Università
della
Svizzera
italiana

Facoltà
di
scienze
economiche

The value of security for Swiss residential electricity consumers

A discrete choice analysis

Alessandra Motz

Istituto di Ricerche Economiche (IRE) @ USI Lugano

Switzerland and Security of Supply (SOS)

- 2011: Switzerland decides to phase out nuclear generation
- Swiss Energy Strategy 2050:
  - Decommissioning of nuclear plants starting from 2019
  - Expansion of low-carbon generation
- Challenges:
  - Security, sustainability and affordability of electricity supply
  - Public acceptance of new generation plants/technologies and new transmission lines
- Three referenda on energy-related topics since 2013:
  - “Green Economy” – September 2016, rejected
  - “Nuclear Withdrawal Initiative” - November 2016, rejected
  - “Energy Act” - May 2017, approved

Aim of the analysis

- Assessing the preferences of Swiss households toward the risk of experiencing a blackout, while accounting for their preferences toward different primary energy sources used for generating electricity

- Investigating the drivers of houseolds' preferences:
  - Socio-economic drivers: age, gender, income, area of residence, …
  - Behavioural drivers: "green" behaviour, previous blackout experiences, …
  - Psychological drivers: literacy, awareness, risk attitudes, …

Hints from the literature on SOS

Several analyses have assessed the value of SOS for specific countries or regions and market segments. How?

1. Macroeconomic methods:
    - Production function → Value of lost load (VOLL)
    - Damage function
    - Proxy methods

