

<https://doi.org/10.1038/s44458-026-00149-0>

Conditional bidirectionality between climate policy acceptance and perceived effectiveness



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The causal relationship between climate policy acceptance and perceived effectiveness is contested. Traditional models assume effectiveness perceptions drive acceptance, while alternative accounts suggest the reverse. Additionally, whether general climate policy support moderates how design features affect acceptance is understudied. Factorial survey experiment results on heating sector instruments (N = 2579) hint at conditional bidirectionality. We show that the traditional pathway—where optimistic effectiveness information boosts acceptance via effectiveness perceptions—operates only for general climate policy supporters and the undecided. The alternative path—where acceptance shapes effectiveness perceptions—appears across all groups, including opponents. Instruments with low personal cost and fair design show higher acceptance, which may lead to increased perceived effectiveness. These findings suggest limits to unidirectional models in climate policy research. For policymakers, they imply that, even among opponents, support may be fostered via fairness and limited personal costs, as these factors not only drive acceptance but also contribute to perceptions of policy effectiveness.

Climate policy implementation faces a fundamental puzzle worldwide: while policy effectiveness is necessary for achieving climate goals, the most effective policies often lack public acceptance or support¹ needed for political feasibility². Global expert surveys confirm this tension. Instruments that experts judge as most effective attract comparatively low public support^{3,4}. In the wake of much-needed intensification of political action to meet Paris Agreement commitments⁵, understanding how individuals form acceptance and effectiveness perceptions is thus crucial for designing broadly supported, implementable climate policy. However, the causal relationship between these factors—whether citizens support policies they perceive as effective, or perceive policies as effective when they support them—remains debated with profound implications for policy design and communication strategies globally.

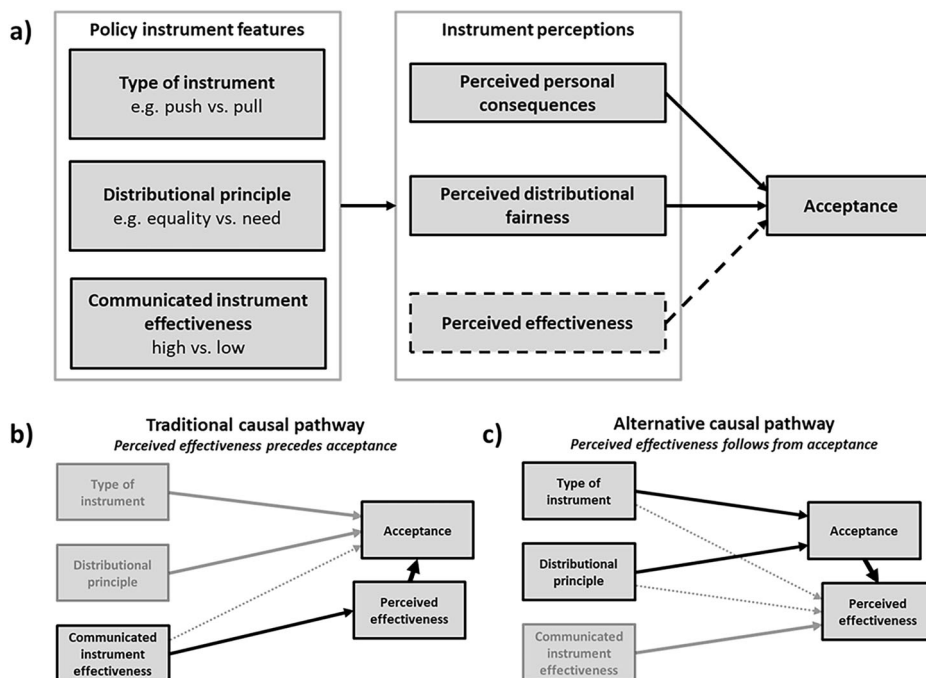
The bulk of the literature on acceptance determinants assumes a straightforward causal chain from an instrument's design to its specific perceptions and acceptance^{6–11}. For instance, pull instruments are assumed to be more accepted because they are less intrusive and have fewer negative consequences for the individual than push instruments^{12,13}. Instruments that distribute benefits and costs proportionally, such as according to the polluter-pays and need principles rather than the equality principle, are more accepted because these principles are generally preferred¹⁴ and perceived to be fairer⁷. Finally, instruments that are communicated to be effective in the eyes of experts, which are considered a policy instrument

feature in this study, are more accepted because individuals perceive them to be effective¹⁵. However, this latter causal chain is not unanimously argued for. See Fig. 1a for a conceptual overview of these assumptions.

Two competing arguments offer fundamentally different causal accounts of the relationship between perceived instrument effectiveness and its acceptance. In line with the bulk of the literature on determinants of policy instrument support, the Greed-Efficiency-Fairness hypothesis (GEF) notably posits that perceived effectiveness causally determines acceptance^{10,16}—henceforth termed the *traditional causal pathway*. It assumes a rational evaluation process, where citizens first assess whether a policy will be effective. They then decide whether to support it based on this assessment alongside considerations of personal benefit and fairness. Many publications implicitly or explicitly assume the traditional causal pathway^{9,17–21}, but only a few have tested it experimentally^{15,22,23}.

The alternative account of reversed causality, however, has also been argued for^{22–25}—henceforth termed the *alternative causal pathway*. In line with motivated reasoning, effectiveness beliefs may follow from acceptance in a way that justifies preferred instruments. Bolderdijk et al.²³ argue, because the effectiveness of policy instruments—particularly when they are yet to be implemented—is difficult to gauge, individuals rely on other more readily available considerations, such as personal costs or perceived fairness that are anchored in directly observable design features. Considerations based on these more tangible instrument features can then shape an overall attitude

Fig. 1 | Conceptual models of the formation of climate policy acceptance and perceived effectiveness. **a** Hypothesized influence of policy instrument features on instrument perceptions and acceptance. The literature on policy acceptance generally assumes a straightforward causal chain from policy instrument features to instrument perceptions to support, i.e., acceptance. While this general structure is widely accepted, the directionality of the relationship between perceived effectiveness and acceptance remains debated. The dashed line and arrow indicate the theoretically debated position of perceived effectiveness in this causal chain. **b**, **c** draw on this inconclusive evidence and represent simplified analytical models that conceptualize the two opposed causal roles of perceived effectiveness proposed in the literature addressed by RQ1. **b** Conceptual model of the traditional causal pathway: perceived effectiveness precedes acceptance. In this traditional pathway model, an instrument's effectiveness information will determine perceived effectiveness, which in turn will determine acceptance. **c** Conceptual model of the alternative causal pathway: perceived effectiveness follows acceptance. In this alternative pathway model, instrument features other than effectiveness information will determine acceptance, which in turn will determine how effective an instrument will be perceived (even while keeping the impact of effectiveness information constant). Dotted arrows represent indirect effects.



that biases consumers' perceptions of less tangible policy attributes²³, such as effectiveness²³. Importantly, this does not imply that effectiveness information is necessarily influential under such conditions. Rather, when objective effectiveness is uncertain, individuals may be especially prone to interpret or discount effectiveness information in line with their prior attitudes. In the case of climate policy instruments, once they are implemented, direct experience of effects is still elusive, reliance on prior beliefs remains, and might limit the influence of communicated information. We therefore focus on the perceived effectiveness's potential bidirectionality. The presented literature has scrutinized its construction under uncertainty, whereas—as laid out—fairness and personal benefit are more consistently treated as directly grounded in observable policy features. To our knowledge, no study has examined the contradictory causal pathways in detail. While Tiede et al.²⁶ tested a mediation model where perceived effectiveness follows support, they only included effectiveness information and no other policy features as support determinants.

