UNIVERSITY OF CAMBRIDGE | Energy Policy Research Group

Which Smart Electricity Services Contracts will Consumers Accept?

The Demand for Compensation in a Platform Market

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OUTLINE

- **Background**
- **Discrete Choice Experiment (DCE) on Smart Energy Services**
- **Implications of Results**

My Background

- PhD Economics, University of Cambridge (2013-2015)
- Econometrics Group & Energy Policy Research Group (EPRG)
- Thesis: *Econometric analysis of consumer preferences in the context of the integration of microgeneration and smart grid technologies into the electricity system*
- This presentation is based on Chapter 2 of the thesis: *Consumers' Call for Compensation - Which Smart Electricity Service Contracts Will They Accept?*

Conducted Discrete Choice Experiment to elicit heterogeneity in consumer preferences

Discrete Choice Experiments (DCE) can elicit consumer preference for existing and hypothetical products.

Preference & WTP analysis can be based on market or survey data:

- Revealed preference studies: based on **real** choices.
- Stated preference studies: based on **hypothetical** choices.

WTP can be derived directly or indirectly:

- **Contingent valuation**:
  - People are asked *directly* how much they would be willing to pay/accept for specific services; contingent on a specific **hypothetical** scenario.
  - Cannot retrieve valuations of distinct attributes.
  - Prone to under/over-reporting.
- **Discrete choice experiment** (DCE):
  - In **hypothetical** scenarios people are asked to choose one out of several service alternatives.
  - **In choice cards alternatives** are presented with several **attributes** that vary in their **levels**.
  - WTP for distinct attributes is derived via econometric estimation.

- Background
- **Discrete Choice Experiment (DCE) on Smart Energy Services**
- Implications of Results

DCE on consumer preferences for smart energy services (2015).

Discrete choice experiments require careful design:

1. Understand market context and define questions of interest
2. Define relevant alternatives, attributes and levels
3. Choose experimental design
4. Run pilot and full experiment
5. Estimate parameters
6. Derive implications, e.g. for policy recommendations or contracts that incentivise consumer acceptance

Data from DCE can be exploited for:

- Demand estimation (e.g. market shares).
- Identify consumer segments with similar tastes.
- Inform product/service design to match consumer preferences

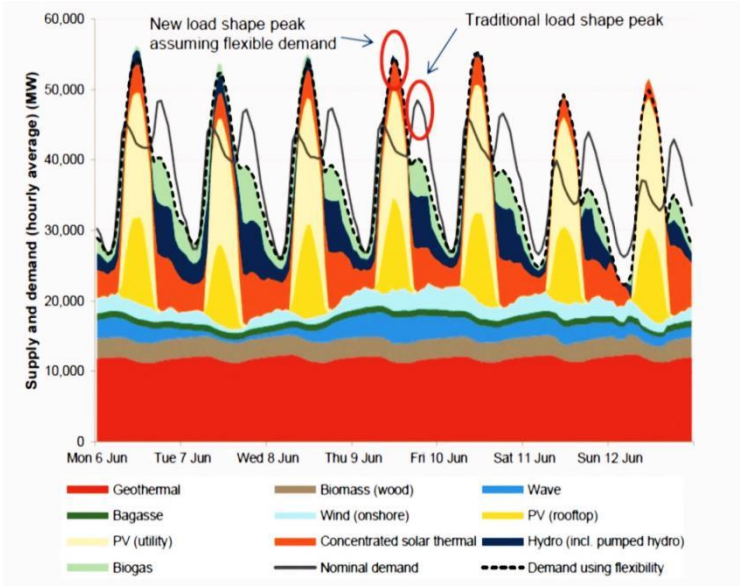
ICT enabled demand side response can help balancing the grid.

- Renewables contribute to CO2 reduction targets.
- BUT: intermittency implies variable electricity supply.
- Demand response (DR) can help balancing the grid - in real time.
- For this, Information & Communication Technology (ICT) is essential.