2. Microeconomic methods:
    - Stated preferences
    - Revealed preferences

3. Case studies

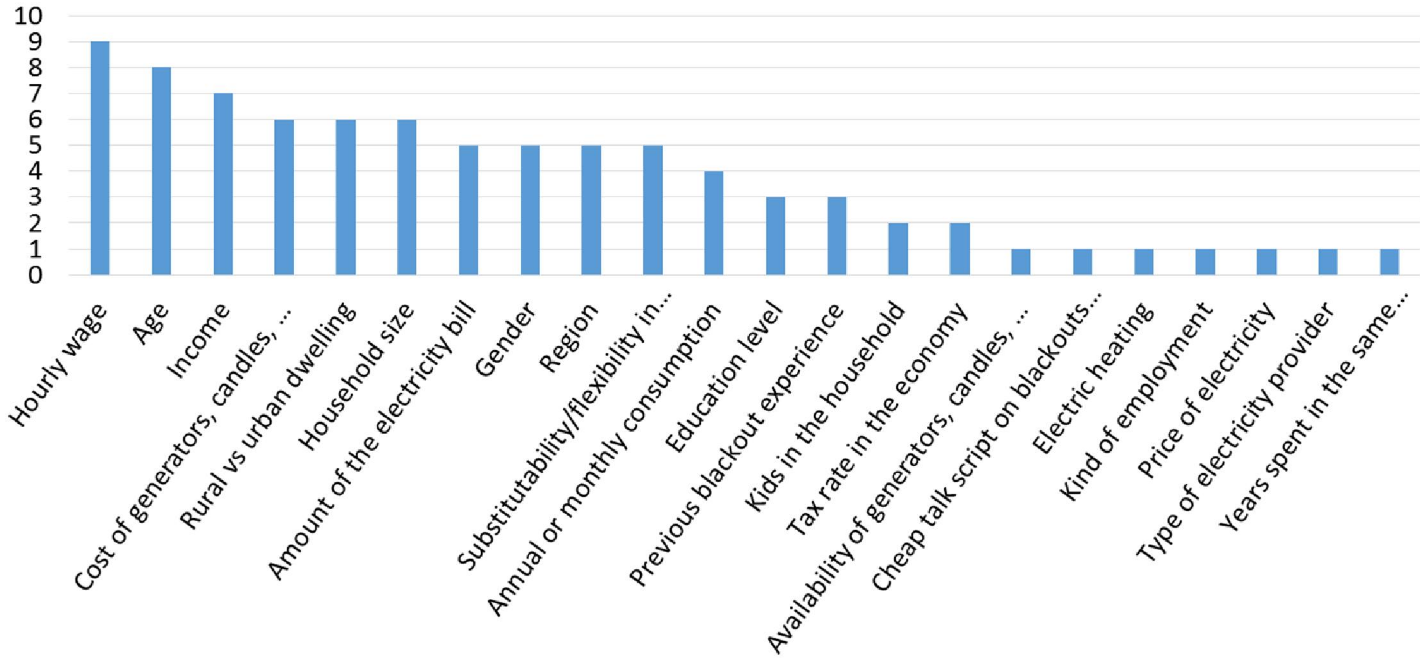
Limitations of existing studies

1. Macroeconomic methods:
   - Lack of detailed information on GDP and electricity consumption
   - Underestimation of electricity substitutability
   - Estimates directly proportional to GDP and inversely proportional to electricity intensity
   - For households: very simplistic representation of preferences, only linked to the value of time as measured by hourly wages
2. Microeconomic methods:
   - SP regarded as less reliable if not validated through RP
   - RP not suitable to evaluate scenarios with new technologies
3. Case studies:
   - Low external validity

Available estimates show a very high variability

Hints from the literature: drivers of heterogeneity

30 analyses on household electricity consumers, years 1982-2016, 50% using a macroeconomic and 50% using a microeconomic approach:



Attitudinal and behavioural drivers are usually neglected

Method used: a discrete choice experiment on stated preferences

- Discrete Choice Analysis (DCA): operational theory of human behaviour:
  - When facing a set of alternatives (goods or services), the decision maker selects the alternative providing the highest utility
- Random Utility Theory: the agent's utility is made up of:
  - An observable, systematic component
  - An unobservable, probabilistic component – Statistical assumptions needed
- If applied to stated preferences, DCA allows the evaluation of attributes of the goods/services that are not yet observable in the market

Data collection: survey

Web-based survey:

- February 2015
- Stratified sample of Swiss 1’006 residents
- Response rate: 37%

The survey covered:

- Discrete Choice Experiment (DCE)
- Demographic variables
- Energy-related behaviour: «Green» behaviour, «green» equipment, energy literacy
- Energy-related attitudes: Agreement/disagreement with a set of statements concerning climate change, pollution, nuclear…

Choice tasks: an example

Please choose the electricity supply contract that you like most for your dwelling:					
	nuclear	mix - of which 60% from renewables	hydro	sun	wind
price (rp/kWh)	18	27.5	21	24	50
nr of 5 minutes blackouts per year	0	1	1	4	1
nr of 4 hours blackouts per year	4	4	0	0	0
Your choice:					

Alternatives, attributes, and levels

Attribute levels reflect average 2014 values (in red) and extremes we could expect in the future

		alternatives				
		nuclear	mix	hydro	sun	wind
attributes	price (rp/kWh)	14.5, 18, 21, 24, 27.5, 50	14.5, 18, 21, 24, 27.5, 50	18, 21, 24, 27.5, 50	21, 24, 27.5, 50	18, 21, 24, 27.5, 50
	nr of 5 minutes blackouts per year	0, 0.25, 1, 4				
	nr of 4 hours blackouts per year	0, 0.25, 1, 4				
	% of electricity from renewable energy sources		40, 60, 80, 100			

Demographic variables

Additional questions on:

- City of residence
- Education level
- Occupational status
- Income
- Nr of people living in the household
- Nr of children (age<15) living in the household
- Size and ownership of the flat/house

Gender	Sample	Population
Man	49.1%	49.5%
Woman	50.9%	50.5%
Age group		
15-29	27.9%	27.3%
30-44	31.1%	32.0%
45-59	33.0%	33.9%
60-64	8.0%	6.8%
Language		
German	73.9%	74.0%
French	26.1%	26.0%
Lives in:		
Stadt + Agglo	79.1%	73.8%
Land	20.9%	26.2%
Nationality		
Swiss	80.4%	75.7%

Energy-related behaviour

Derived variables:

- Energy illiteracy

  (0-8; sum of «I don’t know» answers to equipment questions + amount of the electricity bill question)

- Green devices

  (0-7; sum of «yes» answers to equipment questions)

- Green behaviour

  (0-3; switches lights off + switches heating off + has a renewable electricity contract)

