta}^*_s + \gamma m_i + \tilde{\epsilon}^*_{si}\\ \tilde{U}^*_{1i} &= \gamma(m_i - P_{si}) + \tilde{\epsilon}^*_{1i},\end{aligned} \tag{1}$$

where $\tilde{U}^*_{si}$ is the indirect utility under occurrence of the interruption, and $\tilde{U}_{1i}$ is the indirect utility under payment and avoidance. The former is a function of outage duration d_s, household characteristics $\mathbf{x}_i$, income m_i, and an error term $\tilde{\epsilon}^*_{si}$ that captures unobservables. For ease of interpretation after differencing utilities we let d_s enter with a negative sign. If the outage is avoided payment P_{si} is subtracted from income, as shown in the second equation.

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[1] The notion of enhancing electricity reliability by adding backup capacities and redundancies to all parts of a power grid is also supported by the engineering literature – see e.g. Ren et al. (2008).

As is evident from (1) we use the same explanatory variables $\mathbf{x}_i$ for all S outage equations, but we scale them by duration d_s to allow for a uniform interpretation of the corresponding coefficients $\boldsymbol{\beta}_s^*$ as the marginal effect of covariates on the *average hourly WTP* for each scenario. By allowing $\boldsymbol{\beta}_s^*$ to be scenario-specific our model accommodates non-linearity of hourly outage costs over duration. For example, if per-hour winter outage costs for the typical household monotonically decrease with outage duration (perhaps because people take countervailing measures after the first hour or two), we would expect average hourly WTP to be smaller for, say, a 24-h duration compared to a 1-h duration. Different patterns may emerge for summer outages, as will become evident from our empirical results.

Taking the difference between utilities yields

$$\begin{aligned} &U_{si}^* = \tilde{U}_{1i}^* - \tilde{U}_{si}^* = d_s * \mathbf{x}_i'\boldsymbol{\beta}_s^* - \gamma P_{si} + \epsilon_{si}^* \quad \text{where} \\ &\epsilon_{si}^* = \tilde{\epsilon}_{i1}^* - \tilde{\epsilon}_{si}^* \end{aligned} \tag{2}$$

To facilitate model estimation and the interpretation of results we convert the utility-differenced model into willingness-to-pay (WTP), or “surplus”, space. This requires dividing (2) by the price coefficient γ, yielding

$$\begin{aligned} &U_{is} = \frac{U_{si}^*}{\gamma} = d_s * \mathbf{x}_i'\boldsymbol{\beta}_s - P_{si} + \epsilon_{si} \quad \text{where} \\ &\boldsymbol{\beta}_s = \frac{\boldsymbol{\beta}_s^*}{\gamma} \quad \text{and} \quad \epsilon_{si} = \frac{\epsilon_{si}^*}{\gamma} \end{aligned} \tag{3}$$

Adjusted utility U_{si} now has the interpretation of “surplus,” defined as the difference between the full WTP to avoid the interruption (given as $d_s * \mathbf{x}_i'\boldsymbol{\beta}_s + \epsilon_{si}$) and the required payment P_{si}.[2]

The acceptability section of our survey asked respondents how they would react to a hypothetical new power line with tall pylons in their neighborhood. Participants were asked to choose from four response categories, ordered by strength of opposition. In addition, some survey participants were informed that the new constructions would be associated with broader benefits to the local population in addition to improved energy provision, as described below in more detail. For this econometric exposition we will generically refer to these ancillary benefits as “treatments”.

Pooling the categories “definitely accept without opposition” and “probably accept without opposition” into a single “accept” group, the observed responses can be expressed via a standard binary outcome model that is related to a continuous latent construct with unrestricted range. In our case this latent variable can be thought of as “net benefits” associated with the new power line. Perceived benefits could include economic and environmental incentives (as stipulated in our treatments) and, importantly, reduced outage risk if households see a link between the new infrastructure and future power reliability. The cost side, in turn, would likely include the usual concerns of view shed contamination, health impacts, and losses in property values (e.g. Rosiers, 2002; Atkinson et al., 2004; Soini et al., 2011; Cotton and Devine Wright, 2013).

Formally, individual i’s perceived net benefit, or latent propensity to accept the new infrastructure project, can be written as

$$y_{ai}^* = \mathbf{z}_i'\boldsymbol{\beta}_a + \mathbf{y}_i'\boldsymbol{\delta} + \epsilon_{ai}, \tag{4}$$

where $\mathbf{z}_i$ includes household demographics and the stipulated treatments (described below in more details), $\boldsymbol{\beta}_a$ denotes a set of associated coefficients, and $\mathbf{y}_i$ is the S-dimensional vector of observed responses to the outage scenario questions. Our main analytical focus thus centers on coefficient vector $\boldsymbol{\delta}$. Specifically, if households indeed perceive a linkage between a richer transmission infrastructure and reduced risk of outages, we would expect the elements of $\boldsymbol{\delta}$ to be positive and significant, as households with higher WTP should be more likely to accept both the outage bid and the new transmission lines.

Our full estimation framework, expressed in latent variable terms, thus includes S surplus equations and one net benefit equation. Importantly, since there may be unobservables that affect both the surplus of an avoided power interruption and

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[2] Sonnier et al. (2007) and Scarpa et al. (2008) find that a surplus specification avoids excessively long tails for predicted WTP that often arise when the model is estimated in “utility space”, as given in (2). The utility-space model forces marginal WTP for a specific attribute (often referred to as “implicit price”) to be derived as the ratio of two separately estimated parameters, that is $\boldsymbol{\beta}_s^*/\gamma$ in our notation. Since the marginal utility of income γ can be very small, excessively large estimates for WTP can arise. In contrast, this ratio is specified as a single parameter in the surplus model, i.e. $\boldsymbol{\beta}_s$ in Eq. (3). It is important to note that the Sonnier et al. (2007) model and ours differ in an important aspect from the surplus model traditionally employed in a random utility context for non-market valuation, such as in Train and Weeks (2005) and Scarpa et al. (2008). Specifically, the latter examples do not divide utility by the price coefficient γ, but rather specify the model as (using our notation) $U_{si}^* = d_s * \mathbf{x}_i'(\boldsymbol{\beta}_s * \gamma) - \gamma P_{si} + \epsilon_{si}^*$, where, as in our case, $\boldsymbol{\beta}_s = \boldsymbol{\beta}_s^*/\gamma$. In Bayesian estimation, as employed in Scarpa et al. (2008), a joint prior is then specified for $\boldsymbol{\beta}_s$ $\log(\gamma)$. While this framework generates separate estimates of $\boldsymbol{\beta}_s$ and γ, thus avoiding the “ratio” problem for predicted WTP mentioned above, it still poses dilemma in Bayesian estimation, as the implied prior for $(\boldsymbol{\beta}_s * \gamma)$ used in the likelihood function can take extreme values. We therefore prefer the Sonnier et al. (2007) approach, at the cost of not obtaining a separate estimate for the marginal utility of income. However, this construct is of secondary importance in our analysis, which focuses directly on WTP.

the net benefit of an added transmission line, we ex ante allow all $S+1$ equations to be correlated via their respective error terms. The full system of surpluses thus takes the following form:

$$
\begin{aligned}
&U_{1i} = \mathbf{x}_i'\boldsymbol{\beta}_1 - P_{1i} + \epsilon_{1i}\\
&U_{2i} = d_2 * \mathbf{x}_i'\boldsymbol{\beta}_2 - P_{2i} + \epsilon_{2i}\\
&\vdots\\
&U_{Si} = d_S * \mathbf{x}_i'\boldsymbol{\beta}_S - P_{Si} + \epsilon_{Si}\\
&y_{ai}^* = \mathbf{z}_i'\boldsymbol{\beta}_a + \mathbf{y}_i'\boldsymbol{\delta} + \epsilon_{ai}, \quad \text{with}\\
&\boldsymbol{\epsilon}_i = \begin{bmatrix} \epsilon_{1i} & \epsilon_{2i} & \dots & \epsilon_{ai} \end{bmatrix}' \sim n(\mathbf{0}, \boldsymbol{\Sigma}) \quad \text{and}\\
&\boldsymbol{\Sigma} = \begin{bmatrix} \sigma_{11}^2 & \sigma_{12} & \dots & \sigma_{1S} & \sigma_{1a}\\ \sigma_{21} & \sigma_{22}^2 & \dots & \sigma_{2S} & \sigma_{2a}\\ \vdots & \vdots & \ddots & \vdots & \vdots\\ \sigma_{S1} & \sigma_{S2} & \dots & \sigma_{SS}^2 & \sigma_{Sa}\\ \sigma_{a1} & \sigma_{a2} & \dots & \sigma_{aS} & 1 \end{bmatrix},
\end{aligned}
\tag{5}
$$

where $\sigma_{kl} = \sigma_{lk} \, \forall \, l \neq k$. Thus, our combined error vector follows a multivariate normal distribution with zero mean and a full variance–covariance matrix, with the last variance restricted to unity, following standard convention for probit-type models. Importantly, we allow all surplus variances to be scenario-specific. Since our stipulated outages differ in duration this allows ex ante for more uncertainty from unobservables (i.e. a larger error variance) for longer interruptions. This proves to be justified in our empirical application.

In essence, this setup builds on the recursive bivariate probit model discussed in Greene (2012), Chapter 17, with the following extensions: (i) our system comprises $S+1$ fully correlated equations instead of two, (ii) the variances for equations one through four and all covariances are identified since outage responses are given with respect to an observed bid, and (iii) we include S endogenous variables in the acceptance equation instead of one. To our knowledge, such a high-dimensional version of a Recursive Binary Choice (RBC) model has not been attempted in the applied economics literature.

As mentioned in Maddala (1983), section 5.7, for the system to be identified the latent equations underlying the endogenous variable(s) in the final equation need to include regressors that are not used in that equation. In our case, the vector of explanatory variables $\mathbf{x}_i$ in the outage equations comprises details on outage history, satisfaction with the local utility, and beliefs regarding outage impacts. These variables are absent in the vector of regressors $\mathbf{z}_i$ in the infrastructure acceptance equation.

