

# **ELECTRICITY BLACKOUTS FOR BUSINESS CONSUMERS: PERCEIVED IMPACTS, HETEROGENEOUS RESPONSES, AND THE ROLE OF COGNITIVE DRIVERS**

Alessandra Motz, Università della Svizzera italiana, +41 58 666 4167, [alessandra.motz@usi.ch](mailto:alessandra.motz@usi.ch)

## **Overview**

Within the broad and on-going debate concerning the value of security of supply in electricity (5, 7, 14), a stream of the literature devoted to demand-side analyses has investigated the perspective of business consumers, with the aim of assessing the magnitude and kind of damage that blackouts with different characteristics may cause to firms with different consumption patterns. Most of the analyses conducted on this topic rely on three kinds of methods. The first and most widely used one is the production function approach: these studies approximate the cost of a blackout with the so-called “value of lost load”, namely the ratio between the gross value added and the electricity consumption for each economic sector (5, 12, 13). The second one is the analysis of stated or revealed preferences: this kind of studies exploit either ad hoc surveys, or market data concerning the purchase of back-up devices or the enrolment into interruptible supply programmes to infer the value that business consumers place on security (2, 3, 4, 6, 8). Finally, a third group of studies, usually targeting lower income countries, relies on the econometric analysis of cross-section or panel data concerning the performance of firms and the occurrence of blackouts within a given region to estimate the loss of productivity or turnover determined by blackouts over one or more years (1).

My analysis contributes to this debate by proposing a stated preference study for the case of Switzerland. I focus on the value of security for business electricity consumers and study: a) the kind and magnitude of damage that blackouts may cause to business consumers, b) the willingness-to-accept of business consumers for blackouts with variable duration and with or without advance notice, c) the magnitude and drivers of heterogeneity in the preferences of business consumers with respect to blackouts, with a focus on the heterogeneity stemming from the use of lexicographic decision rules.

## **Methods**

I explore the value of security by investigating stated preferences data collected by means of an original on-line survey distributed among 543 firms located in Canton Ticino, Switzerland, between December 2018 and January 2019. The sample covers all economics sectors and firm sizes, and is reasonably representative of the economy of the region. The survey included questions regarding the firm’s size, activity, and electricity consumption pattern, questions concerning the magnitude and kind of damage suffered in the event of a blackout, and finally a discrete choice experiment where each respondent was asked to repeatedly choose one out of two blackout scenarios differing in blackout length, advance notice, and possible compensation expressed as a percentage of the monthly electricity bill. Figure 1 reports the short text that introduced the discrete choice experiment, and an example of a choice task.

These are the last six questions. In each question you will see two hypothetical scenarios in which your company is hit by a blackout.

Please imagine that the blackout hits your company in the season, day of the week, and time of the day in which it causes the highest damage.

The blackout scenarios that you will see differ in terms of:

- Duration of the blackout
- Availability of advance blackout notice
- Compensation that your electricity supplier may pay to your company for the inconvenience and damage caused by the blackout.

Please consider the consequences that your company may suffer in each scenario, and select the most acceptable scenario among the two.

Scenario 1	Scenario 2
Blackout lasting 4 hours	Blackout lasting 1 hour
24-hour advance notice	No advance notice
Compensation: 5% of your monthly electricity bill	Compensation: 25% of your monthly electricity bill

Your choice:



Figure 1 – Discrete choice experiment: introductory text and example of a choice task

Table 1 reports the attributes and corresponding levels that were used in the discrete choice experiment. The attributes and levels were defined based on the surveyed literature and on the security levels observed in Switzerland and in other comparable countries. The choice tasks were defined with an efficient design with blocking using the software Ngene: the result was six blocks with six choice tasks each, and two unlabelled alternatives per choice task. As a consequence, each respondent was randomly assigned to one of the six blocks, and had to complete six choice tasks.

Blackout attribute	Value	Corresponding description
Blackout duration (minutes)	0	No blackout
	5	Blackout lasting 5 minutes
	60	Blackout lasting 1 hour
	240	Blackout lasting 4 hours
	720	Blackout lasting 12 hours
Compensation (% of the monthly electricity bill)	0	No compensation
	5	Compensation: 5% of the monthly electricity bill
	10	Compensation: 10% of the monthly electricity bill
	15	Compensation: 15% of the monthly electricity bill
	20	Compensation: 20% of the monthly electricity bill
	25	Compensation: 25% of the monthly electricity bill
Advance notice (no / yes)	0	No advance notice
	1	24-hour advance notice

Table 1 – Attributes of the discrete choice experiment and corresponding levels

The analysis of the survey data is carried out in two steps.

