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Public support for carbon taxes varies across countries and policy design must consider the national context

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Although carbon taxes are an effective way for countries to meet the emissions targets set out in the Paris Agreement, these policies remain unpopular. Here we present a survey experiment conducted in China, Germany, India, and the UK, based on over 13,000 evaluations of policy designs. We examined four factors influencing public support: effectiveness in reducing emissions, impact on household costs, use of tax revenues, and international coordination. Communicating environmental effectiveness increased support, while making costs explicit reduced it. Preferences for revenue use varied: some respondents favoured direct payments, while others preferred investments in welfare. Contrary to expectations, only German respondents showed increased support when other countries also adopted similar measures. These findings highlight the importance of national context in shaping public attitudes. Carefully designed and clearly communicated carbon tax policies can improve public acceptability and enhance the political feasibility of effective climate action.

A growing number of countries are considering introducing domestic carbon taxes to meet the carbon reduction targets set in the Paris Agreement. These measures aim to raise the cost of fossil fuels and the electricity generated from these sources, with the goal of reducing their consumption[1]. While carbon pricing is considered one of the most effective strategies for reducing greenhouse gas emissions[2,3], its adoption presents significant challenges for decision-makers worldwide[4,5]. Although carbon pricing has the potential to drive environmental change, it often faces public opposition, as people fear its negative impacts on the economy and perceive it as unfair[6,7]. Despite its effectiveness, it remains the least popular policy instrument, creating the need to explore the reasons[8]. To ensure the political feasibility of implementing carbon pricing, it is essential to assess and understand the strategies for reducing public resistance. It is also important for policymakers engaged in climate change and policy development to consider the costs and effectiveness of policy designs.

Recent research has proposed policies to enhance public acceptance of carbon pricing. These policies include using fee-and-dividend models and earmarking tax revenue for essential investments[8,9]. However, there is a notable lack of research focusing on public attitudes towards climate policy in low- and middle-income countries. China is currently the world's largest emitter of carbon dioxide (CO_2) and India ranks third. Both countries face the dual challenge of developing their economies while mitigating climate change to reduce global CO_2 emissions. The approach to carbon taxation and emission reductions in low- and middle-income countries may differ from that in high-income countries because of varying development targets, climate change adaptation needs, and historical emissions responsibilities. Therefore, it is necessary to study a diverse set of countries with harmonised designs to explore the impact of their characteristics on these global issues.

In public discussions, the most prevalent concerns are about the fair distribution of the burden, both nationally and internationally, the use of revenue, scepticism about environmental effectiveness, and the costs of carbon taxes[10–12]. To address these concerns and barriers to the acceptance of carbon taxation, we conducted a harmonised full factorial survey experiment in China, Germany, India, and the UK, allowing us to leverage the benefits of the causal interpretation of experiments and the generalisability of surveys. This approach allowed us to address the most prevalent challenges to the popularity of carbon taxes, as discussed in academic research, policy analysis, and public discourse. Given the full factorial design of our survey experiment, we were able to analyse both the predicted impact of the evaluated policy design and the relative importance of the policy dimensions for each country.

Most public opinion polls assess support for carbon taxation in general terms[13–15], for example, by asking for general support for carbon taxation. However, few studies have systematically explored the conditional nature of this support on the most significant aspects of policy design[16]. These studies often have limitations such as failing to thoroughly analyse how different revenue recycling schemes can sustain support as tax levels rise, assess the impact of costs, or measure policy effectiveness. They also tend to overlook global differences in the implementation of carbon taxes. This highlights the

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need for more comprehensive studies that adopt a holistic approach to carbon tax policies.

Previous studies have used conjoint analysis, typically with limited fractional factorial designs. This restricts the number of comparisons between the dimensions and attributes of interest. To address this limitation, we conducted a full factorial survey, which allowed us to explore the full range of interactions between factors that determine effective policy designs, while reducing some of the social desirability bias associated with conjoint analysis[17]. Our findings suggest that with careful policy design and communication of relevant information, relatively unpopular policies can be made more attractive to the public, even at higher tax levels.

This study makes several key contributions to the literature on public support for carbon taxation across four major economies: China, Germany, India, and the UK. First, it provides novel insights into how differences in social, political, cultural and economic structure and existing policy approaches affect public support for carbon taxation in diverse contexts. Second, using carefully designed survey experiments, we assess public support towards the introduction of carbon taxes at various prices, with the amounts adjusted for purchasing power parity. Third, we systematically investigate the redistributive mechanisms and revenue recycling schemes that could meaningfully increase public support. Fourth, we test the impact of communicating the costs and effectiveness of carbon taxes on shaping public support. Finally, we examine how framing carbon taxes as an internationally cooperative solution influences public support across national contexts. Taken together, these findings provide valuable guidance for policymakers seeking to design politically viable, publicly acceptable, and environmentally impactful carbon tax policies.

To better understand the conditions under which carbon taxation can gain public support, we draw on insights from environmental sociology, behavioural economics and public policy analysis. Central to our theoretical framework is policy feedback theory[18], which highlights how public attitudes to taxation are shaped by both material experiences, such as household costs and the visibility of revenue uses, and interpretive effects, including perceived fairness and effectiveness.

Previous research on environmental taxation[12,16,19] suggests that people are more likely to support carbon taxes if they believe the revenues will be used fairly and effectively. Complementing this, fairness theory provides further nuance by emphasising that public evaluations of policy interventions are not driven solely by economic self-interest, but also on considerations by distributive and procedural justice, which play a crucial role in shaping public attitudes towards taxation[10,11,20].

Furthermore, studies in behavioural economics highlight loss aversion as a major factor influencing support for tax policies[21,22]. Transparency in cost communication can lead to negative reactions due to increased loss salience, whereas revenue recycling through lump-sum transfers can alleviate these concerns by providing visible, tangible benefits[23].

In the literature on public responses to environmental taxation, the nuances between support, acceptance, and preference are often used interchangeably, leading to ambiguity in the interpretation of research findings (for a more detailed discussion, see Ott et al.[24]). In what follows, we explicitly define the terms central to our study and justify their relevance to our research context.

Following Dreyer et al.[25] conceptual distinctions, we distinguish between acceptance and support for carbon taxation. According to their framework, acceptance represents relatively passive attitudes, primarily characterised by individuals' expressed willingness to accept a policy (e.g., expressing approval of a carbon tax in surveys). In contrast, and in line with the definition of support as an active evaluative response to policy proposals, we treat the outcome of our factorial survey experiment as an indicator of public support for different carbon tax policy designs.

Preference refers specifically to individuals' evaluations and relative judgments of alternative policy scenarios, typically assessed through factorial survey experiments or vignette studies[17]. Preference thus captures the extent to which individuals consistently prefer particular policy attributes or

combinations of them, indicating their relative desirability compared to alternative options.

