The Role of Information for the Adoption of Heat Pumps: Experimental Evidence for Germany

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EEA 2025, Bordeaux, 25 August 2025

Heating sector decarbonisation in Germany

- Heating of buildings and water accounts for c. 20% of Germany's carbon emissions (BDEW, 2021)
- In 2023, the German government revised the Building Energy Act (GEG) to **prescribe installation of heating systems** that are **operated with at least 65% of renewable energy** in new buildings in development areas as of 2024 (e.g., heat pumps) (GEG, 2023)
- For other new and existing buildings, rules will come into force a few years later
- The legislation **strongly promotes** installation of **heat pumps** (GEG, 2023)
- Immediate effect in 2023: record level of 350,000 heat pump (BWP, 2024) and 800,000 gas heating system installations (NTV, 2024)

⇒ **Pivotal to understand how households decide on their heating systems**

Investment and operating costs of heating systems

- Upfront investment cost of heating systems is relatively certain, while future operating cost depends on the development of fuel or electricity prices
- **Heat pumps are more capital-intensive** → Higher upfront investment cost than heating systems based on natural gas or heating oil (IEA, 2022)

⇒ Unclear ex ante which system is most cost-efficient over the life cycle

⇒ **Uncertainty** regarding future price development **and the relative novelty** of heat pumps **may hamper heat pump adoption**

This paper

Research question: How does the provision of information on the cost associated with different heating solutions affect households' willingness to pay (WTP) for heat pumps compared to a fossil fuel heating system?

Experimental design:

- Pre-registered **online survey experiment** with final sample of **1,115 participants** in September/October 2023
- WTP elicitation using a Multiple Price List
- Information treatment on investment and operating cost of heat pumps and fossil fuel heating systems

Results:

- Participants are willing to pay a price premium of 5,950 EUR for a heat pump
- Transparent information provision increases price premium by c. 1,880 EUR ($>$ 30%)

Experimental design

Hypothetical decision situation

- Respondents were asked to **imagine that their current heating system was damaged and needed to be replaced** on short notice
- Tenants were told to imagine that they can advise their landlord on the decision, and that their annual rent may be increased by up to 8% of the investment cost (German law)
- **Two replacement options**:
  - An equivalent of their current fossil heating system
  - An air-to-water heat pump
- **Randomisation into 2 groups**: information and control

Treatment: Cost comparison for heat pump and fossil heating system

- **Treatment**: cost overview for a single-family house based on a study commissioned by the Federal Ministry of Economic Affairs and Climate Action (BMWK)
- **Explicit conclusion**: installation of heat pump is cheapest alternative; saves approx. 320 EUR per year over the heating system's lifespan
- Information on assumed lifespan (20 years), increase of electricity prices (0.5% p.a.) and natural gas prices (1% p.a.)

	Fossil heating system	Air-to-water heat pump	Difference (Heat pump - fossil system)
Investment (one-time)	10,980 euros	28,620 euros	+ 17,640 euros
Consumption + operating costs (p.a.)	4,918 euros	3,689 euros	- 1,229 euros

Multiple Price List to elicit WTP

Fossil fuel heating system (oil or gas)	Heat pump
10,980 euros	28,620 euros
10,980 euros	25,758 euros
10,980 euros	22,896 euros
10,980 euros	20,034 euros
10,980 euros	17,172 euros
10,980 euros	14,310 euros
10,980 euros	11,448 euros
10,980 euros	8,586 euros
10,980 euros	5,724 euros
10,980 euros	2,862 euros

- Investment cost for fossil heating system remains constant, while cost for heat pump decreases by 10 percentage points in each step
- Additional response options: don't know, no answer