Equipment	Yes	I don't know
Insulating window panes	82%	4%
Insulating walls	62%	15%
Solar heating	11%	5%
Photovoltaic panels	7%	3%
Minergie standard	13%	13%
Other energy saving equipment	21%	26%
Other renewable energy equipment	8%	19%
Behaviour		
Light off when not needed	91%	
Heating off at night	65%	
Renewable electricity contract	44%	38%
In charge of paying electricity bill	81%	
Electricity bill per semester		
Below 200 CHF	25%	
201-400 CHF	38%	
401-800 CHF	13%	
Above 800 CHF	3%	
I don't know		21%
Blackout experience		
Short blackout at home	27%	
Short blackout at work	10%	
Long blackout at home	21%	
Long blackout at work	8%	

Facoltà
di
scienze
economiche

Attitudes

	How much do you agree with the following statement on a scale from 1 (completely disagree) to 7 (completely agree)?	Average	Std.Dev.
att_16	I'm NOT worried about the risk of a nuclear accident in CH	3.4	2.0
att_9	I think the risk of a nuclear accident in Switzerland is very low	4.2	1.8
att_25	It is dangerous to live close to a nuclear generation plant	4.6	1.9
att_2	Decommissioning Swiss nuclear plants is a good idea	5.1	2.0
att_4	CO2 emissions from coal, oil and gas cause global warming	5.8	1.3
att_26	Climate change would be bad for mankind and enviroment	6.0	1.3
att_29	I am worried about climate change	5.5	1.5
att_12	I am worried about pollution	5.8	1.3
att_24	I am personally in charge of my environm. friendly behaviour	6.0	1.3
att_23	Our society should use less fossil fuels to reduce pollution	5.9	1.3
att_19	Everybody should behave in an environmental-friendly way	6.4	1.0
att_5	Saving energy in everyday life is important	6.2	1.1
att_30	I find blackouts annoying	4.9	1.7
att_20	I am frightened when there is a blackout at my place	2.4	1.5
att_18	Blackouts can be very costly for private companies	5.3	1.5
att_6	Blackouts can be costly for households	4.1	1.7
att_7	I am worried about increasing electricity prices	4.4	1.8
att_28	Generating electricity via RES is important	6.4	1.0
att_14	Most private buildings should have PV panels	5.6	1.5
att_10	New plants from RES needed for increasing el. demand	6.0	1.3
att_1	New generation plants important to cover increasing el. demand	4.7	1.7
att_11	It is dangerous to live close to a coal generation plant	4.3	1.7
att_17	It is dangerous to live close to a gas-fired generation plant	3.9	1.6
att_3	it is safe to import electricity from abroad	3.4	1.5
att_15	Import dependency for el. supplies endangers our economy	4.5	1.6
att_22	I'm worried about depending on foreign countries for energy	4.4	1.6
att_27	Electricity can be safely imported from abroad	3.2	1.6
att_21	Wind turbines spoil the landscape	2.9	1.7
att_8	Wind turbines are noisy and disturb local populations	3.1	1.6
att_13	Wind turbines kill birds and damage fauna	3.3	1.6

Estimation strategy: MNL and DC (1)

Multinomial Logit model (MNL):

$$U_{n,i} = V(Z_i, X_n, \beta) + \varepsilon_{n,i}\ ,\quad \varepsilon_{n,i} \sim i.i.d.\ E\ V$$

$$P_n(i) = \frac{e^{V(X_{i,}Z_n)}}{\sum_{j\epsilon C} e^{V(X_{j,}Z_n)}}$$

Latent Class model (LC, following Bhat 1997):

$$P_n(i|s) = \frac{e^{V^s(X_{i,}Z_n)}}{\sum_{j\epsilon C_s} e^{V^s(X_{j,}Z_n)}} \rightarrow P_n(i) = \sum_s P_n(i|s) * P(s)$$

Estimation via simulated maximum likelihood

Estimation strategy: LC with attitudinal indicators (2)

Following Hurtubia et al. (2014): the probability that respondent *n* selects a certain score in attitudinal indicator *k*, given that *n* belongs to class *s:*

$$P_n(i, I_k) = \sum_{s \in S} P_n(i|s)\, P_n(s) \prod_{k=1}^{K} P_n(I_k|s)$$

The response probability to indicator *k* is modelled as a function *g* of respondent's *n* demographic variables *Z*:

$G_{I_k,n}^{s} = g(Z_n; \alpha_k^s) + \varepsilon_{kn}^{s}$ and $\varepsilon_{kn}^{s} \sim$ Logistic (0, 1)