Demand response: Intentional modifications of electricity consumption to alter timing & level of electricity demand

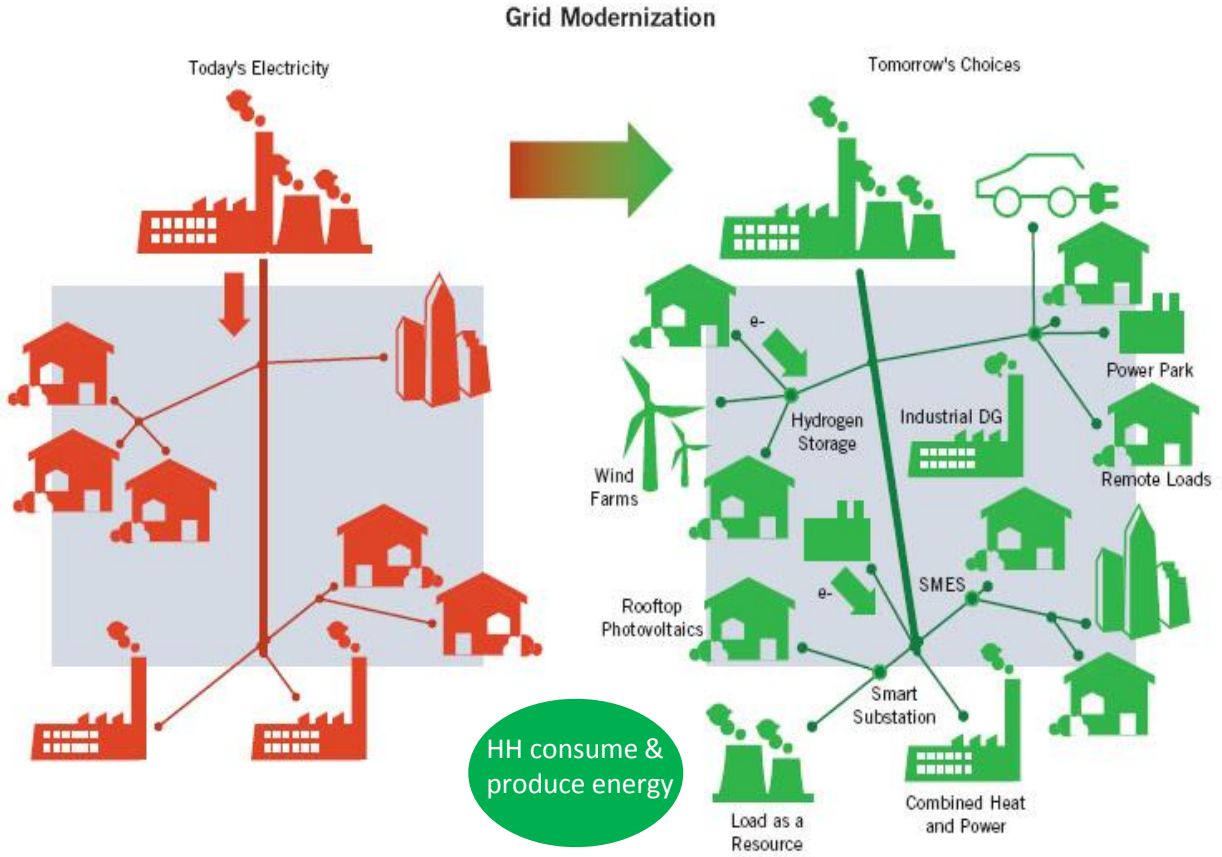
ICT

Households consume & produce energy and provide flexible load



Household loads as grid resource are at the heart of the transition towards a smart grid.
But: how can households be incentivised to participate?