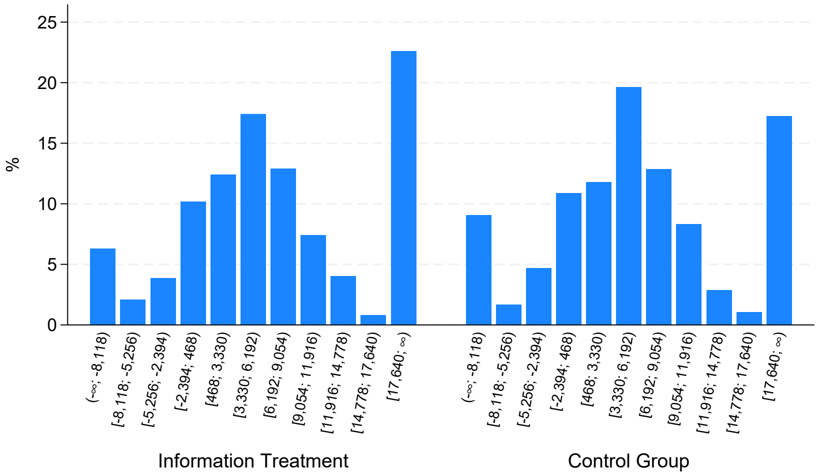
Empirical method: Interval regression

- **Interval regression** (Stewart, 1983) takes into account that the **outcome variable is only observed to fall into a certain category**, but the precise value is unknown
- Accounts for left- and right-censored intervals at the ends of the MPL
  - left-censored: participants who never choose the heat pump
  - right-censored: participants who always choose the heat pump
- Robustness checks using different regression specifications:
  - Ordered logit
  - OLS regression using midpoints of intervals

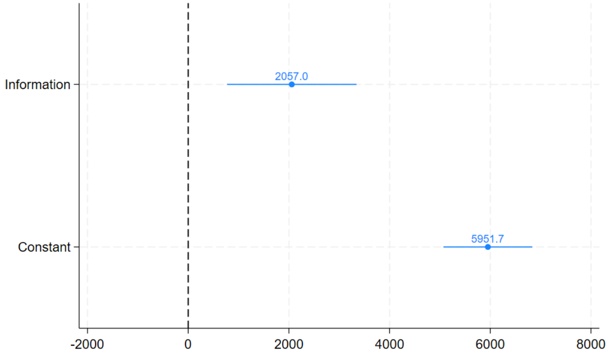
  $\Rightarrow$ **Results are very similar across methods**

Results

Price premium at which respondents switch to heat pump



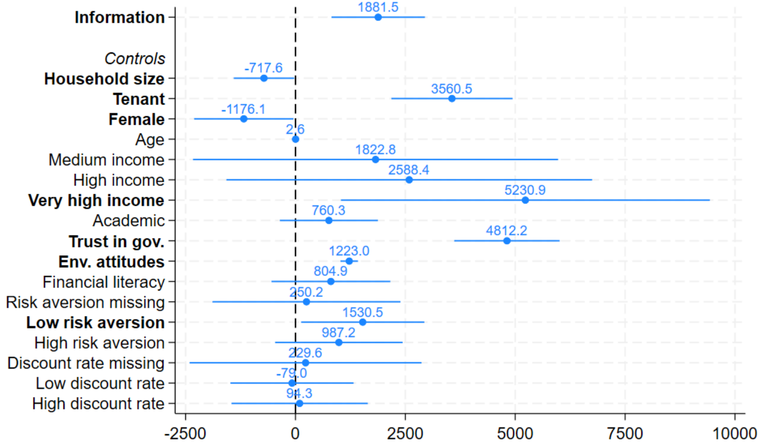
Cost information increases accepted price premium



Outcome: accepted price premium in EUR; point estimates and 95% confidence intervals from simple interval regression

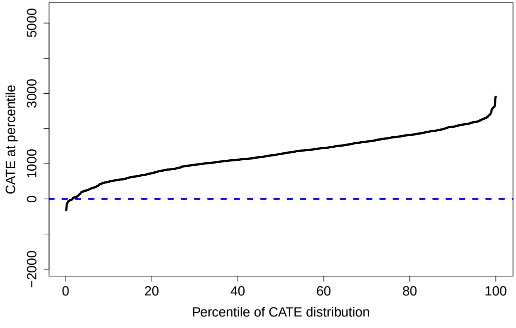
- Price premium for heat pump in control group: 5,952 EUR
- Transparent cost information increases WTP

Price premium related to trust in government, higher for tenants

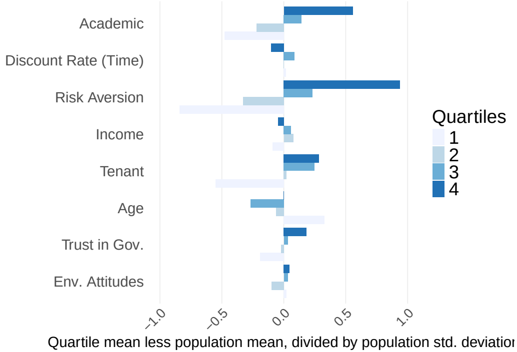


Outcome: accepted price premium in EUR; point estimates and 95% confidence intervals from interval regression.

Treatment effect heterogeneity using causal forests



(a) CATE distribution



(b) Covariate means by quartiles

Figure: CATEs from causal forest analysis

Summary and policy implications

- **Accepted price premium for heat pump** in control group: **5,950 EUR**
  - This is **much lower than actual price difference** between heat pumps and fossil fuel heating systems (= 17,640 EUR according to BMWK (2023))
- Tenants show a higher WTP than owners
- WTP increases with trust in government, income, and environmental attitudes
- **Cost information increases Price Premium** ($\neq$ WTP for heat pump) **by 30 %**
  - Thus, transparent communication of cost advantage of heat pumps can foster heat pump adoption (provided such cost advantage exists)
- **Need for subsidies or similar financial support remains** for many households

Thank you!