The likelihood function becomes:

$$L = \prod_{n} \left\{ \sum_{s} \left\{ P_n(i|s) \prod_{k} P_n(I_k|s) \right\} P_n(s) \right\}$$

Results: overview

The following results are stable across MNL, LC, and LC_IND:

- Sensitivity to price increases depends very much on the primary source used
- The negative impact of long blackouts is 2-3 times higher than that of short blackouts
- Sensitivity to blackouts is also influenced by the primary energy source used
- Respondents that already show a “green behaviour” are more likely to choose a renewable-based contract (sun, hydro, wind, or 100% renewable mix)
- Man are more likely to choose nuclear than women, and less likely to choose sun
- Older respondents are more likely to choose the “Mix” alternative

In both LC and LC_IND, two classes emerge whose attitude toward blackouts is different.

LC_IND: Results (1)

Different attitudes toward primary energy sources and long/short blackouts:

- ALPHA tend to favour already used sources
- BETA have a relatively strong aversion to nuclear and mix, and favours renewables

P(ALPHA) = 0.485***

Parameter	Value	p-value	
B_price_hydro_ALPHA	-0.055	0.000	***
B_price_mix_ALPHA	-0.063	0.000	***
B_price_nuc_ALPHA	-0.081	0.000	***
B_price_sun_ALPHA	-0.100	0.000	***
B_price_wind_ALPHA	-0.091	0.000	***

Parameter	Value	p-value	
B_price_hydro_BETA	-0.058	0.000	***
B_price_mix_BETA	-0.120	0.000	***
B_price_nuc_BETA	-0.182	0.000	***
B_price_sun_BETA	-0.053	0.000	***
B_price_wind_BETA	-0.083	0.000	***

Parameter	Value	p-value	
B_long_blackout_hydro_ALPHA	-0.342	0.000	***
B_long_blackout_mix_ALPHA	-0.268	0.000	***
B_long_blackout_nuc_ALPHA	-0.247	0.000	***
B_long_blackout_sun_ALPHA	-0.534	0.000	***
B_long_blackout_wind_ALPHA	-0.532	0.000	***

Parameter	Value	p-value	
B_long_blackout_hydro_BETA	-0.586	0.000	***
B_long_blackout_mix_BETA	-0.489	0.000	***
B_long_blackout_nuc_BETA	-1.760	0.150	
B_long_blackout_sun_BETA	-0.536	0.000	***
B_long_blackout_wind_BETA	-0.658	0.000	***

Parameter	Value	p-value	
B_short_blackout_hydro_ALPHA	-0.204	0.000	***
B_short_blackout_mix_ALPHA	-0.026	0.390	
B_short_blackout_nuc_ALPHA	-0.124	0.000	***
B_short_blackout_sun_ALPHA	-0.258	0.000	***
B_short_blackout_wind_ALPHA	-0.384	0.000	***

Parameter	Value	p-value	
B_short_blackout_hydro_BETA	-0.080	0.010	**
B_short_blackout_mix_BETA	-0.186	0.000	***
B_short_blackout_nuc_BETA	-0.757	0.030	*
B_short_blackout_sun_BETA	-0.102	0.000	***
B_short_blackout_wind_BETA	-0.162	0.000	***

LC_IND: Results (2)

Average WTP for avoiding 1 additional blackout: 30% of 2014 electricity prices for 4-hour blackouts, 10% for 5-min blackouts

- ALPHA: relatively stable WTP; higher WTP for renewable sources
- BETA: WTP for avoiding long blackouts much higher than WTP for avoiding short blackouts; higher WTP for renewable sources

Parameter	Value	
WTP_long_blackout_hydro_ALPHA	6.218	***
WTP_long_blackout_mix_ALPHA	4.254	***
WTP_long_blackout_nuc_ALPHA	3.068	***
WTP_long_blackout_sun_ALPHA	5.345	***
WTP_long_blackout_wind_ALPHA	5.865	***

Parameter	Value	
WTP_long_blackout_hydro_BETA	10.103	***
WTP_long_blackout_mix_BETA	4.075	***
WTP_long_blackout_nuc_BETA	9.670	
WTP_long_blackout_sun_BETA	10.075	***
WTP_long_blackout_wind_BETA	7.966	***

