Preferences for smart and bidirectional workplace EV charging

A two-country discrete choice experiment

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Outline

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Why workplace-charging flexibility?

The problem

- EV uptake is accelerating; home-evening charging concentrates demand and stresses the distribution grid at peak
- Workplaces offer long, predictable daytime dwell times: a natural place to *shift* and even *reverse* charging
- Two managed strategies: *smart* (delay/shift timing) and *bidirectional* / vehicle-to-grid (V2G, export to the grid) [Anwar et al., 2022]

But

Managed charging only delivers if employees *accept* it, and that is a behavioural question.

The evidence gap

What is missing

- Most evidence is on technical potential; behavioural *acceptance* of managed *workplace* charging is thin [Delmonte et al., 2020]
- Vehicle-to-grid *export* (with its compensation) is rarely valued in a choice setting [Geske and Schumann, 2018, Kubli, 2022]
- Little *cross-country* comparison, despite different tariffs, institutions and attitudes [Wolff and Madlener, 2019, Visaria et al., 2022]
- We need scale-free values (WTP) and realistic uptake, not just stated interest

Research question

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How do workplace commuters value key attributes of smart and bidirectional EV charging plans?

Contribution

- A two-country (UK + Germany, $n = 858$) stated-preference discrete choice experiment
- Mean preferences, *unobserved heterogeneity* (sign-constrained mixed logit), willingness to pay, and an adoption simulation
- The behavioural *levers* for managed workplace charging, and how they differ across countries

Outline

The choice experiment

Design

- Unlabelled, three-alternative task: two *managed* workplace plans (A, B) vs the uncontrolled *status quo* (C)
- Six choice tasks per respondent; efficient design; UK + Germany, identical instrument
- Attributes span the price, the guaranteed range, the override option, the V2G reward, and the environmental benefit

Status quo (Option C)

Uncontrolled charging at the standard tariff, with a generous guaranteed range (commute +120 mi / +200 km).

An example choice task (commute $D = 50$ mi)

Choice Task 1

Please select your preferred plan from the following three options:

For further explanations of each attribute, click the 'ⓘ' symbol. If you are conducting the survey on your smartphone, please use landscape mode.

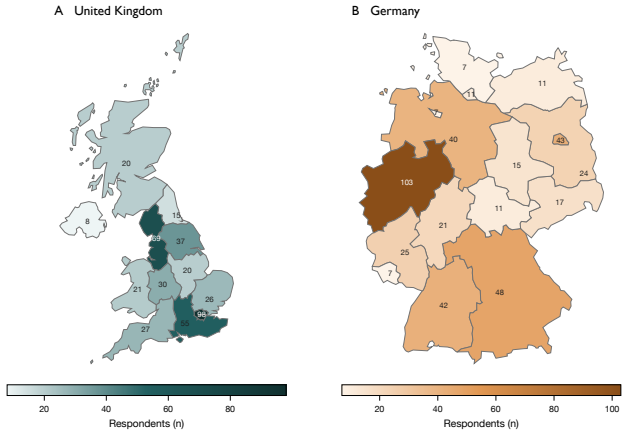
	Option A	Option B	Option C
Price ⓘ	£ 0.10 /kWh	£ 0.40 /kWh	£ 0.40 /kWh
Guaranteed range ⓘ	110 miles	65 miles	170 miles
Energy Export ⓘ	10 kWh (12.5%)	40 kWh (50%)	none
Compensation ⓘ	£ 0.30 /kWh	£ 0.50 /kWh	--
Override Fee ⓘ	£ 2	£ 1	--
CO_2 savings by using smart charging ⓘ	0.8 $kgCO_2$	3.2 $kgCO_2$	--
Which would you choose?	◌	◌	◌

Attributes and levels

Attribute	Levels (native units)	Note
Price	0.10 / 0.20 / 0.40 per kWh	£ (UK) / € (DE)
Guaranteed range	buffer over the commute	respondent-specific
Override fee	0.50 / 1 / 2 per use	pay to charge on demand
Compensation	0 / 0.20 / 0.30 / 0.50 per kWh	for V2G export
Energy export	0 / 10 / 20 / 40 kWh	bidirectional (V2G)
CO_2 avoided	scales with smart charging	respondent-specific

