Does Knowledge of CO_2 Prices Impact Homeowners' Choices?

An Analysis of Energy Retrofit Preferences in Germany

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Motivation and Background

- In 2021, households in the EU were responsible for 27% of gross final energy consumption, of which 64% was used for space heating (e.g. Eurostat 2023)
- EU-wide carbon emissions from space heating in buildings have stagnated over the past decade (e.g. IEA 2023)
- Low adoption rates of low-carbon heating technologies for energy retrofits (e.g. Michelsen and Madlener, 2012, 2016)
- Introduction of policy instruments to overcome barriers and increase uptake of low-carbon housing measures
- Carbon taxes will apply to the heating sector in Germany from 2021
- Yet the impact of carbon taxes on the purchase of new heating systems remains unclear

This Paper

- Relies on a representative sample of homeowners in Germany
  (n = 1452)
- Presents results of a within-between design stated choice experiment
  with four treatment and one control group
- Provides insights into homeowners' preferences for energy retrofit
  measures in Germany
- Analyses the effect of different future carbon tax scenarios to
  investigate whether information provision has an impact on retrofit
  decisions

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Experimental design

- Target group: Homeowners in Germany who are involved in decisions on the purchase of major household items or services in the household and occupy their property as their main residence
- Decision context: Owner-occupiers are faced with the decision to retrofit the property they live in
- Four alternatives: Three energy retrofit options and the status quo (no retrofit)
- Every group receives identical information prior to the choice experiment
- Two-stage design with information treatments following the first six choice sets

Sample Choice Set

Attributes	Option 1	Option 2	Option 3	No energy retrofit
Heating system replacement	No replacement	Gas heating	Pellet heating	No replacement
Scope of the insulation measures	Low	Medium	High	No insulation measure
Investment costs	22.500 €	51.400 €	89.700 €	0 €
Investment cost subsidy	9.000 €	0 €	17.900 €	0 €
Heating and hot water costs 2022	720 €	530 €	240 €	960 €
Annual CO_2 emissions	3.9 t	2.2 t	0.1 t	5.3 t
I choose	☐	☐	☐	☐

Information Treatments

- Participants receive identical information prior to the experiment, i.e. development of the price for CO_2 in accordance to the German Fuel Emissions Trading Act
- Treatment information is provided after the first six choice sets and is followed by six additional choice sets
    - **Placebo treatment:** General information about the proportion of residential buildings by date of construction
    - **T1:** Carbon taxes are no longer applicable from 2023 onward
    - **T2:** Low carbon pricing and individual consequences
    - **T3:** High carbon pricing
    - **T4:** High carbon pricing and individual consequences

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Mixed Logit Estimates in Preference Space

	Main effects		Interaction effects				
	(1) Mean	(2) Std. dev.	(3) Placebo	(4) Removal	(5) Low	(6) High general	(7) High individual
No retrofit	0.313***	2.505***	0.005	−0.032	−0.171	−0.010	−0.025
	(2.92)	(24.67)	(0.02)	(−0.11)	(−0.60)	(−0.03)	(−0.08)
Subsidy	0.122***	0.149***	0.026	0.009	−0.000	0.013	0.031
	(10.04)	(12.82)	(0.98)	(0.25)	(−0.01)	(0.38)	(0.88)
Heating costs 2022	−0.487***	1.418***	−0.353	0.236	0.601	**0.921****	0.339
	(−3.25)	(10.14)	(−1.10)	(0.58)	(1.52)	**(1.99)**	(0.76)
Gas	−0.957***	1.288***	−0.140	0.196	0.041	0.112	−0.056
	(−8.90)	(13.04)	(−0.69)	(0.71)	(0.14)	(0.40)	(−0.20)
Gas-solar	−0.126	1.237***	−0.130	0.183	−0.040	−0.163	0.008
	(−1.50)	(14.63)	(−0.74)	(0.75)	(−0.18)	(−0.64)	(0.03)
Wood pellets	−0.603***	1.723***	0.125	0.045	0.255	0.025	0.124
	(−5.48)	(17.82)	(0.62)	(0.16)	(0.93)	(0.09)	(0.43)
Heat pump	0.363***	1.554***	−0.209	0.272	−0.005	−0.022	0.262
	(4.30)	(19.18)	(−1.33)	(1.21)	(−0.02)	(−0.10)	(1.15)
Low insulation	0.310***	0.272	−0.061	0.065	0.281	−0.122	−0.286
	(3.29)	(0.52)	(−0.32)	(0.25)	(1.04)	(−0.47)	(−1.08)
Medium insulation	0.482***	−0.335	−0.068	−0.012	0.430	0.112	−0.133
	(4.11)	(−1.45)	(−0.29)	(−0.04)	(1.27)	(0.33)	(−0.40)
High insulation	0.635***	−0.650***	−0.239	−0.081	0.637	0.077	0.109
	(4.19)	(−6.25)	(−0.77)	(−0.20)	(1.50)	(0.17)	(0.25)
Emissions	−0.099***	0.428***	−0.017	0.041	0.014	**−0.135****	−0.0341
	(−3.98)	(14.60)	(−0.39)	(0.67)	(0.24)	**(−2.25)**	(−0.59)
Investment cost	−0.161***						
	(−13.25)						

