How much load flexibility a euro can buy?

Findings from a choice experiments with companies in the German commerce and services sector.

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Background

Markets

The Electricity Industry Is Giving Europe's Power Traders a Headache

By Rachel Morison, Jesper Starn, and Brian Parkin

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- Power prices plunge at midday with photovoltaic supply surge
- Utilities working to integrate more variable energy flows

Bloomberg

CREDIT RSS MAY 8, 2018 / 1:15 PM / 5 DAYS AGO

REUTERS

German energy regulator says new renewable targets create grid challenges

Background

Little known about load flexibility in the tertiary sector.

- **Industry**
  - Germany: 2.5% of installed electricity capacity is flexible
    (Dena 2010, Apel 2012, Klobasa et al. 2013, Ausfelder et al. 2018)
  - Potential in <u>core process functions</u>

- **Commercial and services sector**
  - Little studied
  - 29% of elec. consumption in Germany
  - Potential in <u>cross-sectional functions</u> (HVAC, cooling/freezing)
    (Klobasa 2007, Apel 2012, Gils 2014)

- **Gaps**
  - Potential in cross-cutting technologies?
  - Responsiveness to incentives and other attributes?
  - Role of firm heterogeneity?

Objectives

Subsidizing automated load management in the tertiary sector: hot or not?

1. **What subsidy do companies need to accept automated load management?**
   - (WTA (€))?

2. **What attributes does that (threshold) subsidy depend on?**
   - Attributes of the load management proposition
   - Attributes of the company

3. **What is the expected effectiveness of a subsidy for automated load management?**

Methodology

1. **Quantitative survey**
   - German commercial and services sector
   - Contingent valuation choice experiment

2. **Econometrics: maximum likelihood estimation**
   - Estimate (distribution of) threshold subsidy S_i^*
   - Association with proposition and company characteristics

3. **Simulation**
   - Analytical model
   - Estimate adoption and cost-effectiveness as a function of subsidy

Survey and Data

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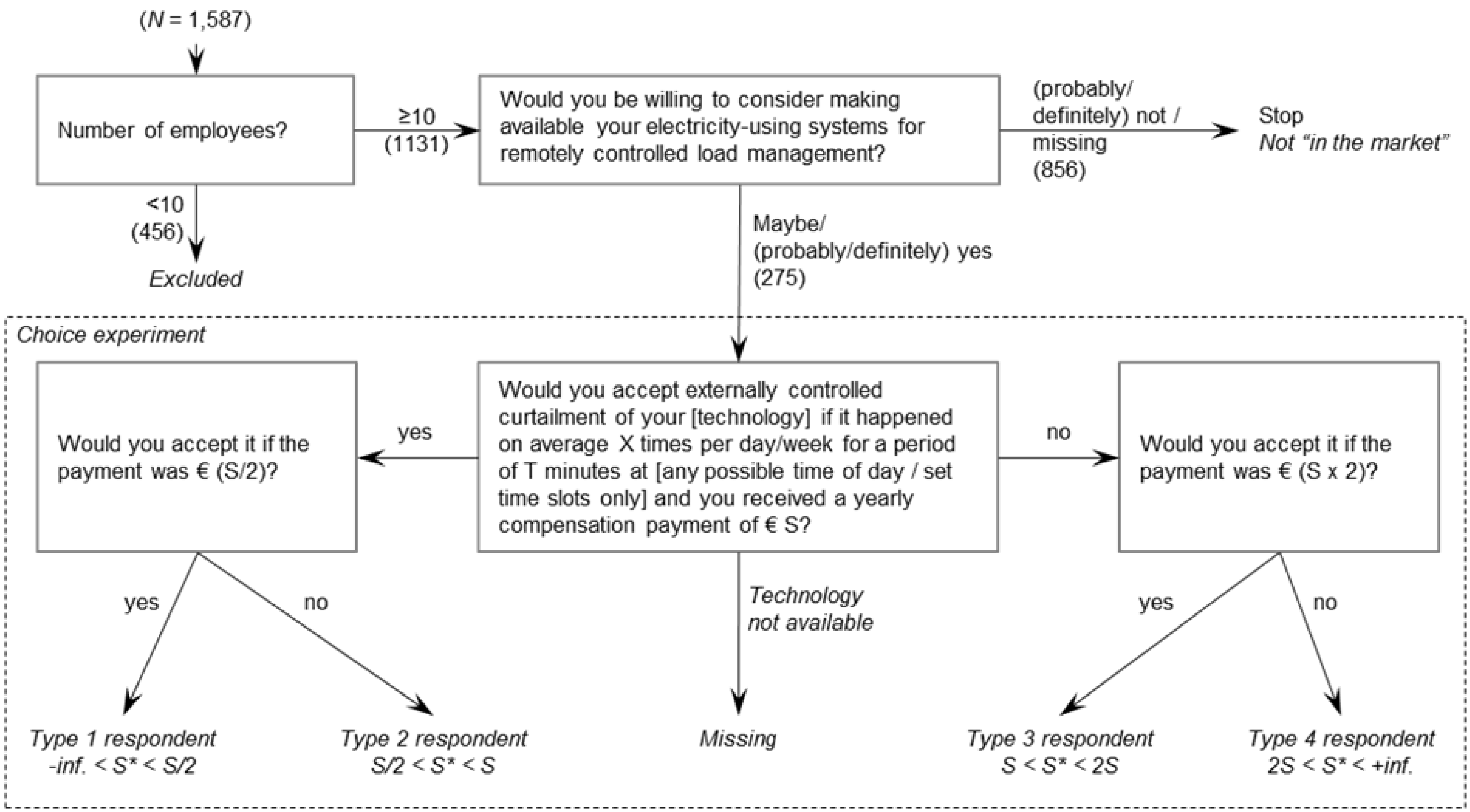
Survey design