Smart Grids change the consumer-producer relationship



Households consume energy

HH consume & produce energy

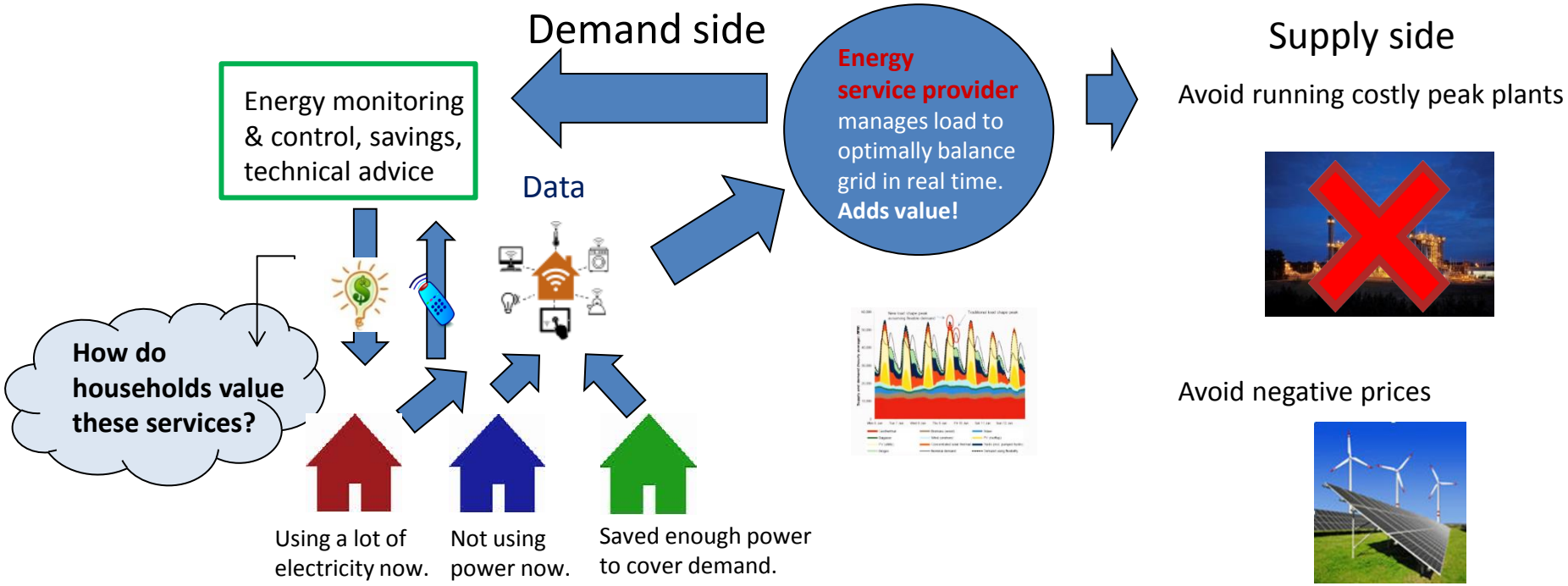
Service provider has potential to manage loads

Fig. 1. The IEEE's version of the Smart Grid involves distributed generation, information networks, and system coordination, a drastic change from the existing utility configurations.

The new complexity of the demand side, with consumers simultaneously being producers and flexible resources, makes an intermediary with smart optimisation capabilities viable and possibly necessary.

Main direct benefits of flexible demand response lie on supply side.

- Household load is highly valuable for grid operators and generators.
- Benefits for individual households are small; they have an incentive to free-ride.
- Since there is a system-level benefit of an optimally balanced grid, the challenge is **how to incentivise households to participate…**