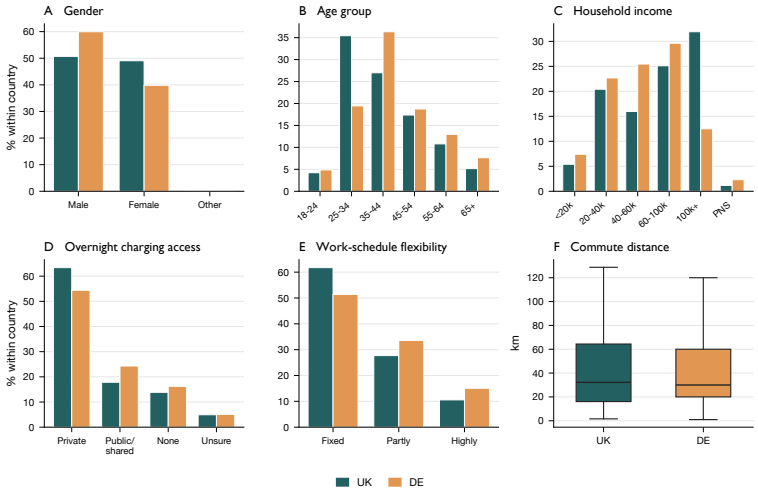
Money in native currency (country-specific coefficients); range and CO_2 depend on the respondent's commute.

Sample: where our respondents come from



UK + Germany, $n = 858$ (426 UK / 432 DE); broad regional coverage, with the largest cells in Greater London and North Rhine-Westphalia.

Sample: who our respondents are



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Random utility: the preferred specification

Systematic utility of alternative j (task t, respondent n)

$$V_{ntj} = \alpha_j + s_{n,j} + \beta_{p,n}p + \beta_{f,n}f + \beta_{w,n}w + \beta_{r,n}r + \beta_b b + \beta_x x + \beta_e e$$

- Status quo C is the reference ($\alpha_C \equiv 0$, $\gamma_{\cdot,C} = 0$); acceptance shift *alternative-specific*: $s_{n,j} = \gamma_{\mathsf{EV},j}\mathsf{EV}_n + \gamma_{\mathsf{T},j}\mathsf{T}_n$, plans A and B *separate* (not pooled)
- Money coefficients *country-specific*: $\beta_{m,n} = \beta_m^{\mathsf{DE}}\mathsf{DE}_n + \beta_m^{\mathsf{UK}}\mathsf{UK}_n$ ($m \in \{p, f, w\}$); range shifts with commute: $\beta_{r,n} = \beta_r + \delta_r \tilde{c}_n$

Conditional (multinomial) logit

$$P_{ntj} = \frac{\exp(\mu V_{ntj})}{\sum_{k\in\{A,B,C\}} \exp(\mu V_{ntk})}$$

μ is the logit *scale* (not identified separately) $\Rightarrow$ normalised to $\mu = 1$, here and in the mixed-logit kernel

Preferred model: a sign-constrained mixed logit

- A Normal mixed logit puts mass on the *wrong sign* of some tastes ⇒ contaminates WTP ratios
- Fix: range and compensation are *log-normal* (strictly correct sign for every respondent)

Random, sign-constrained tastes ($\xi_{\bullet,n} \sim N(0,1)$, once per respondent)

$$\beta_{r,n} = \exp\left(\mu_r + \delta_r \tilde{c}_n + \sigma_r \xi_{r,n}\right), \quad \beta_{w,n} = \exp\left(\mu_w^c + \sigma_w \xi_{w,n}\right), \quad \eta_{n,j} = \sigma_{ec,j} \xi_{ec,j,n}$$

median $= \exp(\mu)$, mean $= \exp(\mu + \frac{1}{2}\sigma^2)$ (right-skewed); the $\mu_\bullet$ are log-*locations*, not the logit scale

- Price, fee, CO_2, export fixed; *alternative-specific* managed-plan error components $\eta_{n,A}, \eta_{n,B}$ capture persistent, person-level acceptance (unobserved heterogeneity in each managed-plan constant, independent across A and B)

Panel likelihood, WTP, and adoption

Panel trajectory + maximum simulated likelihood ($T_n = 6$, $R = 1500$ MLHS draws)

$$P_n = \int \prod_{t=1}^{T_n} P_{nt}(j_{nt} \mid \xi_n)\, \phi(\xi_n)\, \mathrm{d}\xi_n, \qquad \widehat{\mathrm{SLL}} = \sum_n \ln\Big[\tfrac{1}{R} \sum_{r=1}^{R} \prod_t P_{nt}\big(j_{nt} \mid \xi_n^{(r)}\big)\Big]$$

