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Markus Bliem

Institut für Höhere Studien Kärnten
Domgasse 3, 9020 Klagenfurt, Austria
info@carinthia.ihs.ac.at
Tel.: +43 463 592 150-18
Fax: +43 463 592 150-23

Abstract: The liberalisation of the European energy market has led to a fundamental re-organization of the Austrian electricity market. Currently, the Austrian distribution network is regulated on the basis of a price-cap system and quality aspects are not taken into account. Many theoretical and empirical studies have shown that service quality and price go hand in hand. Therefore, in the last years there has been increasing interest in electricity supply and customer outage cost in many countries. This paper presents the results from a comprehensive study of the economic value of reliability of supply carried out in Austria in 2007. Two different customer groups (households and businesses) were asked to state their preferences for service reliability in a choice experiment. The results of the survey can be used to develop a regulation scheme that explicitly takes into account reliability of supply as the main quality dimension.

Keywords: Choice experiment, Quality, Reliability, Electricity

JEL-Classification: C25, C93, D12, Q41

Introduction

The liberalisation of energy markets has been a key energy policy objective in Europe over the last fifteen years (IEA, 2005). Within the electricity market the sectors with natural monopoly have been separated from those which are subject to competition. Since 2001, the Austrian electricity market has been completely liberalised and all customers can freely choose their supplier. Due to the special cost structure the transmission and distribution networks represent a natural monopoly and required different forms of regulation after successful deregulation. Hence, in the year 2001 - as a first step - a cost-plus regulation scheme has been introduced. Only five years later, in 2006, the Austrian Regulation Authority (E-Control GmbH) introduced an incentive regulation scheme; namely a price-cap regulation. In the current price-control period (2006-2009) the regulation mainly takes account of the control of the tariff without accounting for network quality.

There is evidence that independent price-cap regulation of utilities can directly influence the quality of supply (Fraser, 1994; Kidokoro, 2002). Price and quality are strongly correlated. Economic theory predicts that where utilities are subjected to a price-cap it is profitable for them to reduce costs by cutting down on quality; a higher service reliability usually costs more money.

In monopolised markets the regional utilities can easily pass on their investment costs. In a competitive market the investment decision (related to generation capacity, for example) is based on calculations of the profitability of the installation. Investments into the quality of the distribution network depend heavily on the net tariffs set by the regulator. From a theoretical point of view, an optimal level of service quality implies that the marginal costs equal the consumer willingness to pay for one extra unit. The regulator must take into consideration consumer preferences for service quality, and a customer survey should be conducted before implementing a quality incentive scheme.

It is evident that an outage can provoke significant economic damages, both as a direct consequence of the outage, as well as through spinoff effects due to the strong inter-linkages between industry sectors (Hamachi LaCommare, 2004). It is usually assumed that the value of electricity not supplied is many times higher than the retail price of electricity (CEER, 2005). However, the net value a consumer attaches to a supply interruption depends primarily on the type of electricity user and the perceived reliability level. If consumers expect a low level of reliability they can adopt measures to mitigate negative effects. The outage costs also vary according to the time of day, the duration of the interruption, the availability of back-up systems and the regional economic structure. Desired reliability levels affect consumers' willingness to pay (WTP) and may differ significantly between regions and local areas. The theoretically prescribed optimal level of service quality may be hard to achieve in practice due to different information-related problems. These include lack of information on (efficiency-related) costs required to produce optimal quality, and consumer demand (expectations) about quality (Sappington, 2005).

The main objective of this study is to illustrate the practicability and value of applying a choice experiment to assess the economic value of reliability of supply. Furthermore, the paper focuses on describing a comparison of residential and commercial preferences and expectations regarding service quality. Recent papers have taken household customers as their exclusive focus and, to the best of my knowledge, no choice experiment on service quality which included business customers has yet been carried out. Hence, this is the first use of the CE method in which both relevant customer groups were asked to state their preferences for service reliability through using the same CE design.

An overview of previous approaches

There is a long-tradition of measuring outage costs to quantify the value of reliability. Ajodhia and Hakvoort (2005) have classified outage cost measurement techniques by direct and indirect methods. One such indirect method is to use the ratio of gross economic output to energy consumption as a proxy, also called the production function approach. This method uses the ratio of a gross economic measure (e.g., gross output, gross domestic product, etc.) and a measure of electricity consumption (e.g. peak kW load or kWh) to estimate interruption costs by industry (Telson, 1975). 'Hard' statistical information is used to perform a straightforward analysis for the business sector for which electricity consumption data exist. The drawbacks of this approach are that it is based on severely limited assumptions that are often invalid; it does not capture many direct costs, and ignores virtually all indirect costs. Another problem is how to put a monetary value for leisure time losses due to an outage as most leisure-time activities depend on electricity to some extent (Munasinghe, 1980). In some studies the wage rate has been used as a proxy to estimate this lost leisure-time (de Nooij et al., 2007).