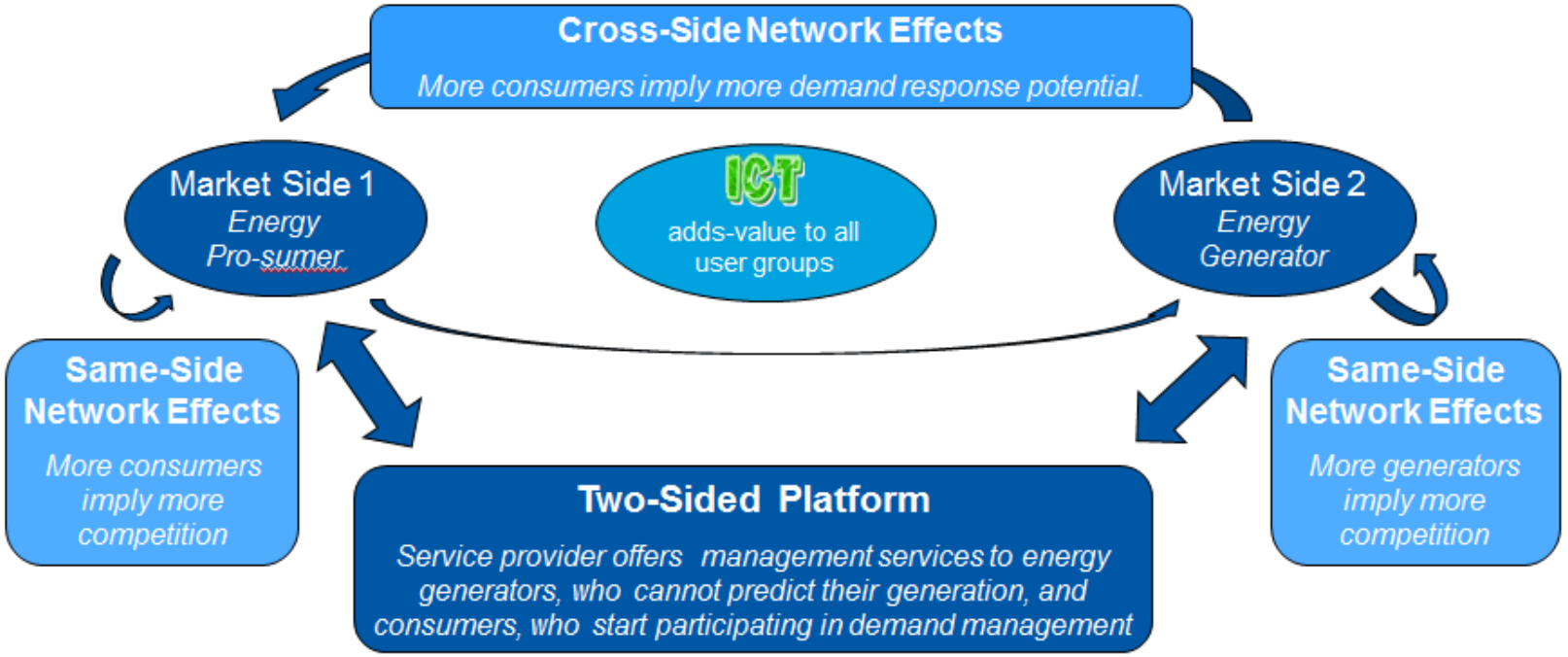


DCEs can shed light on consumer valuations for different smart service attributes.

Smart energy services are traded on two-sided platforms.

Generally, a platform market is characterised by:

1. One or more user groups linked by a coordinating platform provider.
2. Network externalities: utility of platform users depends on the number of other users.
3. ICT that creates added-value by increasing utility to all user groups.



Service providers can price or compensate services on both sides of the market.

Aim: elicit consumer preferences for smart electricity services.

1. How do consumers value smart electricity services?
   - For which service attributes are they willing to pay?
   - For which service attributes do they want to be compensated?

2. What does this imply for the optimal pricing strategies?
   - How can the service provider attract the number of households required to provide the optimal level of demand response?
   - Which customer segments likely exist and how should they be targeted?

We address these questions based on a DCE conducted in 2015.

First discrete choice experiment on smart electricity services.

- Online survey conducted with Accent.
- 1,892 respondents in the UK in 2015.
- Background survey on demographics, experiences and attitudes.
- Choice cards with 3 contract alternatives.
- Six service attributes chosen based on previous research, expert interviews and pilot study.
- Each attribute has up to 5 levels.
- Each respondent was asked to make 8 choices (→ panel).

Define relevant alternatives, attributes and levels based on expert interviews, previous research and pilot study:

Attribute level	Description of attributes and levels	Variable Name
	**Electricity Usage Monitoring**	
Level 1 (base)	Bill or pre-payment meter	
Level 2	Real-time in-house monitor with alerts in case of unusual usage	monitor2
Level 3	Real-time monitoring & personalised advice by service provider	monitor3
	**Control of Electricity Devices**	
Level 1 (base)	Manual control by the household	
Level 2	Remote\automated control by the household	control2
Level 3	Remote\automated control by the service provider	control3
	**Technical Support**	
Level 1 (base)	Initial 90 days technical support	
Level 2	Ongoing basic technical support	support2
Level 3	Ongoing premium support including personalised advice	support3
	**Data Privacy and Security**	
Level 1 (base)	No data shared with 3rd parties	
Level 2	Only electricity usage data shared	privacy2
Level 3	Electricity usage & personally identifying data shared with 3rd parties	privacy3
	**Expected Electricity Bill Savings**	
5 levels	Expected monetary savings presented in £ per month Calculated based on electricity bill as 0%, 5%, 10%, 15% or 20% of bill	Esavings
£	**Monthly Fee**	
5 levels	Monthly fee paid for the service bundle received (£ per month) Calculated based on expected bill savings as 25%, 50%, 100%, 125%	fee

An example choice card:

What would you choose? (Please choose one of these options)			
	Option A	**Option B**	**None**
Usage Monitoring	Real-time monitoring by electricity service provider	Real-time in-house monitor with alerts	
Control of Devices	Remote & automated control by electricity service provider	Manual control by household	
Technical Support	On-going basic technical support	On-going premium support including personalised advice	
Data Privacy & Security	No data shared with third parties	Usage & personally identifying data shared with third parties	
Expected Electricity Bill Savings (£)	7.50	2.50	
Monthly fee (£)	3.40	1.20	
Preferred option (tick)	✓		

Consumers were asked to choose one out of three alternatives.
They faced eight such choices.