Individual i's contribution to the likelihood function is the joint probability of observing the S-fold vector of outage responses $\mathbf{y}_i$ plus the response to the acceptance equation, a_i. Expressing latent WTP as y_{si}^* and collecting all S bids offered to respondent i in $\mathbf{P}_i$ this term can be written as:

$$
\text{prob}(\mathbf{y}_i, a_i | \mathbf{x}_i, \mathbf{z}_i, \mathbf{P}_i; \boldsymbol{\beta}, \boldsymbol{\Sigma}) = \text{prob}\begin{bmatrix} b_{1i,l} < y_{1i}^* < b_{1i,u}\\ b_{2i,l} < y_{2i}^* < b_{2i,u}\\ \vdots\\ b_{Si,l} < y_{Si}^* < b_{Si,u}\\ b_{ai,l} < y_{ai}^* < b_{ai,u} \end{bmatrix} = \Phi_i(\mathbf{x}_i, \mathbf{z}_i, \mathbf{P}_i; \boldsymbol{\beta}, \boldsymbol{\Sigma}; R_i), \tag{6}
$$

where $\boldsymbol{\beta} = \begin{bmatrix} \boldsymbol{\beta}_1' & \boldsymbol{\beta}_2' & \dots & \boldsymbol{\beta}_S' & \boldsymbol{\beta}_a' & \boldsymbol{\delta}' \end{bmatrix}'$, and $b_{si,l}$ and $b_{si,u}$ designate, respectively, the lower and upper threshold for latent WTP, as implied by the observed response y_{si}. Specifically, $b_{si,l} = P_{si}$ and $b_{si,u} = \infty$ if $y_{si} = 1$ ("yes"). If a negative response is observed, i.e. $y_{si} = 0$, we have $b_{si,l} = -\infty$ and $b_{si,u} = P_{si}$. Similar bounds hold for equation $S+1$, with bid threshold P_{si} replaced by zero. As indicated by the last line of (6) this joint probability can be concisely expressed as an $S+1$-fold cumulative normal density Φ_i, truncated to the $S+1$-dimensional region R_i.

For the sample at large the likelihood function is thus given by

$$
\text{prob}(\mathbf{y} | \mathbf{X}, \mathbf{Z}, \mathbf{P}; \boldsymbol{\beta}, \boldsymbol{\Sigma}) = \prod_{i=1}^{N} \Phi_i(\cdot), \tag{7}
$$

where vector $\mathbf{y}$ comprises all individuals' outage and acceptance responses, and $\mathbf{P}$ collects all individual bid vectors. Analogously, matrices $\mathbf{X}$ and $\mathbf{Z}$ collect all $\mathbf{x}_i$ and $\mathbf{z}_i$, respectively.

Maximum likelihood estimation of this model would be cumbersome, given the high-dimensional nature of the equation system with an overlay of individual-specific, simultaneous truncation restrictions. We therefore opt for a Bayesian estimation framework. The resulting Gibbs Sampler (GS) is relatively straightforward to implement and converges after a reasonable number of discarded draws (burn-ins). The GS draws consecutively and repeatedly from the conditional posterior distributions $p(\boldsymbol{\beta}|\{\mathbf{y}_i^*\}_{i=1}^N, \mathbf{X}, \mathbf{Z}, \mathbf{P}; \boldsymbol{\Sigma})$, $p(\boldsymbol{\Sigma}|\{\mathbf{y}_i^*\}_{i=1}^N, \mathbf{X}, \mathbf{Z}, \mathbf{P}; \boldsymbol{\beta})I(\boldsymbol{\Sigma}_{M,M} = 1)$ and $p(\{\mathbf{y}_i^*\}_{i=1}^N|\mathbf{y}, \mathbf{X}, \mathbf{Z}, \mathbf{P}; \boldsymbol{\beta}, \boldsymbol{\Sigma})$, where vector $\mathbf{y}_i^*$ combines latent WTP for all S outage equations and perceived net benefits for the acceptance equation for household i. Posterior inference is based on the marginals of the joint posterior distribution $p(\boldsymbol{\beta}, \boldsymbol{\Sigma}|\mathbf{y}, \mathbf{X}, \mathbf{Z}, \mathbf{P})$. Further details for this GS and its implementation are given in a separate online appendix.

2.1. Posterior predictions of WTP

Combining primary parameters $\boldsymbol{\beta}$ and $\boldsymbol{\Sigma}$ in vector $\boldsymbol{\theta}$, the GS yields draws of $\boldsymbol{\theta}$ from the joint posterior distribution $p(\boldsymbol{\theta}|\mathbf{y}, \mathbf{X}, \mathbf{Z}, \mathbf{P})$. Our first post-estimation construct of interest is the expected hourly WTP for the typical household in each country, for each of the four outage scenarios. Formally, this calls for the posterior predictive distribution of $\widehat{wtp}_{sc}|\mathbf{X}_c, \mathbf{Z}_c$, where c denotes a specific country index. For a given draw of $\boldsymbol{\beta}_s$ from the GS we have $\widehat{wtp}_{sc}|\boldsymbol{\beta}_s = (1/n_c)\sum_{i \in c}\mathbf{x}_i'\boldsymbol{\beta}_s$, that is the sample average of observation-specific estimates of expected WTP for country c. Repeating this computation for all draws of $\boldsymbol{\beta}_s$ from the original sampler yields the desired posterior predictive distribution, which can then be examined for its statistical properties.

2.2. Posterior predictions of marginal effects

The second set of predictive constructs of interest are the marginal effects of observed responses to the outage bids, y_{si}, $s = 1 \ldots S$, on the probability of accepting, without opposition, the new transmission line. As for predicted WTP, we average these effects over all households within a given country and present results at the country level. Formally, we seek the difference in predicted acceptance probability from “switching” y_{si} from zero to one, holding all other y_{ri}, $r \neq s$ at zero, that is:

$$\begin{aligned}\hat{m}_{si}|\boldsymbol{\theta} &= \text{prob}(y_{ai} = 1|y_{si} = 1, \{y_{ri} = 0\}_{\forall r \neq s}, \mathbf{x}_i, \mathbf{z}_i, \mathbf{P}_i; \boldsymbol{\theta}) - \text{prob}(y_{ai} = 1|y_{si} = 0, \{y_{ri} = 0\}_{\forall r \neq s}, \mathbf{x}_i, \mathbf{z}_i, \mathbf{P}_i; \boldsymbol{\theta}) \\ &= \frac{\text{prob}(y_{ai} = 1, y_{si} = 1, \{y_{ri} = 0\}_{\forall r \neq s}|\mathbf{x}_i, \mathbf{z}_i, \mathbf{P}_i; \boldsymbol{\theta})}{\text{prob}(y_{si} = 1, \{y_{ri} = 0\}_{\forall r \neq s}|\mathbf{x}_i, \mathbf{z}_i, \mathbf{P}_i; \boldsymbol{\theta})} - \frac{\text{prob}(y_{ai} = 1, y_{si} = 0, \{y_{ri} = 0\}_{\forall r \neq s}|\mathbf{x}_i, \mathbf{z}_i, \mathbf{P}_i; \boldsymbol{\theta})}{\text{prob}(y_{si} = 0, \{y_{ri} = 0\}_{\forall r \neq s}|\mathbf{x}_i, \mathbf{z}_i, \mathbf{P}_i; \boldsymbol{\theta})}\end{aligned} \tag{8}$$

We compute $\hat{m}_{si}|\boldsymbol{\theta}$ for each person and draw of $\boldsymbol{\theta}$ from the original GS, then average over households within a country to obtain $\hat{m}_{sc}|\boldsymbol{\theta} = (1/n_c)\sum_{i \in c}\hat{m}_{si}|\boldsymbol{\theta}$. As for predicted WTP, repeating these steps for each draw of $\boldsymbol{\theta}$ from the original GS produces the posterior predictive distribution for these marginals. In addition to switching responses to individual scenarios from “no” to “yes” we also consider the following marginals based on bundles of switches: (i) switching responses to both winter outages (scenarios one and two) from zero to one, (ii) switching responses to both summer outages (scenarios three and four) from zero to one, and (iii) switching all four responses from zero to one.

3. Empirical application

3.1. Data description

Our data flow from a survey of residential electricity customers that was conducted between fall 2012 and spring 2013 in all 27 member countries of the EU at that time. The survey team contacted over 176,000 households and recruited between 260 and 300 respondents in each member state. A progressively more targeted screening of potential participants assured that the final sample was representative of the broader country-wide population in key demographic aspects. Households had the choice to complete the questionnaire by phone or online. Details of the sampling process and survey implementation can be found in Garcia Gutierrez et al. (2013), which is available online. Appendices A–D of that report include all survey-related materials.

The questionnaire consisted of three main parts. Part one focused on power outages. We first asked respondents about their history of power interruptions and their satisfaction with their local power provider. We then elicited their WTP to avoid each of a set of eight unplanned power interruptions. Part two, in turn, focused on respondents’ attitudes toward new electricity infrastructure, specifically the (hypothetical) construction of a new high-voltage power line near their residence. Households were then asked about their degree of acceptance of the new installation, with ordered response options based on strength of support. Part three then collected standard information on household demographics.

For this study we focus on a subset of 15 countries that are selected based on their historical frequency of power outages, as revealed by survey participants’ reported number of outages they experienced during the last 12 months. We average these values over all participants from the same country to obtain the number of interruptions experienced by the “typical resident.” We then choose, from the total set of 27 nations, the five most reliable countries, the five EU members with “median reliability”, and the five members with the worst outage record. Within each country, we eliminated observations

Table 1
Sample statistics for power provision.

Country	Year joined EU	Sample (HHs)	Annual kwh per capita	Price/kwh (euros)	Num. of outages last yr.			Longest outage last 5 yrs.		Satisfied w. utility (%)
					% zero	mean	std.	<1 h	>4 h	
Low reliability										
Romania	2007	210	528	0.108	18.6%	5.4	6.4	27.6%	37.1%	80%
Bulgaria	2007	212	1396	0.096	17.0%	4.8	5.7	34.4%	25.9%	76%
Greece	1981	266	1604	0.142	23.3%	3.8	4.8	29.3%	25.2%	72%
Hungary	2004	242	1118	0.156	24.0%	3.2	4.1	29.8%	38.4%	94%
Poland	2004	235	750	0.153	35.3%	3.1	4.6	33.6%	29.4%	89%
Medium reliability										
Finland	1995	218	4418	0.156	39.9%	2.4	3.5	44.5%	23.4%	96%
Slovenia	2004	240	1574	0.154	45.8%	2.2	3.7	45.8%	23.3%	96%
Spain	1986	245	1688	0.228	40.0%	2.2	3.2	44.1%	20.0%	78%
Estonia	2004	232	1510	0.112	42.2%	2.1	2.8	32.3%	35.3%	80%
France	1958	228	2511	0.145	49.6%	2.0	3.9	50.0%	21.9%	95%
High reliability										
Sweden	1995	234	4328	0.208	60.3%	1.2	2.4	52.6%	21.8%	96%
Denmark	1973	213	1876	0.297	59.2%	1.1	1.9	58.7%	11.7%	98%
Ireland	1973	235	1903	0.229	61.7%	0.9	1.5	44.7%	17.0%	97%
Netherlands	1958	230	1490	0.190	61.7%	0.8	1.4	52.6%	16.5%	97%
Germany	1958	256	1732	0.268	65.2%	0.7	1.3	64.1%	5.9%	96%

kwh = kilowatt hour.
. std. = standard deviation.