Double-bounded contingent valuation choice experiment

- **Quantitative survey (*N* = 1587)**
- **German commercial and services sector**
- **Subsectors: offices, wholesale, retail, hospitality**
- **6 Technologies:**
  Ventilation, AC, Refrigeration, Freezing, **Heat pump, CHP**
- **Contingent valuation choice experiment**
  - Double-bounded dichotomous choice
    (Cameron & James 1986, Hanemann et al. 1991)
  - WTA automated load management
    (Alberini & Bigano 2015, Olsthoorn et al. 2017)

Structure of the choice experiment



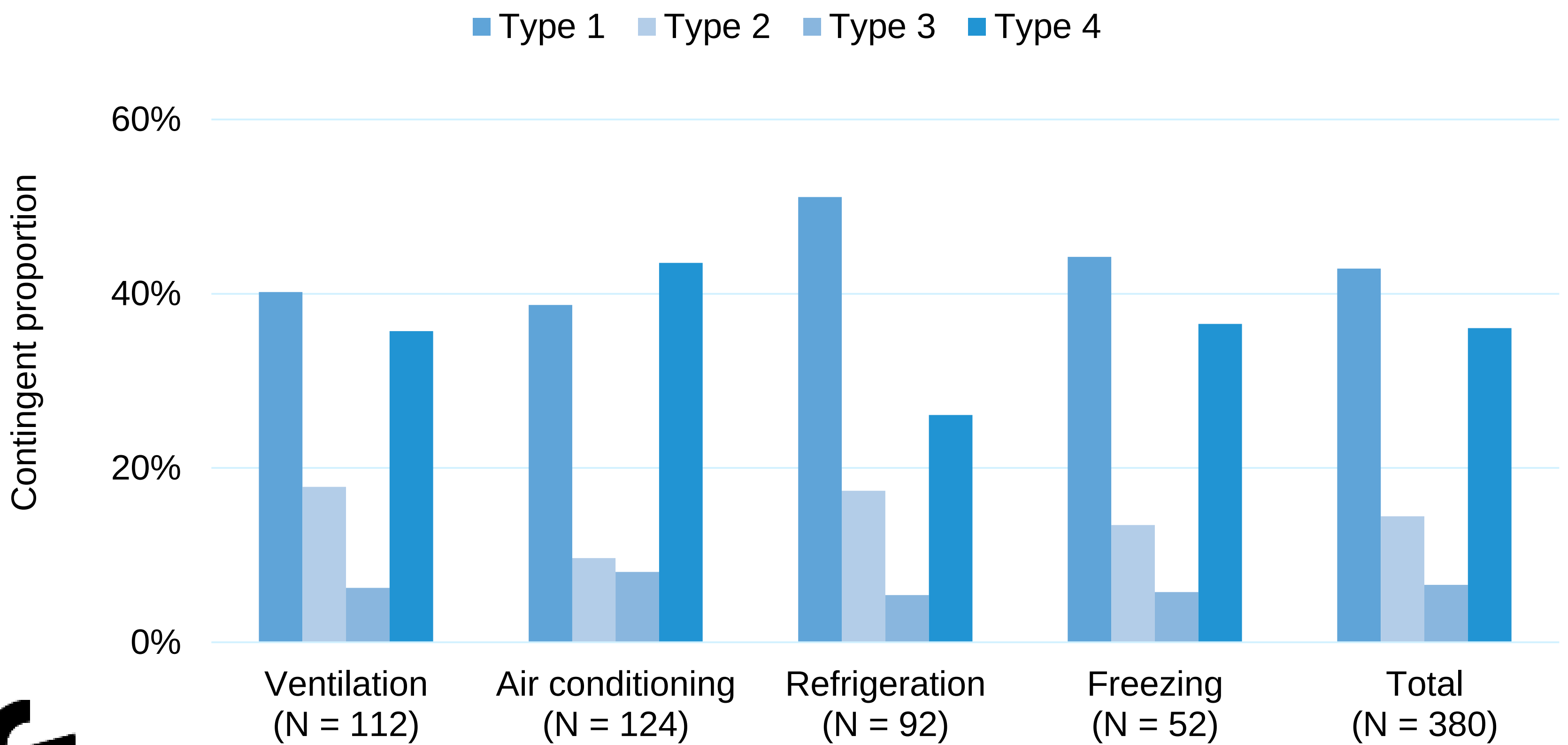
Choice cards

Propositions' attributes and attribute levels

Attribute	**Ventilation**	**Air conditioning**	**Refrigeration**	**Freezing**
Payment (Euros)	250/500/1000/1500/2500		500/1000/2000/4000/8000	
Frequency	2 times daily / daily / weekly			
Duration (minutes)	30 / 60 / 90			
Restriction	Can be activated any time / at agreed time slots only			

