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Co-dynamics of climate policy stringency and public support

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ABSTRACT

Public support for stringent climate policies is currently weak. We develop a model to study the dynamics of public support for climate policies. It comprises three interconnected modules: one calculates policy impacts; a second translates these into policy support mediated by social influence; and a third represents the regulator adapting policy stringency depending on public support. The model combines general-equilibrium and agent-based elements and is empirically grounded in a household survey, which allows quantifying policy support as a function of effectiveness, personal wellbeing and distributional effects. We apply our approach to compare two policy instruments, namely carbon taxation and performance standards, and identify intertemporal trajectories that meet the climate target and count on sufficient public support. Our results highlight the importance of social influence, opinion stability and income inequality for public support of climate policies. Our model predicts that carbon taxation consistently generates more public support than standards. Finally, we show that under moderate social influence and income inequality, an increasing carbon tax trajectory combined with progressive revenue redistribution receives the highest average public support over time.

1. Introduction

To mitigate climate change, countries need to implement stringent policies. But public support for such policies is weak (Anderson et al., 2017; Klenert et al., 2018; Levi et al., 2020). It moreover tends to decrease with stringency (Lachapelle and Paterson, 2013; Carattini et al., 2017; Beiser-McGrath and Bernauer, 2019). Public opinion affects the feasibility of effective climate policy in various ways: through general elections, illustrated by a repeal of carbon pricing in Australia (Crowley, 2017); through direct referenda, illustrated by rejections of carbon taxes in Washington State (USA) (Reed et al., 2019); and through social movements, illustrated by the 2018 Yellow Vest protests in France against a fuel tax with a carbon component (Douenne and Fabre, 2020). On the other hand, experiences such as with the carbon tax in British Columbia, Canada show that favourable public opinion and increasing policy ambition can also go hand in hand (Murray and Rivers, 2015).

To achieve sufficiently strong policies that can count on critical public support, we propose a new approach to study climate policy. It treats climate policy design as dynamic and endogenous on policy support. The idea is that a policy can be implemented only if public support for the current design exceeds a critical threshold. Our approach deviates from the conventional economic approach to identify optimal policy trajectories in that welfare impact is not the dominant criterion (Hänsel et al., 2020) but only one among several factors that influences policy design.

Given the extent of emissions reduction required, it is questionable to focus on a theoretically ideal carbon tax that has little chance of being implemented under actual political circumstances (Goulder, 2020). Once policymakers have committed to a climate mitigation goal, their objective is no longer to maximize welfare but to implement effective policies under acceptability constraints. In view of these considerations, we offer a method to identify a politically more realistic perspective on climate policy design. It consists of a model, called GE-ABM, with three modules to describe the interconnection between public opinion and climate policy stringency, and study the political feasibility of climate policy, focusing on carbon taxation with several revenue use options and performance standards. The first module is a simple general equilibrium model (GE) that is derived from the climate economics literature (Klenert et al., 2018; Jacobs and van der Ploeg, 2019). The second module is an agent-based model (ABM) to capture the social interactions that

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underlie opinion dynamics regarding policy support. In each period, the (change in) stringency of the policy depends on the prevailing public opinion, giving rise to interactive dynamics of policy support and policy design in a third module.

We model public opinion as depending on policy performance in terms of economic, environmental and equity impacts. This choice is motivated by earlier empirical studies showing that public acceptability of carbon taxes is mediated by perceptions of effectiveness and fairness (Maestre-Andrés et al., 2019), where the latter is further distinguished into individual fairness, i.e. focused on personal wellbeing, and distributional fairness, comprising distribution of costs and benefits among all agents (Dreyer and Walker, 2013; Kim et al., 2013; Clayton, 2018).

A major challenge for public support of carbon taxation is the misperception of the economic effects of taxation. People consistently overestimate its costs and underestimate its effectiveness (Douenne and Fabre, 2022). The main assumption of the model is that when a policy is implemented, people learn and gradually adjust their perceptions until they match the actual effects. The model then predicts which policy trajectories and revenue uses allow achieving a predetermined mitigation target while ensuring sufficient public support over time. In addition, we investigate the impact of opinion stability and social influence dynamics on the public support of distinct policy trajectories. Finally, we study the role of underlying income inequality in obtaining critical public support for climate policies.