Given our primary research objective of examining individual citizens' attitudes towards carbon taxation in different national contexts, we focus specifically on support and preference for carbon taxation.

People rarely oppose carbon taxation per se but rather its design and perceived consequences[26,27]. The extent to which people support climate policy instruments is influenced by their perceived effectiveness, fairness, and costs[28]. Leveraging these factors through the communication of effectiveness, cost transparency, and fair policy design could make carbon taxes more attractive to the broader public[29]. Accordingly, we develop hypotheses on the motivations for opposing or supporting carbon taxes. As these factors are manifold and include many socio-psychological factors such as fairness considerations, perceived effectiveness in mitigating climate change, and economic impact, we concentrate on the most prominent factors from recent policy recommendations in the relevant literature and current political debates as potential levers to support carbon taxation[10,12,16]: types of revenue recycling schemes, communication of policy effectiveness and costs, and international cooperation.

Environmental taxes serve as an incentive for individuals and businesses to engage in environmentally friendly behaviours[30]. Carbon pricing mechanisms such as carbon taxes are often proposed for several reasons. They incentivise emission reductions and are straightforward to implement and operate without requiring government fiscal resources[12]. Surveys usually find a negative correlation between higher taxes and public support for carbon taxation[8,12,16].

H1: Public support for carbon taxation is lower at higher tax levels.

Because carbon taxes are regressive, people may worry that they will disproportionately burden low-income households without appropriate counterbalancing measures[8,19,31]. To address concerns about tax burdens, policymakers should consider how revenue from carbon taxes may benefit the public. One option is revenue recycling in which the revenue generated from carbon taxation is returned to society. This generates additional direct and indirect benefits and addresses one of the key challenges associated with implementing carbon taxation. This approach is the most practical solution to gain sufficient public support for the implementation of an effective carbon tax[8,11,32].

The selection of the specific revenue recycling schemes for this study (investments in welfare, investments in climate adaptation, social cushioning, and lump-sum transfers) is based on their prevalence in a combination of sources, public discussions, academic research, and policy analysis (e.g. Carattini et al.[12]). Although the existing literature provides theoretical arguments on the individual determinants of support for carbon taxation (such as those presented by Carattini et al.[12]) and the general impact of revenue recycling (as discussed by Beiser-McGrath et al.[16]), insufficient information is available on the variations in support for specific types of revenue recycling in different countries.

Empirical evidence from existing carbon tax policies highlights the critical role of revenue recycling in determining public acceptance. Canada's federal carbon tax, introduced in 2019, provides an important case study, as it uses lump-sum rebates to return revenue directly to households (Wood, 2022). Although designed to offset household costs, research suggests that these rebates have had limited effect in increasing public support, highlighting the complexity of public attitudes towards carbon taxation (Mildenberger et al.[33]; Winter et al.[34]). Our study builds on these findings by systematically testing different revenue recycling mechanisms in different national contexts, providing a broader comparative perspective on public preferences.

We expect all revenue recycling schemes to increase support for carbon taxation, with differences in countries' preferences, particularly between the Global South and North. We also expect revenue recycling schemes that return taxes directly to everyone as a lump sum and social cushioning for low-income households to have the most positive impacts.

A recent study in Germany[23] found that direct financial transfers were the most effective in garnering support.

Conversely, investing carbon tax revenue in welfare and running climate adaptation programmes is expected to have the least positive impacts. Finally, we expect a higher preference for investments in climate adaptation in the Global South, which is already experiencing and is expected to experience the consequences of ongoing climate change more severely than the North.

Another revenue recycling scheme discussed in the literature, 'reducing other taxes', was not included as a revenue recycling option due to differences in tax systems across countries, which made a consistent assessment impractical. Furthermore, previous research shows that the aforementioned compensation measures are comparatively more effective in increasing public support for carbon taxation[7,12,16].

A preference for revenue recycling can arise from a number of mechanisms, the main one being a desire for fairness, but also for schemes that generate more tangible benefits and impacts. The empirical literature has established that perceived fairness is an important determinant of public support for carbon taxation[10]. From this perspective, revenue recycling schemes such as social cushioning are deemed fair. Lump-sum transfers are considered in line with the equality dimension of the justice literature[11].

H2: Public support for carbon taxation is higher when a revenue recycling scheme is specified.

Public opposition to carbon taxation may decrease over time because voter aversion usually falls after a policy is implemented, as individuals become more accustomed to the measure and can assess its benefits and costs more accurately[12]. For example, Schuitema et al.[35] conducted a field study in Stockholm and found that implementing the congestion charge policy led to increased acceptance, as individuals realised that the perceived costs of the charge were lower than expected and did not outweigh the personal and social benefits. Caratini et al.[12] suggested that effective policy communication strategies entail educating individuals about anticipated household expenditure to garner support. They argued that individuals frequently lack the same level of knowledge as experts and that addressing this information gap through communication would lead to increased support for policies. Thus, informing the public of the expected costs of environmental taxes may increase their support. However, as demonstrated by Douenne and Fabre[14] in their study of the Yellow Vests movement (see Supplementary Discussion), making costs explicit may heighten people's awareness of their personal financial impact, leading to decreased support, especially among those with economic anxiety.

In addition, drawing on prospect theory[36], highlighting the costs of carbon taxation may trigger loss aversion, whereby people tend to be more sensitive to potential losses (in this case, increased household expenditure) than to potential gains (environmental benefits). This psychological bias can lead to reduced support for a policy when costs are made transparent. Given this ambiguity, we propose the following hypothesis:

H3: Public support for carbon taxation is higher when information on the average cost to households is provided.

Although the environmental economic literature expects beneficial environmental effects, the general public does not always perceive carbon taxes as effective[19]. The results obtained from survey studies suggest that carbon taxes are not perceived as an effective means of discouraging high carbon behaviour[37] and that individuals often overestimate the costs of transitioning from high- to low-carbon options[12]. However, most studies have focused on the perceived effectiveness of carbon taxes[19] or lacked experimental setups[38]. Recent studies have emphasised the perceived ineffectiveness of carbon taxes on the environment as a major barrier to their acceptability[19]. Carattini et al.[12] theorised that communicating the anticipated reduction in greenhouse gas emissions resulting from a carbon tax could increase acceptance of the tax before its implementation. Hence, it is necessary to provide experimentally varied estimates of the effectiveness of specific carbon tax levels to respondents to gauge their support for carbon taxation. Accordingly, we hypothesise the following:

H4: Public support for carbon taxation is higher when information on its effectiveness is provided.

Solving global environmental problems depends on global cooperation, as evidenced by many international environmental conventions that vary widely in scope and effectiveness. However, the success of these efforts often depends on mutual participation and is threatened by a lack of cooperation among key nations. Consequently, our final hypothesis concerns how individuals' support for carbon taxation may depend on their perceived commitment to the equitable implementation of such a tax globally.