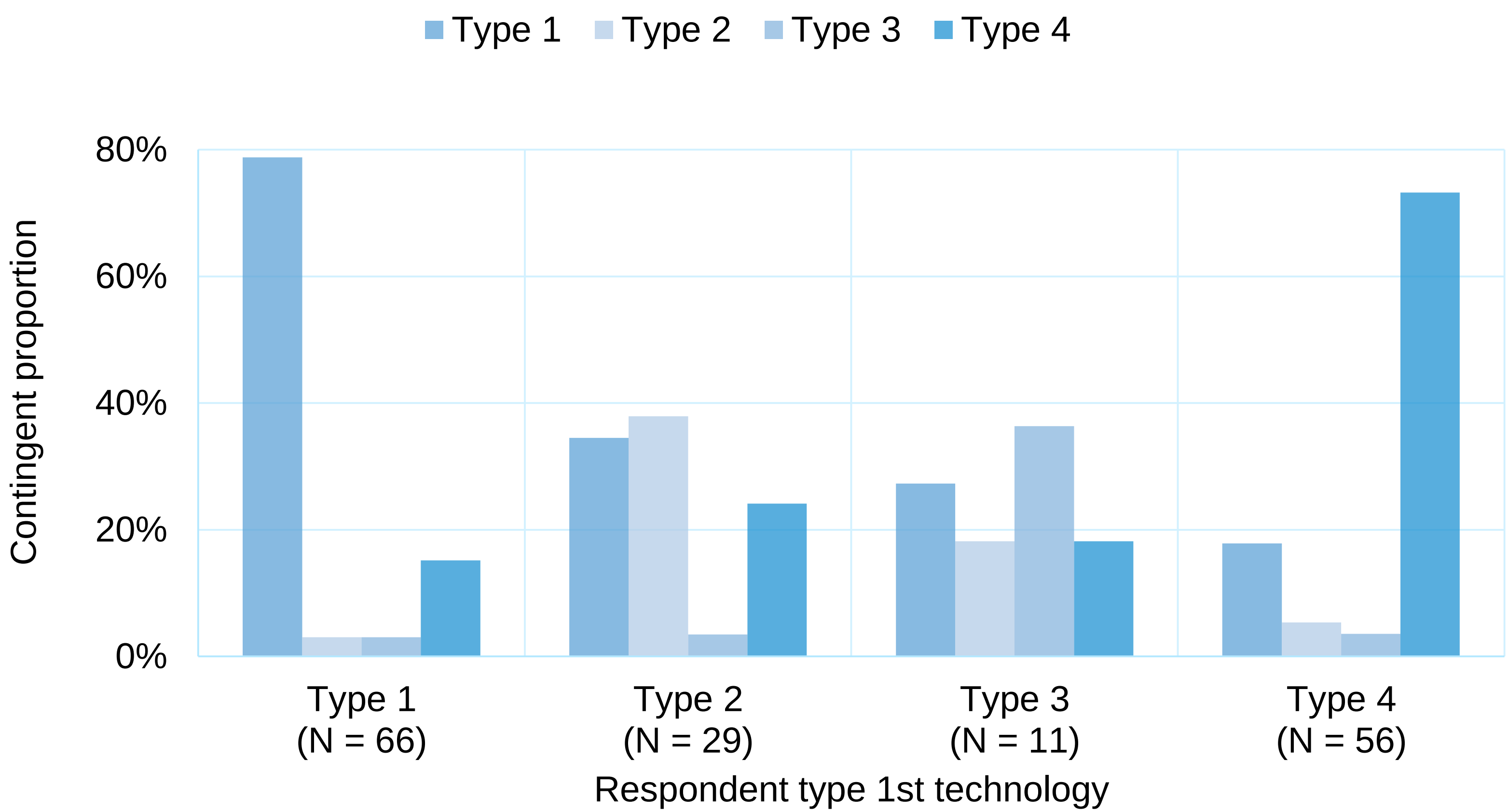
Respondent types by technology

Respondents tended to repeat their first choice.