Our study contributes to the literature on design and public support of climate policies. While several papers recognize that public support for climate policy is dependent on dynamic factors (Drews and van den Bergh, 2016; Beiser-McGrath and Bernauer, 2019; Maestre-Andrés et al., 2019; Douenne and Fabre, 2022; Bergquist et al., 2020; Sommer et al., 2020; Douenne and Fabre, 2020; Carlsson et al., 2021), this has not translated into studies that systematically investigate co-dynamics of policy design and support. This is understandable as it requires an integration of policy design, economic impact assessment and public-support analysis – which tend to be studied in separate disciplines. An exception is a game-theoretic study that examined how firms form lobbies that influence the stringency of government's emission reduction policies (Isley et al., 2015). Another study developed a simple framework to describe feedback from public opinion to environmental problems through environmental policy and then back to public opinion (van den Bergh et al., 2019). Here we provide a richer and arguably more realistic and flexible approach that can identify policy trajectories meeting emissions reduction targets and maximizing public support, by accounting for its components, namely wellbeing and equity. The GE-ABM allows to represent the labour and goods market in a tractable way while identifying economic impacts on heterogeneous households and providing detailed information about individual support for the policy (Castro et al., 2020; Niamir et al., 2020). Using GE-ABM in this way represents a novel approach that enriches the literature on policy acceptability, which traditionally relies on survey and experimental methods (Carattini et al., 2018; Maestre-Andrés et al., 2019; Bechtel et al., 2020). Conceptually, our approach shares some characteristics with so-called "robust decision-making" (Hall et al., 2012), which suggests to sacrifice some economic efficiency to reduce the probability of adverse climatic events. Our model instead suggests to sacrifice economic efficiency to increase the likelihood of public support for climate policy.

Several studies have shown that environmental and climate policies have potential inequitable impacts, undermining their acceptability. Our model assumes that households require a minimal consumption level of the high-carbon good, reflecting the empirical regularity that low-income households spend a larger share of their income on carbon-intensive subsistence goods (Klenert and Mattauch, 2016; Oswald et al., 2020). As a result, carbon taxes absent of revenue recycling, as well as performance standards, have regressive distributional impacts, meaning that they place a relatively high burden on low-income households (Levinson, 2018; Pizer and Sexton, 2019). However, the use of carbon-tax revenues can compensate for regressive effects (Grainger and Kolstad, 2010; Klenert and Mattauch, 2016; Goulder et al., 2019; Aubert and Chiroleu-Assouline, 2019), which has been shown to critically affect public opinion (Beiser-McGrath and Bernauer, 2019; Savin et al., 2020). For this reason, we devote attention to different revenue uses in our analysis, and show that the impact of regressive distributional effects on policy acceptability is closely linked to the features of the social network in which agents interact.

Our paper further adds insights to the literature studying the interaction between climate policy and behavioural economics. Following research showing that the social environment affects agents' decisions (Elster, 1989; Bowles, 1998; Mailath and Postlewaite, 2010; Hoff and Stiglitz, 2016), many authors have argued that social interactions should be taken into account when designing policy instruments addressing labour market and saving decisions (Lindbeck, 1997), public good contribution (Bénabou and Tirole, 2006; Meunier and Schumacher, 2020), energy conservation (Allcott, 2011), or environmental externalities (Nyborg, 2018; Ulph and Ulph, 2018; Konc et al., 2021). These contributions analyze how the introduction of social interactions changes what constitutes an optimal policy. We add to this literature by studying the role of social influence for the acceptability and implementation of desirable policy instruments. Our model reflects that interactions with peers and behavioural biases play a significant role to shape political opinion and voting decisions (Bond et al., 2012; Muchnik et al., 2013; Levine and Mattozzi, 2020). In particular, Braha and Aguiar (2017) show that social influence has a growing importance to explain the results of U.S. presidential elections, which could be linked to the emergence of large digital social networks. We integrate these insights in our study and model the acceptability of climate policies as dependent on the political opinion of agents who influence each other.

Our results indicate that carbon taxation is more likely to achieve a wider public support than performance standards, assuming that policy

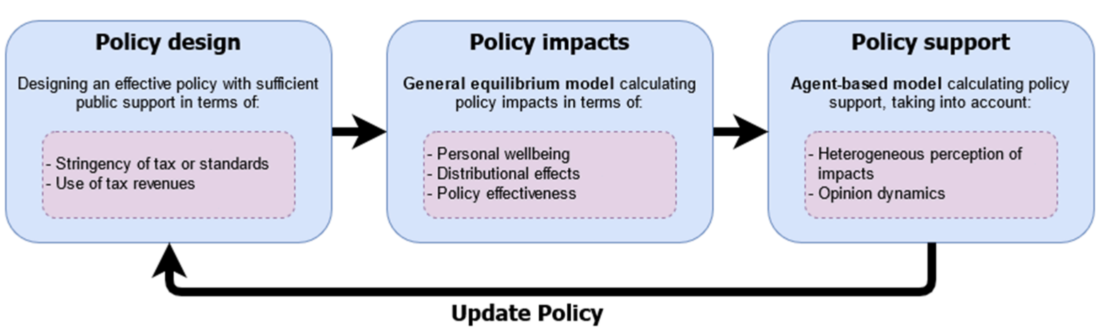


Fig. 1. A schematic representation of the three modules, which can be seen as a timeline of events in our model, repeated for a pre-specified number of periods (years). The impacts of a specific policy design are calculated with a general-equilibrium model. These impacts determine the support for climate policy, assessed with an agent-based model, which in turn affects the policy design for the subsequent period.