Parameter	Value	
WTP_short_blackout_hydro_ALPHA	3.709	***
WTP_short_blackout_mix_ALPHA	0.419	
WTP_short_blackout_nuc_ALPHA	1.540	***
WTP_short_blackout_sun_ALPHA	2.583	***
WTP_short_blackout_wind_ALPHA	4.234	***

Parameter	Value	
WTP_short_blackout_hydro_BETA	1.383	**
WTP_short_blackout_mix_BETA	1.550	***
WTP_short_blackout_nuc_BETA	4.159	*
WTP_short_blackout_sun_BETA	1.917	***
WTP_short_blackout_wind_BETA	1.961	***

LC_IND: Results (3)

- On average, BETA have a higher constant in all relevant attitudinal indicators
- Fear of nuclear generation: "green behaviour" and "energy illiteracy" associated to higher scores in class BETA; "male" with lower scores in both classes
- Damage from blackouts: "previous blackout experience" and "male" associated to higher scores in class BETA; "in charge of paying the electricity bill" associated to higher scores in class ALPHA
- Fear of price increases: "previous blackout experience" always associated to higher scores, "in charge of paying the electricity bill" associated to higher scores in class ALPHA

Parameter	Value	p-value	
"It is dangerous to live close to a nuclear generation plant"			
Constant_att_nuclear_alpha	3.460	0.000	***
Constant_att_nuclear_beta	3.800	0.000	***
B_greenbehav_att_nuclear_alpha	0.166	0.190	
B_greenbehav_att_nuclear_beta	0.322	0.010	**
B_illiteracy_att_nuclear_alpha	0.104	0.110	
B_illiteracy_att_nuclear_beta	0.154	0.020	*
B_male_att_nuclear_alpha	-1.160	0.000	***
B_male_att_nuclear_beta	-0.454	0.010	*
"I find blackouts annoying"			
Constant_att_blackouts_alpha	4.090	0.000	***
Constant_att_blackouts_beta	4.340	0.000	***
B_male_att_blackouts_alpha	0.276	0.140	
B_male_att_blackouts_beta	0.632	0.000	***
B_paysbill_att_blackouts_alpha	0.564	0.010	**
B_paysbill_att_blackouts_beta	0.174	0.470	
B_bl_exp_att_blackouts_alpha	0.005	0.960	
B_bl_exp_att_blackouts_beta	0.227	0.050	*
"I am worried about future increases in electricity prices"			
Constant_att_prices_alpha	3.260	0.000	***
Constant_att_prices_beta	3.520	0.000	***
B_paysbill_att_prices_alpha	0.854	0.000	***
B_paysbill_att_prices_beta	-0.195	0.430	
B_bl_exp_att_prices_alpha	0.247	0.010	*
B_bl_exp_att_prices_beta	0.287	0.000	***

LC_IND: Results (4)

As in the MNL and DC models, beavioural and demographic variables play a role in determining preferences for specific primary energy sources:

- “Green behaviour” associated to a lower probability of choosing nuclear, and a higher probability of choosing a renewable-based supply
- Men more likely to choose nuclear and less likely to choose sun
- Older people more likely to neglect the content of their supply mix

Parameter	Value	p-value	
Constant_hydro	-0.303	0.400	
Constant_nuc	-0.199	0.670	
Constant_sun	0.207	0.700	
Constant_wind	0.677	0.090	
B_mix100	0.222	0.310	
B_mix40	0.009	0.970	
B_mix80	0.162	0.240	
B_greenbehav_mix100	0.271	0.000	***
B_greenbehav_hydro	0.559	0.000	***
B_greenbehav_mix	0.327	0.010	*
B_greenbehav_sun	0.692	0.000	***
B_greenbehav_wind	0.511	0.010	*
B_male_hydro	0.125	0.320	
B_male_nuc	0.961	0.000	***
B_male_sun	-0.655	0.000	***
B_male_wind	-0.126	0.370	
B_age_mix	0.017	0.000	***

Conclusions

- WTP for avoiding one additional blackout: 30% of 2014 prices for 4-hour blackout, 10% for 5-min blackouts – slightly above comparable estimates
- Blackout sensitivity depends on the energy mix used
- The heterogeneity of blackout sensitivity is relatively high
- Two classes of similar size emerge:
  - Price-conscious consumers with a preference for traditional sources (hydro, nuclear, mix)
  - Environmentally sensitive consumers with a preference for sun, hydro and wind
- Attitudinal drivers play a role in determining households' preferences toward blackouts (and primary energy sources)
- The impact of attitudes is comparable to that of obsevable demographic and behavioural variables. Neglecting asttitudes might lead to biased estimates – at least for household consumers.