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Appendix

Sample and set up

- **Online survey experiment** with German household members in September/October 2023
- 3,000 members of forsa.omninet panel
- Additional questions on socioeconomic characteristics, environmental and policy attitudes, financial literacy, risk and time preferences
- Inclusion criteria: owner or tenant, currently using fossil fuel heating system, meaningful responses to all relevant questions (except risk and time preferences, for which we also include "No" dummies) $\rightarrow$ final sample of 1,115 individuals
- Compared to German population, final sample tends to have higher income, be older and more educated, and more likely to own their accommodation

	(1)		(2)		(3)	
Information	2057.0**	(656.0)	1922.8***	(542.3)	1881.5***	(542.4)
Household size			-728.6*	(352.0)	-717.6*	(350.8)
Tenant			3573.2***	(702.5)	3560.5***	(703.5)
Female			-1291.3*	(570.0)	-1176.1*	(576.4)
Age			-0.00704	(21.47)	2.613	(22.05)
Medium income			2114.1	(2128.1)	1822.8	(2119.2)
High income			2914.9	(2125.3)	2588.4	(2122.9)
Very high income			5602.5**	(2149.7)	5230.9*	(2141.4)
Academic			841.1	(567.0)	760.3	(568.8)
Trust in gov.			4747.3***	(613.8)	4812.2***	(612.0)
Env. attitudes			1220.8***	(102.6)	1223.0***	(101.9)
Financial literacy					804.9	(690.3)
Risk aversion missing					250.2	(1091.1)
Low risk aversion					1530.5*	(715.3)
High risk aversion					987.2	(740.2)
Discount rate missing					229.6	(1346.4)
Low discount rate					-79.05	(714.8)
High discount rate					94.32	(791.3)
Constant	5951.7***	(450.4)	-12611.5***	(2887.9)	-13923.2***	(2903.7)
$ln(\sigma)$	9.267***	(0.0313)	9.062***	(0.0311)	9.059***	(0.0310)
Observations	1115		1115		1115	
$log\mathcal{L}$	-2528.7		-2331.9		-2328.7	

Robust standard errors in parentheses. *, **, and *** indicate statistical significance at the 5 %, 1% and 0.1 % level, respectively. The outcome variable in each regression is the price premium households are willing to pay to switch from a fossil fuel heating system to a heat pump.

Details on causal forest and heterogeneity analysis

Difference to main regression specification:

- We use interval midpoints as outcome variables
- We use continuous variables for income risk aversion and time preferences
- This reduces n to **909 observations** but facilitates interpretation

Causal forest approach:

- Simple random forest (10,000 trees) to select 8 most important variables (dimensionality reduction due to low n)
- Then set up causal forest (100,000 trees with price premium as outcome)
- ATE: 1,269 euros, significant at 1 %
- Best linear projection analysis confirms heterogeneity for risk aversion, ownership and tertiary degree
- Subsequent linear regressions with interaction terms confirm this, too (somewhat weaker evidence for tertiary degree)

Subsidy calculations

Table: Population share that prefers a heat pump, by funding rate

	Funding rate	Cost after subsidy	Price premium	CDF value
Information	0 %	28,620	17,640	3.86 %
	30 %	20,034	9,054	43.57 %
	50 %	14,310	3,330	77.94 %
	60 %	11,448	468	87.87 %
	70 %	8,586	-2,394	95.22 %
Control	0 %	28,620	17,640	0.53 %
	30 %	20,034	9,054	33.98 %
	50 %	14,310	3,330	66.37 %
	60 %	11,448	468	80.04 %
	70 %	8,586	-2,394	91.07 %

- At 50 % funding rate, 2/3 of households in control group would prefer a heat pump
- Making cost more salient increases this to nearly 4/5
- Simple calculations show that the **abatement cost of such a 50 % subsidy is likely to exceed 100 euros per ton of CO2**

Details on subsidy calculations (1/2)

Table: Assumptions for abatement cost calculations

	Value	Source
Emission factor natural gas	0.201 tons of CO2/MWh	BAFA (2025), p.10
Emission factor electricity (Std.)	0.380 tons of CO2/MWh	UBA (2024), p.18
Emission factor electricity (RES)	0 tons of CO2/MWh	
Annual heating energy demand	15 to 25 MWh/a	
Annual gas consumption	15 to 25 MWh/a	
Annual electr. consumption	5 to 8.33 MWh/a	
Lifetime heating system	15 to 25 years	Elsland et al., 2014

