

Carbon pricing and heat pump adoption: the roles of real options, risk aversion and heterogeneity

Claudio Baccianti

Deutsche Bundesbank, Frankfurt, Germany

Extended Abstract

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Abstract Summary

Residential heating accounts for roughly 11% of Germany's CO₂ emissions, with around 30 million homes still relying on gas or oil boilers. Heat pumps are the main decarbonisation pathway, yet annual sales remain well below policy targets. Residential heating emissions in Germany are already covered by carbon pricing, a policy that will extend to the whole European Union from 2028. Despite the central role of CO₂ pricing in Europe, it remains unclear whether moderate CO₂ prices can trigger meaningful fuel switching.

We develop a real options model of heat pump adoption for owner-occupied homes in Germany. Because the investment is large and irreversible, households rationally delay switching even when a heat pump appears profitable on average — holding a valuable option to wait. This implies that the carbon price needed to induce adoption substantially exceeds standard NPV estimates. We extend the framework by introducing risk aversion: households that dislike volatile fossil fuel bills value the switch to a heat pump as insurance against gas or oil price shocks, reducing their effective switching threshold. We solve the model and aggregate across millions of owner-occupied homes, calibrated to German housing data, to construct a marginal abatement cost curve for residential fuel switching. We find that, without purchase subsidies, very high carbon prices would be needed to drive adoption at policy-relevant scales given Germany's high heat pump installation costs and unfavourable electricity-to-gas price ratio. With current BEG subsidies, a carbon price slightly above €100 per tonne could instead meet interim policy targets. Finally, upfront purchase subsidies outperform electricity tariff discounts at high adoption targets, as they directly reduce the sunk cost that generates option value.