We aim to address this gap by employing an experimental design to identify the impact of policy instrument features, while using structural equation modeling to quantify the relative empirical support for competing directional pathways between perceived effectiveness and acceptance. The delineated theoretical tension has profound practical implications: if effectiveness drives acceptance (traditional causal pathway), policymakers should focus on demonstrating technical merit; if acceptance drives effectiveness perceptions (alternative causal pathway), they should rather prioritize building support through fairness and personal benefits. Thus, the first focus of this study is to investigate the mediational pathways around perceived effectiveness and acceptance: Does perceived effectiveness precede acceptance, or is it the other way around (research question (RQ) 1)? Figure 1b, c shows simplified analytical models that represent the opposed causal pathways discussed in the literature.

Investigating the contested causal ordering between perceived effectiveness and acceptance (RQ1) is one step toward an improved process model of climate policy acceptance. A second and related question concerns whether the impacts of policy instrument features on acceptance are homogeneous across individuals, or whether they vary systematically with broader political orientations toward climate policy. A recent review-based

integrative framework that explicates the mechanisms underlying acceptance of public policy highlights a formerly understudied construct. The framework posits that individuals' general support for governmental intervention in shaping citizens' climate-relevant behaviors, henceforth termed general climate policy support, may moderate their responsiveness to policy design features when forming acceptance judgments^{9,13,27}. Specifically, the framework posits that the negative effect of policy intrusiveness—indicated by the type of instrument in this study (push = more intrusive; pull = less intrusive)—is buffered when individuals generally support climate policy, as the general tendency to demand intervention overrides concerns regarding personal restrictiveness. Regarding the policy design features of fairness and effectiveness, the framework assumes their positive effects on acceptance are magnified because support for governmental intervention prioritizes collective goal attainment, causing individuals to interpret these features as critical evidence that the policy is actually capable of delivering the desired collective outcomes. These assumptions, however, have not yet been empirically examined. Understanding this moderating effect is crucial for policymakers, as general attitudes toward climate policy are relatively malleable compared with more distal beliefs and values. Thus, the second focus of this study is to investigate whether general climate policy support moderates the relationship between features of specific climate policy instruments and their acceptance (RQ 2; see Fig. 2).

By jointly investigating these two research questions, we target complementary gaps in the process model of climate policy acceptance—thereby answering several recent calls for more research on the formation of public opinion on climate mitigation measures^{28,29}. As heating is one of many carbon-intensive domains that all share similar behavioral determinants³⁰, we use Germany's heating sector transformation as a test case that reflects broader international challenges to tackle the identified critical knowledge gaps for evidence-based policy design. Like many developed nations, Germany faces the imperative to decarbonize residential heating³¹. Recently implemented policy instruments that “push” away from carbon-intensive heating technologies (via carbon pricing) and “pull” toward low-carbon alternatives (via technology subsidies under the Building Energy Act (GEG)³²), although recommended³³, face low acceptance^{34,35}. This creates an ideal context for examining effectiveness-acceptance dynamics regarding

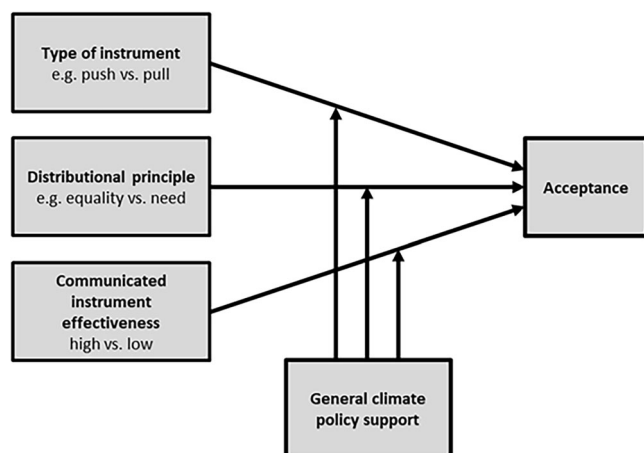


Fig. 2 | Hypothesized moderating role of general climate policy support (RQ2).

Based on recent theoretical advances, the influence of policy instrument features on acceptance depends on general support for government intervention in climate-relevant behaviors; henceforth termed general climate policy support. In line with the literature, we assume that higher general support leads to reduced responsiveness to the type of instrument (push vs. pull will impact acceptance less when general support is high) and increased responsiveness to distributional principles and effectiveness information (proportionality principles and high effectiveness information will have a greater impact on acceptance when general support is high).

instruments similar to real-world examples where both technical merit and public opposition coexist.

In a factorial survey experiment administered to a sample of the German population ($N = 2579$), we experimentally manipulated three instrument features of policy aimed at increasing the adoption of low-carbon heating technology in private households: (1) financial (dis-) incentivization method (termed type of instrument) with the levels push, pull, and combination of both; (2) distribution principle of the (dis-) incentives, with the levels equal distribution, distribution according to need, and according to polluter-pays; and (3) effectiveness information with the levels low (i.e., small contribution to sectoral climate targets) and high effectiveness (i.e., large contribution to sectoral climate targets). Each respondent rated three vignettes regarding their perceived effectiveness and acceptance. While these instruments are hypothetical and would therefore entail the term acceptability rather than acceptance¹, they have direct pendants in current energy and heating policy and therefore opt for the latter. This investigation's focal sample comprises respondents exposed to climate effectiveness information treatments. An additional 678 respondents received only energy-security-framed effectiveness information. These dual effectiveness dimensions—climate and energy security—mirror the primary policy justifications for Germany's heating transition since 2022. Testing both allows us to determine if our results are domain-specific or generalizable. While our main analysis focuses on climate effectiveness, the energy security results serve as a robustness replication (see Supplementary Information Section 2).

Thus, this study examines how policy instrument features shape acceptance and perceived instrument effectiveness. Combining experimental manipulations with mediation analysis, we provide evidence consistent with bidirectional dynamics in climate policy attitudes. Our findings point toward the limits of the dominant unidirectional assumptions in the field and offer new theoretical insights about motivated reasoning in policy evaluation, with practical implications for policy design and communication strategies worldwide.

Results

Perceived effectiveness precedes and follows acceptance

To address whether perceived effectiveness precedes acceptance or follows acceptance (RQ1), we first examined mediation models representing the

traditional causal pathway, that is, perceived effectiveness precedes acceptance. We then investigated models representing the alternative pathway, that is, perceived effectiveness follows acceptance. For the traditional causal pathway and in line with the bulk of the literature, we expect that manipulating perceived effectiveness with low versus high effectiveness information will influence acceptance. Following Bolderdijk et al.'s²³ argumentation for the alternative causal pathway, we expect that individuals will accept pull rather than push instruments and instruments designed according to proportionality principles rather than equality. Subsequently, these instruments are perceived as more effective. However, in their study, they only operationalized proportionality via the polluter-pays principle. We extend their approach by examining need-based proportionality in our tests of the alternative pathway. We excluded the 'push-pull combination' level to maintain a clear contrast between instruments with predominantly positive or negative personal consequences.