impacts are perceived accurately by the agents. Unlike standards, carbon taxation generates revenue that can increase public support if it is used to reduce inequality. We argue that because of likely initial misperception of effects, climate policies are best designed to ensure a high public support during the first periods of implementation We further show that social interactions help generating public support for policies that are beneficial for well-connected individuals. Finally, we demonstrate that a higher income inequality has an ambiguous effect on public support for progressive climate policies. On the one hand, higher income inequality implies that redistributive policies will have a more positive distributional effect, hence increasing the support for such policies. On the other hand, given that social influence tends to increase with income, higher income inequality means that richer agents increase their influence on the opinion of other agents. Since high-income earners do not benefit from progressive climate policies, high income inequality can substantially diminish public support for policies with positive distributional impacts.

The remainder of this article is organized as follows. Section 2 describes the model and its three modules, namely the policy-setting module, policy-impact module and policy-support module. Section 3 contains the empirical parametrization. Section 4 presents numerical simulations to identify effective and acceptable climate policies and discusses the role of distributional impacts, opinion dynamics and income inequality. Section 5 concludes, discusses policy implications and suggests directions for further research.

2. A model of dynamic public support for climate policy

The model consists of three modules to determine emissions and economic impacts, public support, and changes in the policy stringency, as illustrated in Fig. 1:

1. A policy-design module initiates and adapts the policy design (see Section 2.1). It evaluates the policy in place based on the policy support. If more than half of the agents supports the policy, consistent with the widely practiced democratic majority rule, it is strengthened; if not, its stringency remains the same.
2. A policy-impact module using a general-equilibrium model calculates emissions reduction and distribution of wellbeing effects among households in accordance with the policy setting in the policy-design module affecting the consumption of low- and high-carbon goods and services (see Section 2.2). The general-equilibrium nature of the model allows accounting for labour and goods market dynamics that underlie the ultimate policy effects.
3. A policy-support module uses the indicators generated by the policy-impact module to update opinions of households. To this end, we use an agent-based model (see Section 2.3). This takes into account personal weights assigned by individuals to each impact indicator, which depend on their political views. Through interactions in a social network, individual agents then exchange opinions until these converge to a steady-state.

The approach is empirically operationalized for the case of Spain. As described in Section 3, this involves use of results from a recent public opinion survey (Maestre-Andrés et al., 2021) to calibrate how effectiveness, personal wellbeing and distributional effects influence policy support, as well as how people share their opinion about the policy in a social network. We further calibrate the policy-impact module using Spanish national statistics, notably to reproduce the observed productivity growth and income inequality. Because we do not model the Spanish energy sector, we rely on a stylized calibration of the marginal abatement costs, and we abstain from interpreting the absolute values of the tax or standards. We instead focus on the qualitative results by comparing different policies and studying their temporal trajectories.

2.1. Policy-design module

The policy-design module works as follows. The objective of the policy is to keep greenhouse gas (GHG) emissions within a carbon budget consistent with the 2030 mitigation target of the Spanish government. In particular, Spain has the objective to decrease carbon dioxide equivalent emissions by 47% with respect to 2017 levels (Spanish Congress, 2019). Assuming that emissions decrease at a constant rate, this target defines a trajectory of emissions with a mitigation rate of approximately 5% per year to achieve the required emissions reduction. We model two widely used policies, namely carbon taxation and performance standards. A carbon tax is a pricing instrument that directly affects the production costs of high-carbon goods. A performance standard is a non-price instrument that fixes a certain intensity of emissions on the production of goods, which is used to regulate the transportation or energy sectors, e.g. the European Emission Standards, the Corporate Average Fuel Economy and Clean Energy standards in the U.S., or the various white certificates schemes. An important difference between the two policies is that a tax generates revenue that can be used in a variety of ways, among which we consider three types:

1. Return the revenue through progressive transfers that favour poorer households (labelled hereafter as *progressive*).
2. Return the revenues proportionally to household income, i.e., through a reduction of income taxes (*labour tax reduction*).
3. Fund projects that reduce GHG emissions (*green spending*).

For details on how revenue uses are implemented in the model, see Section 2.2.

The policy-maker sets an initial stringency τ_0 for either a tax or the performance standard. Adaptation of the stringency level then depends on the policy support. If more than 50% of the population supports the policy at the end of a period, consistent with a political majority-voting rule, the stringency is increased. This is implemented in the model by setting a fixed growth rate, $\rho : \tau_{t+1} = \tau_t(1 + \rho)$. Assuming that the stringency increases over time at a fixed rate is consistent with what we see already in various countries – notably Sweden, Argentina, Canada (British Columbia) and South Africa (Ramstein et al., 2019). If public support for the current policy design is less or equal the support threshold (50%), then the stringency remains unaltered: $\tau_{t+1} = \tau_t$. Implicitly, we assume that the stringency cannot decrease even if public support is very low. This is in line with the case of France where in response to public resistance the carbon tax was halted but not reduced (Criqui et al., 2019). A complementary argument is that gradually strengthening policy would avoid a "shock therapy" for the economy (Pahle et al., 2018), which would also contribute to stabilize policy support. The policy goal differs from traditional analysis in public economics, which seeks to identify welfare-maximizing climate policy trajectories. Our approach can be seen as more realistic in the sense that governments do not necessarily pursue optimal policies but ones that are feasible to implement given public support.