Main Effects

- General preference for the status quo option (no retrofit)
- Positive preference for heat pumps and preferences against other heating systems
- Preference for higher level of insulation measure
- Owner-occupiers prefer retrofit measures with low amount of emissions
- Negative preference for higher investment costs and postive preference for higher subsidy measures

Treatment effects

- **Placebo treatment:** Insignificant effect of placebo treatment
- **T1:** No effect of CO_2 tax removal
- **T2:** No effect of low carbon pricing with individual consequences
- **T3:** Significant effect of high CO_2 taxes and general information
  - Aversion for higher heating costs decreases after treatment relative to placebo treatment
  - Individuals prefer retrofit measures with lower level of emissions compared to the placebo treatment
- **T4:** No effect of high CO_2 taxes and individualized costs

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Discussion

- Homeowners' have a general preference towards not retrofitting their homes
- Confirms the status quo effect/inertia found in the literature (e.g. Kwak et al., 2010; Michelsen and Madlener, 2013)
- Homeowners prefer heat pumps over their current heating system
- General trend for higher levels of insulation across the sample
- Homeowners prefer retrofitting options with lower levels of CO_2 emissions

Discussion

- Little to no effect of information provision on the retrofit decisions of homeowners irrespective of magnitude and salience of emission taxes
- Only significant effect of the treatment with high CO_2 taxes and general information
  - Individuals are not used to assessing their CO_2 emissions in metric tons
  - Overestimation of their actual emission level and related costs
- Treatment effect vanishes once total emissions costs instead of costs per ton of CO_2 is shown
  - Simple evaluation of emissions costs relative to total retrofit investment
  - Shift in focus from total emissions to total costs of emission
- Underlines the importance of subsidy measures for energy retrofits

Comments and Questions (Thank you!)

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Attributes and Levels

Attribute	Level
Heating system replacement	Gas heating; Gas with solar thermal heating; Heat pump; Pellet heating; No replacement
Scope of the insulation measures	Low; Medium; High; No insulation measure
Investment costs	70%; 85%; 100%; 115%; 130% of the individual specific costs and option-related measures.
Investment cost subsidy	0%; 20%; 40%; 60% 80% of investment costs
Heating and hot water costs 2022	0%; 20%; 40%; 60%; 80% based on the stated or calculated heating cost without carbon tax. Considers option specific scope of insulation measure.
Annual CO_2 emissions	95%; 85%; 75% if option specific scope of insulation measure is low 75%; 55%; 35% if option specific scope of insulation measure is medium 35%; 25%; 15% if option specific scope of insulation measure is high 100% if option specific no insulation measures

Description of the Attribute

Heating system replacement
The existing heating system is replaced with one of the following heating systems: gas heating, gas heating with solar thermal energy, pellet heating or heat pump. No heating system replacement is also possible.

Scope of the insulation measures
It is possible to insulate the external facade, the roof, the basement and/or the top floor ceiling and to replace the windows. The resulting scope of individual or combined insulation measures is classified as low, medium or high. Depending on the extent of the insulation measures, energy and CO_2 emissions are saved. No insulation measures on the building envelope, and therefore no savings in energy and greenhouse gas emissions, are also possible.

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Description of the Attribute

Investment costs

The investment costs indicate the total amount to be paid for the energy modernization. This includes all costs (materials, personnel, etc.). The investment costs are calculated on the basis of the information you have already provided about your apartment or house.