We used path analysis in STATA 16 with cluster-robust standard errors to account for the nested design of our data (up to three sets of responses per participant). Policy type levels (push vs. pull), fairness principle levels (equality vs. polluter-pays and equality vs. need), and effectiveness information levels (low vs. high effectiveness) were entered as dichotomous predictors in all models. Age, gender, education, monthly income, party identification, and climate concern were included in all models to control for their effects on acceptance. Paths are to be interpreted such that positive coefficients indicate the effect of switching from push to pull, from equality to polluter-pays or need, and from low to high effectiveness on a given outcome. We report unstandardized coefficients appropriate for our data³⁶. For the traditional causal pathway model, acceptance was entered as outcome and perceived effectiveness as mediator (see Fig. 3a). For the alternative pathways model, perceived effectiveness was entered as outcome and acceptance as mediator (see Fig. 3b). To better gauge the indirect effect importance when there is still a residual direct effect, we report the ratio of indirect effect to direct effect (RID)³⁷. As a descriptive complement, we also report Shapley decomposition of outcomes- R^2 (see Tables S8 and S9). Figure 3 shows mediation model results for both hypothesized causal pathways without depicting controls. See Fig. S1 in Supplementary Information for the same model results showing controls.

Results hint at both causal pathways being at play simultaneously. Regarding the *traditional causal pathway*, we find that while controlling for the effect of type of policy and fairness principle, high effectiveness information has a significant total effect on acceptance (total effect = 0.33, 95% CI = [0.18, 0.49], $z = 4.16$, $p < 0.001$), which is mediated by perceived effectiveness (indirect effect = 0.44, 95% CI = [0.32, 0.56], $z = 7.12$, $p < 0.001$) (see Fig. 3a). Sobel and Monte Carlo tests for indirect effect significance mirror these mediation results (see Table S5 in Supplementary Information).

The RID indicates that the indirect effect of effectiveness information on acceptance via perceived effectiveness is approximately 4.1 times the direct effect, underlining the importance of this mediational pathway. The traditional causal pathway model has an acceptable fit (Standardized-Root-Mean-Squared-Residual (SRMR) < 0.08³⁸). These results indicate that communicating a climate instrument as highly effective compared to only somewhat effective causes support because it increases perceived effectiveness, albeit only to a small degree.

To optimize comparability between models for both causal pathways, we tested an extended, more symmetrical traditional model, including direct paths from instrument type and fairness to perceived effectiveness, as in the alternative pathway model. Model fit only improved slightly (see Table S7), and the influence of effectiveness information on acceptance was still primarily mediated via perceived effectiveness (see Fig. S1).

Regarding the *alternative causal pathway*, we find that, while controlling for the effect of effectiveness information, type of instrument has a significant total effect on perceived effectiveness (total effect = 0.47, 95% CI = [0.34, 0.60], $z = 6.96$, $p < 0.001$), which is mediated via acceptance (indirect effect = 0.47, 95% CI = [0.36, 0.57], $z = 8.79$, $p < 0.001$) (see Fig. 3b). For Sobel and Monte Carlo tests coinciding with these mediation results, see

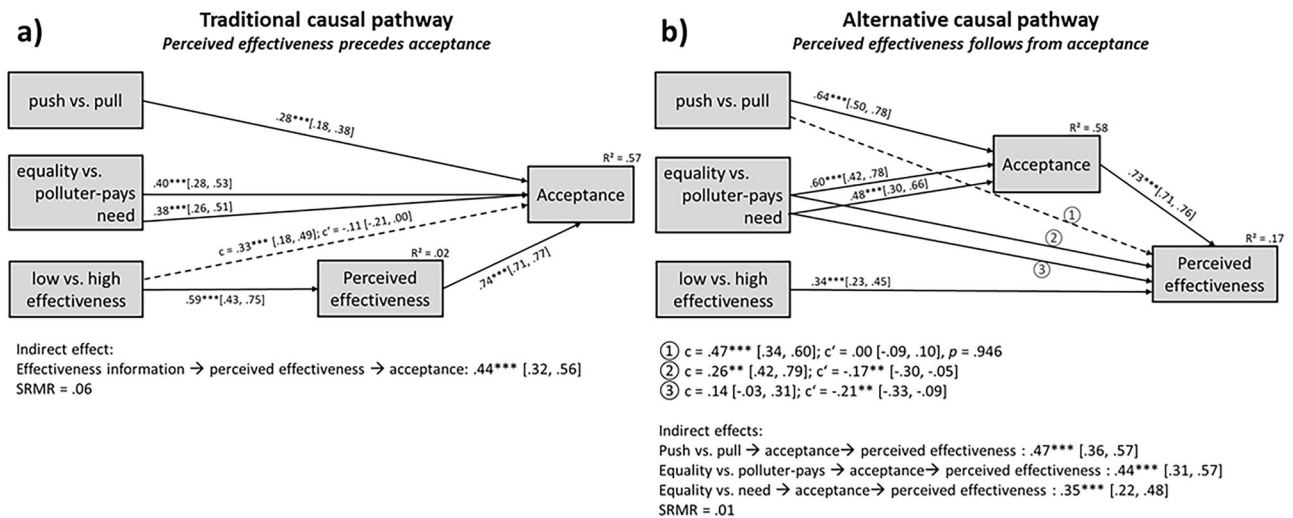


Fig. 3 | Mediation models of the influence of policy instrument features on acceptance and perceived effectiveness. **a** Perceived effectiveness precedes acceptance (traditional causal pathway). **b** Perceived effectiveness follows acceptance (alternative causal pathway). Distributional fairness principles were entered as dummy-coded variables, indicating the effect of the proportionality principles polluter-pays and need compared to the reference category of equality.

Table S5. As there is virtually no direct effect left, RID indicates that the indirect effect is approximately 141.1 times the direct effect (note that the RID is highly sensitive to small direct effects; given that both remaining direct effects are non-significant, the RID values primarily indicate (near) full mediations rather than meaningful differences in magnitude). Thus, our data implies that, in addition to the impact of effectiveness information, perceived effectiveness increases when the policy instrument is a preferred pull type because individuals support them more than push measures. This also replicates earlier findings that lay people's effectiveness ratings are opposed to experts' ratings, who usually attest higher effectiveness to push measures⁷.

Distributing costs and benefits of an instrument proportionally rather than equally exerts a significant positive total effect on effectiveness when instruments are designed according to the polluter-pays principle (total effect: 0.26, 95% CI = [0.09, 0.44], $z = 2.92$, $p = 0.004$) but not according to the need principle (total effect: 0.14, 95% CI = [-0.03, 0.31], $z = 1.57$, $p = 0.117$) (see Fig. 3b). We investigated the indirect effect because a significant total effect is not a precondition for a significant indirect effect^{39–41}. Both proportional distribution fairness principles determined perceived effectiveness via acceptance (equality vs. polluter-pays: indirect effect = 0.44, 95% CI = [0.31, 0.57], $z = 6.44$, $p < 0.001$; equality vs. need: indirect effect = 0.35, 95% CI = [0.22, 0.48], $z = 5.26$, $p < 0.001$), extending Bolderdijk et al.'s²³ results by demonstrating that need-based design positively impacts effectiveness beliefs via increased acceptance. Again, Sobel and Monte Carlo tests mirror these results (see Table S5). RID shows that the indirect effect of the fairness principle is 2.5 and 1.6 times as large as the direct effect for both indirect effects, respectively. This shows that they overpower the remaining competitive direct effects. Finally, the alternative causal pathway model has a very acceptable fit (SRMR = 0.01).