D-efficient experimental design easily implementable using NGene:

- The choice profiles were combined into sequences of choice situations according to a D-efficient experimental design.
- Efficient designs are non-orthogonal; but efficient in the sense that the (co)variances of parameter estimates are minimized.

The most comprehensive software for designing choice experiments.

- A number of restrictions were placed on the design:
  - Prevent dominant/dominated alternatives within a choice situation.
  - Avoid implausible combinations of attributes.
    - E.g.: more monitoring and control must lead to higher cost savings; remote and automated control require a smart monitor…

Combine flexible mixed logit model in WTP space with posterior analysis:

- Random parameter model.
  - Allows for preference and scale heterogeneity.
- Estimation in WTP space.
  - Allows to directly estimate the WTP/WTA.
- Consumer profiling based on posterior analysis.
  - Can inform differentiated contract design.
- Estimate:

$$E(U_{jit}) = \alpha_i \text{fee}_{\text{jt}} + \omega_{ASC3jit} + \omega_{1i}\text{monitor2}_{\text{jt}} + \omega_{2i}\text{monitor3}_{\text{jt}} + \omega_{3i}\text{control2}_{\text{jt}} + \omega_{4i}\text{control3}_{\text{jt}} + \omega_{5i}\text{support2}_{\text{jt}} + \omega_{6i}\text{support3}_{\text{jt}} + \omega_{7i}\text{privacy2}_{\text{jt}} + \omega_{8i}\text{privacy3}_{\text{jt}} + \omega_9 \text{Esavings}_{\text{jt}},$$

Mean estimates give first insights into consumers' WTP.

	GMNL-II
Mean	
ASC3	-2.400***
monitor2	0.133
monitor3	-0.548***
control2	-0.0376
control3	-1.643***
support2	0.446***
support3	0.483***
privacy2	-0.996***
privacy3	-3.110***
E(Bill Savings) (£)	0.338***
[Het] Const	-0.120
	(0.0986)
τ	1.016***
	(0.0643)
SD	
ASC3	5.330***
monitor2	1.036***
monitor3	0.0787
control2	0.493**
control3	1.262***
support2	0.294
support3	0.0807
privacy2	1.295***
privacy3	2.923***
E(Bill Savings) (£)	0.674***
AIC	23591.4
BIC	23783.3

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Customers ask for significant compensation:

- To accept automated monitoring & control.
- To share usage & personally identifying data.

They are willing to pay for:

- Ongoing technical support & premium support.
- Expected bill savings (£0.34) if savings are about three times the fee.

There is significant heterogeneity in valuations for most attribute levels.

Posterior analysis sheds further light on WTP distributions:

Summary statistics of the individual posterior means:

	Posterior				Priori		
Variable	$\hat{\mu}_{\mu_i}$	$\hat{\sigma}_{\mu_i}$	min $\hat{\mu}_i$	max $\hat{\mu}_i$	$\hat{\mu}_{prior}$	$\hat{\sigma}_{prior}$	$(\hat{\sigma}_{\mu_i}/\hat{\sigma}_{prior})$
monitor2	0.14	0.50	-2.71	2.73	0.13	1.036	48.40%
monitor3	-0.55	0.03	-0.73	-0.38	-0.55	0.0787	44.45%
control2	-0.04	0.22	-1.36	1.16	-0.04	0.493	45.55%
control3	-1.65	0.64	-4.57	1.70	-1.64	1.262	51.02%
support2	0.45	0.14	-0.17	1.02	0.45	0.294	47.00%
support3	0.48	0.04	0.27	0.70	0.48	0.0807	46.48%
privacy2	-1.01	0.65	-4.04	1.77	-1.00	1.295	50.22%
privacy3	-3.17	1.84	-10.81	5.64	-3.11	2.923	62.85%
E(Bill Savings) (£)	0.33	0.49	-1.40	2.18	0.34	0.674	72.72%

There is significant heterogeneity in valuations:

- Some consumers ask for very high compensation to share their data (up to more than £10 per month)! Others perceive the data services as valuable and are willing to pay!

- The majority of consumers expects savings that exceed the fee. Most want to pay a third of what they expect to save.