BAFA (2025) = Bundesamt für Wirtschaft und Ausfuhrkontrolle, 2025; UBA (2024) = Umweltbundesamt, 2024. 'Emission factor electricity (Std.)' refers to the average German electricity mix in 2023. 'Emission factor electricity (RES)' refers to electricity based exclusively on renewable energy sources. Annual gas consumption is based on typical values for a single-family dwelling. Annual electricity consumption assumes a seasonal performance factor of 3, i.e., the heat pump generates 3 kWh of heating energy from 1 kWh of electricity. We assume the same heating energy demand for a heat pump as for a gas heating system.

Details on subsidy calculations (2/2)

Table: Abatement cost and emissions savings

Energy demand	Lifetime	Gas → Electricity (Std.)	Gas → Electricity (RES)
2*15 MWh/a	2*15 years	855.6 €/t CO2	316.4 €/t CO2
		16.73 t	45.23 t
2*20 MWh/a	2*20 years	481.3 €/t CO2	178.0 €/t CO2
		29.73 t	80.40 t
2*25 MWh/a	2*25 years	308.0 €/t CO2	113.9 €/t CO2
		46.46 t	125.63 t

Example calculation for row 1, column 3:

$$[15MWh/a * 0.201t/MWh] - [5MWh/a * 0.380t/MWh] = 3.015t/a - 1.9t/a = 1.115t/a.$$

Over 15 years, this yields total emissions savings of 16.73 tons of CO2. To obtain the abatement costs in €/t of CO2, divide the subsidy amount (14,310 euros) by these savings.

Robustness check: different regression specifications

	Interval regression		OLS		Ordered Logit	
Information	1881.5***	(542.4)	486.1	(369.1)	0.336**	(0.108)
Household size	-717.6*	(350.8)	-416.5	(220.9)	-0.140*	(0.0696)
Tenant	3560.5***	(703.5)	2994.8***	(433.3)	0.656***	(0.139)
Female	-1176.1*	(576.4)	-1038.8**	(375.8)	-0.230*	(0.116)
Age	2.613	(22.05)	-12.40	(13.68)	-0.00193	(0.00435)
Medium income	1822.8	(2119.2)	1482.9	(1169.1)	0.344	(0.399)
High income	2588.4	(2122.9)	2785.8*	(1165.4)	0.566	(0.399)
Very high income	5230.9*	(2141.4)	4048.9***	(1182.4)	1.118**	(0.403)
Academic	760.3	(568.8)	938.8*	(374.8)	0.170	(0.115)
Trust in gov.	4812.2***	(612.0)	3455.3***	(393.4)	0.979***	(0.121)
Env. attitudes	1223.0***	(101.9)	925.2***	(65.13)	0.263***	(0.0221)
Financial literacy	804.9	(690.3)	1021.5*	(466.7)	0.140	(0.141)
Risk aversion missing	250.2	(1091.1)	0	(.)	0.0381	(0.229)
Low risk aversion	1530.5*	(715.3)	1001.8*	(424.8)	0.313*	(0.140)
High risk aversion	987.2	(740.2)	463.8	(448.2)	0.176	(0.143)
Discount rate missing	229.6	(1346.4)	0	(.)	-0.00975	(0.281)
Low discount rate	-79.05	(714.8)	-183.6	(450.9)	-0.0893	(0.141)
High discount rate	94.32	(791.3)	79.00	(493.9)	-0.0578	(0.155)
Constant	-13923.2***	(2903.7)	-8765.9***	(1695.9)		
$ln(\sigma)$	9.059***	(0.0310)				
Observations	1115		1115		1115	
$log \mathcal{L}$	-2328.7		-11361.9		-2171.6	

Financial literacy, risk and time preferences

Financial literacy (Lusardi & Mitchell, 2011):

- Solve arithmetical problem associated with interest rates and compound interest
- Dummy indicator for whether respondents solves exercise correctly or not

Risk preferences (Holt & Laury, 2002):

- Repeated choice between two lotteries that determined the value of a voucher one could potentially receive
- Each lottery had two potential outcomes with varying probabilities
- Difference between two outcomes of lottery A smaller than between outcomes of lottery B
- Frequency of choosing A as indicator of risk aversion; then grouped in terciles

Time preferences (Meier & Sprenger, 2010):

- Repeated choices between receiving a voucher in one month or in six months
- Late voucher had value of 30 EUR, value of early voucher varied between 9 and 29 EUR
- Monthly discount rate based on last instance when they chose earlier payment → terciles

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