A common concern among policymakers and in public discourse is that domestic economies may be at a competitive disadvantage if other countries do not adopt similar carbon taxes, which could undermine the equitable global effort that all nations seek to achieve in principle. A caveat of many studies is that they make the (implicit) assumption that every country will implement a carbon tax rate in a coordinated manner to achieve fairness, which is unrealistic[16].

According to a recent study[16], individuals in the US may consider the actions of other countries when forming their carbon tax preferences. However, it is uncertain whether this applies to developing and emerging economies in the Global South, which directly face many consequences of ongoing climate change. Carbon taxation has economic impacts distinct from those of broader climate policies. As India and China have highlighted, the historical responsibility[39] of Western countries in relation to carbon emissions may indicate a greater relevance of mitigating behaviour in high-income countries. This may lead to a greater emphasis on international fairness in carbon tax preferences.

H5: Public support for CO_2 taxes is higher when other countries implement comparable taxes.

Public support for carbon taxes does not depend solely on people's perceptions of climate change or environmental urgency. Broader political, economic and cultural contexts also influence how carbon taxes are received and whether they gain sufficient support to be enacted[6,28,40,41]. To begin with, governance structures and the degree of centralisation can have a significant impact on policy implementation. In highly centralised systems, such as China's, decision-making processes often involve fewer veto points, allowing carbon taxes to be enacted with relatively little public dissent[41]. In contrast, in more decentralised systems, such as the United States, divergent political ideologies and more complex political processes can dampen the momentum for new or higher carbon taxes. Meanwhile, in robust democracies (e.g. Germany), policy proposals tend to be subject to heightened scrutiny, leading to intense public debate on issues such as fairness, accountability and transparency[42]. Economic conditions also alter how citizens weigh up a carbon tax. In wealthier countries with established welfare systems, carbon taxes may be more tolerable if surplus revenues are redistributed in ways that reduce the burden on low-income households or fund social programmes[11]. In contrast, developing countries such as India have pressing needs for poverty alleviation and infrastructure development alongside climate change mitigation[43]. Here, policies that directly link carbon tax revenues to economic development or social support may prove more politically acceptable[23]. Finally, cultural norms and social attitudes help shape preferences for different revenue recycling mechanisms. Citizens in more individualistic societies often prefer lump-sum dividends or other direct rebates, while collectivist cultures may find taxes that fund shared community services or public goods more appealing[44]. Taken together, these factors underscore why different countries achieve different levels of public support for carbon taxation: each nation's unique mix of political constraints, economic priorities and cultural values intersect with how individuals perceive cost transparency, fairness and policy effectiveness in practice[9,15].

We conducted a pre-registered $2^2 \times 3^2 \times 5$ full factorial design survey experiment with a representative sample of 4664 from four major economies—Germany, the UK, India, and China—to examine how the dimensions of fairness and the transparent communication of costs and effectiveness causally affect support for carbon taxation, while also investigating the generalisability of these empirical findings across national contexts. The respondents were asked to evaluate three randomly assigned policy proposals, resulting in 13,992 observations. Table 1 displays the key characteristics of the carbon tax policy designs on which we focused in our full factorial survey experiment. The level of support for carbon taxation was measured by asking respondents to indicate their level of support or opposition to specific

Table 1 | Dimensions and levels of the full factorial survey experiment

| Dimension	Level
1. Cost of the carbon tax	1. $79 2. $187 3. $285
2. Use of the carbon tax revenue	1. No information 2. Investments in welfare 3. Investments in climate adaptation 4. Social cushioning (i.e., cash transfers to the poor/most affected households) 5. Lump-sum transfers (i.e., per capita reimbursements)
3. Effect of the carbon tax on average household costs	1. No information 2. Increase costs by 1.22% [$79], 2.11% [$187], and 2.88% [$285] annually depending on the tax
4. Effectiveness of the carbon tax on reducing carbon emissions	1. No information 2. Reduce emissions by 10% [$79], 22% [$187], or 39% [$285] annually depending on the tax
5. Extent of international cooperation	1. No information 2. Implementation of comparable carbon taxes by the EU and the US 3. Implementation of comparable carbon taxes by the EU, the US, China, and India
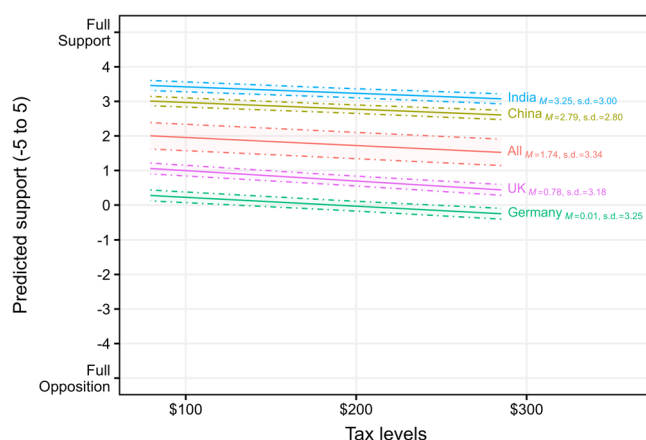
Fig. 1 | Public support for carbon taxation across countries and tax levels. Predicted support for carbon taxation in India, China, the UK, Germany, and the pooled sample across three tax levels ($79, $187, and $285, adjusted for purchasing power parity). Support is measured on a scale from −5 to +5. Sample means (M) and standard deviations (SD) are presented in parentheses. Dotted-dashed lines indicate 95% confidence intervals (CIs).

carbon tax policy proposals on a scale ranging from −5 (completely oppose) to +5 (completely support). Furthermore, the following pre-treatment characteristics of respondents were collected: socio-economic status, trust in government, ownership of a fossil fuel vehicle, type of heating fuel, attitudes towards distributive justice, and environmental attitudes.

Our results show that revenue recycling mechanisms increased support for carbon taxation, though preferences varied considerably. German and Chinese respondents favoured per capita transfers, Indian respondents preferred social cushioning, and UK respondents prioritised welfare investments. Communicating emission reductions markedly increased support, particularly in China. In contrast, providing information about household costs reduced support consistently, with the strongest effect observed in Germany. Contrary to common expectations, international coordination had no effect on support in most countries, increasing it only in Germany. These results highlight substantial cross-national variation, suggesting that the political viability and effectiveness of carbon tax policies require context-specific design features.

Results
Higher tax levels reduce support; baseline support varies across countries
Figure 1 illustrates the main effects of the proposed carbon tax. The results indicated that the proposed tax level could significantly reduce support for

the policy. The strongest effect was observed with a proposed tax level of $285 compared with the baseline of $79 in all four countries.