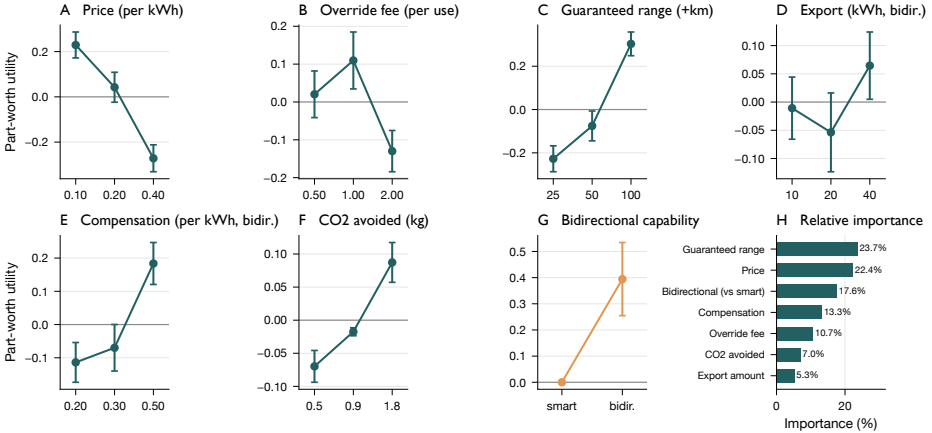
Willingness to pay (scale-free) and adoption

$$\mathrm{WTP}_k = \frac{\beta_k}{|\beta^c_{\mathrm{price}}|}, \qquad \text{log-normal median WTP} = \frac{\exp(\mu_k)}{|\beta^c_{\mathrm{price}}|}$$

95% intervals by a respondent-level bootstrap; adoption by microsimulation of the managed plan vs the status quo over the sample

Outline

Attribute importance (part-worths)



Range and compensation dominate; part-worths are approximately linear, justifying one coefficient per attribute.

Sign-constrained mixed logit: estimates

	Est.	t
ASCs (vs. status-quo C)		
Plan A (α_A)	1.21	12.24
Plan B (α_B)	1.39	14.56
Acceptance shifts (vs. C)		
EV user, plan A	1.21	12.30
EV user, plan B	1.18	12.35
Tech affinity, A	−0.0049	−1.76
Tech affinity, B	−0.00524	−1.89
Price (per kWh, native; fixed)		
Germany	−1.91	−7.91
UK	−1.57	−5.63
Override fee (per use; fixed)		
Germany	−0.173	−4.31
UK	−0.0578	−1.11

	Est.	t
Range, log-normal		
Log-loc. (μ_r)	0.196	1.25
× commute (δ_r)	−0.00799	−3.63
Log-scale (σ_r)	1.29	14.17
Compensation, log-normal		
Log-loc., DE (μ_w^{DE})	−0.371	−1.56
Log-loc., UK (μ_w^{UK})	−0.111	−0.45
Log-scale (σ_w)	0.99	9.11
Other attributes (fixed)		
Export (per kWh)	0.00331	2.02
Bidirectional	−0.0613	−0.50
CO_2 (per kg)	0.0887	3.33
Error components (Normal)		
Plan A ($\sigma_{ec,A}$)	0.496	6.89
Plan B ($\sigma_{ec,B}$)	0.0144	0.46

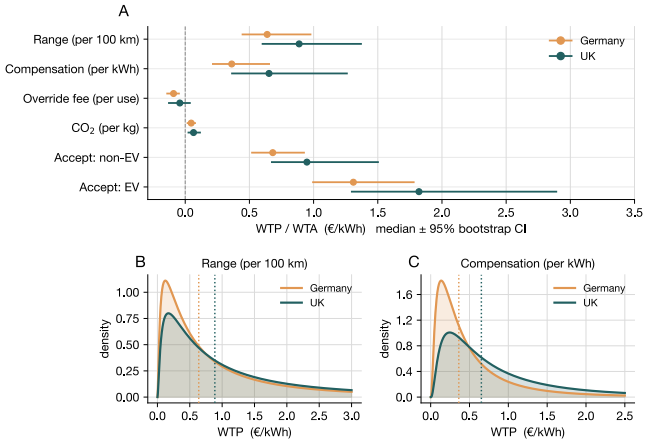
$\log L = -4555.8$, $\bar{\rho}^2 = 0.191$; AIC 9154, BIC 9254; 21 parameters, 1500 draws. Log-normal tastes $\beta = \exp(\mu + \sigma\xi)$; preferred to the Normal mixed logit. $|t| > 1.96/2.58/3.29 \Rightarrow 5/1/0.1\%$.