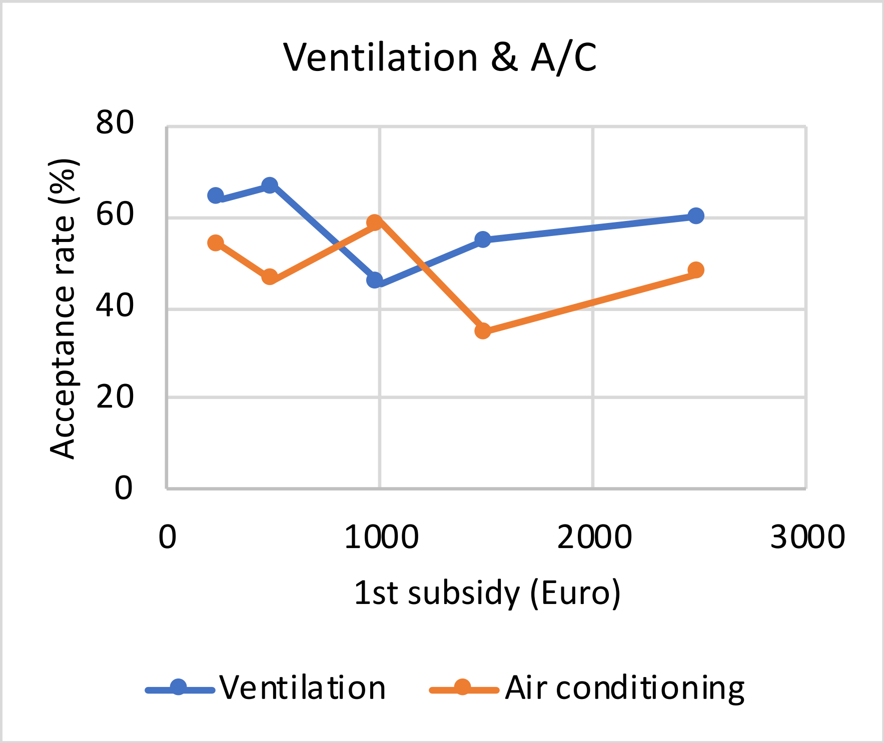
Respondent type 1st and 2nd technology

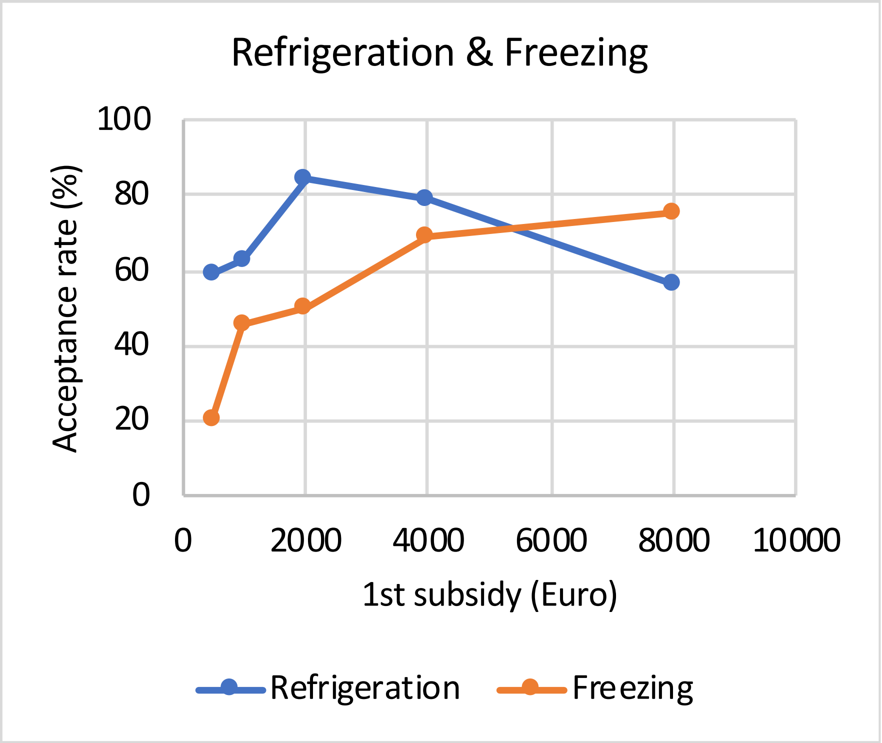
Often same choices for 1st and 2nd technology



Internal validity

Share accepting 1st subsidy





Econometric results

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Econometric Analysis

Interval data model

- **Maximum likelihood estimation**
- **With and without covariates**

$$S_i^* = \alpha + \boldsymbol{x}_i \boldsymbol{\beta} + \boldsymbol{z}_i \boldsymbol{\delta} + \varepsilon_i$$

$\boldsymbol{x}_i$: attributes of the proposition
$\boldsymbol{z}_i$: company attributes

$$\Pr(S_i^L < S_i^* \leq S_i^U) = \left(\frac{\left(S_i^U - E(S_i^*)\right)}{\sigma}\right) - \left(\frac{\left(S_i^L - E(S_i^*)\right)}{\sigma}\right) = \Phi^U - \Phi^L$$

Results: Mean & median subsidy (WTA)

Large spread

$$S_i^* = \alpha + \varepsilon_i$$
$$\varepsilon = N(0, \sigma)$$

	Ventilation	Air conditioning	Refrigeration	Freezing
Constant	1186***	1668***	244	2971**
	(0.002)	(0.001)	(0.853)	(0.036)
Sigma	3465***	4581***	9969***	8574***
	(0.000)	(0.000)	(0.000)	(0.000)
Observations	112	124	92	52
Log-likelihood	-157.25	-151.17	-130.40	-57.09

p-values in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Results: Role of attributes