We found that support for carbon taxes at $130 was the highest in India ($M = 3.25$), the second highest in China ($M = 2.79$), low in the UK ($M = 0.78$), and the lowest in Germany ($M = 0.01$) (see Supplementary Tables 1–5 for the summary statistics). Regarding H1, we found statistically significant effects with $p < 0.05$ in all four countries (see Supplementary Table 7 for the full models).

Revenue recycling schemes increase support, but preferences vary by country
Figure 2 illustrates the impact of revenue recycling schemes compared with the baseline of no scheme. Regarding H2, the data from the pooled sample of all four countries indicated a significant increase in policy acceptance when implementing revenue recycling schemes, with the exception of investments in climate adaptation [$t(8911) = 1.766$, $p \geq 0.05$, $\beta = 0.0831$, 95% CI (−0.009, 0.175)]. However, support for specific schemes varied by country. The German and Chinese respondents tended to favour the per capita reimbursement scheme, whereas the Indian respondents preferred needs-based reimbursement for the poorest households. The UK showed significant support for welfare investments.

Cost transparency reduces support; effectiveness information boosts it
Figure 3 shows that providing information on the expected cost increase for average households decreased overall support for the policies. Consequently, the null hypothesis (H3) was rejected. This pattern was particularly prominent in Germany and China. We observed a statistically significant effect of providing respondents with information on the estimated effectiveness of the specific policy design, thereby rejecting the null hypothesis in favour of H4. This effect was particularly pronounced in China. Finally, informing the respondents about the average consumption-based CO_2 emissions per capita in their respective countries did not change their support [$t(4405) = -0.340$, $p \geq 0.05$, $\beta = 0.024$, 95% CI (−0.160, 0.112)].

International coordination increases support only in Germany
Figure 4 shows that the introduction of carbon taxes as a binding element for other countries in the policy proposal had no significant effect. Therefore, with regard to H5, we did not reject the null hypothesis. Significant positive effects were observed for the German respondents when it was proposed that EU countries, the US, and China would be implementing similar taxation. By contrast, significant negative effects were observed among the Chinese respondents when it was stated that EU countries, the US, and India would introduce similar taxes.

Fig. 2 | Effects of revenue recycling schemes on support for carbon taxation. Average treatment effects of four revenue recycling schemes (relative to a baseline with no scheme): investments in welfare, investments in climate adaptation, social cushioning (cash transfers to low-income households), and lump-sum transfers (per capita reimbursements). Point estimates are shown with surrounding lines representing 95% CIs. Support is measured on a scale from −5 to +5.
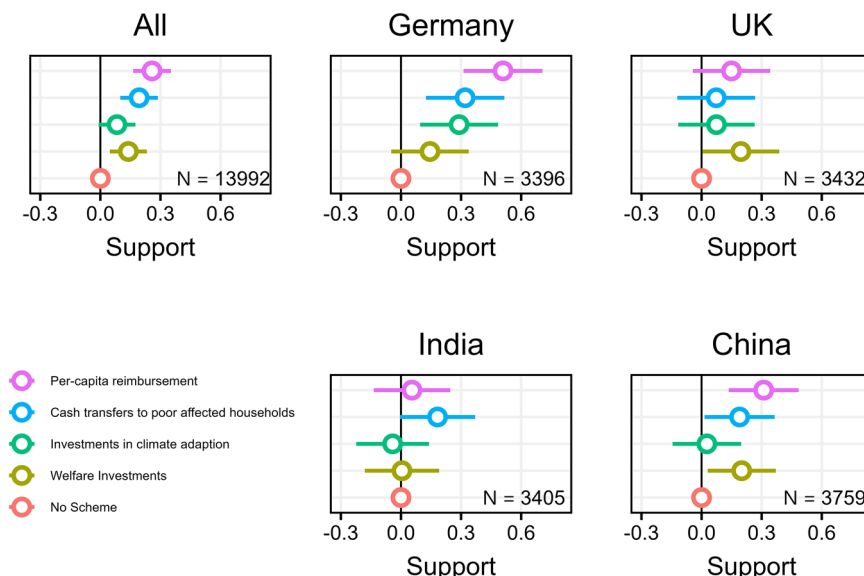

Fig. 3 | Effects of cost, effectiveness, and emissions information on public support. Average treatment effects of providing information about the average household cost (1.22%, 2.11%, or 2.88% annual increase depending on tax level), carbon tax effectiveness (emissions reduction of 10%, 22%, or 39%), and per capita emissions. Support is measured on a −5 to +5 scale. Vertical lines around point estimates denote 95% CIs.
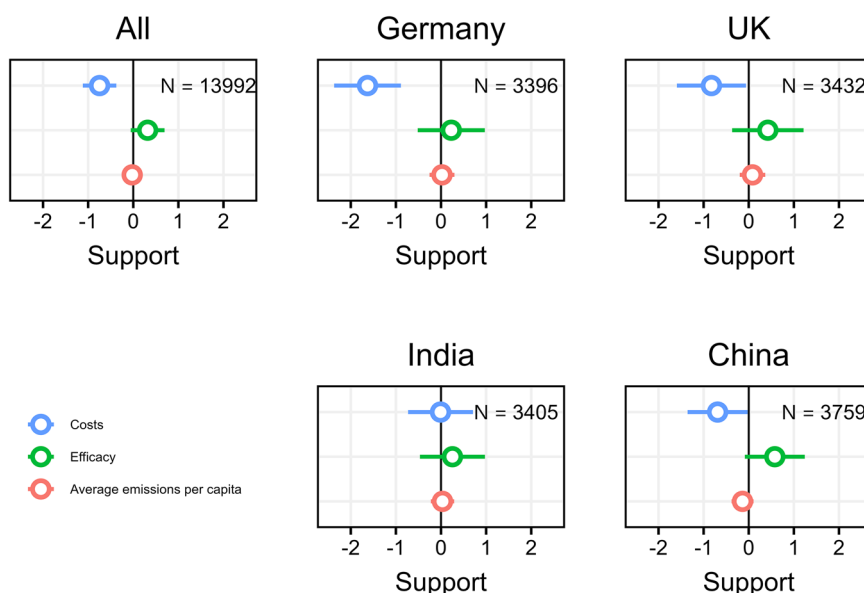
Optimised designs can secure support even for high carbon tax levels

The top panels of Fig. 5(A) show that by proposing optimised policy designs, we could expect support for carbon taxation, even for high tax levels, with the potential to reduce CO_2 emissions. In other words, the policy designs that provided information on the effectiveness of the carbon tax, adopted lump-sum transfers, and did not provide information on the expected costs received the most support. Conversely, the policy designs that provided no information on effectiveness, provided information on the expected cost, and lacked a revenue recycling scheme received the least support (see Supplementary Table 8 for the full model specifications). The bottom panels of Fig. 5(B) show the relative strength of the policy designs supporting carbon taxation, with the tax level being the strongest and international cooperation being the weakest.