Another option for summing up the economic costs of a power outage is known as the preparatory action method. Consumers are asked to choose from a list of likely mitigation actions, i.e. actions they could take to alleviate the impact of interruptions. A very comprehensive study for the UK was carried out by Kariuki and Allan (1996a, 1996b). The underlying concept here is that the value of a good is equivalent to the amount the user is willing to pay for some other good, in this case preparatory actions, which provide the same benefits as the primary good (Wacker and Billington, 1989). Thus, the preparatory action method is very similar to the avoided cost approach, mainly used for the valuation of environmental goods. A disadvantage of this method is that in practice it underestimates the benefit of energy security because preparatory actions and energy supply are not perfect substitutes.

A direct outage costs measurement technique and a very popular approach to gathering any sort of outage-related data has been to use blackout case studies. The basis of this method is an after-the-fact analysis of specific interruptions. This approach has been limited to blackouts of large metropolitan population centres. For example, the 1977 New York City blackout is well documented and studied (Corwin and Miles, 1978). The blackout case study method provides more detailed and direct cost estimates that include indirect costs not adequately captured in other forms of analysis. Case studies evaluate an actual instead of a hypothetical power outage. However, the study findings are limited due to geographic constraints and the characteristics and duration of the specific outage being studied.

An alternative to the above mentioned approaches is to use stated preference methods such as contingent valuation or experimental choice models and to ask consumers for their willingness-to-pay (WTP) (or willingness-to-accept) to avoid an outage through different hypothetical scenarios. In comparison to the other methods, stated preference methods are a comprehensive measure of the total value of electricity supply to the consumer. The success of a stated preference approach depends heavily on how well the study is designed, carried out and interpreted. In the last twenty years, a lot of surveys have been carried out all over the world. Eto et al. (2001) provide an overview of existing studies for the U.S. economy. Willis and Garrod (1997) used a contingent valuation to estimate the value of supply reliability of industrial firms in the UK. Hartman et al. (1991) and Beenstock et al. (1998) used a choice modelling approach to monetise the value of service reliability for residents and compared the choice model estimates with results obtained by applying the contingent valuation method. A similar approached has been used by Goett et al. (1988) and Doane et al. (1988). More recent studies for European counties are available for the Netherlands (Baarsma et al., 2005), Sweden (Carlsson and Martinsson, 2007; Carlsson and Martinsson, 2008; Söderberg, 2008), Italy (Bertazzi, 2005) and the UK (Accent Marketing and Research, 2004). So far, there have been no studies published on the value of service reliability service in

Austria and to my knowledge this paper presents for the first time a comparison of households versus business choice experiment results. The design used for the choice experiment which was carried out in Austria will be presented in the next section.

Choice experiment

Choice experiment (CE) belongs to the family of stated preference methods and is based on traditional microeconomic theory. CE combines Lancaster's characteristics theory of value and random utility theory (RUT). Lancaster asserted that consumers derive utility from the characteristics of the good and not from the good itself (Lancaster, 1966). The value of reliability of supply can, for example, be expressed as a sum of its characteristics, such as duration and frequency of outages, time of day, etc. The main proposition of the RUT is that utility cannot be observed directly, but indirect valuation of consumer preferences is possible with some degree of randomness (Manski, 1977). The utility function for a representative consumer can be written as:

$$U_{in}=V_{in} + \varepsilon_{in} \qquad (1)$$

Where V_{in} is the systematic component of the utility held by consumer n for choice alternative i and ε_{in} is the random or stochastic part. Assuming there exists a binary choice situation where the individual n can choose between alternative i and alternative j, then the probability that individual n chooses alternative i in order to maximize his or her utility is:

$$P_n(i)=\Pr(\varepsilon_{jn}- \varepsilon_{in} \leq V_{in} - V_{jn})$$

$$= \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{(V_{in}-V_{jn})/\sigma} \exp\left[-\frac{1}{2}u^2\right] du = \Phi\left(\frac{V_{in}-V_{jn}}{\sigma}\right), \qquad (2)$$

where Φ ( ) denotes the standardised cumulative normal distribution (Ben-Akivia & Lerman, 2000).

In order to be able to estimate the probability of someone choosing an alternative, it is necessary to make assumptions about the distribution of the random term. Different assumptions about ε_{in} lead to different choice models (Train, 2003). The binary probit model arises from the assumption that ε_{jn} and ε_{in} are both normally distributed. Since the respondents in this case are asked to make repeated choices, the assumption of independency between observations may be violated. Therefore the random term is specified as

$$\varepsilon_{in} = u_{in} + \upsilon_{in} \qquad (3)$$

where u_{in} is the unobservable individual-specific random effect and υ_{in} is the remaining disturbance (Green, 1997). This way of specifying the error term leads to a random effect probit model.