In the first step I analyse with the usual descriptive statistics the responses collected in the first part of the survey, namely the questions concerning the strategies to cope with blackouts or reduce their impact, as well as the actual damage suffered by the business consumers in the event of a blackout. This analysis provides a detailed picture of the

perceptions and reactions of the business consumers located in Ticino with respect to blackouts, and serves as a basis for the second step, in which I analyse with the appropriate modelling tools the second part of the survey, devoted to the discrete choice experiment.

In the second step I analyse the discrete choice data starting from the basic assumptions of choice modelling: individuals considering a set of mutually exclusive and collectively exhaustive goods or services will select the alternative providing them the highest indirect utility; according to the random utility theory, the researcher may analyse their choices decomposing the utility associated to each alternative into an observable and an unobservable component.

Following (3), I adapt this framework to a firm's setting, and set up the model as a profit maximization problem: each firm  $i$  is expected to choose in each choice task  $t$  the blackout scenario  $j$  that causes the lowest damage, and thus allows the maximization of an otherwise exogenous profit  $\Pi_i$ . The firm's profit is modelled as a function of blackout's characteristics, firm's characteristics, and an error term accounting for unobserved heterogeneity and measurement error.

I start from a multinomial logit specification, in which the estimated parameters are constant across all the respondents, and expand this basic structure to account for heterogeneous preferences across individual firms. More in detail, I develop a random parameter specification in which I assume that some of the estimated coefficients follow a normal distribution, and estimate both their means, and their standard deviations. This allows me to include and measure the heterogeneity existing in the respondents' tastes.

As a preliminary analysis of the responses collected in the discrete choice experiment shows that 38.8% of the respondents systematically choose the blackout scenario with the shortest blackout duration, I also devote some further attention to the analysis of the heterogeneity that the respondents show in the process of choosing, next to the heterogeneity observed in the respondents' tastes.

The behaviour of the respondents who always choose their preferred option based on a subset of attributes is described in terms of lexicographic preferences in the literature concerning the choice heuristics, i. e. the rules that individuals apply when processing information in discrete choice experiments (9; 10). Lexicographic preferences, as other forms of heuristic decision making, may either witness the extremely high importance that some respondents place on avoiding lengthy blackouts, or rather be due to boredom, fatigue, disengagement, or simply the desire of reducing the cognitive effort required for completing each choice task (10;11). In the past twenty years a growing body of literature has been focussing on detecting and understanding the heterogeneity in the process of choosing, next to the heterogeneity in the observed preferences. From a methodological point of view, the challenge lies in developing the most appropriate strategies to detect possible violations to the random utility assumptions, e.g. cases in which the respondents do not use all information or are not willing to trade among attributes, identifying the kind of heuristic rule that was used by the decision maker, and finally dealing with this kind of responses in the estimation of the parameters of interest (9; 10; 11).

Drawing from (11) and (3), I first develop a simple probit regression in order to investigate the drivers of the probability of showing lexicographic preferences, then estimate the same multinomial logit and random parameter specifications on the whole sample, as well as on a subsample excluding the lexicographic respondents, i. e. those who always chose the alternative with the shortest blackout duration. In the former case, the model accounts for the lexicographic preferences a form of heterogeneity in the respondents' behaviour. In the latter case, the model accounts instead for lexicographic preferences as a form of heterogeneity in the decision process, that needs to be excluded from the estimation of the true value that the respondents place on security. The comparison of the two specifications sheds light on the kind of impact that choice heuristics can have on the estimates. As I will discuss in greater detail within the next paragraph, I retain the latter specification as my preferred one.

## Results

The first step of the analysis provides interesting information as regards the strategies adopted by business consumers to prevent blackout damage, the impact of blackouts on the production activities, and finally the magnitude of blackout damage.