Discussion

Carbon pricing is effective in reducing emissions, but it is politically challenging. Rising fuel prices have spurred worldwide resistance to its implementation. Our study focused on people's preferences for carbon taxation in four major economies and carbon emitters from the Global North and South: China, Germany, India, and the UK. To gain insights into public preferences and identify the optimal policy strategies that simultaneously enhance climate change mitigation and garner public support, we employed a full factorial survey experiment among samples representative at the country level.

We found significant differences in support for carbon taxation across countries. On average, people in China and India expressed higher support for carbon taxation than those in the UK and Germany. This difference in support reflects the social cost of carbon in terms of future vulnerability to climate change, underlining how different countries may face various challenges and risks from climate change depending on their geographical, economic, and social characteristics[45]. Beyond these structural factors, two well-documented attitudinal drivers, trust in government and environmental concern, also offer a potential explanation for cross-country variation. Extensive research shows that citizens who believe their government manages resources transparently and effectively are more inclined to endorse environmental policies, including carbon taxes[40,46,47]. Likewise, individuals with heightened environmental concern consistently display

Fig. 4 | Impact of international cooperation on carbon tax support. Average treatment effects of international cooperation scenarios, including implementation by the EU and the US, or by the EU, US, China, and India, compared to a baseline of no cooperation. Support is measured on a −5 to +5 scale. Lines around point estimates represent 95% CIs.
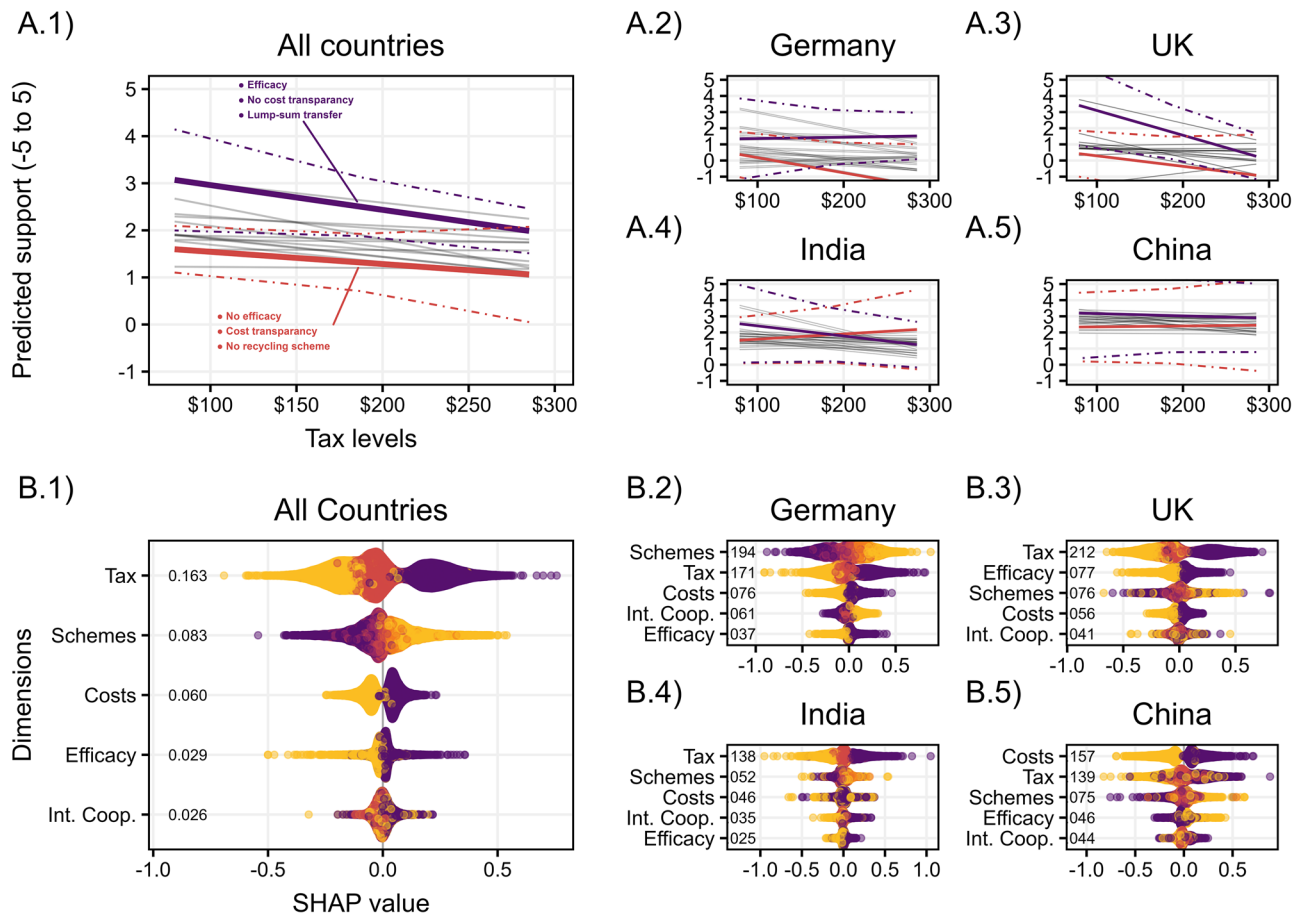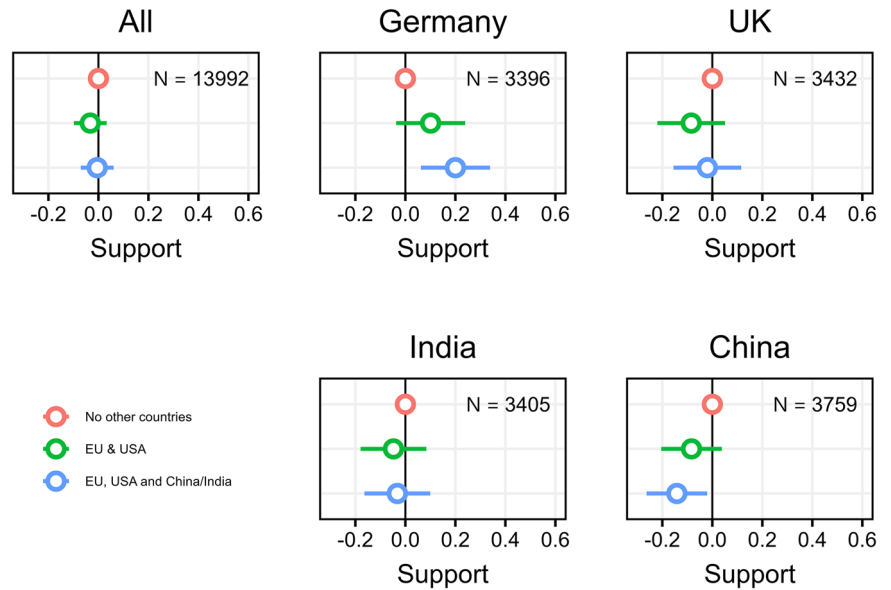