Survey design and implementation

In the study described, a choice experiment (CE) was chosen for the economic valuation of reliability of supply. Two different customer groups (households and business electricity consumers) were asked to state their preferences. The CE was constructed around the current level of reliability and each choice set consisted of two options (binary choice), one of which represented the status quo. In alternative A, the level of the attributes included varied in all choice sets, while alternative B represented the status quo. Table 1 provides an overview of the attributes and the levels.

Table 1: Attributes and levels

Attribute	Level/Alternative
Duration (duration of outages in minutes/hours)	3 minutes, 30 minutes (current situation), 4 hours, 10 hours
Frequency (number of outages per year)	0.5 (one outage in two years), 1 (current situation), 4, 10
Time of day	Day, Night
Day of the week	Tuesday, Sunday
Advance notification of outage	No, yes
Price (Change in current bill)	No change, - 20 %, - 10 %, + 10 %

Currently, the Austrian Regulation Authority (E-Control) collects data on the frequency (SAIFI[1]) and duration (SAIDI[2]) of outages. Based on these statistics it is possible to determine a *status quo* level for the average interruption duration and frequency per year. Starting from the current situation the levels were presented to the respondents as changes from the *status quo*. Both, a deterioration and an improvement were possible. The duration of outages were expressed in minutes or hours. Four levels were utilised, varying from '3 minutes' to '10 hours'. Frequency was defined as the

[1] The annual average interruption frequency (SAIFI) is determined by dividing the total number of interruptions to the supply of customers of grid manager i by the total number of connected customers of grid manager i.
[2] The average annual interruption duration (SAIDI) is determined by dividing the total lost time (in minutes) by the number of connected customers.

number of outages per year, with the four levels: 0.5, 1, 4 and 10. One outage per year (SAIFI = 1/a) corresponds to the *status quo*. Further attributes were the time of day, the day of the week and presence or absence of prior notification. The monetary attribute was specified as a percentage change in current electricity bill. Payment levels used in the choice experiment were -20 %, -10 %, no change and +10 %.

The estimation of the random effect binary Probit model generates parameter estimates according to the following indirect utility function:

$$V_j = \alpha_j + \beta_1 Duration_j + \beta_2 Frequency_j + \beta_3 Time_j + \beta_4 Day_j + \beta_5 Notification_j + \beta_6 \Pr ice\_Change_j \quad (4)$$

where alpha (α) is a constant and the betas (β) refer to the vector of coefficients related to the attributes duration, frequency, time of day (time), day of the week (day), advance notification of outage (notification) and the price. Inclusion of a monetary attribute allows the estimation of the marginal rate of substitution (MRS) between two attributes. The MRS is simply the ratio of the coefficients (Louviere et al., 2003). The MRS for a change in the duration of outages is estimated as follows:

$$MRS = -\frac{\partial V / \partial Duration}{\partial V / \partial \Pr ice} = -\frac{\hat{\beta}_1}{\hat{\beta}_6} \quad (5)$$

In order to combine the levels of the attributes into a number of options, a D-optimal design[3] was used. The design was accomplished by using the software JMP. 16 choice sets were randomly assigned to four blocks so that a single respondent was confronted with four choice sets. Dominant strategies were removed from the design and replaced by new alternatives.

The questionnaire was developed after two pre-tests and consisted of four parts. The first part of the questionnaire contained questions about respondents' general experience with power interruptions and measured respondent satisfaction with the overall service reliability. Respondents were asked what kind of electrical equipment they use and how disruptive an outage would be. In the second part, respondents were asked to state their choices using four different choice sets. In the introduction to the

[3] The D-optimality criterion seeks to maximise the determinant of the information matrix, or to minimise the determinant of the variance-covariance matrix of the parameter estimators.

choice experiment, respondents were told that the future level of service reliability depended on how much money the local network operator invested into the grid. Thus consumer demand for quality should directly influence the regulator's decision. The final part of the questionnaire was focussed on gathering data on respondents' socio-economic situation (income, age, living conditions, etc.) or in the case of businesses, general information about the company (number of employees, turnover, sectoral classification, etc.).