Thus, our results also hint at the existence of the alternative causal pathway. Effectiveness perceptions may also follow acceptance and might be indirectly increased by the type of instrument and, to a somewhat lesser degree, the underlying fairness principle. In line with the alternative pathway assumptions, pull rather than push instruments and instruments that distribute costs and benefits proportionally are perceived to be more effective. This higher perceived effectiveness arises because such instruments are more widely accepted, regardless of whether they are communicated with high or low effectiveness information. This challenges the conventional communication logic behind climate policy campaigns, which

Models show that both causal pathways are in line with the data. Effectiveness information impacts acceptance via perceived effectiveness, but the latter is also impacted by the type of instrument and the underlying fairness principle via acceptance. $N = 2462$. Dotted paths are non-significant at $p < 0.05$. 95% CI's in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. See Fig. S1 for z -statistics and exact p values when $p > 0.001$.

often focus on effectiveness claims as a starting point. While both causal pathways seem to be at play simultaneously, comparisons of Akaike's information criterion (AIC) and Bayesian information criterion (BIC), which penalize model complexity, favor the alternative causal pathway over the traditional one—even when including paths from instrument type and fairness to perceived effectiveness for increased model symmetry (Table S7). The alternative model includes more paths and still wins by margins that exceed conventional thresholds⁴². The lower SRMR observed for the alternative causal pathway model (SRMR = 0.01 vs. 0.06) is consistent with this conclusion.

This suggests that individuals in our sample may be more likely to develop attitudes toward the instruments along the alternative causal pathway, a reversal of the dominant assumption in climate policy literature. All the mediation model results patterns reported here are mirrored when using the energy security effectiveness information treatments (see Supplementary Information Section 2, RQ1).

Fair design and effectiveness information matter—but not for those generally opposing climate policy

To answer whether general support for governmental intervention in public climate behavior, i.e., GCPS, moderates the relationship between climate policy design and acceptance (RQ2), we ran regressions with three cross-level interaction terms, one for each manipulated policy instrument feature dimension. Due to the nested design of our data, we employed cluster robust random effects regressions, allowing direct estimation of respondent-level variables while maintaining statistical efficiency (for further details, see ref. 43). Randomizing vignettes across respondents ensured independent experimental levels.

Moderation results are displayed in Fig. 4 and Tables S10, S12 and S13. Compared to the model with only respondent level characteristics (Wald $\chi^2(14) = 1290.24$, $p < 0.001$), i.e. controls and general climate policy support, the addition of the experimentally manipulated instrument features increases the explained instrument acceptance variance by 2.8 percentage points—indicating that, beyond respondent level characteristics, support is also shaped by policy instrument features, coinciding with the path analysis results above (Wald $\chi^2(19) = 1694.34$, $p < 0.001$). Including interaction terms further increases overall explained variance by 0.4 percentage points, and within-respondent variance increases by 1.2 percentage points (Wald $\chi^2(24) = 1774.53$, $p < 0.001$)—indicating that the magnitude of the policy

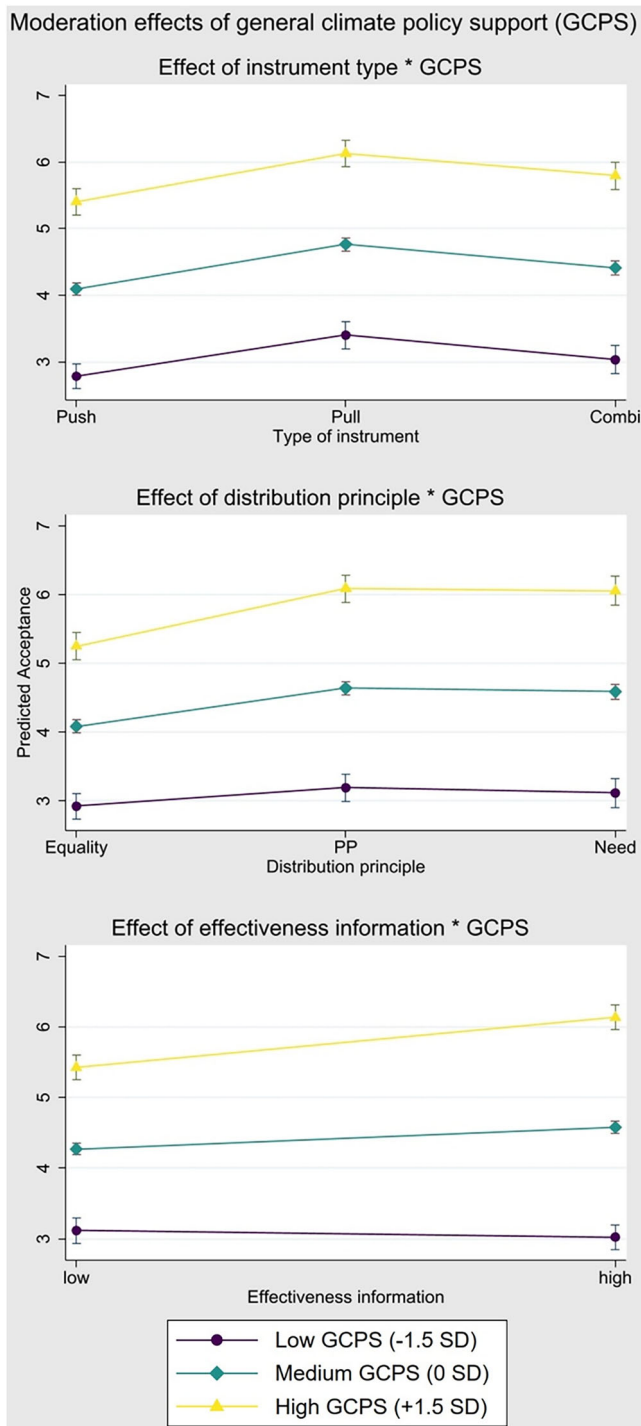


Fig. 4 | Predicted acceptance of climate policy instruments as a function of policy features and general climate policy support (GCPS). Marginal means are plotted for low (−1.5 SD), medium (0 SD), and high (1.5 SD) GCPS scores. Shaded areas represent 95% CIs. GCPS only moderates the effects of distributional principle and effectiveness information on acceptance, but not type of instrument. Designing climate policy instruments in accordance with proportional distributional principles (polluter-pays (PP) and need) rather than equal distribution increases acceptance more strongly when individuals generally support climate policy. We find the same moderating effect for the impact of providing high compared to low effectiveness information on acceptance.

instrument feature effects on support depends on individuals' GCPS. Regarding the main effects, pull instruments ($b = 0.669$, 95% CI = [0.54, 0.80], $z = 10.08$) and, to a lesser extent, combined push-pull approaches ($b = 0.318$, 95% CI = [0.19, 0.44], $z = 5.04$) receive higher support than push

instruments (all $p < 0.001$). Distributional principles based on proportionality (polluter-pays, $b = 0.553$, 95% CI = [0.43, 0.67], $z = 8.98$, and need, $b = 0.500$, 95% CI = [0.37, 0.63], $z = 7.37$) are more accepted than equality-based approaches (all $p < 0.001$). Communicating instruments with high compared to low effectiveness information also increases support ($b = 0.306$, 95% CI = [0.20, 0.41], $z = 5.81$, $p < 0.001$). Respondent-level general climate policy support (GCPS) expectably strongly predicts specific instruments' acceptance ($b = 0.616$, 95% CI = [0.48, 0.76], $z = 8.63$, $p < 0.001$). While the explained variances may appear small in absolute terms, the results nevertheless reflect meaningful theoretical nuances. That is, GCPS significantly moderates the effects of distribution principles, polluter-pays (interaction- $b = 0.190$, 95% CI = [0.07, 0.31], $z = 3.14$, $p = 0.002$) and need (interaction- $b = 0.204$, 95% CI = [0.07, 0.33], $z = 3.09$, $p = 0.002$) as well as effectiveness cues (interaction- $b = 0.266$, 95% CI = [0.16, 0.37], $z = 5.09$, $p < 0.001$), while the interaction between instrument type and GCPS was not statistically significant.