Fig. 5 | Combined effects of tax levels and policy design on support for carbon taxation. A.1–A.5 Predicted levels of public support (−5 to +5 scale) across different tax levels and policy design features (revenue recycling schemes, cost transparency, and effectiveness information) using a four-way interaction model. A.1 displays results for the pooled sample of all countries, while **A.2–A.5** show country-specific results for Germany, the UK, India, and China, respectively. Purple lines represent combinations that include lump-sum transfers, effectiveness information, or no cost transparency. Red lines represent combinations with no revenue recycling, cost transparency, or no effectiveness information. Grey lines represent all other combinations. Dotted dashed lines indicate 95% confidence intervals. **B.1–B.5** SHAP (SHapley Additive exPlanations) values from an XGBoost model predicting support for carbon taxation. Higher SHAP values indicate stronger positive influence on support. Yellow indicates high values of a given feature, blue indicates low values. B.1 shows results for the pooled sample; **B.2–B.5** show country-specific SHAP results for Germany, the UK, India, and China, respectively. Features are ordered by their average importance.

stronger support for climate-mitigation instruments, viewing climate change as an urgent problem demanding policy intervention[29,48]. The baseline support is comparatively higher in China and India, where trust in government and environmental concern are substantially above the levels observed in the UK and Germany (see Supplementary Table 6).

First, the results of our study support the hypothesis that revenue recycling increases public support for carbon taxation. Although we found that all the proposed schemes increased support for carbon taxation independently, we also identified clear differences in preferences across the countries, challenging the generalisability of revenue recycling schemes on a global scale.

We found that respondents in Germany preferred per capita reimbursement, consistent with a recent study in Germany. Respondents in China also preferred the same revenue recycling system.

However, respondents in India preferred social cushioning. By contrast, the respondents in the UK strongly favoured investments in the welfare system. It is beyond the scope of this study to examine the mechanisms underlying the observed variation in support for these revenue recycling schemes across the countries. Nevertheless, cultural differences, social costs, political ideologies, economic structures, and historical responsibilities may have contributed to the observed variance. The findings suggest that policy analysts and decision-makers should engage in public discourse on the optimal utilisation of revenue derived from carbon taxation to enhance public support. These findings suggest that although revenue recycling may be beneficial in terms of building public support for carbon taxation, it is not a panacea, as suggested by previous studies.

Second, we tested the degree to which communicating the effectiveness of carbon taxation could increase public support. We designed a survey experiment to inform respondents about the carbon tax's effectiveness using specific numbers, which is often lacking in similar studies in the literature and political discourse.

Policy opposition is often driven by information asymmetry, where citizens lack the necessary information, which is supported by a recent study showing that people severely underestimate the effectiveness of carbon taxes in reducing carbon emissions[23]. We addressed this gap by informing citizens about the expected environmental effectiveness, which in turn increased support for the policy[28].

We found evidence supporting this hypothesis, with the effect being most pronounced in China.

Our findings align with real-world evidence from Canada, where a revenue-neutral carbon tax with lump-sum transfers has been in place since 2019. While these transfers are intended to mitigate the regressive effects of carbon taxation, studies show they do not necessarily lead to broad public support for carbon pricing. Mildenberger et al.[33] found that despite the financial compensation provided by these rebates, many citizens remain sceptical about the fairness and effectiveness of the tax. Similarly, Winter et al.[34] highlight that while lump-sum transfers help to offset household costs, their progressivity does not fully translate into greater political support for the policy. Our findings suggest that revenue recycling increases acceptability, but policy effectiveness is crucial in shaping attitudes towards carbon taxes.

Third, based on analogous theoretical considerations, it is frequently presumed that disclosing the financial implications of policies can have a comparable impact, suggesting that once individuals are made aware of the true costs of a design, it enhances their support. We provided respondents with specific information about the tax's financial implications, an element often absent in similar experimental studies. However, we found that individuals were less supportive when informed of the costs. This fact calls for a discussion of the appropriateness of disclosing the cost implications for policymaking.

Our findings suggest that omitting explicit cost information can temporarily increase public support, likely due to cognitive biases such as loss aversion, as theorised in prospect theory[21]. However, this does not advocate withholding essential cost information in policy practice. Rather, it highlights the need to strategically frame costs within broader narratives that emphasise collective benefits and fairness considerations. Similarly, Woerner et al.[23] found that the salience of immediate monetary compensation mechanisms, such as upfront climate premiums, can effectively counteract cost-related resistance and increase public support, suggesting the importance of communication strategies in policy design.

Furthermore, there is also suggestive evidence of a gradual increase in support once taxes are in place. For example, Murray and Rivers[49] document that acceptance of British Columbia's carbon tax increased three years after its implementation, and Carattini et al.[28] find similar improvements in other areas of environmental taxation, attributing these changes to experiential learning.

Fourth, previous studies have often assumed that all countries act in coordination and adopt the same carbon tax (e.g. Carattini et al.[8]). However, this assumption may be unrealistic given the differences in political consensus and economic development stages worldwide. Given that China and India are among the world's largest greenhouse gas emitters, pricing carbon emissions in these countries is pivotal for reducing emissions globally. We assessed the relevance of global fairness in supporting domestic carbon taxation and noted that only in Germany did the support respond to contributions and international cooperation with the EU, the US, and China. A review of the empirical literature revealed that only one study[16] tested this hypothesis with German participants, corroborating our results. However, expanding the scope beyond Germany, we found no significant effects in the UK, India, and China. Although this surprising negative effect observed in China is beyond the scope of the study, further investigation is warranted. In light of this, it seems that this factor is not as generalisable as previously theorised[16], making it less relevant beyond Germany. Consequently, opposition to carbon taxes did not appear to be driven by concerns about free-riding on climate change mitigation as a form of global public good, which is consistent with the idea of collective action in the commons[28,50]. The results suggest that concerns about international free-riding are not a significant factor shaping people's policy preferences and support for carbon tax rates, particularly in the Global South. In contrast to historical emissions from the West, highlighted by India and China, these are not reflected in people's political preferences.

Our findings revealed varying effect sizes across the tested hypotheses. Regarding revenue recycling schemes (H2), the strongest significant effects were observed with per capita reimbursements, showing particularly large effects in Germany and China. However, regarding the provision of cost information (H3), a negative effect twice as strong was observed, with the largest effect being observed in Germany. These differences in effect sizes suggest that policymakers, particularly in Germany and China, can achieve the greatest gains in public support by focusing on revenue recycling schemes. Further, communicating the effectiveness of the policy was observed to have an effect size close to that of revenue recycling schemes, which did not fully offset the negative effect of cost transparency. The smaller effect sizes for international cooperation (H5) suggest that this factor may be less crucial for designing carbon tax policies that garner public support, except in Germany (Supplementary Table 7). Policymakers should carefully consider and address the negative impact of cost transparency on public support for a carbon tax. To design more effective and publicly acceptable policies, they should thus focus on communicating the benefits and effectiveness of carbon taxes while developing targeted strategies to mitigate or offset the perceived financial burden on households.