with incomplete information on key household characteristics and cases that were identified as "protest responses" for the acceptability question.[3]

The resulting list of countries and final sample sizes is given in Table 1. The countries are sorted by the self-reported number of outages in the preceding 12 months, averaged over the sample (column seven). We further group them into tiers of low, medium, and high reliability for ease of exposition. As is evident from the third column, sample sizes are comparable over nations, ranging from 210 (Romania) to 266 (Greece). With the exception of Greece, countries with poor reliability tend to be more recent members of the EU (column one). They also tend to consume less electricity per capita and pay lower prices per kilowatt hour (kwh) served (columns four and five). Clearly, reliability in electricity supply comes at a price, with per-kwh rates in the highest group generally exceeding those for the other two tiers by 60–100%.[4]

Average outage frequencies range from approximately three to over five interruptions per year for the lowest tier, from 2 to 2.4 outages for the middle tier, and from under one to just over one for the most reliable tier (column seven). The variability of outage frequency within a given country also decreases with higher mean reliability, as can be seen from the standard deviations for annual frequency in column eight. Similarly, more vulnerable members exhibit a much larger percentage of households who have experienced at least one outage in the preceding year, as indicated by the "% zero" column. Approximately two thirds of customers report non-zero frequencies for the lowest tier, compared to approximately 50-60% for the middle tier, and 35-40% for the highest segment. The survey also elicited information on the longest outage respondents had experienced in the preceding five-year period. Summary statistics for this variable are given in columns nine and ten. Focusing on the >4 h category, we can see that countries with higher outage frequencies also exhibit a higher per-capita probability of *prolonged* interruptions, ranging from 25–40% for the lowest tier to 6–20% for the most reliable group.

The final column of the table shows the percentage of respondents that stated that they were very or fairly satisfied with the general reliability of their electricity supply. Not surprisingly, satisfaction rates generally increase going from the lowest to the highest group. A noteworthy exception is Spain, with a satisfaction percentage that is 20% lower than that of most other members in its tier. This is likely related to the fact that Spain pays high per-kwh rates comparable to those in the most reliable group (€0.228), and yet endures twice as many outages as the most reliable contingent. Overall, the table depicts a picture of pronounced variability in electricity reliability across member states, as measured along multiple dimensions of provision security.

Table 2 shows aggregate respondent and household characteristics for our sample. As can be seen from the table, survey respondents are relatively similar across countries in terms of gender, age, urbanization, education, and the number of children in the household. In contrast, households tend to be larger and household income substantially lower for the lowest

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[3] Specifically, respondents that indicated that they would accept the new project without opposition were asked a follow-up question as to the reason for their support. If they answered that they thought that "a protest has no chance of success", they were flagged as protest responses and eliminated from the data for all three steps of our analysis.

[4] Statistics on electricity consumptions in 2010 (the most recent year available) were obtained from European Environment Agency (2015). Electricity prices for 2012 are given in European Commission (2015c).

Table 2
Household demographics.

Country	% female	Age		% urban or suburban	Education % A level	HH size (# people)	Children <14%	Income (€000's)	
		mean	std.					mean	std.
Low reliability									
Romania	52%	50.05	14.14	75%	76%	2.79	0.30	2.90	1.53
Bulgaria	56%	48.35	14.60	94%	70%	2.76	0.31	4.02	2.27
Greece	51%	43.56	13.22	85%	80%	2.98	0.38	15.91	8.17
Hungary	53%	49.89	15.02	60%	63%	2.77	0.28	5.12	2.05
Poland	54%	47.97	15.80	83%	74%	2.93	0.31	6.33	2.91
Medium reliability									
Finland	49%	51.69	14.65	74%	58%	2.00	0.26	26.95	11.60
Slovenia	52%	49.64	14.98	73%	57%	2.97	0.34	14.76	6.16
Spain	51%	46.84	14.56	88%	66%	2.96	0.37	18.41	9.30
Estonia	61%	49.96	14.31	76%	63%	2.62	0.36	8.60	4.30
France	54%	46.84	13.93	65%	69%	2.64	0.42	27.28	12.63
High reliability									
Sweden	44%	47.41	15.39	75%	74%	2.00	0.37	24.22	11.15
Denmark	41%	49.90	15.66	74%	53%	2.08	0.29	31.99	13.00
Ireland	46%	48.56	14.53	74%	47%	2.88	0.42	29.26	14.58
Netherlands	52%	48.97	14.36	82%	40%	2.17	0.34	24.11	10.12
Germany	45%	47.68	14.86	71%	56%	2.22	0.28	25.48	12.66

std. = standard deviation.
A level degree = prerequisite for university admission in most countries.

reliability tier compared to the highest segment.[5] Table A.11 in Appendix A shows official country-level statistics for some of these demographic variables for comparison purpose. As is evident from that table, while we over-sample urban residents and individuals that do not hold an A-level diploma for most countries, our sample is generally representative of the broader population in terms of gender of respondent, household size, and income.

The eight outage scenarios given in the first part of the questionnaire differed in scope, with four of them impacting only the local neighborhood, and the remaining four the entire country. For this paper we focus exclusively on the country-wide interruptions, given that the electricity infrastructure improvement campaign was also stipulated to occur at the national level, and to "contribute to the enhancement of the power grid in the whole country." Each country-level outage scenario presents a specific interruption, defined by *duration* (1, 4, 12, 24 h), and *season* (summer, winter). Respondents were given the option to pay a specified bid (in form of an add-on to their next electricity bill) and avoid the outage or to decline payment and experience the interruption.[6] Therefore, our preference elicitation format corresponds to a repeated discrete-choice format as employed in Layton and Moeltner (2005). The settings for duration generally reflect the spectrum found in the existing literature (e.g. Layton and Moeltner, 2005; Carlsson and Martinsson, 2007, 2008; Baarsma and Hop, 2009; Reichl et al., 2013).

Budget restrictions preempted a more complete design with all possible combinations of season and duration, or a more refined distinction by day-of-week or time-of-day (Layton and Moeltner, 2005; Baarsma and Hop, 2009). All of our stipulated outages occur on a weekday and include a time span of likely high activity in the household, i.e. either early morning or early evening. Table 3 depicts the outage attributes for the four country-level scenarios. Fig. 1 shows an example of an outage scenario, as it was presented to the respondent.

Each outage scenario is associated with either three or four different bid values, each administered to a sub-sample of respondents.[7] Furthermore, these sets of values differ by country. Due to the lack of existing information on WTP for

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[5] The A-level diploma is the prerequisites in most European countries for university entry. It thus corresponds approximately to a high school diploma in the U.S.

Income was elicited via ten interval bins. We use the mid-point of each interval in our computations. We approximate the upper bound of the highest category as the lower bound of that category plus the bandwidth of the preceding bin.

[6] Since our outage scenarios are described as "unplanned" the question arises of how the declared intention to make the payment could prevent the interruption in reality. Layton and Moeltner (2005) used a freely installed backup generator that would "kick in" every time an outage occurs as prevention mechanism. Carlsson and Martinsson (2007) refer to some central "backup electricity board" to provide (presumably household-specific) service during an unplanned interruption. In our case there was concern that such backup technology would not be considered as feasible or credible for many countries in our sample. At the same time, stipulating different intervention technologies for different members would potentially confound other country-specific effects. We thus opt for a relatively vague description of a prevention mechanism. Specifically, prior to answering the WTP questions respondents were told that "*the following outage scenarios were judged by experts to be realistic for your country and region*," and "*These days there are technical solutions that can prevent critical events from leading to power outages . . . [examples provided] . . . These measures improve service reliability significantly, especially during critical events, but their cost is also significant*." This was followed by the actual elicitation question: "*For each scenario . . . I will read out a sum of money and ask you to tell me whether you think you would prefer to pay this sum and therefore not be affected by this power outage, or whether you would prefer not to pay but instead experience this outage*."

[7] Originally, a total set of four bids were selected for each country across all eight outage scenarios – the four outages with "local" impact, and the four interruptions with "national" impact. Since we only consider the latter for this analysis, the number of effective bids is reduced to three for some country/scenario combinations.

Table 3
Attribute settings for outage scenarios.

Scenario	Duration (h)	Season	Time span
1	1	Winter	8 pm–9 pm
2	24	Winter	10 am–10 am
3	4	Summer	6 am–10 am
4	12	Summer	8 am–8 pm

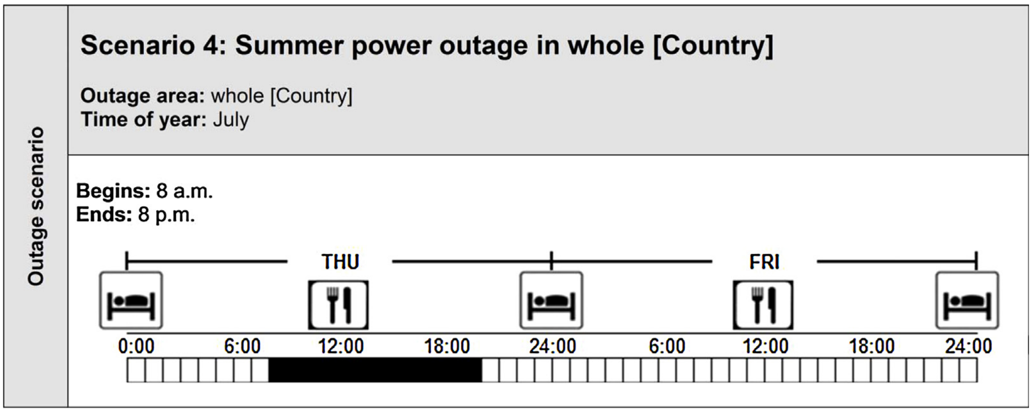

Fig. 1. Outage scenario example.

power reliability or energy-related expenditures at the household level for most of the nations in our sample, the bid design process is anchored in a recent study on energy reliability conducted in Austria, an EU member that is not included in our data (Reichl et al., 2013). Specifically, we adopt the four bids administered in that survey for outages of equal length to those in our scenarios, with an adjustment for income differences between Austria and any one of our 15 countries.[8] During sampling, the survey team examined the share of "yes" responses for all bids and countries for the first 25 observations to assure adequate coverage. This screening process did not prompt any ex-post adjustments to the bid ladders.