K-means clustering of posterior valuations reveals 4 customer clusters:

Valuations and background characteristics by customer clusters:

Cluster name	Cluster 1 Customary	Cluster 2 Private data	Cluster 3 Risk averse	Cluster 4 Open data
Observations	602	278	750	262
control3	-1.59	-1.62	-1.72	-1.58
privacy3	-2.29	-5.90	-3.93	-0.07
E(Bill Savings) (£)	0.35	0.44	0.24	0.41
age	4.87	4.85	4.95	4.74
female	54%	63%	57%	51%
SEG DE	24%	23%	26%	37%
occupants	2.21	2.19	2.07	2.35
PAG tariff	17%	15%	14%	20%
technology type	2.49	2.55	2.72	2.33
concerns remote control	41%	53%	51%	39%
above avge choice confidence	50%	53%	52%	37%
above avge understanding of DCE	39%	38%	40%	31%
above avge perception of realism	67%	68%	59%	66%

Most differentiation potential lies in data privacy & security services

- Background
- Discrete Choice Experiment (DCE) on Smart Energy Services
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The combination of different service attributes implies different mean compensations:

Mean fixed compensation for several service combinations:

Service Bundle	Compensation (£)
Remote monitoring & control ONLY	-2.19
Remote monitoring & control PLUS	
+ usage data sharing	-3.20
+ usage and personally identifying data sharing	-5.36
+ ongoing support	-1.75
+ premium support	-1.71
+ ongoing support & usage data sharing	-2.76
+ ongoing support & usage and personal data sharing	-4.91
+ premium support & usage data sharing	-2.72
+ premium support & usage and personal data sharing	-4.88

Here: differentiation by service type, not by customer type.

- Consumers ask for a compensation of around £2 per month to give access to allow remote monitoring and control by the service provider.
- Technical support services decrease the compensation required.
- Data usage increases the average compensation required.

Calculating Acceptance Rates:

The optimal platform pricing strategy depends on the externalities.

- If the cross-side externalities are strong enough, generators and suppliers could fully pay for the platform services to attract the number of households required to provide the optimal level of demand response.

Acceptance rates for exemplary contracts combining fixed compensation & transaction based component:

	All	Cluster 1 Customary	Cluster 2 Private data	Cluster 3 Risk averse	Cluster 4 Open data
-£2.19 + £0.50 per exp. £1 saving	20%	21%	27%	13%	27%
-£2.19 + £0.33 per exp. £1 saving	24%	26%	33%	16%	34%
-£4 + £0.50 per exp. £1 saving	35%	36%	49%	26%	44%
-£4 + £0.33 per exp. £1 saving	46%	48%	60%	36%	59%

The acceptance rate ceteris paribus increases…

- the higher the fixed compensation payment,
- the lower the fee to expected savings ratio
  (i.e. the higher the share of savings being granted to the customer).

Conclusion

In general:

- DCE can elicit valuations for distinct service attributes and bundles.
- DCE require careful design.
- Consumer profiling based on posterior analysis can inform contract design.

Here:

- Consumer valuations for most smart energy service components vary significantly.
- Consumer heterogeneity can be exploited for effective demand management.
- With more information on local balancing cost and the optimal customer acceptance rate, results could promote efficient pricing strategies that carefully take consumer preferences into account.
- A combination of fixed and transaction based payment is recommended.

Summary of High-Level Lessons

The Integration of ICT with the Power System Transforms the Market

- ICT enables smart grids that balance supply and demand – in real time
- Smart grids change the consumer-producer relationship – the 'prosumer' is in focus
- Smart energy services are traded on platforms, with service providers as intermediaries

Discrete Choice Analysis Can Inform Optimal Pricing Strategies

- Discrete choice analysis can reveal valuations for service attributes and service bundles
- Consumer profiling based on posterior analysis can inform contract design
- Fixed monthly compensation combined with differentiated transaction based payments can incentivise consumer acceptance