Our study aimed to ascertain whether a combination of the most theoretically and publicly discussed policy elements could lead to support for one of the most unpopular but most effective policies. Our study contributes to the small body of research that examines attitudes towards climate policy instruments in the Global South. As signatories to the Paris Agreement, these countries face the challenge of reducing their emissions. Therefore, information on the attitudes and factors that shape them in contexts beyond the Global North is urgently required.

Our findings have significant policy implications. Although revenue recycling may increase support, the most popular schemes are contingent

on the national context. This reinforces the need for country-specific empirical investigations to determine the public's preferred options for revenue recycling before making policy decisions. Although this task remains challenging, we demonstrated that with appropriately designed policy instruments, it is possible to achieve support for even higher carbon tax levels. Ultimately, the literature consistently identifies trust in government and concern about climate change as the two most influential factors shaping public support for carbon taxation[29,40,47,48]. Therefore, environmental policy should first focus on strengthening these two key determinants while optimising policy designs to make carbon taxes more feasible.

The findings of this study suggest that policy designs commonly favoured in environmental policy but often opposed by the general public may prove more effective in garnering public acceptance when policy elements pertaining to revenue recycling schemes, effectiveness, and cost as well as communication strategies tailored to the country context, are carefully considered. These findings can inform the development of effective carbon taxes that citizens accept at levels likely to induce significant emission reductions, as they address revenue recycling transparently and communicate its effectiveness. Addressing the general public's concerns is crucial for avoiding resistance to effective climate change mitigation policies.

Further research is required to determine the most effective combinations of policy instruments, including carbon taxes, subsidies for renewable energy, green technology, and regulations. Future research should also consider socio-transformative aspects such as programmes to address potential job losses in the post-fossil fuel era to develop and implement policies that can generate additional support for mitigation policies[32]. Furthermore, as indicated previously, social costs appear to align with support for carbon taxation. This suggests that countries such as China and India, which are predicted to be more adversely affected by climate change[51], also show higher support for carbon taxation. Future research could consider the social cost of carbon by providing respondents with this information to increase support. Similarly, future research should explore how variations in political institutions, economic conditions, and cultural values jointly shape public support for carbon taxation. In addition, we addressed the vertical distribution effects of carbon taxation using the revenue recycling schemes of lump-sum transfers and social cushioning. However, horizontal distribution effects remain and must be addressed in terms of fairness because different circumstances can burden households with similar characteristics differently. Therefore, further research is required to address this gap. Furthermore, it is important to consider that the role of trust in the government and environmental concerns as well as the extent to which citizens prefer market instruments such as carbon taxes and subsidies over conventional regulatory instruments may vary depending on the characteristics of political and economic systems and cultural contexts[41]. For example, the preference for market instruments may be greater in countries with a more market-oriented approach to environmental policies[52].

Although this study was conducted in countries with large populations, the overall number of countries was small. Extending the sample to other countries using representative samples could reveal potentially important nuances.

Whether broad support for carbon taxation is a sufficient condition for adoption cannot be addressed using this design. Nevertheless, this study suggests considerable scope for designing a carbon tax policy that is not only popular with the general public but also benefits them directly and indirectly.

Methods

A multi-country online survey experiment was conducted using the Qualtrics platform in four countries. Our sample[53] was based on nationally representative samples from Germany, the UK, India, and China, all of which are major economies and high CO_2 emitters.

We used a $2^2 \times 3^2 \times 5$ full factorial design to create vignettes and policy proposals by combining all possible attribute combinations. More than 4000 respondents evaluated three randomly selected vignettes from a full factorial survey, resulting in more than 12,000 assessed vignettes. The study employed a full factorial design with hypotheses pre-registered in the OSF Registries[54] prior to data collection.

The respondents were randomly assigned and provided with information on the anticipated impact of carbon taxation on emission reductions or the associated cost as a percentage of average household income, or both, based on calculations from Kaestner and Sommer[55]. To make tax levels internationally comparable in terms of cost and burden on the average household, 2022 purchasing power parities[56] were employed to convert them into national currencies. In addition, we experimentally varied the information on average consumption-based CO_2 emissions per capita in each country to test whether this affected support for carbon pricing and provide additional guidance on the costs of taxes.

Analytical strategy

We used hierarchical linear modelling to account for the nested structure of our data, which included both respondent- and country-level variations. We estimated random intercepts for each country and assessed their heterogeneity (Supplementary Table 7). The pooled sample of all four countries was used to test the hypotheses. In accordance with the pre-registration, the threshold of $p < 0.05$ was applied to identify significant effect sizes. The p-values for H1, H3, and H5 referred to one-tailed t-tests, whereas those for H2 and H4 referred to two-tailed t-tests, as per the pre-registered test choices. We modelled predictions of support for carbon taxation (on a scale from −5 to 5) using a four-way interaction between tax levels and vignette dimensions (revenue recycling schemes, costs, and effectiveness), allowing us to examine how these factors jointly influenced public support for carbon tax policies. The two-way interaction effects for the vignette dimensions are shown in Supplementary Figs. 1–5. We used a machine learning approach with the XGBoost algorithm to assess the importance of each dimension in the full factorial survey experiment in the presence of non-linearities and complex dependencies within the data[57]. The R package *lmer* was used to estimate the cluster-robust models, *xgboost*[57] for the machine learning model, *ggeffects*[58] for the predicted values, and *ggplot2*[59], *modelsummary*[60], *patchwork*[61], *ggrepel*[62], and *shapviz*[63] for presentation.

Statistical analysis

The primary analysis employed a mixed-effects linear regression model to estimate the impact of various policy attributes on support for carbon taxes. This approach was chosen to account for the hierarchical structure of our data, as each participant provided multiple vignette responses. The model is specified as:

$$\text{Support}_{ij} = \beta_0 + \beta_1 \Big(\text{Tax Level}_{ij}\Big) + \beta_2 \Big(\text{Revenue Use}_{ij}\Big) + \beta_3 \Big(\text{Costs}_{ij}\Big)$$
$$+ \beta_4 \Big(\text{Effectiveness}_{ij}\Big) + \beta_5 \Big(\text{International Cooperation}_{ij}\Big)$$
$$+ \boldsymbol{\gamma}^{\mathbf{T}} \text{Covariates}_j + u_j + e_{ij}$$

where i indexes the vignette-level observations and j indexes the participants. In this specification, β_0 represents the fixed intercept, β_1 through β_5 denote the fixed effects coefficients for the policy attributes, and $\boldsymbol{\gamma}$ represents the fixed effects coefficients associated with the participant-level covariates. The term u_j is a random intercept for participant j, assumed to be normally distributed as $u_j \sim N(0, \sigma^2 \text{participant})$ to account for unobserved heterogeneity across individuals, while e_{ij} captures the residual error and is distributed as $e_{ij} \sim N\big(0, \sigma^2 \text{error}\big)$.