2.2. Policy-impact module

The policy-impact module relies on a general equilibrium model, which features two firms that produce either a low- or a high-carbon consumption good. Households then decide about their labour supply and how to allocate their budget between the two consumption goods. They require a minimal consumption level of the high-carbon good, reflecting the empirical regularity that low-income households spend a larger share of their income on carbon-intensive subsistence goods (Klenert and Mattauch, 2016; Oswald et al., 2020).

In line with previous modelling studies (Klenert et al., 2018), we model two representative profit-maximizing firms by a Cobb-Douglas production function with labour, L, and energy input, E. One firm produces the low-carbon – or clean– good, C, and the other the high-carbon

– or dirty– one, D. Firms buy labour from the agents at the market wage, w. Without loss of generality, we assume that the clean energy input has a zero carbon intensity. GHG emissions G_t are linear in the use of the carbon intensive input, $G_t \equiv \kappa E_{D,t}$. The carbon tax, τ_D, increases costs of the carbon-intensive energy input, E_D. Firms sell their good at the market price, p_j. The firms' profit maximization problem at time t can then be formally described as:

$$\max_{L_{j,t},E_{j,t}} F\left(L_{j,t},E_{j,t}\right)p_{j,t} - E_{j,t}\left(q_{j,t}+\tau_{j,t}\right) - L_{j,t}w_t \forall j \in \left[C,D\right]$$
$$\text{with } F\left(L_{j,t},E_{j,t}\right) \equiv A_t L_{j,t}^{\alpha} E_{j,t}^{\zeta}$$

Here, $q_{j,t}$ is the price of the energy input and A_t is the total factor productivity. The first-order conditions of the firms problem are:

$$\alpha A_t L_{j,t}^{\alpha-1} E_{j,t}^{\zeta} = w \forall j \in \left[C,D\right] \tag{1}$$

$$\zeta A_t L_{j,t}^{\alpha} E_{j,t}^{\zeta-1} = q_{j,t} + \tau_{j,t} \forall j \in \left[C,D\right] \tag{2}$$

Agents are heterogeneous in terms of productivity, which translates into heterogeneous income for workers. We introduce a minimal consumption level of the high-carbon good, $\overline{D}$ (known as Stone-Geary preferences), to reflect that low-income households spend a larger share of their income on carbon-intensive basic goods, such as food and heating. Agent $i \in N$ maximizes its welfare in each period, subject to a budget constraint, formalized as:

$$\max_{D_{i,t},C_{i,t},L_{i_t}} U_{i,t}\left(D_{i,t},C_{i,t},L_{i,t}\right) \equiv \left(D_{i,t}-\overline{D}\right)^{\sigma} C_{i,t}^{\eta}\left(1-L_{i,t}\right)^{1-\sigma-\eta}$$
$$\text{s.t. } D_{i,t}\left(p_{D,t}-\tau_S\right) + C_{i,t}\left(p_{C,t}-\tau_S\right) \leqslant \phi_i w_t L_{i,t}\left(1-\tau_{L,t}\right) + b_{i,t}$$

Here σ and η represent the utility weights of the high- and low-carbon goods, respectively, ϕ_i the productivity of agent i, $(1-L_i)$ the leisure time, τ_L the labour tax and b_i potential direct transfers (based on carbon-tax revenues) to agent i. The income of agent i is therefore equal to $\phi_i w_t L_{i,t}(1-\tau_{L,t}) + b_{i,t}$. We model performance standards as a tax on carbon-intensive inputs and a subsidy on output, τ_S (Goulder et al., 2016). The first-order conditions of the households problem are:

$$\frac{\sigma\left(1-L_{i,t}\right)}{\left(1-\sigma-\eta\right)D_{i,t}} = \frac{p_{D,t}}{\phi_i w_t\left(1-\tau_{L,t}\right)} \forall i \in N \tag{3}$$

$$\frac{\sigma C_{i,t}}{\eta D_{i,t}} = \frac{p_{D,t}}{p_{C,t}} \forall i \in N \tag{4}$$

$$D_{i,t}p_{D,t} + C_{i,t}p_{C,t} = \phi_i w_t L_{i,t}\left(1-\tau_{La,t}\right) + b_{i,t} \forall i \in N \tag{5}$$