Investment cost subsidy

The investment cost subsidy indicates the amount that you receive as a state subsidy for energy modernization. The subsidy reduces the investment costs you have to pay yourself.

Description of the Attribute

Heating and hot water costs 2022

The heating and hot water costs 2022 indicate the amount you will have to pay for heating and hot water in your apartment or house in 2022. These are calculated on the basis of the information you have already provided about your apartment or house. The CO_2 costs are not included.
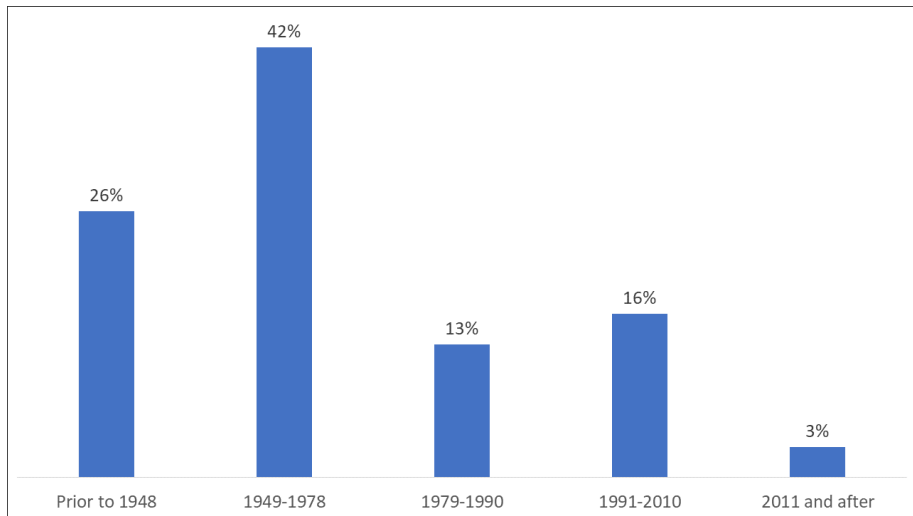
Annual CO_2 emissions