The inclusion of a random intercept is essential to account for within-participant correlation arising from repeated measures, thereby improving the precision and inference of our model. Although our experimental design randomly assigns policy attributes to vignettes, meaning that causal estimators are theoretically identifiable, the addition of control variables and random effects increases statistical power by reducing residual variance[64,65]. This increases the robustness of our causal inferences regarding the direct impact of policy design on carbon tax support.

Sample

The samples were selected based on the quota criteria. The study included individuals based on their demographic background characteristics, such as sex, age, region, and census data from each country to obtain a nationally representative sample of these sociodemographic dimensions. The participants were randomly assigned to different policy proposals (treatments) without prior knowledge of their group assignments. In addition, they were asked about their sex, age, education, annual household income, dwelling & heating type, social justice attitudes, and climate concerns.

Measures

To ensure robust and reliable estimates of public support for carbon taxation, we adjust for key baseline characteristics that have been shown to influence climate-related attitudes and policy preferences (see Supplementary Table 7 for full model specifications). These variables were selected based on the existing literature and take into account socio-demographic, economic and attitudinal factors that may influence respondents' evaluations of carbon tax designs. The full wording of the measures used can be found in the Supplementary Notes.

Trust in government. Trust in government institutions is an important determinant of public support for climate policies, as individuals with higher institutional trust are more likely to perceive carbon taxes as fair and effective[6,12]. We measured trust in government using a 7-point Likert scale.

Environmental concern. Environmental concern has been widely identified as a key driver of public attitudes towards carbon taxation[6,7]. Individuals who perceive climate change as a serious threat are more likely to support carbon pricing mechanisms[16]. We measured environmental concern using a 7-point Likert scale, which assesses respondents' perceived severity of climate change and their willingness to support policy interventions.

Social justice attitudes. The Basic Social Justice Orientation Scale assesses individuals' preferences for four basic distributive justice principles: equality, need, merit and entitlement[66]. These principles reflect order-related justice attitudes, as they define the norms that guide allocation and distribution decisions in society. The scale provides a structured framework for understanding how individuals prioritise these dimensions in different policy contexts, including environmental and fiscal policy[66]. In the context of this study, the scale helps to capture how underlying perceptions of fairness shape public support for carbon taxation and revenue recycling mechanisms. The scale was administered using a five-point Likert scale (1 = strongly disagree to 5 = strongly agree), with higher scores indicating stronger support for a particular distributive justice principle. The full list of items used in the survey can be found in the Supplementary Notes.

Gender. Gender differences in environmental attitudes are well documented, with women consistently showing stronger pro-environmental preferences than men[67]. Gender was included as a categorical variable.

Age. Age is a known determinant of environmental attitudes, with younger people generally expressing greater concern about climate change[68]. Younger respondents may also be more receptive to policy interventions due to their longer expected exposure to climate risks[69]. We included age as a categorical variable.

Education. Higher levels of education are positively correlated with pro-environmental attitudes and behaviours[70]. Education is consistently associated with awareness of climate science and acceptance of market-based environmental policies[6,7]. We measured education as an ordinal variable, distinguishing between different levels of formal education.

Income. Previous research shows that household income is associated with greater support for environmental taxes[20]. We included income as a categorical variable based on self-reported household income.

Household size and dwelling type. Previous research has shown that household size and dwelling type influence energy consumption[71]. Larger households tend to have higher energy consumption, which may influence support for carbon taxation[7]. We adjusted for these pre-treatment characteristics by including categorical variables for household size and dwelling type.

Fossil-fueled vehicle ownership and heating fuel type. Ownership of a fossil-fuelled vehicle is an important determinant of attitudes towards carbon taxation, as individuals dependent on petrol or diesel cars may perceive higher personal costs associated with carbon taxation[72]. Research suggests that car-dependent individuals are more likely to oppose carbon pricing due to concerns about fuel affordability and transport alternatives[7,10]. We have included a variable that distinguishes between respondents who own at least one fossil-fuelled car (coded as 1) and those who do not (coded as 0).

Similarly, heating fuel type has been shown to influence public perceptions of carbon pricing, as households that use fossil fuels for heating (e.g. natural gas, coal or oil) face greater direct cost impacts from carbon taxes[7,15]. Prior research has found that individuals who are more dependent on fossil fuels for heating tend to be less supportive of carbon pricing policies unless mitigation measures (such as subsidies for clean energy transitions) are provided[10,32]. To adjust for this effect, we asked respondents about the type of fuel they use for heating.

Although random assignment in survey experiments ensures statistical equivalence between treatment groups, including pre-treatment characteristics in the analysis can improve the precision of estimated treatment effects. By explaining some of the variance in the outcome variable, covariates such as age, education or socio-economic status reduce residual error. This in turn leads to more efficient estimates with smaller standard errors and narrower confidence intervals, improving statistical power without requiring a larger sample size. In this context, pre-treatment covariates are not used to correct for bias, but to increase the efficiency and clarity of causal inference[65,73].

Data collection

Qualtrics' proprietary panels and sampling technology were used to collect the data. The sampling software controlled the flow of the participants into each survey based on quotas, according to the population census. Panellists were invited via email, and the survey was accessed through a provided link.

Qualtrics supervised the panel and continuously monitored its quality using a scoring and monitoring process. The criteria were established to exclude those participants who dropped out during the survey, rushed through it, or provided straight-line responses. Informed consent was obtained from all the study participants in accordance with ethical regulations and guidelines, and compliance with the Institutional Review Board of the University of Luxembourg was ensured (reference number: ERP 23-095 ECO2TAP).

The phrasing of the experimental interventions and outcome variables is provided in Supplementary Notes.

Policy Proposal Number: 25

One policy option of the UK government to reduce CO_2 emissions is the introduction of a CO_2 tax of £48 per ton. This political measure will lead to a 1.15% increase in average household costs per year. This CO_2 tax will likely reduce CO_2 emissions in the UK by 10%. The CO_2 tax revenue will be used to increase investments in climate change adaptation measures (e.g. flood and fire protection). This political measure will only come into effect if the European Union and United States collaborate and introduce similar CO_2 taxes. To what extent do you support or oppose this?

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Author contributions

H.B. and R.S. jointly conceptualized the study and developed the methodological framework. H.B. led the formal analysis, data curation, investigation, and preparation of the original draft. Both authors contributed to the writing and critical revision of the manuscript. R.S. supervised the research, secured funding, and administered the project. Both authors reviewed and approved the final manuscript.

Competing interests

The authors declare no competing interests.

Additional information

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