Finally, we impose equilibrium conditions on supply and demand for the goods and labour, and on the government budget:

$$F\left(L_{D,t},E_{D,t}\right) = \sum_{i\in N} D_{i,t} \tag{6}$$

$$F\left(L_{C,t},E_{C,t}\right) = \sum_{i\in N} C_{i,t} \tag{7}$$

$$L_{D,t} + L_{C,t} = \sum_{i\in N} \phi_i L_{i,t} \tag{8}$$

$$E_{D,t}\tau_{D,t} + \sum_{i\in N} \tau_{S,t}\left(D_{i,t}+C_{i,t}\right) + \phi_i w_t \tau_{L,t} - b_{i,t} = 0 \tag{9}$$

We use the fact that Stone-Geary utility functions have a Gorman polar form (Jacobs and van der Ploeg, 2019) and solve the model defined by Eqs. (1)–(9) for a representative household with productivity $\overline{\phi} = \sum_{i\in N}\phi_i$. The distribution of consumption among households is determined ex post by the distribution of productivity. We find the equilibrium prices and wage as well as the equilibrium consumption of the two goods, denoted by $D_{i,t}^{\star}$ and $C_{i,t}^{\star}$. In addition, we use the notation $V_{i,t} \equiv U_{i,t}(D_{i,t}^{\star}, C_{i,t}^{\star})$ to express the indirect utility (or wellbeing) of agent i in period t.

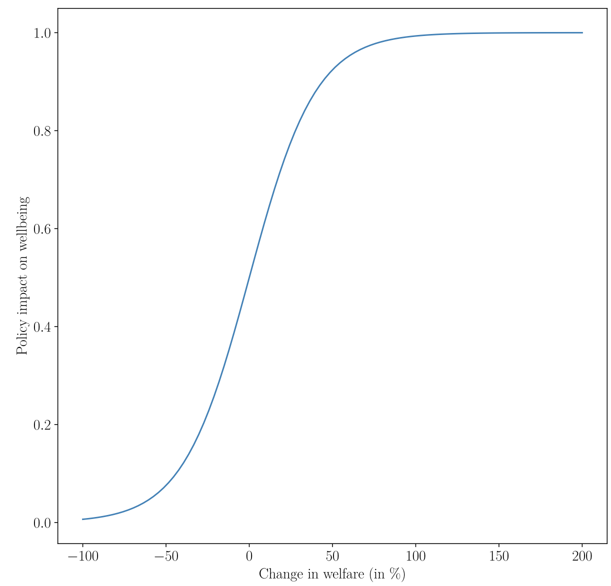


Fig. 2. Relation between the policy impact on wellbeing indicator and the relative change of individual welfare due to the policy.

Implementing performance standards and a tax combined with a reduction in labour taxes is straightforward. Abatement through green spending is assumed to cost 40 Euros per avoided ton of yearly CO2 emission (Gillingham and Stock, 2018). Finally, modelling a progressive redistribution of tax revenues through direct transfers is more ambiguous, since the redistribution scheme can be made more or less favourable to low-income households (see Appendix). For the sake of simplicity and comparability with other model studies, we assume that progressive redistribution takes the form of equal transfers to all agents.

We parametrize the economic model to match the income distribution and carbon intensity of production in Spain (National Statistical Office of Spain, 2020), and recent estimates of the social cost of carbon by integrated assessment models (Metcalf and Stock, 2017; Quinet, 2019; Kaufman et al., 2020). In line with empirical estimates, we set the minimal consumption level of the high-carbon good such that a doubling in income corresponds to an increase in emissions of 70% (Büchs and Schnepf, 2013). As a result, low-income households have a more carbon-intensive consumption basket than high-income ones, even though they emit less in absolute terms. This implies that low-income households will experience a higher relative wellbeing loss from the carbon tax.

The module generates three indicators of policy impact: (1) personal wellbeing W_i, defined as the welfare variation due to the policy; (2) distributional effects Q_i defined as the change in the Gini coefficient of the welfare distribution M due to the policy; and (3) policy effectiveness E_i, defined as the ratio of the remaining annual carbon budget $B_t \equiv \frac{\text{initialbudget}-\sum_{k=1}^{t} G_k}{T_{final}-t}$ and the current level of emissions G_t. W_i is heterogeneous across households. Q_i and E_i are also indexed by i as they may account for potential heterogeneity in people's perceptions about distributional effects and effectiveness. Yet, we assume that everyone has access to the same information about the effects of the policy so that Q_i and E_i are the same across individuals. While one could assume diversity among agents in terms of information access and interpretation, the approach we follow seems a logical starting point for a first study of this kind.