Thanks for your attention!

E.g.: studies for Austrian households

3-min-long blackout	Value (€)	Reference paper	Year	Method
WTP for avoiding a 3-min blackout based on 2002 electricity bills (Bliem 2009: WTP = 1.35% of the monthly bill)	0.73	Bliem (2009)	2002	Discrete choice
VOLL for a 3-min-long blackout (Bliem 2005: VOLL = 16.00 €/kWh)	1.76	Bliem (2005)	2002	Production function
WTP for avoiding a 3-min blackout based on 2007 electricity bills (Bliem 2009: WTP = 1.35% of the monthly bill)	0.87	Bliem (2009)	2007	Discrete choice
1-hour-long blackout	**Value (€)**	**Reference paper**	**Year**	**Method**
VOLL for a 1-hr-long blackout (Bliem 2005: VOLL = 16.00 €/kWh)	8.81	Bliem (2005)	2002	Production function
WTP for avoiding a 1-hr-long blackout in 2011	1.40	Reichl (2013)	2011	Discrete choice
4-hour-long blackout	**Value (€)**	**Reference paper**	**Year**	**Method**
WTP for avoiding a 4-hr blackout based on 2002 electricity bills (Bliem 2009: WTP = 16.07% of the monthly bill)	8.71	Bliem (2009)	2002	Discrete choice
VOLL for a 4-hr-long blackout (Bliem 2005: VOLL = 16.00 €/kWh)	35.26	Bliem (2005)	2002	Production function
WTP for avoiding a 4-hr blackout based on 2007 electricity bills (Bliem 2009: WTP = 16.07% of the monthly bill)	10.33	Bliem (2009)	2007	Discrete choice
WTP for avoiding a 4-hr-long blackout in 2011	3.80	Reichl (2013)	2011	Discrete choice

Choice of the attitudinal indicators

- Principal component analysis on the available attitudinal statements

	Candidate latent variables			
Attitudinal statements	**Green**	**Cautious**	**Open to electricity imports**	**Positive wrt conventional gen.**
I am worried about climate change	0.30			
I am worried about pollution	0.30			
Generating electricity via RES is important	0.29			
Blackouts can be costly for households		0.31		
I am worried about increasing electricity prices		0.31		
Import dependency for electricity supplies endangers our economy		0.33		
I am frightened when there is a blackout at my place		0.30		
I am worried about depending on foreign countries for energy		0.31	-0.35	
It is safe to import electricity from abroad			0.48	
Electricity can be safely imported from abroad			0.50	
I think the risk of a nuclear accident in Switzerland is very low				0.32
It is dangerous to live close to a nuclear generation plant				-0.40
It is dangerous to live close to a gas-fired generation plant				-0.42
Proportion of variance	**20.8%**	**10.4%**	**7.4%**	**6.7%**
Chronbach Alpha	**0.76**	**0.56**	**0.73**	**0.69**

Hybrid DC model with latent variables

DC model

Structural eq. $V_{i,k} = X_i^* \beta_1 + X_i \beta_2 + Z_k \beta_3 + \varepsilon_{i,k}, \qquad \varepsilon \sim EV(0, \Sigma_\varepsilon)$

Measurement eq. $y_{i,k} = 1 \text{ if } V_{i,k} = \max_{\forall j \in C_n} \{V_{i,j}\},\ y_{i,k} = 0 \text{ otherwise}$

LV model

Structural eq. $X_i^* = X_i \gamma + \mu_i, \qquad \mu \sim N(0, \Sigma_\mu)$

Measurement eq. $I_i = X_i^* \alpha_1 + X_i \alpha_2 + v_i, \qquad v \sim N(0, \Sigma_v)$

Likelihood function:

$$f(y, I | X, Z; \alpha, \beta, \gamma) = \int_{X^*} P(y | X, X^*, Z; \beta) f(I | X, X^*; \alpha) f\,(X^* | X; \gamma) dX^*$$