Simple slope analyses reveal a clear pattern. Among respondents with low GCPS, we found no credible evidence that either proportional distribution principles (polluter-pays and need) or higher effectiveness information meaningfully increased policy support. Among those with medium or high GCPS, the same design features substantially boosted support. The exact coefficients and p values at different GCPS levels are reported in Table S12, and significance tests for slope differences confirm this pattern (Table S13). The same moderation pattern emerges in the energy-security framing conditions (Supplementary Information Section 2, RQ2).

In summary, the positive effect of proportional distribution of instrument costs and benefits and high effectiveness information of specific policy instruments on their support depends on individuals' prior orientation toward climate policy. That is, low general support for climate action mostly nullifies their positive impact on acceptance, whereas they substantially increase support among those undecided or strongly generally in favor of climate policy. In contrast, we found no evidence that preferences for the presented instrument types depend on GCPS. These results highlight the need for targeted policy communication strategies.

Who shows which causal pathway—traditional or alternative? Exploratory analyses comparing different levels of general climate policy support

Building on our results, first showing that features of specific policy instruments may induce traditional and alternative causal pathways regarding the order of acceptance and perceived effectiveness, and second, that the effects of these policy features depend on GCPS, we raise the question: which causal pathways will individuals with different levels of general climate policy support exhibit? To answer this question, we ran multi-group path models allowing us to estimate and compare our traditional and alternative causal pathway mediation models from RQ1 across three groups simultaneously⁴⁴: general supporters (>0.5 SD in GCPS; 42% of our sample) and opponents of climate policy (< −0.5 SD in GCPS; 31% of our sample) as well as a neutral group—the undecided—who neither generally tend to endorse nor reject climate policy (≤ 0.5 SD and ≥ -0.5 SD in GCPS; 27% of our sample). The ± 0.5 SD cutoffs were chosen, first, because they yield three groups of relatively comparable, sufficient size, suitable for multi-group analysis. Second, they allow a meaningful distinction between the more committed tails of the GCPS distribution and the neutral middle, in line with recent work emphasizing the potential of the latter for climate policy feasibility⁴⁵. Due to the exploratory nature of these analyses, we did not constrain any parameters to be equal across groups. Again, all models were run with acceptance controls. Positive coefficients in the models again indicate the effect of switching from push to pull, from equality to polluter-pays or need, and from low to high effectiveness on a given outcome. To test whether the mediation effects (indirect effects) significantly differ between the groups, we conducted Wald tests⁴⁴. Figure 5 shows simplified mediation model results without depicting controls (for full models with controls, see Fig. S2).

For all groups, general climate policy supporters, opponents and the undecided, the *alternative causal pathway* seems to be at play (see right side

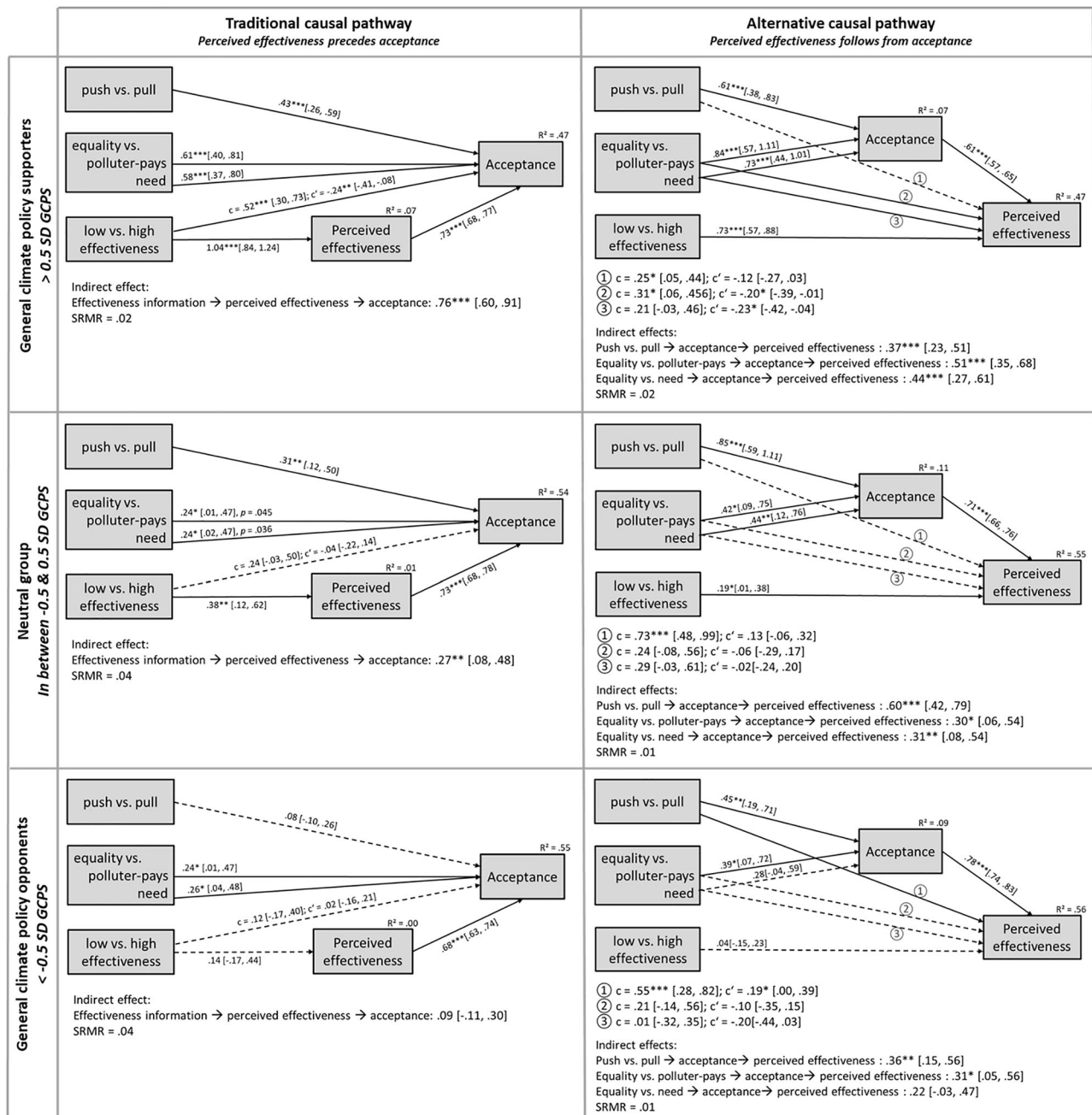


Fig. 5 | Traditional (effectiveness precedes acceptance; left-side models) and alternative causal pathway (effectiveness follows acceptance; right-side models) mediation models for general climate policy supporters (top models), a neutral group, i.e., the undecided (mid models), and opponents (bottom models). Distributional fairness principles were entered as dummy-coded variables indicating the effect of the proportional polluter-pays and need principles compared to the reference category of equality. Results indicate that the traditional pathway—where effectiveness information increases acceptance via higher perceived effectiveness—was not supported for general climate policy opponents. By contrast, the alternative

pathway—where more attractive instrument types and most distribution principles (i.e., except need-based instruments for opponents) increase perceived effectiveness via heightened support—applies to all groups. $N = 2448$ for all traditional and alternative causal pathway multi-group mediation models. General climate policy supporters are defined as those above 0.5 SD in GCPS (42% of the sample). The neutral group is those in between or equal to ± 0.5 SD GCPS. General climate policy opponents are defined as those below -0.5 SD in GCPS (31% of the sample). Dotted paths are non-significant at $p < 0.05$. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. See Fig. S2 for z-statistics and exact p values when $p > 0.001$.

models in Fig. 5): our data supports that perceived effectiveness follows from acceptance that in turn is influenced by type of instrument and fairness principle underlying the instrument. The sole exception to this rule is that for opponents, our data did not support that need-based instrument design increases perceived effectiveness via acceptance. Note that according to the formal comparisons of indirect effects, quasi all indirect effects are not statistically distinguishable from one another (see Table S14), which reinforces the notion that all groups behave similarly in the alternative pathway

model. As in the RQ1 mediation models above, RIDs show that the remaining significant direct effects of the experimental manipulations on effectiveness for supporters and opponents are overpowered by the indirect effects.