Each indicator is normalized between 0 and 1, by capping E at 1 and transforming W and Q with a logistic function. A value 0 indicates the worst outcome and 1 the best. Following the findings in behavioural

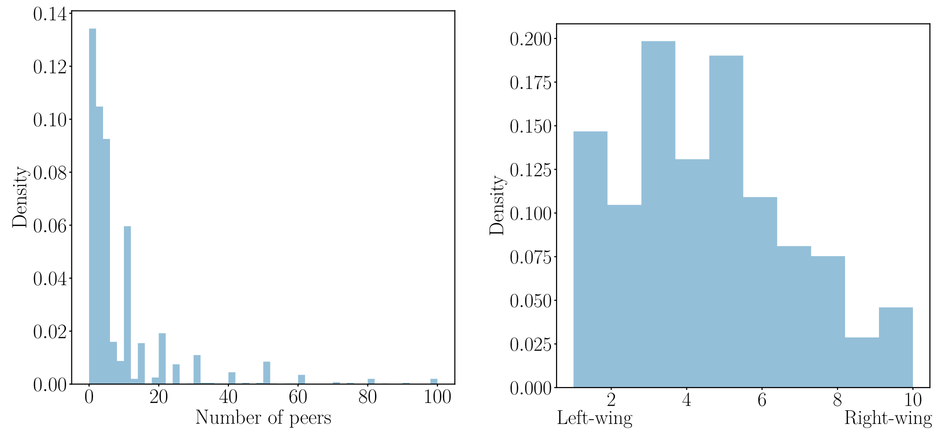


Fig. 3. Distributions of number of peers and political ideology.

economics about the perceptions of gains and losses (Kahneman and Tversky, 1979), we assume that personal wellbeing and distributional effects are concave in gains and convex in losses, and formulate the indicators using a logistic function (Eqs. 10 and 11). If an agent's welfare or the welfare distribution are unchanged by the policy, the indicators equal 0.5 (see Fig. 2). We set the steepness parameter of the logistic function to $a = 0.2$, so that the indicators converge to 0 as the change in welfare or inequality approaches -100%. Finally, effectiveness is defined as the completion of the climate target. It is maximal if the emissions at time t (G_t) are smaller or equal than the annual remaining carbon budget (B_t), and below 1 if they exceed it (Eq. 12).

$$W_{i,t} = \frac{1}{1 + exp\left(a\frac{V_{i,t} - Vli,0}{V_{i,0}}\right)} \tag{10}$$

$$Q_{i,t} = \frac{1}{1 + exp\left(a\frac{M_t - M_0}{M_0}\right)} \tag{11}$$

$$E_{i,t} = \begin{cases} \dfrac{B_t}{G_t} & \text{if}\ \dfrac{B_t}{G_t} \in \left[0, 1\right] \\ 1 & \text{if}\ \dfrac{B_t}{G_t} > 1. \end{cases} \tag{12}$$

2.3. Policy-support module

The policy-support module uses an agent-based model (ABM) to represent heterogeneous, dynamic and interactive opinions about the policy. ABMs are flexible tools which allow to depart from traditional assumptions about representative and socially isolated agents, namely by describing a population of heterogeneous agents with a wide range of possible behaviours and interactions (Castro et al., 2020). We parametrize the module using empirical data from a survey conducted among the population of Spain in August 2019 through a web-based questionnaire (see Section 3). The intrinsic opinions of agents in the model depend on the impacts of the policy and political orientation. This is motivated by ample evidence that political views strongly correlate with attitudes to climate change and climate policy (McCright et al., 2016; Cruz, 2017). The module reflects that evaluating public support is more complex than merely assessing the impacts of a policy, by recognizing that an agent is influenced by opinions of its peers in a social network. We assume that agents are more influenced by opinions of peers that share a similar political stance. Overall public support for climate policy depends on the ability of agents who (do not) support it to influence other agents into supporting (rejecting) it. We also address opinion stability. We assume that agents imperfectly learn about the actual effects of climate policy and are resistant to change their initial support about the policy, in line with evidence from psychology (Howe and Krosnick, 2017) and demonstrated by research on carbon-tax perceptions (Douenne and Fabre, 2022). This feature of opinion dynamics may have been at work in the case of carbon pricing in Australia, where opinions have remained relatively stable despite public debate about the policy (Dreyer et al., 2015).

Table 2
Regression Table

Dependent Variable: Policy opinion	
Independent Variables	**OLS**
Personal wellbeing effects	0.365***
	(0.018)
Distributional effects	0.205***
	(0.014)
Effectiveness	0.511***
	(0.013)
Personal wellbeing × Political ideology	0.008**
	(0.003)
Distributional effects × Political ideology	−0.005*
	(0.003)
Effectiveness × Political ideology	−0.011***
	(0.003)
N	2004
R^2	0.902

***$p < 0.01$, *$p < 0.05$, $p < 0.1$

We estimate the intrinsic opinion on climate policy based on the three indicators from the policy-impact module: personal wellbeing, distributional effects and effectiveness. The relative importance of these factors depends on political ideology I_i of the agents. The empirical value of political ideology is assessed by the survey (see Fig. 3 in Section 3) and lies in the interval [1,10], with 1 denoting far-left and 10 far-right. The intrinsic opinion of climate policy in the absence of social influence is calculated as follows:

$$PO_{i,t} = \left(\beta_1 + \beta_4 I_i\right) W_{i,t} + \left(\beta_2 + \beta_5 I_i\right) Q_{i,t} + \left(\beta_3 + \beta_6 I_i\right) E_{i,t} \tag{13}$$

The weights β are obtained by means of an econometric estimation of Eq. (13). From the data, we obtain $\beta_4 > 0, \beta_5 < 0$, and $\beta_6 < 0$, which means that agents with a right-wing political ideology put a higher than average weight on personal wellbeing and lower than average weights on effectiveness and distributive effects, while the opposite holds true for left-wing agents. The estimated coefficients are reported in Table 2 in Section 3.