Substantial unobserved heterogeneity

Preferred (sign-constrained) mixed logit

- Large, right-skewed heterogeneity in range and compensation tastes (log-scales $\sigma_r = 1.29$, $\sigma_w = 0.99$)
- Range median 1.22 but mean 2.78: a long tail of high range-valuers
- Alternative-specific managed-plan error components ($\sigma_{ec,A} = 0.50$, $\sigma_{ec,B} \approx 0$): persistent person-level acceptance
- EV-user acceptance shift large and robust (≈ 1.2 on both plans); tech affinity vanishes once heterogeneity is modelled

Willingness to pay / accept



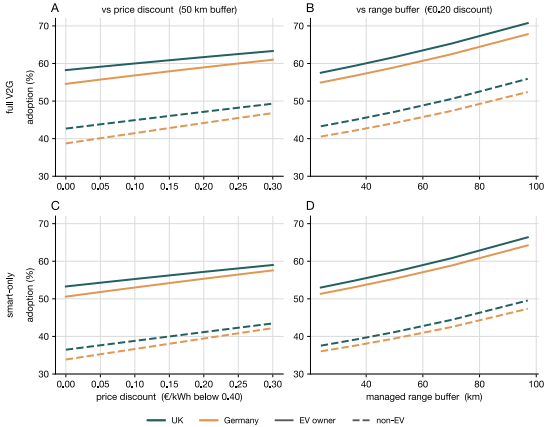
Per-kWh WTP for range, compensation and CO_2; the right skew reflects the log-normal heterogeneity. UK in a common €.

Willingness to pay: values

	Germany (€)			UK (common €)		
	per kWh	[95%]	per charge	per kWh	[95%]	per charge
Range (per 100 km)	0.64	[0.45, 0.98]	5.68	0.89	[0.60, 1.37]	8.25
Compensation (per kWh)	0.36	[0.22, 0.65]	3.22	0.65	[0.36, 1.26]	6.07
Override fee (per use)	−0.09	[-0.14, -0.05]	−0.81	−0.04	[-0.13, 0.04]	−0.39
CO_2 (per kg)	0.05	[0.02, 0.08]	0.41	0.06	[0.03, 0.11]	0.60
Accept: non-EV	0.68	[0.52, 0.92]	6.07	0.95	[0.68, 1.50]	8.82
Accept: EV	1.31	[1.00, 1.78]	11.66	1.82	[1.30, 2.89]	16.93

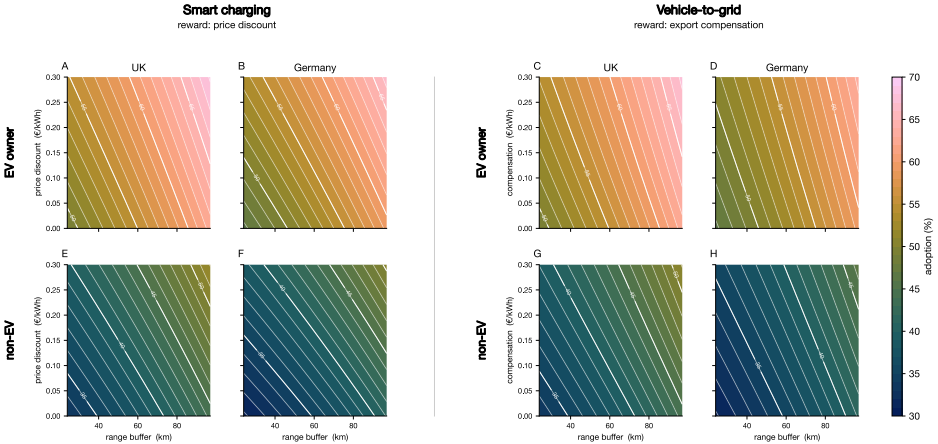
Median WTP with 95% bootstrap intervals; "per charge" covers the average commute at the survey's efficiency. UK converted at 1.148.