The resulting bid amounts for each scenario and country are given in Table A.12 in Appendix A. As is evident from the table, the percentage of "yes" responses decreases monotonically over increasing bids for the majority of cases. Depending on scenario, the share of positive responses generally lies in the 60-80% range for the lowest bid, and in the 10–30% range for the highest amount. This suggests that the bids are generally suitable to map out the survival function (i.e. 1 – *cdf*) of the underlying WTP for a given scenario and population.

In the acceptability part of the survey respondents were told that the long-term reliability of electricity supply rested on the construction of new transmission infrastructure. They were then asked to imagine that as part of a country-wide program to enhance the power grid, a high voltage power line with 60 meter (m) high pylons would be constructed within the next year, at a distance of 250 m from the respondent's residence.

In the baseline version of the survey ($T0$), participants were then asked how they would react to the new project, by choosing one of four responses: "Definitely accept without opposition," "Probably accept without opposition," "Probably *not* accept without opposition," and "Definitely *not* accept without opposition." For econometric simplicity we combine the first and last two categories in our analysis and label them "accept" and "not accept," respectively.

In the three treatment versions of the survey, participants were given additional information before the ordered-response question. In the "economy" treatment ($T1$) they were asked to imagine that, via media reports, they became aware that the infrastructure project would also entail enhanced economic growth and new jobs for their region, and decreased dependence on foreign energy supplies. In the "environment" version of the survey ($T2$) they were informed that the transmission lines project would bring significant benefits for the environment and combat climate change, by facilitating the use of renewable energy such as wind power. In the "compensation" version of the questionnaire ($T3$) respondents were told that their local community would be receiving funds to improve other infrastructure such as parks and schools in compensation for accommodating the new power line. It was also stipulated that use of these extra funds was to be determined at the local level by popular vote.[9]

Table 4 shows the percentage of "accept" responses to the acceptability question for each country and treatment. Three main insights flow from this table. First, the three countries with the highest percentage of positive responses are primarily

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[8] The bids in the Austrian study were derived based on a D-optimality criterion with balanced utilities (Huber and Zwerina, 1996; Burgess and Street, 2003, 2005; Ferrini and Scarpa, 2007).

[9] Sub-sample sizes for each treatment version, over countries, range from 78 to 101 for $T0$, from 37 to 51 for $T1$, from 35 to 56 for $T2$, and from 38 to 59 for $T3$.

Table 4
Percentages of positive responses to acceptability question.

Country	*T*0	*T*1	*T*2	*T*3
Low reliability				
Romania	59.0%	76.5%	67.6%	59.0%
Bulgaria	34.6%	60.0%	41.3%	28.9%
Greece	12.9%	33.3%	19.6%	30.8%
Hungary	38.1%	47.1%	52.2%	29.2%
Poland	42.6%	68.1%	55.6%	54.8%
Medium reliability				
Finland	50.0%	45.0%	41.9%	51.0%
Slovenia	19.8%	37.8%	49.1%	23.6%
Spain	21.6%	36.5%	29.6%	23.8%
Estonia	26.3%	18.4%	35.7%	20.9%
France	12.1%	40.5%	17.1%	13.6%
High reliability				
Sweden	32.6%	34.0%	41.0%	28.0%
Denmark	28.1%	24.4%	33.3%	17.0%
Ireland	15.0%	25.0%	30.2%	25.0%
Netherlands	20.2%	28.3%	45.7%	12.7%
Germany	37.6%	40.4%	36.5%	25.4%

*T*0 = baseline treatment, no additional information.
*T*1 = economy treatment, project enhances regional economic growth.
*T*2 = environment treatment, project benefits environment by facilitating use of renewable energy.
*T*3 = compensation treatment, community receives funds to enhance local infrastructure.

located in the low reliability group for all three treatments, with occasional spillover into the medium category (Finland for *T*0 and *T*3, Slovenia for *T*2). This hints at a positive relationship between outage vulnerability and infrastructure acceptance at the country level. To the extent that outage frequency is related to insufficient infrastructure, one could also interpret this pattern as evidence of a higher marginal benefit for infrastructure in places where it is currently lacking. Second, with few exceptions (Greece, Poland, Ireland) the effect of the "local compensation" treatment (*T*3) is modest, and in many cases even negative compared to the baseline sample. This may be related to concerns that the compensation funds may not be administered equitably. It may also reflect perceived costs related to participating in the decision-making process for fund allocation. Third, the table shows pronounced heterogeneity across countries with respect to the effect of the economy and environment treatment. The economy treatment (*T*1) induces large gains in positive responses in all low-tier countries, as well as in mid-tier nations Slovenia, Spain, and France, while triggering a negative effect in Finland, Estonia, and Denmark. The environment treatment (*T*2), in turn, boosts "yes" percentages in all nations except Finland (no effect over baseline) and Germany (pronounced negative effect). These disparate effects are likely related to factors such as local trust in government, environmental concerns, and – given the environmental treatment's reference to wind farms – preferences for wind-generated power. We refer the reader to Cohen et al. (2016) for a more detailed analysis of these treatment effects, and focus instead on the role of outage costs on infrastructure acceptability in our econometric estimation.

3.2. Estimation results

Table 5 offers a first look at the relationship between acceptance of the scenario-specific outage bids and acceptance of the proposed transmission line. For each outage scenario and country the table simply compares the percentage of positive ("accept") responses to the infrastructure question between those who answered "no" to the outage question and their counterparts who answered "yes," across all stipulated bid amounts. Each such comparison is associated with a Pearson χ^2 test of differences in proportions, with the corresponding significance levels given in a separate column. For example, in Hungary, 48.3% of those who accepted the outage bid for the winter, 1 h interruption would accept the new infrastructure. In contrast, only 30.3% of those who rejected the bid have a favorable disposition to the new transmission line. The resulting difference of 18% is statistically significant at the 1% level.

In general, while most of the acceptance percentages are higher for the segment that also accepted the outage bid, only few of them are statistically significant in this preliminary comparison. High significance levels are primarily found for the high-reliability tier and scenario one (winter, 1 h). In fact, none of the countries are consistent in producing significant differences in proportions across all outage scenarios, though Ireland comes close. We thus conclude that while there are some early signals of a relationship between WTP to avoid interruptions and a favorable attitude toward new energy infrastructure, a full econometric model that controls for household characteristics, outage history, and the inter-related nature of responses via unobservables is needed to provide further guidance.

We implement our RBC model using the following explanatory variables in both the outage and infrastructure equations (vectors $\mathbf{x}_i$ and $\mathbf{z}_i$ in Eq. (5)): A fixed effect for each country (omitting Ireland as the baseline category) to capture country-level drivers of WTP and acceptance, such as cultural attitudes toward power provision, the density of the existing transmission grid, and climate characteristics, three age categories (35–45 years, 46–60 years, over 60 years, with omitted baseline of

Table 5
Percentages of positive responses to the acceptability question, by response to the outage question.

Bid response	Winter, 1 h		Winter, 24 h		Summer, 4 h		Summer, 12 h	
	No	Yes	No	Yes	No	Yes	No	Yes
Low reliability								
Romania	64.20	65.12	63.16	66.09	63.96	65.66	62.14	70.00
Bulgaria	34.52	45.31	34.31	47.27*	39.53	43.37	36.49	51.56**
Greece	20.66	23.45	16.38	26.67**	21.19	23.48	16.99	29.20**
Hungary	30.30	48.25***	43.70	38.21	36.92	45.54	38.96	44.32
Poland	51.72	52.70	55.21	50.36	49.09	55.20	51.49	53.47
Medium reliability								
Finland	47.37	47.97	41.56	51.06	47.33	48.28	48.82	46.15
Slovenia	23.58	35.82**	30.23	30.52	26.35	36.96*	27.74	33.98
Spain	23.93	29.69	20.43	30.92*	26.75	27.27	23.68	32.26
Estonia	22.41	30.17	20.20	30.83*	22.60	32.56*	25.00	29.41
France	15.94	21.11	17.27	19.10	17.06	20.69	19.89	11.54
High reliability								
Sweden	32.77	33.91	27.72	37.59	30.20	38.82	34.48	31.46
Denmark	17.65	31.25**	22.39	27.40	22.22	30.21	25.00	26.73
Ireland	16.13	25.35*	21.70	21.71	16.43	29.47**	18.06	28.75*
Netherlands	14.78	33.04***	21.30	26.23	21.33	28.75	20.67	30.00
Germany	28.77	43.64**	34.09	35.71	31.68	41.05	31.58	40.38

* Pearson's χ^2 statistic significant at 10%.
** Pearson's χ^2 statistic significant at 5%.
*** Pearson's χ^2 statistic significant at 1%.

20–35 years), an indicator for an "urban" residential location (as opposed to suburban or rural), an indicator for gender (with "female" the omitted baseline), household size, and educational attainment (an indicator equal to one if the respondent holds an A-level diploma).

Within $\mathbf{x}_i$ we also include the following additional regressors: The historic 12-month outage frequency, indicator categories for the longest outage experienced in the preceding five years (1–4 h, 4–8 h, 8–24 h, and over 24 h, with the implicit baseline category consisting of respondents that had not experienced an outage during that time frame or one lasting for less than 1 h), a binary indicator variable for the household's declared satisfaction with the local power utility (1 = "very" or "fairly" satisfied, 0 = "not very" or "not at all" satisfied), and indicator variables for eight elements of the public infrastructure that the respondent believed would or would not be affected by a prolonged outage (1 = "strongly" or "very strongly" affected, 0 = "not at all" or "moderately" affected). The eight infrastructure segments include medical care, fuel/gas supply, electronic payment options, land & mobile telephone networks, heating systems, internet, public transportation, and sanitation.[10] We also include in $\mathbf{x}_i$ an indicator variable taking a value of one if the respondent was given a survey booklet that showed the local outage scenarios first, followed by the country-wide scenarios, and zero if the ordering was reversed, to test for (undesirable) formatting effects.

Vector $\mathbf{z}_i$, in turn, contains the following additional variables not included in $\mathbf{x}_i$: Indicators for the three special incentive-treatments (economy, environment, community), and income (in €10,000s). Most importantly, the infrastructure acceptability equation also includes the observed responses from the four outage questions as endogenous regressors, as captured in Eq. (5). Based on the insights gained from our preliminary comparison-of-proportions analysis discussed above, we interact each endogenous response variable with all 14 country indicators (keeping, again, Ireland as the baseline location). This allows for each country to have its own feedback-effect of WTP to avoid outages on acceptability of new infrastructure.