We need to make several assumptions to estimate the intrinsic opinion function. The survey only provides information about the perception of hypothetical policies. We assume that the difference between hypothetical and real-life policies is small, such that it is reasonable to use the estimates provided by the survey as weights for actual policy support. Our method also assumes that people's assessment of climate policy is driven by objective information through observable indicators. In reality, a difference between objective and perceived effects could arise, for example, due to media outlets reporting biased news or people not being able or willing to observe all relevant information. Despite this limitation, we think it is reasonable to assume that there is a correlation between the objective effects of climate policies and their perception by the public (see Appendix).

Next, the initial opinion of an agent is subjected to social influence. We represent social interactions as a similarity-biased process, where individuals give a higher weight to the opinion of peers with similar political views.

The social interactions influence policy opinion in the following manner (Konc and Savin, 2019):

$$SO_{i,t} = (1-\gamma)PO_{i,t} + \gamma \frac{\sum_{j \in N_i} \theta_{i,j} PO_{j,t}}{\sum_{j \in N_i} \theta_{i,j}} \tag{14}$$

$$\theta_{i,j} = exp\left(-\left|I_i - I_j\right|\right)$$

Here $SO_{i,t}$ is the current opinion of the policy, N_i is the set of peers in the social network of agent i, and $\theta_{i,j}$ is the measure of ideological similarity between the agent i and its peers. The parameter $\gamma \in [0,1]$ captures the weight of social influence in an individual's opinion formation. Note that Eq. (14) defines a steady state, denoting the state after repeated social interactions when no further change in policy acceptability is observed. We parametrize the social network in line with the household survey (see Section 3 for details). According to it, richer households tend to have more social peers and thus exert more social influence. Assuming that affluent agents have a higher political influence better represents feasibility constraints. It is reminiscent of studies showing that richer agents have more lobbying power to influence certain policy scenarios (Gilens and Page, 2014; Isley et al., 2015; Berthe and Elie, 2015).

Finally, we assume that agents are resistant to changing their initial support about the policy. The support of agent i for the policy implemented at time t is:

$$S_{i,t} = \delta S_{i,t-1} + (1-\delta)SO_{i,t} \tag{15}$$

with δ the weight of the opinion in the previous period. The opinion $S_{i,t}$ takes values in the interval [0,1]. We assume that the policy has sufficient public support if the median support is above 0.6, in line with the majority-voting rule. The value above of 0.6 corresponds to the response "somewhat acceptable" of the 5-point Likert scale we use to parametrize the model, see Section 3. The initial support $S_{i,0}$ is calibrated on the survey data. It means that in our model the initial opinion of climate policy can be biased by inaccurate perceptions. We assume that the effects of policies reduce the initial bias at the rate δ.

3. Parametrization

Our model uses empirical data from a survey conducted among the population of Spain in August 2019 through a web-based questionnaire (Maestre-Andrés et al., 2021). The sample of citizens was restricted to individuals over 18 years old. The survey had 2004 completed responses (response rate 59%) obtained using a quota sampling technique representative of the Spanish population in terms of age, gender and geographical location. Respondents were first asked to evaluate the effects of a climate policy and then to rate their acceptability of it. The survey data include respondents' perception about the effectiveness, and how they consider the carbon tax may affect them personally (personal wellbeing) and low-income households in general (distributional effects). They could respond on 5-point Likert scales, ranging from "completely ineffective/unacceptable" to "completely effective/acceptable" in the case of the first set of questions and from "I would be much worse off/ they would be much worse off" to "I would be much better off/ they would be much better off" in the case of the second set of questions (see Table 1). From this information we derive the weights of personal wellbeing effects, distributional effects and policy effectiveness in the support of climate policies (see Eq. 13). We normalize the weights in Table 2 so that PO_i always lies in the interval [0,1].

We also derive from the survey the characteristics of the opinion social network. To this end, we use responses to the survey question "With how many of [your peers] do you talk about climate change or climate policy? You can enter a value between 0 and 100." The resulting network has an average degree of 8 and resembles a "scale free" topology, with a highly asymmetric degree distribution where few so-called 'star agents' have a high number of peers and the majority of other agents have few connections (Fig. 3). The survey further shows a positive correlation (0.10) between income and the number of peers. We reproduce this feature in our model, which implies that wealthier citizens tend to be more central in social networks (Fafchamps and Gubert, 2007).