Attributes of the proposition

$$S_i^* = \alpha + \boldsymbol{x}_i \boldsymbol{\beta} + \varepsilon_i$$

Attributes of proposition	HVAC	Cooling
Frequency (#/week)	**19.32**	**-19.90**
	(0.727)	(0.918)
Duration (min)	**-3.799**	**11.72**
	(0.751)	(0.769)
Only on predefined time slots	**-1737*****	**1536**
	(0.004)	(0.421)
Constant	2353**	-165.4
	(0.014)	(0.957)
Sigma	3841***	9578***
	(0.000)	(0.000)
Observations	236	144
Log-likelihood	-304.9	-188.1
Chi-square	8.498**	0.714

p-values in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Company attributes (z)

Descriptive statistics

$$S_i^* = \alpha + \boldsymbol{x}_i\boldsymbol{\beta} + \boldsymbol{z}_i\boldsymbol{\delta} + \varepsilon_i$$

Variable	Obs	Mean	Std. Dev.	Min	Max
Stated intention					
Maybe	275	0.498	0.501	0	1
Probably yes	275	0.313	0.464	0	1
Definitely yes	275	0.189	0.392	0	1
Load management used	206	0.252	0.435	0	1
Employees	264	336	1444	10	20000
Ln(Employees)	264	4.075	1.520	2.303	9.903
Sector					
Office-type	275	0.371	0.484	0	1
Wholesale/retail	275	0.331	0.471	0	1
Hospitality	275	0.298	0.458	0	1
Number of cooling appliances	81	10.83	17.83	0	150
Average T(deg. C) in cooling appliances	79	4.620	6.300	-20	23
Average T(deg. C) in cold stores	103	3.184	6.709	-22	20