Adoption simulation



Colour = country; solid/dashed = EV owner/non-EV; rows = plan, columns = swept lever. Range is the stronger lever in both countries; the UK adopts more overall, Germany is more price-responsive.

Operator trade-off: range vs. reward



Guaranteed range (x) vs. per-kWh reward (y): smart (price discount, left) vs. V2G (compensation, right), by country $\times$ EV; shared scales. A discount lifts adoption slightly more per € than compensation.

Synthesis

What drives acceptance

- Range assurance and fair compensation are the strongest levers; the override fee deters (esp. Germany)
- Genuine CO_2 valuation; EV owners far more accepting than non-owners ($\approx +1.2$ utility)
- Cross-country differences are chiefly in money sensitivity (Germans more price-sensitive; UK values compensation more)
- Heterogeneity is large and mostly *unobserved* $\Rightarrow$ no one-size-fits-all scheme

Outline

Policy and practice implications

Designing managed workplace charging

- Anchor schemes on a *guaranteed range* and *transparent compensation*: the two levers people value most
- V2G export needs a *credible, adequate reward* to mobilise participation
- Country-tailored tariffs; avoid deterrents such as override fees
- Employers + grid operators can target EV owners first, then broaden with range guarantees

Conclusions

Take-aways

- Managed workplace charging (smart & V2G) is broadly acceptable when *range-secured* and *fairly compensated*
- Robust EV-owner and cross-country differences; the range buffer is the strongest adoption lever
- Large unobserved heterogeneity, captured by a sign-constrained mixed logit with correct-sign WTP
- Limitations: stated-preference (hypothetical) bias; workplace/charging context. Future: revealed-preference validation

Thank you

Thank you; questions welcome

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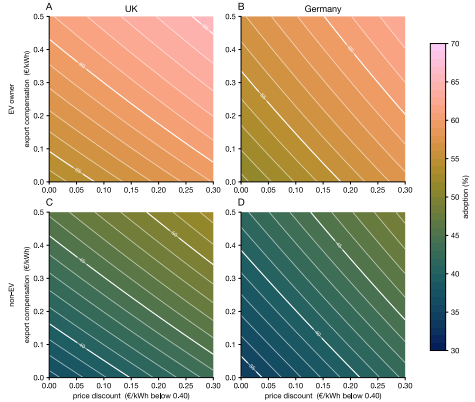
Price–compensation trade-off (V2G; monetary view)



Full-V2G adoption over price × compensation (population; 50 km buffer). Flatter UK contours: compensation is the more effective lever there ($|\beta_p|/\beta_c = 1.8$ vs 2.8); the contour slope is the compensation–price substitution rate.

Preferred MNL: estimates

	Estimate	Robust SE	t
Alternative-specific constants (vs. status-quo Option C)			
Managed plan A (ASC_A)	0.62	0.127	4.88
Managed plan B (ASC_B)	0.744	0.126	5.91
Managed-plan acceptance shifts (alternative-specific, vs. C)			
EV user, plan A	0.626	0.0833	7.52
EV user, plan B	0.532	0.0817	6.52
Tech affinity, plan A ($\geq$2 home techs)	0.233	0.0893	2.60
Tech affinity, plan B	0.342	0.0871	3.93
Price (per kWh, country-specific, native currency)			
Germany (per €/kWh)	−2.41	0.201	−12.01
UK (per £/kWh)	−0.838	0.193	−4.33
Override fee (per use, country-specific)			
Germany	−0.168	0.0376	−4.46
UK	−0.0649	0.0377	−1.72
Compensation (per kWh, country-specific)			
Germany	0.761	0.192	3.96
UK	1.27	0.191	6.64
Guaranteed range (per 100 km buffer)			
Range buffer	0.74	0.0583	12.71
× commute (mean-centred, per 100 km)	−0.227	0.0696	−3.26
Other attributes			
Export (per kWh)	0.00298	0.00153	1.95
Bidirectional (indicator)	−0.0247	0.111	−0.22
CO_2 avoided (per kg)	0.071	0.0233	3.05

$\log L = -5228.1$, $\bar{\rho}^2 = 0.073$; 858 respondents, 5,148 tasks, 17 parameters. Significance from t: $|t| > 1.96/2.58/3.29 \Rightarrow 5/1/0.1\%$.

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