Sample characteristics

The sampling frame covered all Austrian households and companies, while results are based on a separate survey sent out to 2,500 Austrian households and 1,500 businesses. In order to guarantee a representative sample, the survey covered all Austrian regions (Bundesländer). The household sample was randomly generated using an electronic telephone directory. The business sample was drawn from a business database (Aurelia) which provides detailed information about 140,000 Austrian companies. The samples were weighted to reflect relevant socio-economic characteristics (age, gender, household size, etc.) and for the business sector, company size (number of employees, turnover, etc.). Companies were initially selected through a recruitment screening procedure. During a brief telephone interview a person eligible to take part in the survey was sought. The challenge was to find a person responsible for the company's reliability of supply with enough knowledge to appraise how the company would be affected by a power outage. After an eligible person was found the questionnaire was sent directly to this individual.

Individuals were invited to complete the survey online or by mail, depending on their preferences. Most people chose to answer by mail because many respondents had no access to the web or felt uncertain about how to use an online survey. In addition, some telephone interviews were used to complement the postal/web-based survey.

Table 2: Response rate

	Sample	Responses	Response rate (%)
Households	2,500	421	16.84
Business	1,500	396	26.40
Total	4,000	817	20.43

The main survey was carried out between January 2007 and March 2007 with a total of 4,000 individuals invited to participate. Table 2 gives an overview of the response rate. A total of 421 households and 396 companies completed the final questionnaire, giving a total response rate of 20.43 percent.

Sample characteristics across the two subsamples are summarised in the following tables. Table 3 displays household sample characteristics. Generally, the socio-economic parameters of the household sample are fairly representative (when compared to the Austrian population) although men are slightly overrepresented. The age structure of respondents lies well within the distribution of the Austria population, with the largest share (76 percent) of respondents between 25 and 65 years. The age category ">65" years is disproportionally low. One explanation may be that a web-based survey method was chosen and elderly people have less access to the web or are unsure about using an online survey. The mean monthly disposable household income falls in the income category € 1501-2500 which is slightly below average for household income in Austria (approx. € 2,500 per month). The respondents were asked whether they use their homes for business activities. 21 percent stated that they work at home and less than 10 percent take action to avoid power outages.

Table 3: Sample characteristics households

Variable	Sample (number)	(%)
Gender male	255	61.15
Age (percentage share of older than 65 years)	56	13.43
Home business	89	21.24
Precautions	36	8.57
Consumer satisfaction		
Very satisfied	203	48.45
Satisfied	174	41.53
Neither	38	9.07
Somewhat dissatisfied or very dissatisfied	4	0.96
Number of outages (experienced during last 12 month)	191	45.48
1 outage	75	17.86
2 outages	77	18.33
3 outages	21	5.00
4 outages and more	18	4.29
Damage	29	6.90
Family size (number of persons)		
1 person	69	16.47
2 people	157	37.47
3 people	87	20.76
4 people and more	106	25.30
Housing type		
flat	191	45.58
Single family house / multi-family house	228	54.42
Average electricity bill (€/month)	72.84	
Average electricity usage (kWh/year)	5,412	

Consumer satisfaction with service reliability and their experiences with power outages were elicited though a series of questions. A majority of 90 percent are very satisfied or satisfied with the current level of reliability. Half of all respondents have experienced at least one power outage during the last 12 month and only a relatively low share of the sample population (10 percent) have experienced more than 3 power interruptions.

Table 4 provides some information about the sample characteristics of business customers. More than 86 percent are small and medium enterprises (SMEs) with less than 250 employees. Two-thirds of these SMEs actually employ less than 20 full-time employees. Fully 65 percent have a turnover of less than € 500,000, while 15 percent generate less than € 100,000.

Table 4: Sample characteristics business customers

Variable	**Sample (number)**	**%**
Organisation size		
1 - 19 employees	270	68.53
20 - 249 employees	71	18.02
250 employees and more	53	13.45
Precautions	174	44.05
Voltage stabiliser	4	2.30
Uninterrupted power supply (UPS)	105	60.34
Customer generation	46	26.44
Other	19	10.92
Consumer satisfaction		
Very satisfied	153	38.73
Satisfied	181	45.82
Neither	47	11.90
Somewhat dissatisfied or very dissatisfied	14	3.54
Number of outages (experienced during last 12 month)	202	51.14
1 outage	66	32.67
2 outages	59	29.21
3 outages	41	20.30
4 outages and more	36	17.82
Damage		
No financial loss	78	38.61
Less than als € 100	37	18.32
€ 100 - € 1,000	35	17.33
€ 1,001 € 10,000.-	33	16.34
More than € 10,000.-	19	9.41
Average electricity bill (€/month)	292	
Average electricity usage (kWh/year)	26,465	

23 percent of all business respondents have a turnover between € 2 and 5 million and relatively few (24 %) have a turnover of more than five million Euros. 44 percent of

companies have installed voltage stabilisers, UPS or a back-up generator to deal with power quality or reliability concerns. In order to assess company experience with power outages, firms were asked to state the number of outage events during the past 12 month. More than 48 percent of firms had experienced no supply interruptions and only a few firms were confronted with 4 outages or more. What is most striking is how many companies experienced no financial loss at all from outages. 202 business customers experienced at least one power outage in the 12 months before receiving the questionnaire but 39 percent experienced no real costs from outage events. Most business customers stated they had suffered relatively small costs of less than € 1,000 and a small number of companies suffered large costs.