Results: Role of attributes

Attributes of the company

$$S_i^* = \alpha + \boldsymbol{x}_i\boldsymbol{\beta} + \boldsymbol{z}_i\boldsymbol{\delta} + \varepsilon_i$$

Variables	HVAC		Cooling	
Attributes of proposition	Yes	Yes	Yes	Yes
Stated intention re load management	Yes		Yes	
Load management used	**1535****		**2665**	
	(0.044)		(0.205)	
Ln(Employees)		**-65.39**		**1267****
		(0.736)		(0.046)
Constant	2572**	2573**	2606	-4382
	(0.014)	(0.040)	(0.423)	(0.238)
Sigma	3502***	3760***	8422***	8501***
	(0.000)	(0.000)	(0.000)	(0.000)
Observations	183	227	113	137
Log-likelihood	-231.8	-294.9	-139.9	-173.6
Chi-square	16.06**	10.05**	10.47	4.267

p-values in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Simulations

Subsidy (cost-)effectiveness

Simple analytical model

Adoption and capacity as a function of the subsidy

Subsidy cost-effectiveness^{-1}:

$$c = \frac{C}{\Delta L}$$

Total subsidy expenditures:

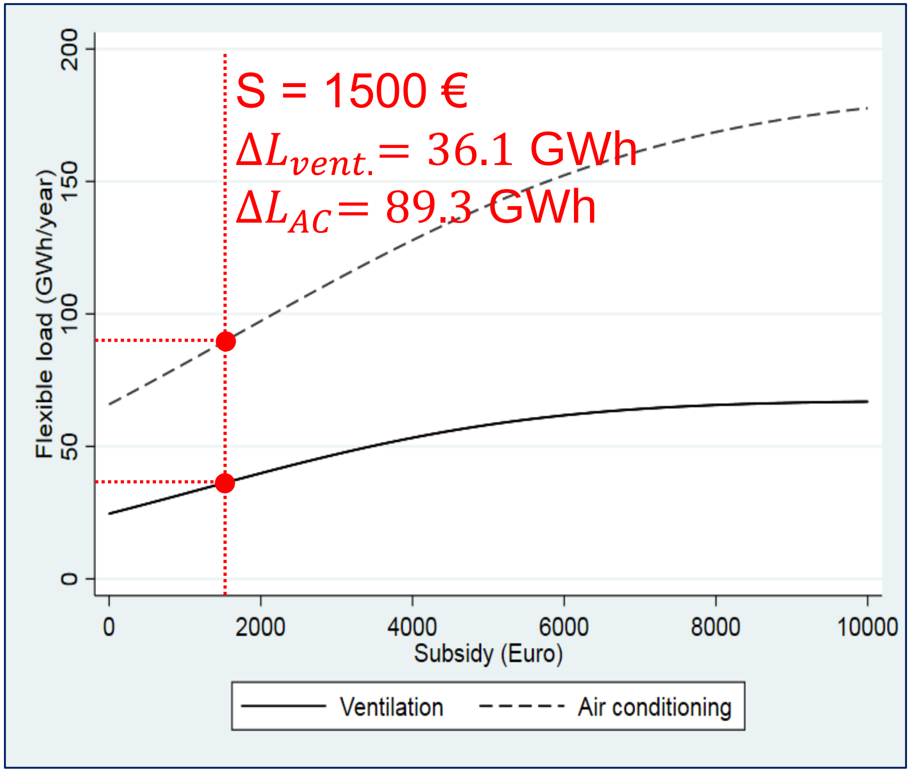
$$C = N_{pop} \times b(S) \times S$$

Load management capacity unlocked:

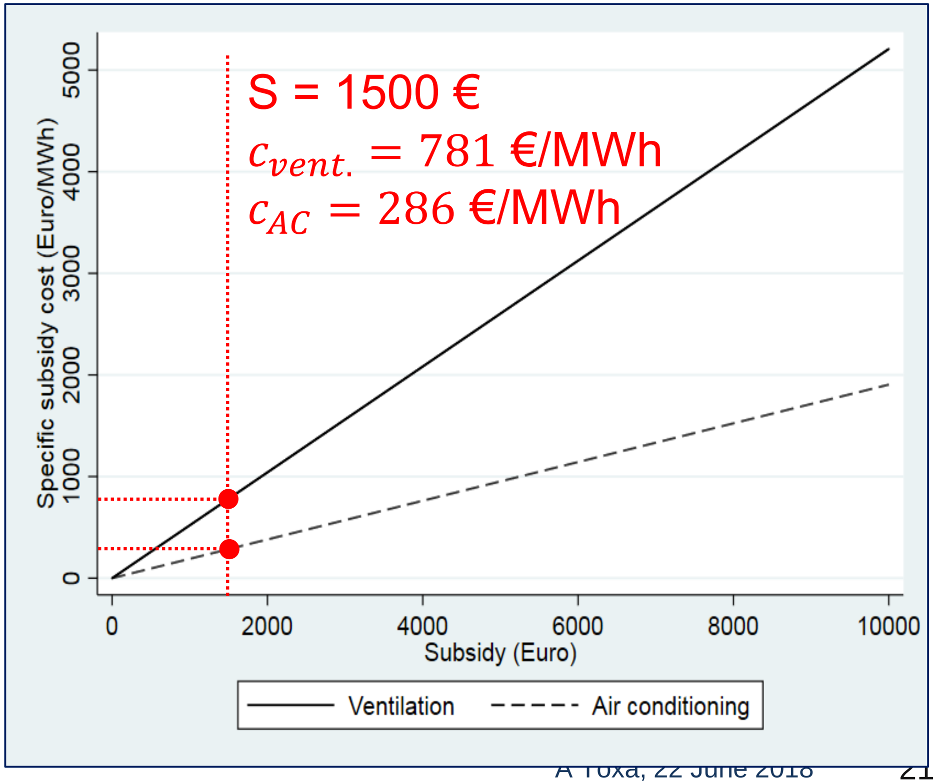
$$\Delta L = b(S) \times N_{pop} \times \Delta l$$

Simulations

Subsidy effectiveness (GWh unlocked)



Specific subsidy cost (€/MWh)



Specific costs in perspective

Flexibility source	Flexibility price
Air conditioning (this study)	286 €/MWh
Ventilation (this study)	781 €/MWh
Balancing Market (Germany)	644 €/MWh
Batteries (Newbery 2018, levelized costs)	76 GB£/MWh (Tesla 2020) – 586 GB£/MWh (lead-acid)
Pumped storage (Newbery 2018, lev. costs)	43 GB£/MWh – 91 GB£/MWh (UK, existing)

Conclusions

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Main findings

- **Significant willingness to accept automated load management**

- **Mean / median subsidy varies by technology**
  - Ventilation: μ = € 1200, σ = € 3500
  - AC: μ = € 1700, σ = € 4500
  - Fridges: μ = € 250, σ = € 10000
  - Freezers: μ = € 3000, σ = € 8500

- **Not find dependence on frequency or duration of intervention**
- **Time restrictions reduce subsidy for HVAC**

- **Subsidy effectiveness**
  - Air conditioning: more volume, better cost-effectiveness
  - Compares to other flexibility options / balancing market