Full estimation results are given in Tables 6–8. Table 6 provides results for the four outage scenario equations, while Table 7 gives results for the transmission line acceptance equation. Table 8 depicts results for the variances and covariances of the error terms, as well as the corresponding correlation coefficients. We provide three posterior statistics for each parameter: the posterior mean, the posterior standard deviation, and the proportion of the posterior distribution that exceeds zero. The latter metric provides an at-a-glance assessment if a given variable has a predominantly positive effect (most of its posterior distribution is to the right of zero, i.e. the "prop > 0" measure is close to one), a predominately negative effect ("prop > 0" is close to zero) or an ambivalent effect ("prop > 0" approaches 0.5). For ease of interpretation and consistency with previous tables we maintain our tiered representation of countries based on historic outage propensity. In the following we will primarily focus our discussion on regressors for which at least 90% of the posterior distribution lies to the left or to the right of zero, and refer to them as "significant", in slight abuse of Classical terminology.

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[10] The exact wording for this survey question was: "*Now please imagine that it is 12 o'clock midday on a regular working day, and that an unplanned, country-wide outage started 4 h ago. You have no information on how many additional hours the outage is likely to last. Please tell me to what extent you believe the medical system [fuel/gas supply, electronic payment options, etc.] is likely to have been affected...*" *This question was given separately from the four outage scenarios that solicited bid responses.*

Table 6
Estimation results for outage cost equations.

Variable	Winter, 1 h			Winter, 24 h			Summer, 4 h			Summer, 12 h		
	mean	std.	prop. > 0	mean	std.	prop. > 0	mean	std.	prop. > 0	mean	std.	prop. > 0
constant	−0.843	0.973	0.192	−0.166	0.382	0.332	−0.868	0.346	0.004	−1.983	0.608	0.000
Romania	−0.145	0.706	0.416	−0.455	0.285	0.055	0.018	0.250	0.524	−0.917	0.428	0.014
Bulgaria	−0.168	0.705	0.409	−0.389	0.284	0.085	−0.311	0.247	0.104	−0.898	0.420	0.019
Greece	−0.957	0.672	0.078	−0.050	0.263	0.422	−0.100	0.236	0.331	0.550	0.394	0.923
Hungary	−0.596	0.674	0.186	−0.682	0.266	0.006	−0.024	0.238	0.458	−0.421	0.399	0.146
Poland	0.077	0.696	0.539	−0.191	0.276	0.244	0.331	0.240	0.918	0.102	0.405	0.595
Finland	−0.268	0.696	0.356	0.640	0.275	0.991	−0.052	0.245	0.414	0.664	0.412	0.949
Slovenia	−0.862	0.675	0.102	0.439	0.266	0.951	−0.272	0.239	0.125	0.509	0.395	0.902
Spain	−1.464	0.670	0.015	0.301	0.268	0.873	−0.584	0.233	0.006	0.065	0.398	0.561
Estonia	−1.704	0.695	0.008	−0.159	0.273	0.279	−0.530	0.242	0.014	−0.931	0.423	0.014
France	−2.890	0.709	0.000	−0.914	0.271	0.001	−0.976	0.250	0.000	−1.340	0.439	0.001
Sweden	−1.491	0.686	0.014	0.126	0.268	0.680	−0.228	0.240	0.167	0.312	0.402	0.782
Denmark	0.356	0.703	0.693	0.936	0.282	1.000	0.281	0.247	0.874	1.300	0.422	0.999
Netherlands	−1.367	0.678	0.021	−0.113	0.264	0.333	−0.237	0.241	0.163	−0.047	0.403	0.456
Germany	−2.597	0.696	0.000	0.547	0.269	0.979	−0.382	0.236	0.051	0.507	0.395	0.905
urban	0.591	0.292	0.978	0.062	0.116	0.700	0.067	0.102	0.745	0.218	0.178	0.894
male	0.565	0.256	0.986	−0.225	0.100	0.012	−0.154	0.089	0.043	−0.589	0.156	0.000
age 35 to 45	0.709	0.384	0.970	0.173	0.153	0.872	0.235	0.135	0.960	0.151	0.230	0.746
age 46 to 60	1.329	0.373	1.000	0.132	0.143	0.825	0.514	0.130	1.000	0.492	0.221	0.988
age 60 plus	2.670	0.418	1.000	0.440	0.154	0.997	0.911	0.142	1.000	1.174	0.241	1.000
longest out. 1–4 hrs	−0.221	0.299	0.229	−0.129	0.116	0.134	−0.215	0.104	0.017	−0.304	0.175	0.039
longest out. 4–8 hrs	−0.279	0.416	0.252	−0.241	0.163	0.070	−0.214	0.145	0.070	−0.358	0.244	0.069
longest out. 8–24 hrs	−0.334	0.574	0.280	−0.149	0.223	0.254	−0.312	0.201	0.061	0.050	0.332	0.559
longest out. > 24 hrs	−1.483	0.680	0.013	−0.359	0.265	0.092	−0.627	0.234	0.003	−0.674	0.409	0.049
num out. 12 months	−0.021	0.038	0.287	0.013	0.016	0.789	0.011	0.014	0.785	0.054	0.023	0.991
HH size	0.412	0.118	1.000	0.093	0.044	0.983	0.118	0.040	0.999	0.227	0.067	1.000
A-level educ.	0.520	0.277	0.970	0.359	0.107	1.000	0.268	0.097	0.997	0.343	0.162	0.983
satisfied	0.107	0.455	0.597	0.551	0.186	0.999	0.064	0.159	0.658	0.551	0.275	0.976
medcare affected	0.459	0.294	0.943	0.176	0.115	0.938	0.184	0.104	0.963	−0.012	0.175	0.470
fuel/gas affected	0.064	0.274	0.598	0.091	0.110	0.799	0.041	0.094	0.669	−0.018	0.165	0.459
ATM affected	0.423	0.323	0.904	0.181	0.126	0.923	0.237	0.113	0.982	0.135	0.191	0.761
telephone affected	0.716	0.281	0.995	0.220	0.110	0.977	0.237	0.097	0.993	0.355	0.165	0.985
heating affected	−0.139	0.300	0.323	0.157	0.118	0.906	−0.113	0.106	0.144	−0.035	0.180	0.425
internet affected	0.027	0.312	0.534	−0.012	0.124	0.463	−0.080	0.111	0.236	0.162	0.191	0.804
transportation affected	0.169	0.346	0.688	0.112	0.141	0.789	0.178	0.125	0.921	0.473	0.214	0.987
sanitation affected	0.144	0.273	0.702	0.320	0.110	0.998	0.104	0.097	0.862	0.391	0.167	0.991
scenario ordering	−0.056	0.248	0.412	0.002	0.099	0.511	0.297	0.088	1.000	0.085	0.146	0.721

mean = posterior mean, std. = posterior standard deviation.
prop. > 0 = share of posterior density to the right of zero.

Table 7
Estimation results for acceptance equations.

Variable	mean	std.	prop. > 0	Effect of observed response (0,1) to bid question on perceived net benefits of new infrastructure											
				Winter, 1 h			Winter, 24 h			Summer, 4 h			Summer, 12 h		
				mean	std.	prop. > 0	mean	std.	prop. > 0	mean	std.	prop. > 0	mean	std.	prop. > 0
constant	–1.060	0.246	0.000	0.011	0.287	0.514	–0.108	0.214	0.306	0.341	0.232	0.930	0.229	0.253	0.817
Romania	1.494	0.271	1.000	–0.224	0.292	0.223	–0.030	0.264	0.451	–0.443	0.287	0.060	–0.009	0.294	0.487
Bulgaria	0.545	0.264	0.980	0.080	0.289	0.609	0.288	0.264	0.861	–0.550	0.281	0.025	0.015	0.293	0.519
Greece	0.022	0.262	0.534	–0.228	0.292	0.219	0.269	0.266	0.848	–0.439	0.279	0.058	0.160	0.279	0.710
Hungary	0.572	0.266	0.984	0.304	0.280	0.860	–0.046	0.253	0.431	–0.296	0.260	0.132	–0.222	0.273	0.208
Poland	1.171	0.268	1.000	–0.273	0.293	0.174	–0.061	0.258	0.401	–0.203	0.281	0.235	–0.199	0.277	0.237
Finland	0.879	0.263	0.999	–0.073	0.291	0.405	0.403	0.267	0.938	–0.490	0.276	0.036	–0.356	0.276	0.099
Slovenia	0.344	0.266	0.899	0.179	0.294	0.723	–0.002	0.265	0.493	–0.292	0.281	0.153	–0.138	0.285	0.313
Spain	0.129	0.268	0.688	0.031	0.296	0.541	0.379	0.264	0.925	–0.529	0.279	0.030	–0.083	0.278	0.381
Estonia	0.138	0.267	0.697	–0.040	0.294	0.447	0.354	0.270	0.905	–0.168	0.285	0.275	–0.265	0.297	0.183
France	0.069	0.253	0.604	0.082	0.301	0.610	0.169	0.288	0.720	–0.158	0.324	0.316	–0.813	0.342	0.009
Sweden	0.469	0.256	0.967	–0.193	0.282	0.244	0.369	0.265	0.917	–0.200	0.273	0.231	–0.478	0.284	0.048
Denmark	0.147	0.293	0.699	0.264	0.315	0.803	0.204	0.295	0.753	–0.444	0.299	0.066	–0.344	0.296	0.119
Netherlands	0.032	0.268	0.546	0.356	0.299	0.882	0.189	0.272	0.750	–0.418	0.287	0.071	–0.208	0.294	0.240
Germany	0.529	0.254	0.982	0.172	0.286	0.725	–0.088	0.267	0.372	–0.281	0.281	0.158	–0.090	0.270	0.374
urban	0.069	0.053	0.907												
male	0.320	0.051	1.000												
age 35 to 45	–0.206	0.073	0.002												
age 46 to 60	–0.198	0.070	0.003												
age 60 plus	–0.204	0.081	0.006												
HH size	–0.016	0.022	0.233												
A-level educ.	0.043	0.052	0.799												
economy	0.330	0.062	1.000												
environment	0.276	0.062	1.000												
community	–0.010	0.063	0.435												
income	–0.026	0.028	0.172												

mean = posterior mean, std. = posterior standard deviation.
prop. >0 = share of posterior density to the right of zero.

Table 8
Estimation results for error covariance matrix.