Regarding the *traditional causal pathway*, however, evidence was weaker among general climate policy opponents (see left side models in Fig. 5): our data supports that perceived effectiveness precedes acceptance and can be manipulated by high effectiveness information when individuals

generally support climate policy or if they are undecided. Yet, formal comparisons of the indirect effects indicate that they do not differ significantly between opponents and the undecided, while the indirect effect for supporters is significantly stronger than in both other groups (see Table S14). There, the magnitude of the indirect effect of effectiveness information on acceptance via perceived effectiveness compensates for the remaining direct effect.

As all groups show alternative causal pathways, and evidence for the traditional causal pathway was found among general climate policy supporters and the undecided, but not among opponents, these exploratory analyses reflect well why, in the whole-sample mediation models of RQ1, we found the alternative causal pathway model to be more appropriate for our data. Again, the same multi-group pathway models but with energy security effectiveness information yield nearly identical indirect effect result patterns (see Supplementary Information Section 2, Explorative analyses).

To summarize, our exploratory analyses suggest that, depending on how strongly individuals generally support climate policy, they exhibit different causal pathway mixes when developing effectiveness beliefs about and acceptance of specific climate policy instruments. While all groups show evidence of the alternative causal pathway and seem to at least partly derive their effectiveness beliefs from their positive or negative attitude toward the instrument, supporters and the undecided respond positively to effectiveness information. Thus, they show the traditional pathway because increasing effectiveness beliefs of specific instruments leads them to be more supportive of said instruments. Conversely, individuals who generally oppose climate policy, that is, they express no desire for governmental support in shaping climate-relevant public behaviors²⁷, appear less receptive to the intended effects of effectiveness information, both in terms of perceived effectiveness and acceptance.

Discussion

This study's results point toward limits of the dominant, linear assumption in climate policy research that citizens' acceptance of a policy instrument follows from their perception of its effectiveness^{6–10,15,17,20}. We were able to discern the traditional assumption that perceived effectiveness precedes acceptance and the alternative account that perceived effectiveness follows acceptance. Our findings hint at both causal pathways being at play. That is, perceived effectiveness might simultaneously precede and follow acceptance, suggesting a bidirectional relationship. Going beyond that, we suggest a conditional framework that reconciles the bulk of the literature which suggests the traditional straightforward causal chain from instrument features to effectiveness perceptions to support^{6–10,15,17,18} with contrarian positions^{23,24}. Our findings suggest a conditional reconciliation. The alternative, acceptance-driven pathway appears to be the more general mechanism, while the traditional, effectiveness-driven pathway is conditional on prior support. The plausibility of the alternative pathway as the more general mechanism rests on two arguments, beyond what can be inferred from better model fit (AIC, BIC; see Table S7). On the one hand, the effectiveness of the intervention increased acceptance only among policy supporters and the undecided, whereas a general causal mechanism would be expected to operate more consistently across prior-attitude groups. On the other hand, instrument type and fairness principles influenced perceived effectiveness without altering actual emission reduction capacity. The theoretical implications of this potential bidirectionality are significant, prompting a reevaluation of linear models of policy acceptance.

Our work extends research on the alternative pathway by showing that proportional distribution principles—specifically, both the polluter-pays and the need-based principle—generally drive acceptance and, subsequently, perceived effectiveness. This is to be highlighted because the polluter-pays principle is intuitively closer to emissions-related effectiveness than designing instruments according to the need-based principle; yet, in our study, the latter still produced a similar pattern of results. This strengthens the interpretation that individuals' stated beliefs follow already established preferences rather than a neutral assessment of facts—an insight central to theories of motivated reasoning^{46–48}, but underappreciated in

current frameworks and hypotheses regarding policy attitudes^{9,10}. Unlike fairness and personal benefit, which are more constrained by observable policy parameters, effectiveness perceptions are characterized by greater informational ambiguity, providing more space for such motivated construction. Effectiveness, in this view, is not just evaluated; it is constructed to be consistent with underlying judgments about a policy's fairness and its impact on the self. Future research should explicitly test whether these dynamics reflect intuitive versus deliberate information processing⁴⁹ and how such dual-process models can refine explanatory theories in the policy acceptance domain.

Furthermore, we contribute to the empirical basis for a recent integrative acceptance framework⁹ by investigating the proposed role of general support for governmental intervention in public climate change behaviors^{13,27}. We were largely able to confirm the moderating impact of this general climate policy support on the relationship between the features of a specific policy instrument and its acceptance. This finding helps explain the conditions under which policy instrument design matters. The moderating effect of general climate policy support is concentrated on cues that signal collective benefit, namely proportional distribution and effectiveness. These cues are significantly more persuasive for those already inclined to support political climate action and the undecided. One framework prediction was not supported by our data. We found no credible evidence that general climate policy support dampened the negative effect of policy intrusiveness (regulatory depth)¹³. This may reflect the limited intrusiveness range of our manipulation. Both push and pull measures are market-based (dis)incentives of comparable, above-average regulatory depth¹³, providing too narrow a contrast for the predicted buffering effect to emerge. Future studies should test this relationship across a wider intrusiveness range, from information interventions to bans and mandates²⁷.

Taken together, our results hint at an asymmetry in how citizens process policy information. All individuals' responses, be they generally supportive of climate policy, opposing it, or still undecided, are in line with the alternative causal pathway, indicating that effectiveness beliefs might be shaped, at least in part, by prior attitudes toward the instrument—consistent with attitude-congruent processing. However, only supporters and undecided individuals additionally align with the traditional pathway, suggesting they remain receptive to effectiveness information and update support accordingly. For opponents, the corresponding indirect effect was not statistically significant. This partly corroborates earlier findings that individuals who neither reflexively support nor oppose can be influenced by policy-qualities⁴⁵. However, this prior work offers a more fine-grained differentiation of this “middle”, suggesting that our undecided group likely conflates disengaged neutrals and persuadable conditionals—a distinction future research on policy information processing should address. Furthermore, our results are consistent with motivated reasoning operating across all groups, while openness to information about specific policy instruments seems to depend on prior general climate policy attitudes. Thus, we contribute to resolving the tension between large parts of the literature that posit the traditional pathway^{6–9,15,17,19,20} and alternative accounts^{23,24} by building on a crucial moderating individual disposition suggested in recent integrative acceptance frameworks^{9,27}. Future research should tackle the question of *why* these differences in information processing exist. Investigating whether this stems from mechanisms like identity-protective cognition⁵⁰ or variations in environmental attitudes⁵¹ could provide deeper insights. A promising avenue would be to experimentally test interventions aimed at strengthening general climate policy support, for instance, with value-based messaging⁵², and observe whether this enhances responsiveness to specific instrument design options.