Limitations and implication

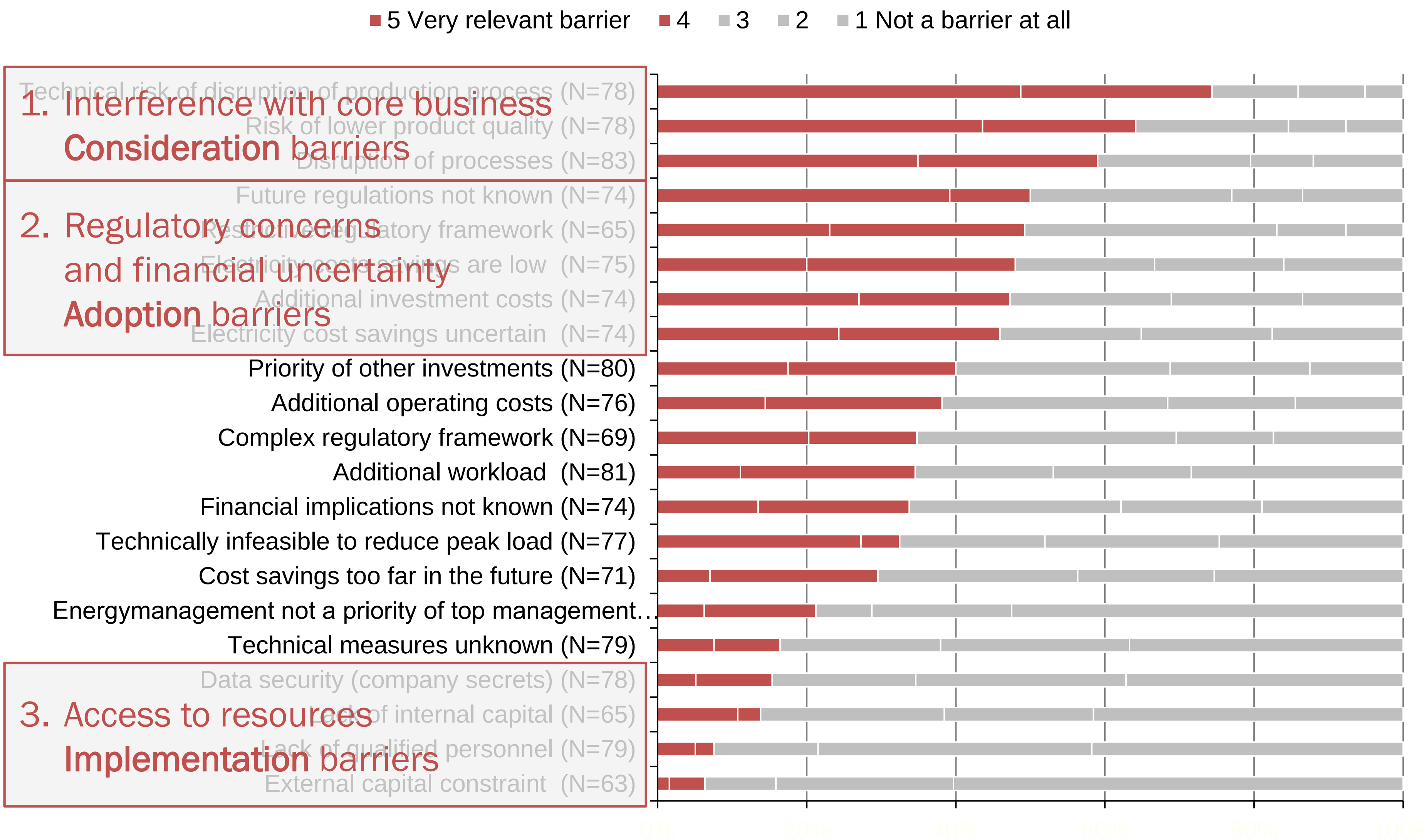
- **Method assumes constant, well-developed preferences**
  But:
  - Emerging phenomenon
  - Response pattern ‘polarized’
  - Lack of internal validity

- **Strategic bias**
  - Survey commissioned by federal agency:
    Consequences for policy?

- **Implication**
  - **Significant share willing to accept automated load management**
  - Develop preferences
  - Inform before subsidize?

Barriers to electricity load shift

Barriers to load shift (% of responses)



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Thank you!

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Sample by sector and size

Firms ≥10 employees only

Sector	Number of employees	Companies in subsample	Share within Subsectors	Companies in Germany (2015)	Share within Subsector	Share in subsample	Share in Germany
Offices	10 - 49	42	41.2%	54,678	74.2%	37.1%	51.1%
	≥ 50	60	58.8%	19,024	25.8%		
Retail food	10 - 49	22	62.9%	5,844	84.5%	12.7%	4.8%
	≥ 50	13	37.1%	1,074	15.5%		
Retail Non-Food	10 - 49	11	57.9%	21,623	86.5%	6.9%	17.3%
	≥ 50	8	42.1%	3,375	13.5%		
Wholesale Food	10 - 49	6	46.2%	3,053	78.6%	4.7%	2.7%
	≥ 50	7	53.8%	831	21.4%		
Wholesale Non-Food	10 - 49	8	33.3%	14,334	76.9%	8.7%	12.9%
	≥ 50	16	66.7%	4,306	23.1%		
Hotel with restaurant	10 - 49	28	73.7%	3,520	81.4%	13.8%	3.0%
	≥ 50	10	26.3%	805	18.6%		
Hotel without restaurant	10 - 49	5	100.0%	2,060	95.2%	1.8%	1.5%
	≥ 50	0	0.0%	103	4.8%		
Restaurants	10 - 49	27	69.2%	8,508	89.3%	14.2%	6.6%
	≥ 50	12	30.8%	1,018	10.7%		
Total		275		144,156		100.0%	100.0%

Simulations

Key assumption:
Average flexible potential per company, Δl

Technology	Share of flexible energy of technology consumption	Flexible potential in GWh of our subsample	Average flexible potential per company in MWh (Δl)
Ventilation	4.1%	0.326	1.92
Air conditioning	10.7%	0.866	5.25

Based on Klobasa 2007