	Variances, covariances			Correlations		
	mean	std.	prop. > 0	mean	std.	prop. > 0
ϵ_1	31.65	4.25	1.00			
ϵ_1, ϵ_2	108.54	10.85	1.00	0.37	0.03	1.00
ϵ_2	2734.26	235.69	1.00			
ϵ_1, ϵ_3	27.09	2.50	1.00	0.63	0.02	1.00
ϵ_2, ϵ_3	183.02	16.40	1.00	0.45	0.03	1.00
ϵ_3	59.57	5.52	1.00			
ϵ_1, ϵ_4	96.59	11.48	1.00	0.43	0.03	1.00
ϵ_2, ϵ_4	1293.25	103.63	1.00	0.63	0.02	1.00
ϵ_3, ϵ_4	191.02	16.51	1.00	0.63	0.02	1.00
ϵ_4	1570.83	193.43	1.00			
ϵ_1, ϵ_5	0.75	0.56	0.91	0.13	0.10	0.91
ϵ_2, ϵ_5	4.35	4.53	0.83	0.08	0.09	0.83
ϵ_3, ϵ_5	0.99	0.70	0.92	0.13	0.09	0.92
ϵ_4, ϵ_5	3.50	4.12	0.80	0.09	0.10	0.80

mean = posterior mean, std. = posterior standard deviation.
prop. > 0 = share of posterior density to the right of zero.

As discussed above, Table 6's coefficients can be interpreted as the marginal effect of a given regressor on the average hourly WTP associated with a given outage. As is evident from the table, household characteristics are generally significant or close to significant for all four equations. Larger households with an A-level diploma, as well as urban and older residents have higher WTP, with a pronounced jump for the "over-60" category. This likely captures the increased vulnerability to electricity interruptions of the elderly segment. Male respondents have higher WTP for the winter, 1 h outage, while their hourly WTP is significantly lower than female's for the remaining three interruptions. This may possibly capture a relatively higher burden of coping that longer outages place on females (preventing groceries form spoiling, getting children ready for school, preparing meals, etc.). Interestingly, while the number of historic outages slightly elevates marginal WTP (significantly so for the summer, 12 h scenario), longer historic *durations* have the opposite impact, especially for the longer outage scenarios. This may hint at a habituation effect, with households that have experienced longer outages in the recent past feeling more prepared to make it through another prolonged interruption in the future.

While significance patterns shift a bit over outage scenarios, WTP generally increases with concerns over losses of infrastructure, especially medical care, electronic payment services, and telephone services. Transportation effects are stronger in the summer, while longer outages in both seasons prompt worries over continued water and sanitation services. Not surprisingly, heating is a significant concern for the longer winter outage.

Country fixed effects relative to Ireland (our baseline category) clearly differ in magnitude and in some cases also in sign over outage scenarios. They are generally negative for the low reliability group, except for Greece for the 12-h long summer interruption. The middle tier, in turn, shows negative incremental effects for Estonia and France across all scenarios, while Finland and Slovenia have higher hourly WTP levels than Ireland for the longer outages (24 and 12 h) in both winter and summer. High-reliability nations show an equally mixed pattern, with most of them exhibiting lower WTP than Ireland for the short winter and summer outage, but incrementally higher hourly WTP for the two longer scenarios (Denmark, Germany).

Overall, there is no clear pattern such as cooler (hotter) countries pay more to avoid winter (summer) outages, or wealthier countries have categorically higher WTP. In part, this is likely due to the fact that most nations in our sample have considerable inter-regional variation in climate, such that there is always some contingent of the population that is relatively more vulnerable to outages that occur in a particular season. In the aggregate these climate effects will then wash out. Furthermore, our country indicators are likely also picking up cultural and attitudinal effects. For example, one striking result captured in the table is the pronounced negative incremental WTP for all four equations for France, one of the wealthier countries in our sample. This is likely related to the fact that the French, who have a comparatively large reliance on low-cost nuclear power, have traditionally enjoyed some of the lowest electricity rates in Europe (see Table 1). French customers may thus feel a certain entitlement to low-priced power and may be reluctant to pay extra for improved service.

The remaining two variables in Table 6 are the binary indicator for satisfaction with the local utility, and the indicator for scenario ordering. The former turns out significant for the two longer outages, with satisfied customers paying over €0.5 more than the less-than-satisfied baseline category. This may hint at a lack of trust of the latter contingent in their utility's ability to use the stipulated avoidance payment effectively.[11] Our model also produces a positive effect for scenario ordering for the summer, 4 h scenario, indicating that respondents that first saw the four local outages and then the four country-wide scenarios (as used in this analysis) show a significantly higher WTP of approximately €0.3. This could suggest

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[11] We also ran our model for the subset of "satisfied" customers only. This resulted primarily in a pronounced reduction in sample size (20–30%) for some of the low and medium reliability countries (see Table 1), but did not affect any of our results in a substantial fashion.

an undesirable anchoring effect for this particular scenario, warranting some caution in interpreting the results related to this equation. Fortunately, significant formatting effects are not observed for the remaining three interruptions.

Table 7 presents the estimation results for the infrastructure acceptance equation. Country fixed effects are positive and significant for all low-tier nations except Greece, as well as for Finland, Sweden, and Germany. This corresponds well with Table 4, which also shows the highest acceptance percentages for those nation under the baseline treatment. Both the "economy" and "environment" treatments further boost acceptability, while the "community" treatment shows no added effect. As for household characteristics, urban and male respondents have a more favorable attitude toward the new power line, while older respondents are less supportive. This may be related to concerns of eroding property values, as older respondents are also more likely home owners compared to the under-35 baseline group.

The next four triplets of columns in Table 7 show, respectively, the effect of each of the four observed responses to the outage questions on the latent outcome for acceptability, which we interpret as perceived net benefits of the new transmission line. The results are generally consistent with the descriptive statistics captured in Table 5, with nations that have a larger span of acceptance percentages between "no" and "yes" responders to the bid question, relative to Ireland, also producing positive and significant (or close-to-significant) coefficients for these direct effects of the endogenous variables. For example, a positive response to the winter, 1 h outage is more likely to trigger a higher acceptance score for locations like Hungary, Slovenia, Denmark, Netherlands, and Germany, though none of the corresponding *prop*.>0 values exceed the 90% threshold. The picture is more crisply defined for the winter, 24 h, outage, with Finland, Spain, Estonia, and Sweden showing significantly stronger, positive linkages between bid acceptance and infrastructure acceptance compared to Ireland. Bulgaria and Greece show the same pattern, though with somewhat lower significance levels. In all of these cases and for both winter outages the magnitude of these effects clearly exceeds the magnitude of the constant term, suggesting that the relationship between WTP to avoid outages and acceptance of new infrastructure is positive for these nations in absolute terms as well.

The picture is essentially reversed for the summer, 4 h, outage, with many nations (Romania, Bulgaria, Greece, Finland, Spain, Denmark, and Netherlands) producing a significant negative effect relative to Ireland. Since the magnitude of these incremental effects exceeds that of the constant term, these countries exhibit a negative relationship between the WTP to avoid outages and acceptance of new infrastructure even in absolute terms. The same holds for the longer summer outage for Finland, France, and Sweden. Since these negative linkages between vulnerability to interruptions and acceptance of new electricity-related infrastructure are restricted to summer outages, this suggests that citizens in these countries may see the benefits of new transmission lines primarily in the avoidance of *winter* interruptions, but of little use for curbing the risk of summer outages. We will return to this point in our concluding section.

Table 8 gives results for the elements of $\boldsymbol{\Sigma}$, the variance–covariance matrix of the correlated error terms in our five-fold system of equations. As expected, variances increase monotonically with outage duration ($var(\epsilon_2) > var(\epsilon_4) > var(\epsilon_3) > var(\epsilon_1)$), which supports our decision to allow for heteroskedasticity across the four outage equations. As can be seen from the second set of columns of the table, all error correlations are positive. They are significantly stronger within the four outage equations compared to each outage equation's correlation with the acceptance equation. The latter set of correlations range only between 0.1 and 0.13. However, most of their posterior distribution lies in the positive realm, suggesting that all five equations are connected, and generally supporting our system-of-equations approach.

3.3. *WTP predictions*

Table 9 presents results for predicted hourly WTP for the typical household in each country and for each outage scenario. For winter outages, all posterior mean estimates are positive, and – with the exception of France for the 1-h version – essentially the entire posterior predictive distribution lies in the positive domain. Not surprisingly, WTP is generally highest for the lowest reliability tier (€2.5–€4), and for some of the wealthiest nations in our sample (Finland, Denmark, Germany). As hypothesized, per-hour WTP for the longer winter outage is significantly lower than for the 1-h interruption for most nations, suggesting a concave relationship between hourly costs and outage duration.

Perhaps the most striking result in the table is the fact that WTP to avoid summer interruptions is an order of magnitude lower than WTP to avoid winter outages. In fact, several predictive WTP distributions are essentially centered at or near zero (Romania, Bulgaria, Estonia for summer, 12 h). France even produces a significant negative estimate for both summer interruptions. As discussed before, this is likely indicative of French citizens' general aversion to any additional costs related to power provision.[12] In contrast to the winter interruptions, we generally observe higher per-hour WTP for the longer (12 h) summer outage compared to the shorter (4 h) one for about half of our nations (Greece, Finland, Slovenia, Spain, Sweden, Denmark, Netherlands, Germany), while the pattern is reversed for the remaining locations. It thus appears that the marginal outage cost–duration relationship for summer interruptions is more location-specific than for the winter case, with some nations experiencing diminishing marginal costs, while others see hourly costs increase with prolonged duration for the typical household.

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[12] We also estimated our model with latent WTP in log form for the outage equations to restrict predicted WTP to the positive domain. However, with only three to four bids per scenario, the tails of the implicit log-normal distributions are poorly characterized. This leads to excessive posterior means for predicted WTP. We therefore opt to use the linear model for inference.

Table 9
Predicted average hourly WTP per household (€).

Country	Winter, 1 h			Winter, 24 h			Summer, 4 h			Summer, 12 h		
	mean	std.	prob. > 0	mean	std.	prob. > 0	mean	std.	prob. > 0	mean	std.	prob. > 0
Low reliability												
Romania	3.439	0.508	1.000	1.242	0.198	1.000	0.719	0.173	1.000	−0.085	0.309	0.404
Bulgaria	3.279	0.506	1.000	1.160	0.204	1.000	0.319	0.174	0.965	−0.266	0.324	0.206
Greece	2.501	0.449	1.000	1.530	0.176	1.000	0.487	0.157	0.999	1.077	0.259	1.000
Hungary	3.194	0.470	1.000	1.122	0.182	1.000	0.726	0.160	1.000	0.469	0.277	0.955
Poland	3.991	0.500	1.000	1.650	0.194	1.000	1.100	0.163	1.000	0.990	0.278	1.000
Medium reliability												
Finland	3.158	0.504	1.000	2.214	0.198	1.000	0.539	0.173	1.000	1.236	0.292	1.000
Slovenia	2.779	0.478	1.000	2.081	0.191	1.000	0.363	0.170	0.985	1.174	0.275	1.000
Spain	2.203	0.467	1.000	1.908	0.190	1.000	0.088	0.164	0.707	0.677	0.284	0.988
Estonia	1.841	0.476	1.000	1.546	0.191	1.000	0.121	0.167	0.768	−0.263	0.318	0.203
France	0.364	0.495	0.771	0.663	0.193	1.000	−0.446	0.186	0.007	−0.780	0.349	0.009
High reliability												
Sweden	1.908	0.463	1.000	1.752	0.187	1.000	0.341	0.167	0.977	0.845	0.288	0.998
Denmark	3.994	0.525	1.000	2.590	0.208	1.000	0.923	0.177	1.000	1.918	0.299	1.000
Ireland	3.595	0.479	1.000	1.598	0.185	1.000	0.574	0.165	1.000	0.538	0.287	0.964
Netherlands	2.096	0.473	1.000	1.493	0.184	1.000	0.343	0.175	0.974	0.468	0.299	0.939
Germany	1.035	0.465	0.987	2.280	0.191	1.000	0.292	0.164	0.961	1.136	0.274	1.000

std. = standard deviation.