Before we close, a number of this study's limitations need to be made explicit. Two limitations revolve around our focus on Germany's heating sector. On the one hand, using a national sample contests whether our conclusions are applicable across cultures. On the other, employing questions pertaining only to heating policy contest the straightforward generalizability to other domains, such as transport or agriculture. We believe, though, that our results provide at least meaningful hints at psychological

processes beyond the concrete focus of this study. First, because recent studies show considerable homogeneity in public support for climate policies across a set of developed countries^{21,24}, and second, because reviews of the literature on behavior determinants in climate-relevant domains find striking similarities^{30,53}, our German heating sector results can be considered as a microcosm of the larger politically driven decarbonization in WEIRD countries. Nevertheless, replication in different political contexts and across climate-relevant domains remains crucial to confirm generalizability. Another limitation stems from our study's design. Despite the experimental design, our interpretations of the order of perceived effectiveness and acceptance rest on cross-sectional mediation analysis, which cannot by itself establish causality⁵⁴. To validate the directional pathways and further strengthen internal validity, future studies could employ longitudinal designs, such as cross-lagged panel models, to discern whether and when effectiveness perceptions precede support over time. Additionally, future studies could leverage instrumental variable approaches (e.g., two-stage least squares) using experimental policy attributes as instruments under appropriate exclusion restrictions^{54,55} and combine SEM with directed acyclic graphs to formally clarify identification assumptions and distinguish between competing causal structures⁵⁶. Regarding effect sizes of the experimental conditions, while some are moderate in absolute magnitude, they are not unusually small in the context of factorial survey experiments using multi-point evaluative scales⁴³ and reveal theoretically meaningful differences in attitude formation. A design feature that may have anchored baseline perceptions and reduced variance in absolute evaluations is that all respondents were exposed to a common introduction, including information on policy goals and expected effects. However, as this was identical across conditions, it does not affect the internal validity of the estimated treatment effects. It is furthermore important to note that we deliberately draw on GEF and GEF-related aspects of the integrative policy acceptance framework. This focus does not capture the influence of social norms or second-order beliefs about peer attitudes, both well-documented determinants of climate policy support^{57–59}. How these social-cognitive determinants interact with perceived policy qualities remains an important question for future research. In the context of the integrative framework used, particularly with regard to the operationalization of GCPS, prior studies showed that this construct has some extent of domain specificity²⁷ that was not addressed by this study's items aiming generally at climate-relevant behavior. Future investigations could therefore complement this study's approach with assessments that pinpoint the desire for governmental intervention in the focal domain³⁵. Relatedly, our use of the term support with regard to the moderator and partly to refer to our main outcome acceptance represents a caveat. Neither the two-item operationalization of GCPS nor the single-item acceptance measure reflects a conative component necessary for support in the strict sense, and results are hence to be interpreted only with regard to passive evaluation¹. Lastly, our experimental setup and outcomes were deliberately kept simple. This is far from reality, where policies are embedded within policy mixes⁶⁰. For instance, with regards to financial instruments, features like revenue use are highly relevant^{61,62} and interact with other instrument-specific beliefs, such as perceived personal consequences and perceived fairness that in turn are linked to effectiveness perceptions and support^{11,17,19}. Future endeavors must therefore embed these psychological mechanisms within the complexity of real-world policy packages and consider a wider array of instrument-specific beliefs.

Despite these limitations, the practical implications of our findings for policymakers and communicators are profound and hint at the need to partly reconsider current strategies. Our findings qualify rather than overturn these strategies: effectiveness information remains effective in reinforcing supporters' and the undecided's commitment to policy and may help translate passive support into active backing, including for more intrusive instruments. However, it is less likely to sway general opponents of climate policy. Our data therefore challenges a uniform "effectiveness-first" approach in favor of an audience-conditional communication. Our results furthermore suggest that the sole "one-size fits all"—approaches that

increase support for opponents, supporters and the undecided alike might on the one hand be designing instruments in accordance with the polluter-pays principle. On the other hand, policy design and communication that leads with the mitigation of personal costs might also reach all groups—even opponents. In line with research that stresses the potential of communicating co-benefits of climate action to motivate the public regardless of belief structures⁶³, emphasizing other advantages of policy measures than their climate effectiveness builds the initial acceptance that, in turn, can foster more favorable perceptions of policy effectiveness among all groups. By contrast, communication leading with need-based fairness, like effectiveness information, gains traction primarily among supporters and the undecided. Relatedly, our findings have implications for the design and communication of policy mixes^{60,64}. Fairness-based design—particularly polluter-pays distribution—appears to enhance acceptance across supporters, undecided, and opponents alike, and may shape how broader policy mixes are perceived to work. Policymakers should therefore prioritize fairness cues across audiences, reserving effectiveness-based framing for already-supportive or undecided segments. Our results align with the sustainability principle that perceived social, economic, and environmental benefits serve both intrinsic and instrumental functions in policy support⁶⁴. In complex policy mixes, communicators should also counter the tendency to focus on costs and contradictions by making concrete benefits salient⁶⁰. In conclusion, our results imply that for climate policy instruments to be seen as effective by those inclined to generally oppose climate policy, it must first be accepted as fair and personally tenable. For this group, this turns the conventional communication logic on its head, urging policymakers to design for acceptance first, before communicating for effect.

Methods

Experimental setup

This study employed a $3 \times 3 \times 4$ factorial survey experiment (FSE) to assess how policy instrument design affects policy-specific beliefs and acceptance. The resulting 36 unique vignettes described financial instruments aimed at accelerating the adoption of low-carbon heating technologies in residential buildings through various (dis)incentivization mechanisms. Due to the climate policy focus of the present analysis, the main manuscript highlights vignettes emphasizing *climate* effectiveness (instrument effectiveness levels 1–2 below). Participants assigned to energy security conditions only (levels 3–4) are excluded from the focal analyses (also see sample description) and reported in the Supplementary Information Section 2. Prior to viewing the instrument descriptions, participants received information about national climate targets, energy security considerations, and the potential contribution of these instruments to both objectives through reduced fossil fuel consumption in the building sector. The experimental design systematically varied three key instrument characteristics hypothesized to influence acceptance and perceived effectiveness at the following levels (for exact wording, see Supplementary Information Section 3):

- (a) Instrument type (three levels):
 - (1) Push mechanism: heating costs increase when households use high-carbon heating technology.
 - (2) Pull mechanism: households switching to low-carbon heating technology receive a subsidy.
 - (3) Combined push-pull mechanism: simultaneous implementation of both incentive types.
- (b) Distributional principle (three levels):
 - (1) Equality: uniform cost increases or subsidies across all households, independent of energy consumption or income.
 - (2) Polluter-pays: cost increases and subsidies are dependent on per capita household energy consumption (higher consumption leading to greater costs and lower subsidies).
 - (3) Need-based: cost increases and subsidies are dependent on household income (lower income resulting in reduced costs and higher subsidies).

- (c) Instrument effectiveness (four levels; climate effectiveness levels 1–2 used in the main analysis; energy security levels 3–4 reported in Supplementary Information, Section 2):
- (1) High climate effectiveness: instrument described as strongly reducing fossil fuel consumption and making a substantial contribution to Germany's sectoral climate targets, according to the latest research.
 - (2) Low climate effectiveness: the instrument is described as moderately reducing fossil fuel consumption and making a small contribution to Germany's sectoral climate targets, according to the latest research.
 - (3) High energy security effectiveness: the instrument is described as strongly reducing fossil fuel consumption and substantially enhancing German energy security, according to the latest research.
 - (4) Low energy security effectiveness: the instrument is described as moderately reducing fossil fuel consumption, providing limited energy security benefits, according to the latest research.

Given the factorial design complexity, we implemented a D-efficient design⁴³ to optimize vignette selection, presenting each participant with three carefully selected vignettes rather than the full set. This approach maintains statistical power for estimating main effects and interactions while minimizing participant burden. To ensure logical consistency, we adjusted scenarios where combined push-pull mechanisms were paired with lower effectiveness ratings than single-mechanism approaches, replacing these with high effectiveness ratings for the corresponding outcome dimension. Table S21 in Supplementary Information provides the complete vignette sets, combinations, level assignments, and sample size per set.