Customers Call for Compensation to Accept Smart Energy Services

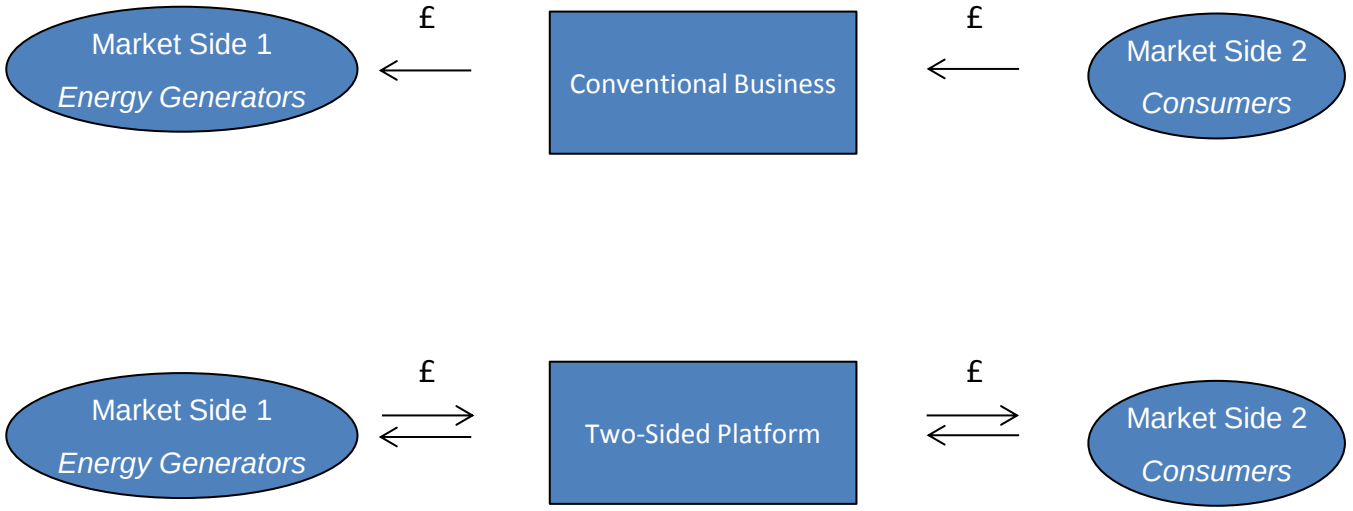
- They accept automated remote control & monitoring – against compensation
- They are willing to share usage & personally identifying data – against compensation
- They are willing to pay for ongoing technical support & premium support services

Customer Heterogeneity Can be Exploited by Service Differentiation

- With more information on local balancing cost and optimal customer acceptance rates, results could promote efficient pricing strategies that carefully take consumer preferences and engagement into account

APPENDIX

Conventional Businesses vs Platforms



A flexible mixed logit model can allow for heterogeneity in consumer preferences:

- How do consumer and product attributes jointly affect choices?
- Estimate implicit prices for attributes and bundled service.
- Heterogeneous scale mixed logit in preference space:

$$U_{ijt} = \alpha_i p_{jt} + \boldsymbol{\omega}_i' \mathbf{v}_{jt} + \sigma_i^{-1} \epsilon_{ijt}$$

$$\alpha_i = \alpha_0 + \alpha_1 \mathbf{x}_{it} + \nu_{1it}$$

$$\omega_{ik} = \omega_{0k} + \boldsymbol{\omega}_{1k}' \mathbf{x}_{it} + \nu_{2ikt} \quad \forall k = 1 \ldots K$$

- While ε follows an extreme value type I distribution, the distribution of ν is chosen by researcher (e.g. multivariate normal, log normal, beta…).
- Heterogeneity in valuations is modeled via interaction terms or unobserved error.

Estimation in WTP space allows direct estimation of WTP; posterior analysis can shed light on heterogeneity:

Estimation in WTP space:

- Re-parameterisation yields the heterogeneous scale mixed logit in WTP space:

$$U_{ijt} = \underbrace{(\sigma_i \alpha_i)}_{\lambda_i}[p_{jt} + \underbrace{(\omega_i'/\alpha_i)}_{\mathbf{w}_i'}\mathbf{v}_{jt}] + \epsilon_{ijt}$$

- Distributional assumptions can be directly imposed on the WTP (here: normality).
- Scale parameter does not impact the WTP estimates but price parameter and scale parameter are confounded.

Posterior analysis:

- Conditional distributions allow to infer the **most likely position** of each sampled individual on the distribution of valuations exploiting the information on their choices made.

$$\widehat{E_i(\omega)} = \frac{\Sigma_{r=1}^{R} L(\mathbf{y}_i|\omega_r)\omega_r}{\Sigma_{r=1}^{R} L(\mathbf{y}_i|\omega_r)}$$

Consumer profiling based on posterior analysis can inform contract design.

Thank you!

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