The business categories of respondent firms are documented in Table 5. The number of manufacturing and construction companies reflects the importance of these industries in Austria. The service sector, especially the financial sector, is slightly underrepresented in the sample.

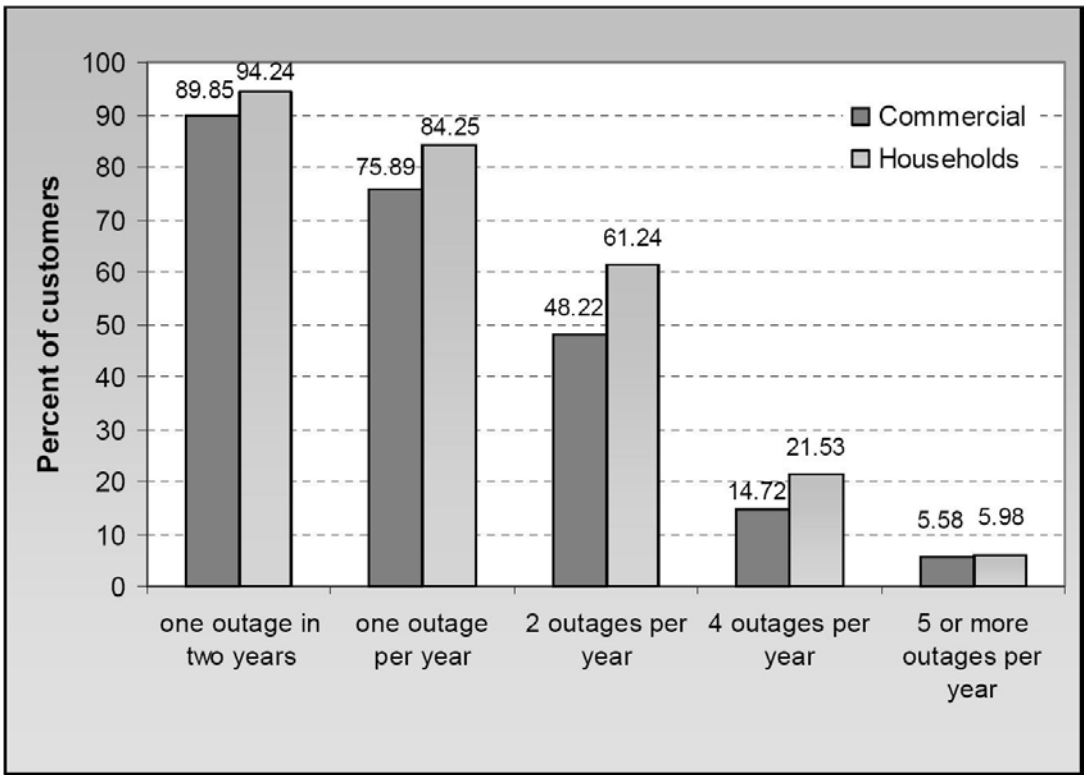
Table 5: Main business sectors

Business Sector	%
Agriculture and forestry	1.26
Mining and quarrying, except for energy producing materials	0.51
Manufacturing	20.45
Electricity, gas and water supply	4.55
Construction	15.66
Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods	28.54
Hotels and restaurants	3.28
Transport, storage and communication	4.29
Financial intermediation	2.27
Real estate, renting and business activities	10.10
Other	9.09
Total	100

In order to compare residential and commercial expectations about service reliability, respondents were asked to indicate the number of outages (of a minimum 30 minute duration) that they consider to be acceptable in a given year.

Figure 1 shows the answer given by households and business customers. Generally, business customers have significantly higher expectations about service reliability. Less than 50 percent of business customers are willing to accept more than two outages per year, whereas more than 61 of households consider two outages per year to be acceptable. On the other hand, 94 percent of business customers and 90 percent of households state they would accept one outage in two years.