Data collection

The FSE was conducted in October 2023 as a follow-up to a larger online survey⁶⁵ initially administered to a representative sample of German adult citizens by the professional survey company "forsa" (<https://www.forsa.de/>). Participants were randomly drawn from a broader nationally representative panel, *forsa.omninet*⁶⁶, comprising about 100,000 respondents at the time of data collection. Panel members are recruited by multistep random sampling using computer-assisted telephone interviews (CATI), and informed consent was obtained from all participants. The FSE was approved by the Research Institute for Sustainability's ethics committee, tested with 10 cognitive interviews, and piloted with 100 respondents before fielding it (10/2-10/13/2023). English and German versions of the survey are provided in Supplementary Information Section 3. The survey was sent to 6418 individuals. Response rates and exclusions were as follows: 1351 declined participation, 1205 did not complete the survey, 413 had missing values on key variables, and 192 were excluded for implausible completion times under 6 min (fastest 5% of respondents). This resulted in a final experimental sample of 3257 individuals. Of these, 678 individuals were assigned vignettes only focusing on energy security rather than climate targets (see Table S21, sets 3, 12, 17, 18, and 23), yielding a focal analytical sample of $n = 2579$. An overview of the samples characteristics is documented in Table S1. Both the full experimental and the focal analyses samples approximate the general population on several characteristics, while showing notable deviations in some categories. These include an underrepresentation of individuals aged 18–29 and respondents at the income extremes (below 60% and above 250% of median income). They overrepresent individuals with upper secondary education and respondents in the 150% to 250% median income bracket. The focal analytical sample closely resembles the full experimental sample, suggesting that sample exclusions did not substantially alter sample composition. Given the experimental design, we do not consider these differences a major threat to internal inference.

Procedure

The survey procedure was as follows: First, participants were greeted and informed about the aim and general context of the study. After participants

answered questions about their housing situation, property owners were asked whether they had already implemented energy-efficient building renovations (e.g., window or heating system upgrades) or were considering such renovations in the coming years. Subsequently, the experiment instructions were given. Participants received standardized instructions to ensure a clear understanding of the study context and the policy instruments under evaluation. Participants were told that a key strategy to achieve national climate targets involves reducing fossil fuel consumption, which depends strongly on the type of heating system used in private homes. To support the transition from fossil fuel-based heating systems to low-carbon alternatives, various potential policy instruments could be implemented. We proceeded by stating that a selection of these instruments will be presented, varying along the characteristics described above. Participants were instructed to carefully review the descriptions of each measure in the subset and evaluate them independently based on their current personal situation. Additionally, participants were informed that they could revise their evaluations of the previous measures using the back button if necessary.

Operationalizations

With each presented vignette, respondents rated each described instrument using a 9-point Likert scale regarding perceived effectiveness and acceptance, which were operationalized as follows:

Perceived effectiveness: when presented with effectiveness levels 1 and 2, participants rated the instrument's suitability for achieving climate targets in the private building sector. When presented with effectiveness levels 3 and 4, participants rated the instrument's suitability for contributing to energy security in Germany. Responses were given on a scale from 1 ("not suitable at all (−4)") to 9 ("extremely suitable (+4)"). Over all vignettes $M = 4.77$ and $SD = 2.28$.

Acceptance: participants were asked to indicate the extent to which they would support or oppose the implementation of the described instrument. This was measured on a scale from 1 ("strongly oppose (−4)") to 9 ("strongly support (+4)"). Over all vignettes $M = 4.42$ and $SD = 2.38$.

After the FSE-survey sections, participants responded to socio-demographic questions and other control variables such as party identification, climate concern, and the two items whose average operationalized general support for governmental intervention in climate-relevant behaviors, i.e., general climate policy support. Table S4 shows means and standard deviations of these respondent-level variables.

Several socio-demographic factors have been reported to influence climate policy acceptance, including gender, education, age, and income¹⁷. Education was assessed using 8 categories: 1 (no school diploma) to 8 (doctoral degree). Household net income was assessed using 10 categories ranging from 1 (less than 900 Euros) to 10 (more than 10,000 Euros).

Moreover, ideology and climate change evaluations have been found to be relevant to climate policy support¹⁷. As a proxy for ideology, party identification is elicited. To parsimoniously integrate this variable in the path analyses, we dichotomized it to reflect voting for the Greens (Bündnis90/Die Grünen), losing only 2.2% of the overall variance explained (see Tables S2 and S3).

As climate skeptics are a marginal group in Germany⁶⁷, we did not include a measure of climate change belief. However, concern over climate change was included as a parsimonious control that has been shown to be the most important climate change evaluation in a meta-analysis¹⁷. The item read "How worried are you about climate change" and was answered on a Likert scale from 1 (not worried at all) to 5 (extremely worried).

General climate policy support: participants first read the instructions, "There are different views on climate policy. Please indicate the extent to which you disagree or agree with each of the following statements". They then rated their agreement with two items on a 5-point Likert scale ranging from ("strongly disagree") to 5 ("strongly agree"): (1) "Legal guidelines and laws are needed to ensure that individuals do enough to protect the climate" and (2) "It should be up to each individual to decide whether and to what extent they do something to protect the climate" (reverse-coded). Responses were averaged to create a composite score, with higher values indicating

greater support for climate policy. The scale showed satisfactory internal consistency (Cronbach's $\alpha = 0.83$).

Statistical analysis

We ran all our models and calculations using STATA 16. For the mediation analyses, we employed path modeling with cluster robust standard errors. Cluster robust analyses were employed to account for the hierarchical structure of factorial survey data. To provide additional robustness to the mediation analysis, we ran the medsem package for STATA³⁷. With medsem, standard Sobel tests for indirect effect significance are supplemented by more appropriate Monte Carlo tests as well as the ratio of indirect effect to direct effect (RID) to better gauge the indirect effect importance when there is still a residual direct effect³⁷. For the moderation analyses, we ran cluster robust random effects regressions. Random effects regressions offer several key advantages: they allow direct estimation of respondent-level variable effects that would be unidentifiable in fixed effects models; they provide greater flexibility when examining multiple respondent characteristics simultaneously without encountering multicollinearity issues; and they leverage more statistical power by utilizing between-respondent variance, resulting in lower standard errors⁴³. Before conducting our analyses, we assessed whether the data were suitable for path analysis and regression. The factorial levels were virtually uncorrelated, and the variance inflation factors (VIFs) for all other predictors entered into the models were below 2. In all models, we controlled for the effect of age, gender, education, income, climate concern, and party identification on acceptance (see Table S4 for Means, SD, and correlations of the individual-level variables used in this study). All statistical significance tests were two-tailed.

Reporting summary

Further information on research design is available in the Nature Research Reporting Summary linked to this article.

Data availability

The survey data that support the findings of this study are available at: <https://osf.io/u8w6v>.

Code availability

The analysis code is available at: <https://osf.io/u8w6v>.

Received: 31 October 2025; Accepted: 24 August 2026;
Published online: 02 September 2026

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Acknowledgements

We thank Ellen Matthies for her advisory assistance.

Author contributions

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Funding

This research was funded by the German Ministry of Education and Research (Grant Ariadne – 03SFK5M0). Open Access funding enabled and organized by Projekt DEAL.

Competing interests

The authors declare no competing interests.

Additional information

Supplementary information The online version contains supplementary material available at <https://doi.org/10.1038/s44458-026-00149-0>.

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Peer review information *Communications Sustainability* thanks Michael Addaney and the other, anonymous, reviewer(s) for their contribution to the peer review of this work. Primary Handling Editor: Yann Benetreau. A peer review file is available.

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