The annual CO_2 emissions are caused by the heating and hot water supply of your apartment or house. The emissions are calculated on the basis of the information you have already provided about your apartment or house.
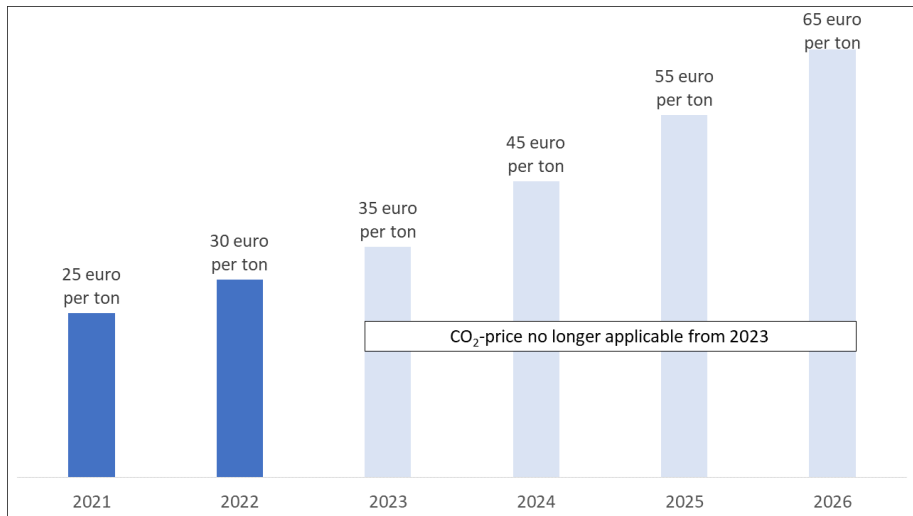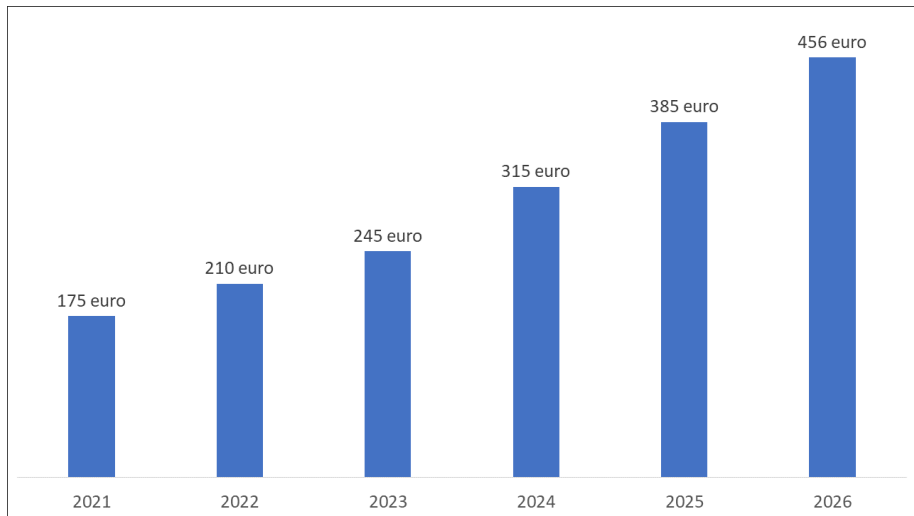
Baseline Choice Scenario
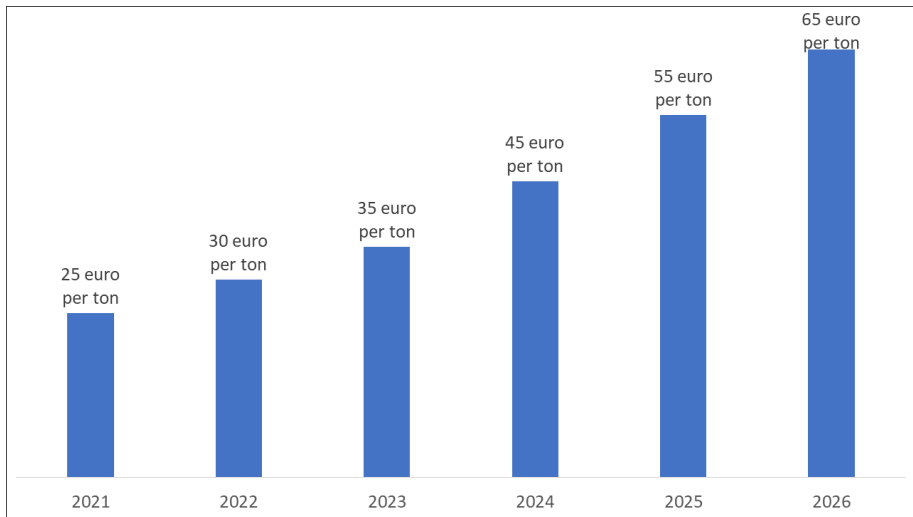
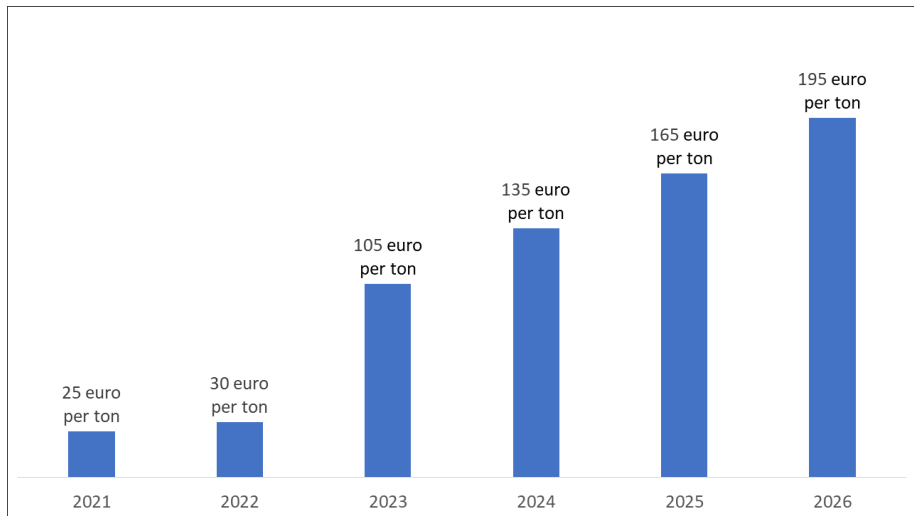# Placebo treatment: dwelling age in Germany by construction period

Treatment 1: zero carbon pricing

Treatment 2: low carbon pricing and individual consequences

Treatment 3: high carbon pricing

Treatment 4: high carbon pricing and individual consequences