Figure 1: Acceptable number of outages



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Empirical results

Table 6 shows the model that was used to estimate households' choices among reliability of supply options. STATA 9.2 econometric software was used to estimate a random effects binary Probit model. In the Probit model all attributes used (including the monetary attribute) were highly significant, indicating that respondents were willing to make tradeoffs between the two alternatives presented. The results show that both groups (households and companies) of consumers are willing to pay for reductions in frequency and duration of outages. Estimated coefficients with a negative sign imply that a change from the *status quo* option to the corresponding level decreases the probability of choosing the alternative. Dummy coding was used for the attribute 'duration'. In the model, duration is described using three variables. The first level (3 minutes) represents an improvement, whereas the two other levels (4 hours and 10 hours) imply deterioration. Thus, the coefficient of these variables quantifies the preferences for these attributes relative to the base of 30 minutes. The value of the first level (3 minutes) was not found to be significant at the 10 percent confidence level. Hence, households have no willingness to pay for reducing the duration of power outages to 3 minutes. The negative and highly significant coefficients for the levels '4 hours' and '10 hours' indicate that households that experience longer power interruptions require higher compensation.

Table 6: Random effects binary Probit model – Results households

Variable	Coefficient
Duration 3min	-0.114
	(0.117)
Duration 4h	-1.354**
	(0.165)
Duration 10h	-1.887**
	(0.153)
Frequency	-0.125**
	(0.014)
Price	-0.084**
	(0.007)
Time of day (night)	-0.061
	(0.119)
Day of the week (Sunday)	-0.617**
	(0.141)
Notification (yes)	0.237
	(0.124)
Working* frequency	-0.061*
	(0.027)
Working* Day of the week	0.325**
	(0.101)
Constant	0.220
	(0.128)
σ_v	0.725
P	0.344
Observations	1573
Number of nr	403
Wald Chi-squared(11) = 297.62	
* significant at 5%; ** significant at 1%	

The equality of the dummy variables for the duration of outages was tested with the help of the Wald test and appeared to be significantly different (Duration 4h versus Duration 10h: chi-square=13.62, sig. level=0.001). The values for duration are nonlinear, which means that a two-hour interruption is considered less than two times as inconvenient as a one-hour interruption.

The frequency of interruptions entered the model in cardinal-linear form. The attribute is highly significant and has the expected sign. The result shows that households favour the prospect of fewer interruptions. Additionally, the estimated coefficient for price is negative and highly significant. The negative sign implies that respondents prefer lower electricity bills. Furthermore, the negative sign of the attribute 'day of the week' indicates that the average respondent prefers to have power outages on a weekday. People are more likely to be away from home during weekdays and therefore an outage will affect them less. In contrast, many leisure activities on the weekend are directly related to the use of electricity.

There is no evidence that time of day or advance notice of outages affect the utility of the average household since estimated values are statistically insignificant. Interactions between frequency and duration of interruption were tested and found to be insignificant. One explanation might be that respondents evaluated each attribute separately. The coefficients for the interactions between working and frequency or working and day of the week are both significant. The first interaction (working and frequency) could indicate that respondents who use their homes for business activities are more sensitive to outages because they anticipate higher interruption costs. The positive sign of the interaction between working and day of the week means that people working at home are, in general, more likely to choose the alternative when the outage is on the weekend. Household characteristics are not entered into the model. It was not the goal of the survey (as is clear from the design of the experiment) to take into account different levels of service reliability for different demographic groups (age, gender, etc.). The primary reason is that a quality regulation scheme is not able to account for some demographic differences, but can use the average willingness to pay to secure a certain level of service reliability for the population of customers as a whole.

Table 7 shows the estimation results for the business customers. Basically, commercial respondents display a very similar pattern of choices to households, although results highlight the fact that business customers expect a higher standard of reliability. Dummy coding was again used for the duration of outages using the same baseline category and significant differences were found when we compared the parameter estimates for different duration levels. The Wald test result is distributed as chi-square with a value of 3.12 ($p<0.0774$).

Table 7: Random effects binary Probit model – Results companies

Variable	Coefficient
Duration 3min	0.127
	(0.127)
Duration 4h	-0.272
	(0.162)
Duration 10h	-0.539**
	(0.142)
Frequency	-0.157**
	(0.028)
Price	-0.027**
	(0.006)
Time of day (night)	0.382**
	(0.142)
Day of the week (Sunday)	0.429**
	(0.148)
Notification (yes)	-0.056
	(0.137)
Precaution*duration	-0.096*
	(0.044)
satisfaction*frequency	0.035**
	(0.013)
Constant	-0.046
	(0.231)
σ_v	1.019
ρ	0.509
Observations	1468
Number of nr	367
Wald Chi-squared(10) = 143.94	
* significant at 5%; ** significant at 1%	

The coefficient for frequency is highly significant from a statistical point of view; commercial respondents have a strong aversion toward alternative reliability options with a high frequency of outages. Furthermore, it was found that business customers are prepared to pay a higher amount to avoid daytime and weekday power outages if a power outage occurs at night and on the weekend. In contrast, households display no clear preference towards time of the day. The attribute 'notified in advance' was found to be insignificant for both samples.