Table 10
Predicted marginal effects of bid acceptance on the probability of accepting new infrastructure – individual scenarios.

Country	"Yes" to winter, 1 h, only			"Yes" to winter, 24 h, only			"Yes" to summer, 4 h, only			"Yes" to summer, 12 h, only		
	mean	std.	prob. > 0	mean	std.	prob. > 0	mean	std.	prob. > 0	mean	std.	prob. > 0
Low reliability												
Romania	−0.072	0.095	0.227	−0.043	0.067	0.256	−0.028	0.070	0.337	0.062	0.062	0.862
Bulgaria	0.028	0.108	0.616	0.065	0.081	0.805	−0.064	0.080	0.209	0.098	0.083	0.876
Greece	−0.058	0.079	0.228	0.045	0.065	0.771	−0.023	0.065	0.344	0.132	0.081	0.954
Hungary	0.112	0.103	0.857	−0.058	0.074	0.226	0.025	0.075	0.628	0.009	0.079	0.527
Poland	−0.101	0.106	0.168	−0.061	0.077	0.214	0.043	0.079	0.727	0.013	0.078	0.584
Medium reliability												
Finland	−0.026	0.103	0.403	0.102	0.087	0.865	−0.048	0.082	0.283	−0.043	0.084	0.284
Slovenia	0.064	0.100	0.743	−0.047	0.079	0.281	0.028	0.081	0.615	0.038	0.081	0.692
Spain	0.010	0.086	0.540	0.082	0.074	0.868	−0.041	0.065	0.254	0.054	0.075	0.763
Estonia	−0.009	0.088	0.456	0.075	0.075	0.847	0.073	0.077	0.825	−0.002	0.073	0.483
France	0.038	0.077	0.691	0.022	0.069	0.642	0.088	0.088	0.835	−0.113	0.061	0.035
High reliability												
Sweden	−0.062	0.091	0.247	0.095	0.081	0.870	0.064	0.080	0.790	−0.082	0.077	0.139
Denmark	0.084	0.100	0.804	0.020	0.088	0.602	−0.024	0.074	0.357	−0.036	0.079	0.310
Ireland	−0.007	0.088	0.471	−0.036	0.065	0.304	0.114	0.077	0.931	0.077	0.075	0.853
Netherlands	0.117	0.088	0.915	0.019	0.066	0.631	−0.007	0.065	0.429	0.014	0.071	0.551
Germany	0.081	0.089	0.808	−0.085	0.086	0.170	0.036	0.085	0.668	0.055	0.083	0.740

std. = standard deviation.

Reassuringly, our WTP estimate for the winter, 1 h, outage for Sweden (€1.91) is within 25% of that derived by Carlsson and Martinsson (2007) when converted to euros and adjusted for inflation. In contrast, our per-hour estimates for the Netherlands are all well below the (inflation-adjusted) estimate derived in Baarsma and Hop (2009), which amounts to €5.5.[13]

3.4. *Predicted marginal effects*

The marginal effects of accepting the bid for individual outage scenarios on the probability of accepting the new transmission line are given in Table 10.[14] Overall, the patterns captured in the table are consistent with the comparative proportions shown in Table 5, and with our main estimation results. There are three significant and positive effects, using our "90% of entire distribution in the positive domain" criterion: In the Netherlands, accepting the bid to the winter, 1 h, outage increases acceptance probabilities by close to 12% for the average household. Accepting the summer, 4 h, bid increases acceptance

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[13] Presumably, their WTP estimate is also averaged over season.

[14] Due to the time-consuming computational operation of evaluating the high-dimensional cumulative distribution functions implied by Eq. (8) for a large number of observations, these results are based on 1,000 random draws of $\boldsymbol{\theta}$, out of the 10,000 original draws produced by the GS.

probability by 11% in Ireland, and acceptance probability goes up by 13% in Greece for those who accept the bid to the longer summer outage. In addition, many other nations show positive effects of smaller magnitude, but still with over 80% of the predictive distribution in the positive domain. These are Hungary and Denmark for winter, 1 h, Bulgaria, Finland, Spain, Estonia, and Sweden for the longer winter interruption, Estonia and France for the shorter summer outage, and Romania, Bulgaria, and Ireland for the summer, 12 h, scenario. France remains an outlier with a significant *negative* marginal effect for the longer summer interruption.

Results for the marginal effects of jointly accepting bids to bundles of scenarios are given in Table A.13 in Appendix A. They are somewhat more diluted because of the inconsistent relationship between bid acceptance to winter outages and infrastructure acceptance, versus bid acceptance to summer outages and infrastructure acceptance for many locations. Nonetheless, accepting both winter bids has a positive effect on a favorable disposition to the new transmission line in the Netherlands (at 20% significance), while accepting both summer bids significantly boosts infrastructure acceptance in the Netherlands and, to less pronounced extent, in Greece. Accepting all four bids produces a positive effect (at 20% significance) for Estonia, Ireland, and the Netherlands.

In summary, our analysis of marginal effects generates the same picture as our main estimation results – the linkage between WTP to avoid outages and acceptance of new electricity infrastructure varies over both countries and outage scenarios. We certainly do not find evidence of a universal positive relationship between vulnerability to outages and a positive disposition to new transmission lines.

4. Conclusion

This study is the first to examine the relationship between the currency-valued disamenity of power outages and the propensity to accept new electricity infrastructure for residential customers. It is also the first to consider both power supply issues at a large, multi-national scale. It is exploratory in the sense of trading information collection on local details related to power provision for a wide geographic coverage of many EU nations. Thus, while our results cannot speak to local *within-country* differences in household vulnerability and preferences related to electricity service, they still allow for a cross-country comparison of vulnerability and acceptance for the “typical” household in each nation.

Overall, we find both commonalities and mixed signals for our international sample of EU-households with respect to their willingness to pay to avoid interruptions, acceptance of new transmission lines, and the linkage between the two. On the common side, our results clearly indicate that (i) all nations exhibit positive, significant WTP to avoid winter outages, (ii) winter outages are substantially more harmful to European customers than summer interruptions, and (iii) average (per-hour) outage costs are lower for longer winter interruptions compared to a short winter outage, suggesting diminishing costs over duration. We also find that larger, urban, and more educated households as well as older residents are more vulnerable to outages as indicated by their higher WTP for all stipulated scenarios, especially if they believe that vital public infrastructure would be affected. Urban and educated households are also more accepting of new power lines, in contrast to older residents, who show a less favorable disposition to such interventions.

However, this is where cross-country commonalities end. The bulk of our results indicate strong country-specific heterogeneity in all aspects of our research. For example, while WTP to avoid summer interruptions is positive for most nations, it is essentially zero for some (Romania, Bulgaria, and Estonia for the 12 h scenario), and even negative in the “outlier” case of France. To some extent, this may be related to fewer or less developed cooling technologies available in those locations, making continued electricity provision relatively less important or relevant.

For some of the countries with positive summer-WTP marginal per-hour costs increase with duration (Finland, Slovenia, Sweden, Denmark, Netherlands, Germany), while they remain flat or decrease for others (Hungary, Poland, Slovenia). On the acceptability side, different added incentives (large-scale economic or environmental benefits) have different effects on acceptance for different countries, though none of them considered the “community compensation” scenario particularly attractive. Some countries show acceptance rates of 50% or higher (Romania, Finland), while others remain well below 20% (Greece, Ireland).

With respect to our main research question of a linkage between outage costs and acceptance of new electricity infrastructure, we find an equally mixed picture. While there are mild signals that a higher WTP to avoid a *specific* outage also increases acceptance of infrastructure for at least one of our scenarios for all but three nations (Poland, Slovenia, Germany), there is no consistency of this effect within any single country across all four scenarios. In fact, for some of them (Finland, Spain, Sweden, Denmark, Netherlands) a higher WTP has a positive effect on acceptance with respect to winter outages, while a positive bid response to our summer scenarios has no or even a negative statistical effect on acceptance. We interpret this discrepancy of a positive association between WTP and acceptance for winter interruptions and the lack of such a relationship for summer outages as a belief amongst these respondents that new power lines only guard against winter interruptions, but offer little protection or have little relevance with respect to summer outages.

However, such a belief may be misguided. Table A.14 provides an overview of major outages that have occurred in Europe over the last 15 years. It is evident from the table that large-scale power interruptions can happen at any time of the year, including the summer months, and for a variety of reasons. While it is beyond the scope of our study to determine which of these incidents could have been avoided altogether with a tighter transmission grid, it is probably fair to assume that the *geographic scale* of the interruption could have been limited for at least some cases with built-in redundancy in the transmission system (UCTE, 2007; Buldyrev et al., 2010).

Overall, we take our findings to indicate that many EU citizens may have a poor or incomplete understanding of the linkage between electricity infrastructure and the risk of power failures in their own region. A widespread information campaign along those lines may help in reducing local resistance to new transmission lines and perhaps other elements of the power grid. Clearly, creating an awareness of the broader economic and environmental benefits associated with a tighter transmission grid also matters, as indicated by our strong and significant treatment effects for the sample at large.

Naturally, our study is best considered as a starting point for a more thorough examination of the linkage between the vulnerability to electricity supply interruptions and the NIMBY phenomenon. Most notably, we only consider one specific infrastructure scenario, a "standard" transmission line with pylons. Stakeholder's reactions and disamenity costs associated with other installations related to electricity supply, such as wind turbines, large arrays of photovoltaic panels, or even different styles of pylons (see e.g. Atkinson et al., 2004; Devine-Wright and Batel, 2013) may vary from the ones observed for our sample. Another promising avenue for future research would be the direct estimation of the perceived reduction in outage *risk* due to new infrastructure. Perhaps the most logical next step, however, would be an implementation of a similar survey and modeling framework on a country-by-country basis with a much larger sample size, given the pronounced heterogeneity across nations that we find for both aspects of power provision – the value of reliability and the perceived net benefits of new infrastructure. This would allow for a more refined analysis of within-country variation of preferences and attitudes at a local scale.