When interviewed about the strategies to prevent blackouts or reduce blackout damage, 50.8% of the respondents declare they own at least one back-up device (UPS, generator, or additional supply line), and more than one third of the respondents are insured for the damages caused by blackouts (damages to machinery, ICTs, furniture and devices, and buildings). A blackout is very disruptive for the firms' activities: on average only 38.8% of the production activities can be carried out in the event of a one-hour blackout without advance notice, and 48.9% if the blackout is announced at least 24 hours before it starts.

When interviewed about the moment of the year, week, and day in which a blackout would cause the worst damage, 75% of the respondents state that there is no difference between Winter and Summer, 66.5% state that blackouts happening during working days would have heavier consequences than blackout happening on Saturdays or Sundays, and 54.5% state that the worst timing during the day is between 10:00 and 16:00.

Cost of labour, damages to information and communication technologies, lost turnover, and damaged machinery rank as the heaviest consequences of a one-hour-long unannounced blackout for most of the respondents. The damage caused by this kind of blackout lies in the range of 501-1000 CHF; the damage decreases to 0-500 CHF if it is announced 24 hours in advance. These figures need to be considered in light of both the structure of the sample, largely

composed of micro and small firms, and the amount of the yearly electricity bill. The magnitude of the median blackout damage tends indeed to increase with the yearly electricity consumption, and hovers between 10% and 20% of the yearly electricity bill for the consumers with yearly bills below 100'000 CHF, and well below 10% for those yearly bills above the 100'000 CHF threshold.

The second step of the analysis focusses instead on the impacts of different blackout lengths, advance notice, and blackout compensation on the perceived blackout damage. Generally speaking, all the estimated discrete choice models suggest that the willingness-to-accept for an increase in blackout length is positive but decreasing with blackout length, and the respondents require a substantial compensation for giving up the advance blackout notice.

Table 2 collects the detailed results of my estimations, obtained using the software PythonBiogeme (Bierlaire, 2016). After considering the measures of goodness of fit and the coherence with our reasoning concerning the magnitude and origin of heterogeneity in the respondents' behaviour, I choose [4], the random parameter model estimated on the subsample of respondents who stick to the random utility maximization rule, as my preferred specification.

	[1] MNL	[2] MNL excluding lexicographic respondents	[3] RP	[4] RP excluding lexicographic respondents
Nr. of observations	543	332	543	332
Nr. of estimated parameters	7	7	10	10
<b>Model fit</b>				
Final log-likelihood	-1875.8	-1321.9	-1660.7	-1294.7
Mc Fadden adj. R squared	0.17	0.04	0.48	0.53
AIC	3765.5	2657.8	3341.4	2609.4
BIC	3795.6	2684.4	3384.4	2647.4
<b>Estimated parameters</b>				
Advance notice	0.372***	0.258***	0.399***	0.276***
Std. dev. advance notice			0.684***	0.382*
Compensation	-0.0189***	0.0186***	-0.0654***	0.0198**
Std. dev. Compensation			0.125***	0.0517***
Ln(duration)	-0.274***	-0.201***	-0.379***	-0.228***
Std. dev. Ln(duration)			0.202***	0.00787
Generator * Ln(duration)	-0.0412	-0.021	-0.0202	-0.00618
Back-up line * Ln(duration)	0.38***	0.245***	0.436***	0.291***
UPS * Ln(duration)	-0.111**	-0.052	-0.117**	-0.0591
Blackout experience * compensation	0.0375***	0.0171**	0.0672***	0.0212**

\*  $p$ -value  $\leq 0.1$ , \*\*  $p$ -value  $\leq 0.05$ , \*\*\*  $p$ -value  $\leq 0.01$

Table 2 – Discrete choice models: estimation results

The estimates resulting from model [4] suggest what follows:

- Blackout duration enters the model in logarithmic form: thus, a long blackout harms more than a short one, but the damage of an additional minute of blackout is decreasing with blackout length;
- The respondents who own a back-up connection to the electricity distribution grid are less affected by blackout duration as compared to those who have different back-up devices, or no back-up system at all;
- The respondents place, on average, a high value on receiving advance blackout notice. The random parameter specification detects however a sizeable heterogeneity in this respect, suggesting that the impact of information provision and the ability of firms to take advantage of advance notice vary substantially across the sample;
- Finally, the respondents' evaluation of the availability of a monetary compensation for the blackout damage is positive, but rather small in magnitude as compared to the parameters of the other attributes. Moreover, the random parameter specification detects a substantial amount of heterogeneity in this respect, with 35% of the respondents expressing a negative compensation coefficient.