The interaction between precaution and duration entered the model in order to indicate whether companies' prior action (aimed at avoiding outages) affect their preferences. Furthermore, the model shows that the satisfaction of business customers with the current level of service reliability influences the choice between the two alternatives presented in the choice experiment.

One relevant question in this paper is to what extent the preference of both customer groups correspond to each other. The interpretation of the estimated models in Table 6 and Table 7 indicates that households and commercial respondents have different preferences. Another way to test for that is to pool the two datasets and to include a dummy variable "Group" representing zero for the household sample and one for the commercial respondents. The estimation for a pooled data is shown in Table 8. The variable "Group" is highly significant and therefore it can be assumed that preferences for both sample groups are significantly different.

Table 8: Random effects binary Probit model for pooled data

Variable	Coefficient
Duration 3min	0.023
	(0.084)
Duration 4h	-0.824**
	(0.110)
Duration 10h	-1.227**
	(0.098)
Frequency	-0.116**
	(0.009)
Price	-0.054**
	(0.004)
Time of day (night)	0.140
	(0.089)
Day of the week (Sunday)	-0.032
	(0.096)
Notification (yes)	-0.145
	(0.089)
Group	0.375**
	(0.082)
Constant	-0.026
	(0.152)
σ_v	0.843
ρ	0.415
Observations	3049
Number of nr	772
Wald Chi-squared(9) = 427.31	
* significant at 5%; ** significant at 1%	

The estimated parameters in Table 6 and Table 7 can be used to calculate implicit prices. In a linear model the ratio of two utility parameters is an estimation of the amount of money a respondent is willing to pay (WTP) to obtain some benefits for a specific change (Louviere et al. 2003). An important precondition for allowing estimation of WTP and the analysis of welfare effects is to define at least one attribute in monetary units. In this binary Probit model, the monetary attribute price is expressed as 'percentage change in current electricity bill'. The corresponding confidence interval was calculated using the delta method. For example, the average household desires a reduction of 16.07 percent of their current bill to accept a 4 hour power interruption.

Since frequency of interruptions enter in linear form, the required compensation increases by 1.49 percent of the current bill for each unit.

Table 9: Implicit price estimates

	Households			Commercial Respondents		
Attribute	**Coefficient**	**95 % Conf. Interval**		**Coefficient**	**95 % Conf. Interval**	
Duration 3min	-1.35	-4.05	4.64	4.64	-4.99	14.28
Duration 4h	-16.07	-18.76	-9.92	-9.92	-19.30	-0.55
Duration 10h	-22.38	-26.21	-19.62	-19.62	-30.85	-8.40
Frequency	-1.49	-1.85	-5.71	-5.71	-8.81	-2.61
Time of day (night)	-0.73	-3.46	13.92	13.92	-0.44	28.30
Day of the week (Sunday)	-7.32	-9.94	15.64	15.64	-0.24	31.53
Notification (yes)	2.81	0.11	-2.03	-2.03	-11.45	7.38

Table 9 also shows the average percentage change of current electricity bills needed to compensate business customers for a given change in frequency and duration from the *status quo*. For example, the average business customer expects their electricity price to be lowered by 9.92 percent to capture the value of a power outage increasing from 30 minutes to 4 hours. As can be seen in the table, commercial respondents are willing to pay a premium of 13.92 percent of their current bill to avoid interruptions during day, and 15.54 percent to shift a power outage to a Sunday.

Integrating customer reliability valuations into a regulation scheme

The results of the survey presented can be used to develop a quality regulation scheme that explicitly takes into account reliability of supply as the main quality dimension. Currently, the Austrian distribution network is regulated on the basis of a price-cap system. Thus tariffs (p) are adjusted by a NPI ('Net Price Index') and a so-called X-factor. X is the efficiency gain fixed by the regulator for a three year tariff period. For quality regulation this price-cap formula can be adjusted via a Q-factor that reflects customers' preferences for service reliability. Accordingly, the tariff in period 1 can be given by:

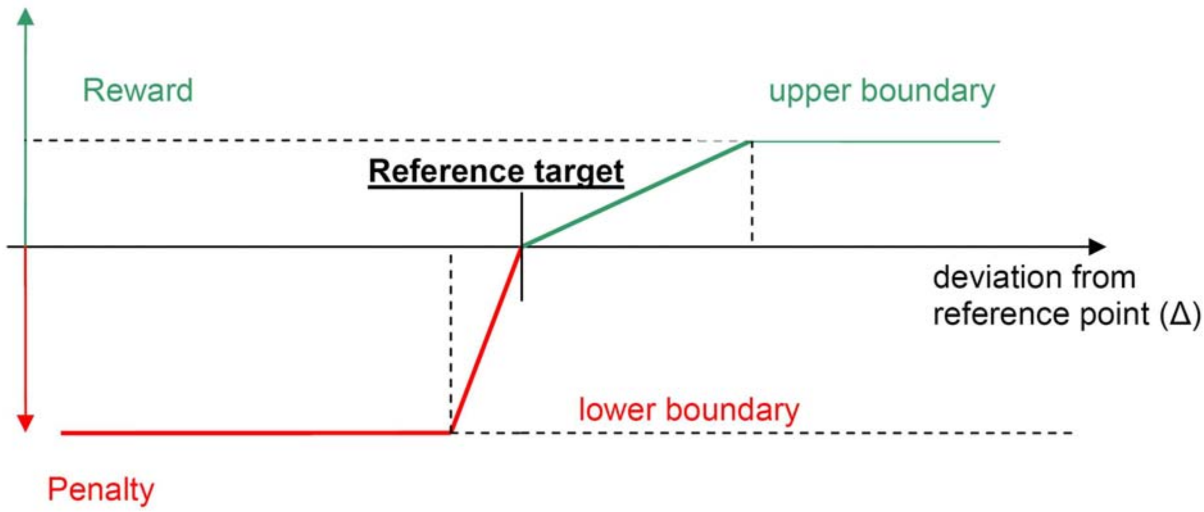
$$p_1=p_0\,(1+NPI-X\pm Q)$$

Yearly values of the parameter Q can be calculated, ex post, on the basis of company performances and relative financial incentives. Furthermore, quality-related company performance can be measured annually, as the difference (negative or positive) between a reference value (e.g. SAIDIref for the duration of outages) and a moving average of the measured reference value (ASAIDI) per each territorial district (i).

$$\Delta_i = SAIDI_{ref} - ASAIDI_{i,}$$

The basic concept is to describe an incentive scheme through using existing reliability indices that are linked to the average WTP for a certain level of reliability. In brief: the task of a penalty and reward system is to weight each temporal change of service reliability with consumers' WTP thereby making it possible to internalise consumer preferences and WTP to avoid interruptions to the firm's decision-making-process (Ajodhia and Hakvoort, 2005).

Figure 2: Reliability incentive scheme



The coefficients presented in Table 6 and Table 7 can be used to specify the slope of the curve in Figure 2. It may be seen that utilities have the incentive to improve service reliability up to the point where the cost equals the consumers WTP for quality. Currently, the Austrian Regulation Authority collects data on the frequency (SAIFI) and duration (SAIDI) of outages. Based on these statistics it is possible to derive an individual reference target for regulated utilities. As shown in Figure 2, the level of reward or penalty depends on the deviation from the reliability target. If the actual level of reliability is higher than the individual reference target, the utility obtains a reward. If the actual level is lower than the reference target, the utility is penalised.

Conclusion

Although almost everyone considers reliability of supply to be very important, it is not straightforward to assess what value society places on it. This paper presented the results of a study on the economic value of reliability of supply in Austria. The main objective of the paper was to illustrate the usefulness of applying the choice experiment method to measure the customer's valuation of service reliability and to compare residential and commercial preferences for service quality through using the same choice experiment design.

The results indicate that reliability of supply is of great value to Austrian customers. Both households and business customers are willing to pay a significant premium over and above their current electricity bill to avoid power outages. However, willingness to pay to avoid a service interruption is heavily dependent on the frequency and duration of the interruption the customer faces. With respect to the timing of an interruption, households have a strong preference for electricity service interruptions during the week, whereas business customers prefer interruptions, as may be expected, on weekends when their business are usually closed. Furthermore, companies prefer interruptions at night when there is less business activity. This finding is consistent with results from previous European studies.

The policy relevance and implications for decisions that influence the security of supply are twofold. First, the results have policy implications for the implementation of an incentive mechanism that focuses on the reliability of the network. Since 2006, the Austrian network has been regulated on the basis of a price-cap system designed to incentivise firms to operate more efficiently. Until now there has been no formal incentive mechanism that applies to transmission system reliability. The results presented in this paper show that both duration and frequency of power interruptions are relevant quality dimensions to consider when accessing negative welfare effects.
Second, the results can be used to justify (large) investments in the transmission system. Using information about the value of service reliability and the effect of the investment on supply security makes it possible to determine whether the benefits of investments into the grid exceed their costs.

Although the survey yields important information about the economic value of service reliability in Austria some improvements are possible. Firstly, it was impossible to further divide the results for commercial customers into subsectors or to distinguish between urban and rural regions. Due to the fact that "only" 396 companies completed the final questionnaire it was not possible to account for differences between the service and production sector, for example.

Second, the socio-economic characteristics and characteristics of business customers were not included in the model. A lot of interactions were tested, but the results were not found significant, even though preference heterogeneity was assumed a priori.

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