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Appendix A. Additional tables

Table A.11
Household demographics, country-level.

Country	% female	% urban	Education % A level	HH size (# people)	Income (000 euros) mean
Low reliability					
Romania	0.53	54%	75%	2.90	2.41
Bulgaria	0.53	62%	81%	2.80	3.28
Greece	0.52	57%	66%	2.60	10.68
Hungary	0.55	53%	82%	2.60	5.31
Poland	0.53	67%	90%	2.80	5.90
Medium reliability					
Finland	0.51	59%	85%	2.10	25.15
Slovenia	0.51	56%	85%	2.50	12.97
Spain	0.51	93%	55%	2.60	16.12
Estonia	0.53	52%	90%	2.20	7.12
France	0.52	70%	73%	2.20	24.50
High reliability					
Sweden	0.50	84%	82%	2.10	26.30
Denmark	0.50	71%	78%	1.90	28.86
Ireland	0.50	28%	75%	2.70	22.06
Netherlands	0.50	99%	73%	2.20	22.95
Germany	0.51	84%	87%	2.00	22.02

Source for % female: European Commission (2015f), year = 2012.
Source for % urban or suburban: European Commission (2015b), year = 2011.
Source for % A-level: European Commission (2015e), year = 2012.
Source for HH size: European Commission (2015a), year = 2013.
Source for income: European Commission (2015d), year = 2012.
Standard deviations were not available for these statistics.

Table A.12
Bids (euros) and % “yes” responses by scenario and country.

Country	Bid 1	Bid 2	Bid 3	Bid 4	%Yes 1	%Yes 2	%Yes 3	%Yes 4	Bid 1	Bid 2	Bid 3	Bid 4	%Yes 1	%Yes 2	%Yes 3	%Yes 4
	Scenario 1 (winter, 1 h)								*Scenario 2 (winter, 24 h)*							
Romania	0.22	1.56	4.91	–	70.64	52.17	50.91	–	0.67	7.82	21.22	67.01	92.73	60.87	41.67	22.45
Bulgaria	0.26	1.54	5.12	–	68.52	57.69	46.15	–	1.02	8.19	23.04	71.69	86.54	63.46	37.93	20.00
Greece	0.25	2.00	5.00	–	64.39	54.41	34.85	–	4.00	8.00	30.00	70.00	80.30	72.06	47.76	24.62
Hungary	0.07	0.26	1.92	5.23	81.97	81.67	43.86	29.69	1.74	8.37	24.93	69.74	85.94	68.42	30.00	18.03
Poland	0.12	0.24	1.92	5.05	77.97	77.78	58.93	40.91	1.68	8.18	24.53	71.65	86.36	75.00	38.89	32.20
Finland	0.25	3.00	5.00	–	73.58	45.28	35.59	–	8.00	41.00	70.00	–	82.14	46.43	46.00	–
Slovenia	0.25	2.00	5.00	–	73.11	45.76	32.26	–	5.00	8.00	32.00	70.00	87.10	81.36	53.23	33.33
Spain	0.25	2.00	5.00	–	68.38	42.42	32.26	–	5.00	8.00	31.00	70.00	83.87	80.30	48.21	32.79
Estonia	0.25	2.00	5.00	–	60.87	45.16	32.73	–	2.00	8.00	25.00	70.00	90.91	69.35	45.45	25.00
France	0.25	3.00	5.00	–	56.14	25.00	20.37	–	7.00	8.00	38.00	70.00	44.44	56.67	25.93	28.33
Sweden	0.23	2.90	5.22	–	65.57	37.74	24.14	–	8.12	40.59	71.90	–	72.97	43.75	41.38	–
Denmark	0.27	3.36	5.37	–	76.42	50.00	38.18	–	8.05	8.72	46.98	69.80	76.92	81.82	60.38	54.72
Ireland	0.25	3.00	5.00	–	72.50	59.26	37.70	–	7.00	8.00	38.00	70.00	85.25	74.07	42.11	20.63
Netherlands	0.25	3.00	5.00	–	64.35	35.19	36.07	–	8.00	40.00	70.00	–	69.57	31.15	42.59	–
Germany	0.25	3.00	5.00	–	53.17	41.79	23.81	–	7.00	8.00	38.00	70.00	79.37	82.09	51.61	48.44
	Scenario 3 (summer, 4 h)								*Scenario 4 (summer, 12 h)*							
Romania	0.22	0.45	3.57	8.93	67.39	67.35	41.67	18.18	4.91	11.17	13.40	44.67	48.33	36.73	32.73	10.87
Bulgaria	0.26	0.51	4.10	9.22	63.46	54.00	22.41	19.23	5.12	11.27	14.34	46.09	34.48	30.00	40.38	15.38
Greece	0.50	5.00	9.00	–	63.16	29.85	16.67	–	5.00	15.00	19.00	45.00	59.70	47.69	39.39	23.53
Hungary	0.21	0.52	4.36	9.42	75.44	72.13	23.33	17.19	5.23	12.55	15.69	46.38	50.00	42.62	31.25	21.05
Poland	0.24	0.48	4.33	9.14	75.00	64.41	46.30	30.30	5.05	12.26	15.15	45.93	61.11	42.37	46.97	21.43
Finland	0.50	1.00	7.00	9.00	64.00	52.83	26.79	20.34	5.00	21.00	25.00	45.00	69.64	42.00	33.90	20.75
Slovenia	0.50	1.00	6.00	9.00	66.67	49.15	20.97	19.35	5.00	16.00	20.00	45.00	54.84	47.37	35.48	33.90
Spain	0.50	5.00	9.00	–	48.82	28.57	16.13	–	5.00	15.00	19.00	45.00	66.07	36.07	38.71	15.15
Estonia	0.50	4.00	9.00	–	48.36	29.09	20.00	–	5.00	13.00	16.00	45.00	45.45	30.00	36.36	8.06
France	0.50	1.00	7.00	9.00	43.33	25.00	16.67	14.81	5.00	19.00	24.00	45.00	27.78	36.67	18.52	8.33
Sweden	0.58	0.93	6.96	9.28	55.17	49.06	23.44	18.97	5.22	19.71	25.51	46.39	54.69	48.28	25.86	18.87
Denmark	0.54	1.07	8.05	8.72	67.92	53.85	32.08	27.27	5.37	24.16	29.53	44.97	69.81	50.94	43.64	25.00
Ireland	0.50	1.00	7.00	9.00	53.97	64.81	28.07	16.39	5.00	19.00	24.00	45.00	61.40	26.98	34.43	12.96
Netherlands	0.50	1.00	7.00	9.00	62.96	48.15	14.75	18.03	5.00	20.00	25.00	45.00	54.10	44.44	24.59	14.81
Germany	0.50	1.00	7.00	9.00	50.00	50.75	29.03	17.46	5.00	19.00	23.00	45.00	56.45	48.44	38.10	20.90

Table A.13
Predicted marginal effects of bid acceptance on the probability of accepting new infrastructure – combined scenarios.

Country	"Yes" to both winter outages only			"Yes" to both summer outages only			"Yes" to all four outages		
	mean	std.	prob. > 0	mean	std.	prob. > 0	mean	std.	prob. > 0
Low reliability									
Romania	−0.122	0.122	0.168	0.038	0.084	0.677	−0.068	0.121	0.267
Bulgaria	0.095	0.142	0.740	0.030	0.110	0.617	0.125	0.149	0.797
Greece	−0.018	0.109	0.432	0.102	0.108	0.827	0.071	0.113	0.740
Hungary	0.055	0.140	0.673	0.033	0.111	0.607	0.086	0.150	0.724
Poland	−0.168	0.149	0.134	0.056	0.110	0.714	−0.103	0.146	0.232
Medium reliability									
Finland	0.076	0.144	0.691	−0.090	0.123	0.220	−0.015	0.142	0.460
Slovenia	0.017	0.138	0.565	0.065	0.112	0.712	0.080	0.136	0.719
Spain	0.095	0.127	0.781	0.008	0.099	0.518	0.096	0.127	0.780
Estonia	0.066	0.127	0.699	0.067	0.107	0.721	0.131	0.124	0.860
France	0.063	0.114	0.695	−0.063	0.082	0.190	−0.033	0.101	0.379
High reliability									
Sweden	0.030	0.132	0.604	−0.023	0.110	0.401	0.000	0.132	0.515
Denmark	0.110	0.149	0.768	−0.057	0.109	0.271	0.029	0.143	0.609
Ireland	−0.040	0.114	0.371	0.201	0.119	0.958	0.146	0.129	0.862
Netherlands	0.144	0.121	0.877	0.005	0.092	0.500	0.137	0.114	0.886
Germany	−0.005	0.123	0.491	0.090	0.120	0.768	0.083	0.131	0.734

std. = standard deviation.

Table A.14
History of large-scale outages in Europe since 2000.

Year	Month	Location	Duration	Scale	Cause
2000	May	Portugal	2–5 h	Regional	Accident
2003	Sep.	Denmark, Sweden	1 h	Regional	Technical failure
2003	Sep.	Italy	2 days	Whole country	Storm
2004	Jul.	Greece	Multiple hours	Most of country	Heat wave
2006	Nov.	Germany, France, Benelux, Spain, Portugal	2 h	Multiple countries	Technical failure
2007	Jul.	Spain	Multiple days	Local	Technical failure
2007	Dec.	Netherlands	3 days	Regional	Helicopter accident
2008	Apr.	Poland	12–18 h	Regional	Snow buildup
2009	Jan.	France	Multiple hours	Regional	Storm
2009	Mar.	UK	2 h	Regional	Technical failure
2009	Jul.	UK	Multiple hours	Regional	Vandalism
2010	Mar.	Ireland	Multiple hours	Regional	Winter weather
2010	Jun.	UK	Multiple hours	Regional	Fire
2011	Jul.	Cyprus	3–5 days	Whole country	Explosion
2012	Apr.	Cyprus	5 h	Whole country	Technical failure
2013	Dec.	France	Multiple hours	Regional	Storm
2013	Mar.	Ireland	Multiple hours	Regional	Storm
2013	Apr.	Poland	Multiple hours	Regional	Storm
2014	Aug.	Malta	6 h	Whole country	Technical failure
2015	Mar.	Netherlands	1–2 h	Regional	Technical failure

Sources: Wikipedia (2015) and Escritt (2015).
Unplanned outages with at least 1,000,000 person-hour disruption.

Appendix B. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.reseneeco.2016.06.003.

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