PUTTING A CARBON PRICE ON HEATING FUELS: HOUSEHOLD WELFARE EFFECTS IN A MICROSIMULATION MODEL WITH ENDOGENEOUS TECHNOLOGY CHOICE

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Overview

Energy services such as heating represent a large share of CO_2 emissions in the household sector, as they are still predominantly provided using fossil fuel-based technologies (Eurostat, 2024). Carbon pricing is an efficient and effective policy to incentivize emission abatement and is increasingly utilized in many jurisdictions (World Bank, 2024). For instance, the European Union plans to introduce a new emissions trading system (ETS-2) in 2027 that includes heating fuels, with allowance prices possibly reaching 175 to 360 Euros per ton of CO_2 by 2030 (Abrell et al., 2024). By targeting CO_2-intensive energy services households may face significant financial burdens. These arise both directly from higher fuel prices and indirectly from high upfront costs for investing in low-carbon heating technologies and energy-efficient refurbishments (Galvin, 2024; Grainger and Kolstad, 2010; Moritz et al., 2024). Therefore, an intense scientific and public debate has emerged regarding the distributional effects of carbon pricing and its impact on the affordability of heating services which are considered a basic need (Berry, 2019; Reuter et al., 2021). Against this background we address the following research questions. First, how does carbon pricing burden households, given that they can adapt by choosing to heat with a low-carbon technology? Second, how do compensation schemes, such as transfers and subsidies, mitigate the burden of carbon pricing in this setting? The main contribution of our study is to account for the fact that households can respond to carbon pricing by choosing a low-carbon heating technology. This important aspect is mostly disregarded by previous studies which typically find that carbon pricing of energy services such as heating initially has a regressive effect and exacerbates problems of affordability and energy poverty (Berry, 2019; Kaestner et al., 2024). Moreover, the literature stresses that redistributing the revenue in the form of transfers can make carbon pricing progressive and mitigate problems of affordability and energy poverty. Recently, a few studies consider technological adjustments by households to analyze the distributional outcomes of carbon pricing (Kaestner et al., 2023; Kalkuhl et al., 2024; Schlattmann, 2024). We further contribute to this emerging strand of literature by providing insights into how the inclusion of endogenous heating technology choice interacts with the welfare impacts of carbon pricing and compensation schemes.

Methods

We develop a theoretical model in which households choose between a fossil fuel-based and a low-carbon heating technology (e.g., a gas boiler versus a heat pump) by maximizing their indirect utility derived from consuming heating services and other goods. We determine conditions for the optimal heating technology choice under carbon pricing and a welfare metric based on equivalent variation. We calibrate our model using data on owner-occupier households using natural gas heating from the German Income and Expenditure Survey (RDC, 2018) and estimate their heating energy demand. We then derive household specific capital expenditure for a new gas boiler and an air-sourced heat pump using cost and technology parameters from the literature. We conduct a comparative static analysis of the welfare impacts of a carbon price of €100/t CO_2 under endogenous technology choice in three distinct settings: carbon pricing without any compensation and carbon pricing with revenue-recycling either a transfer or a heat pump subsidy, both lump-sum. Results are disaggregated by expenditure quintiles.

Results

A carbon price of €100/t $C0_2$ without revenue recycling results in absolute welfare losses that on average slightly increase with the expenditure quintile. Average relative welfare losses on the other hand decrease with the expenditure quintile, ranging from about €366 per year and household for the first quintile to €432 for the fifth quintile. Recycling revenues via lump-sum transfers reverses both of these patterns, resulting in, on average, slight welfare gains (losses) for the lower (upper) expenditure quintiles. These distributional patterns of carbon pricing are well documented in the literature. However, when recycling revenues via a lump-sum heat pump subsidy different distributional effects emerge. Compared to a carbon price without revenue recycling, welfare losses are also reduced by the subsidy. This holds especially for the lower quintiles where the subsidy on average is most effective in incentivizing heat pump choice. The possibility to adapt to carbon pricing via heat pump choice enables households in the lowest expenditure quintile to reduce their welfare losses on average by 46%. In the second quintile this figure amounts to 32% and declines to 19% in the fifth quintile. However, compared to revenue recycling via lump-sum transfers, welfare losses are more severe. This is presumably driven by two channels. First, households for which it is optimal to choose the heat pump under the subsidy scheme would still be better off under a lump-sum transfer scheme. Second, households for which it is optimal to choose the gas boiler despite the heat pump subsidy receive no compensation and bear the full welfare losses of the carbon price.

Conclusions

Previous research on the welfare impacts of carbon pricing on private households mostly assumes that households cannot adjust their fossil fuel based heating technologies. We develop a theoretical model allowing households to choose a low-carbon heating technology in response to carbon pricing. Simulating a carbon price of €100/t CO_2 on German owner-occupier households we find that the distributional welfare impacts may deviate substantially – depending on the use of revenue – from a setting where households cannot adapt via heating technology choice. This is the case for recycling revenues via a heat pump subsidy which especially benefits households in lower expenditure quintiles. Yet, the subsidy is less effective in compensating the welfare losses of carbon pricing across all expenditure quintiles in comparison to a lump-sum transfer scheme. These findings provide novel insights into the welfare impacts of carbon pricing on heating fuels when considering the possibility to respond by choosing a low-carbon heating technology.

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