The lukewarm appreciation of the monetary compensation for blackout damage might be due to the relatively small value of the compensation as compared to the assessment of blackout damage collected in the previous sections of the survey. Some of the respondents might also implicitly associate the provision of a compensation for blackout damage to a possible reduction in the reliability of their supply, and thus express a negative evaluation of this attribute. However, it is interesting to notice that the respondents who experienced at least one unannounced blackout in the previous six months express a more positive evaluation of the monetary compensation, as witnessed by the interaction between blackout experience and monetary compensation.

The estimated parameters can be used for computing the WTP of business consumers for receiving advance notice, as well as their WTA for accepting a longer blackout. The average WTP for advance blackout notice is around 13.9% of the monthly electricity bill. The WTA for a longer blackout ranges instead from 26.3% of the monthly electricity bill for a blackout lasting five minutes up to 53.9% for a blackout lasting one hour, 69.8% for a blackout lasting 4 hours, and finally 82.4% for a blackout lasting 12 hours. As WTP and WTA values are computed as ratios of normally distributed variables, these values should be considered carefully, as the hint of an average value subject to a considerable variability across the respondents.

A quick comparison between the random parameter estimates conducted on the whole sample (model [3]) and on the subsample of non lexicographic respondents (model [4]) shows, next to a modest improvement in model fit, some interesting changes in the estimated parameters. After excluding the lexicographic respondents, the heterogeneity in the respondents' tastes becomes significantly lower, as witnessed by the smaller estimated standard deviations for duration, advance notice, and compensation. This suggests that at least some of the extreme responses leading to counterintuitive results in the estimates conducted on the whole sample are probably due to the non-trading decision rule adopted by some of the respondents while completing the discrete choice experiment, rather than to actual preferences with respect to each of the attributes characterizing the blackout scenarios. Moreover, the sign of the compensation coefficient is negative in model [3] and positive, in line with our expectations, in model [4]; based on the estimated standard deviations, the share of respondents who express a negative evaluation of the compensation coefficients decreases from 70% in model [3] to the above mentioned 35% in model [4]. This suggests that the respondents who considered all attributes tend to evaluate more positively the availability of a compensation. At the same time, the coefficient for the interaction between the value of the compensation and the respondent's previous blackout experience becomes smaller, probably because part of the effect of the latter variable has been washed out by excluding the lexicographic respondents. A series of t-test comparing the parameters of models [3] and [4] leads to rejecting the hypotheses that the parameters of the two specifications are identical.

Following the reasoning of (10), and (3), I conclude that the inclusion of respondents adopting heuristic decision rules leads to distorted estimates, and that within my discrete choice experiment the true preferences of the business consumers can only be inferred by restricting the sample to the respondents who consider all attributes.

## Conclusions

My analysis contributes to the debate concerning the value of security of supply in electricity by providing an insight into the perceived impact of a blackout, the diffusion of coping strategies, and the preferences toward blackout duration, advance notice, and financial compensations for blackout damages among business electricity consumers in Canton Ticino, Switzerland.

The main messages I can draw from this study are the following:

- The magnitude of the damage caused by an unannounced blackout lasting one hour is in the range of 10% - 20% of the yearly electricity bill for business consumers with yearly bills below 100'000 CHF, and below 10% for those yearly bills above the 100'000 CHF threshold;
- The possibility of receiving a compensation from the electricity supplier elicits a lukewarm appreciation, particularly among the consumers who did not experience a blackout in the previous semester and among those who own a back-up device;
- The reactions of business consumers toward blackouts are very heterogeneous: although I am able to measure this heterogeneity and detect some of its demographic and cognitive drivers, a large share of it remains unexplained;
- The results of the discrete choice experiment included in my survey suggest however that a careful assessment of the use of heuristic decision making in answering stated preference questions is crucial to ensure that the heterogeneity stemming from taste variability is disentangled from that originated by cognitive processes that may arise when completing the survey.

Despite being focussed on a relatively small region, this study may provide an interesting term of comparison for other countries with a comparable economic structure. Moreover, this analysis highlights some hints of general interest as regards the sizeable heterogeneity of the preferences of business consumers with respect to blackouts, and the challenges in detecting its drivers.

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