Table 1
Correspondence between survey questions and modelled variables

Variables	Survey question	Measurement	Mean (SD)
Policy Opinion (*PO*)	How acceptable do you find a carbon tax?	Likert scale from 1 (completely unacceptable) to 5 (completely acceptable)	3.00 (1.34)
Personal wellbeing (*W*)	How do you think a carbon tax will affect you personally?	Likert scale from 1 (much worse off) to 5 (much better off)	2.24 (0.99)
Distributional effects (*Q*)	How do you think a carbon tax will affect low-income households?	Likert scale from 1 (much worse off) to 5 (much better off)	1.67 (0.88)
Policy effectiveness (*E*)	How effective do you think a carbon tax is for reducing CO2 emissions?	Likert scale from 1 (very ineffective) to 5 (very effective)	3.16 (1.04)
Political ideology (*I*)	Where would you situate yourself ideologically?	Scale ranging from 1 to 10, where 1 is 'left-wing' and 10 is 'right-wing'	4.47 (2.44)

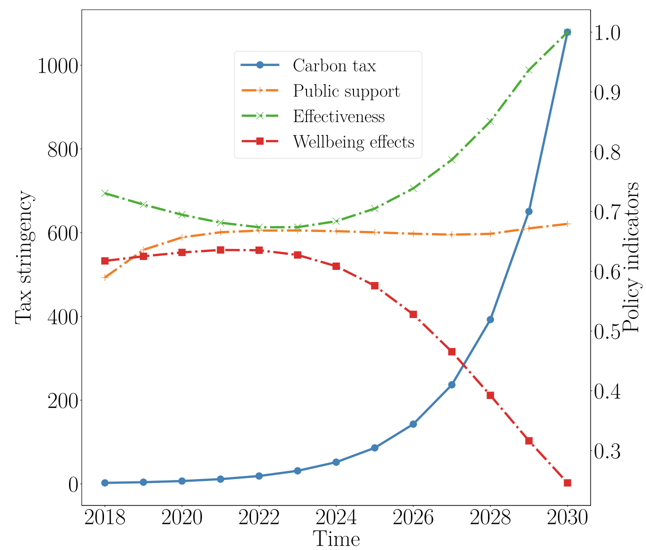


Fig. 4. Co-dynamics between tax stringency, effectiveness, wellbeing effects and public support. Note that the revenue of the tax is returned in the form of a progressive transfer.

Table 4
Support for different policies ensuring that emissions stay within the carbon budget.

Policy	Maximum support	Maximum wellbeing effects	Maximum distributional effects	Maximum effectiveness
Carbon tax with:				
Progressive recycling	0.76	0.58	0.64	1
Labour tax reduction	0.66	0.49	0.46	1
Green spending	0.62	0.30	0.49	1
Standards	0.65	0.47	0.46	1

Note: "Maximum" before each indicator in the title row refers to the maximum average value over time achieved for the respective indicator. Note that maximum values for different indicators do not necessarily relate to the same tax trajectory.

4. Results: Identifying feasible policy trajectories

4.1. Comparison of performance standards and carbon taxation

We simulate the model with different initial values and annual growth rates of stringency. For each initial stringency level, we assess the lowest stringency growth rate such that total emissions stay within the carbon budget until 2030. We examine how the resulting trajectories compare in terms of public support and its components, namely personal wellbeing, distributional effects and effectiveness. Fig. 4 illustrates the output in terms of stringency and support for the trajectory starting with a relatively low carbon tax. Initially, effectiveness decreases because policy stringency does not keep up with the emissions target. The target is fulfilled thanks to high tax rates in later years. These cause wellbeing impacts to decrease quickly, also as progressive transfers do not compensate the welfare losses of the high taxes.

We find that both performance standards and carbon tax can potentially count on sufficient public support, if designed adequately. Table 4 reports the outcomes in terms of public support and its three constituent components for the carbon tax combined with the different revenue uses, as well as for the performance standards. The carbon tax with progressive recycling of revenues achieves the highest public support, because of high wellbeing and distributional effects. It also receives more support from households in low-income deciles (Fig. 5). The redistributive aspect of the progressive policy explains these effects. As low-income households are overcompensated for what they originally paid in carbon taxes, they are better off thanks to the policy. On the other hand, high-income households face a net loss due to the policy. Because the marginal utility decreases with consumption, the utility gains of low-income households outweigh the utility losses of high-income households, resulting in a higher aggregate wellbeing in the population.

The performance standards and the carbon tax associated with a reduction in labour taxes have negative distributional effects. The similarity between these policies is due to both favouring higher income agents with a lower carbon-intensity of consumption. The average wellbeing effect across the population is lower than with progressive recycling. As noted by Levinson (2018) and Goulder et al. (2016), standards introduce an implicit tax on inefficiency and an implicit subsidy on efficiency, and thus benefit agents with a lower carbon-intensity of consumption. Recycling the tax revenue through a labour tax cut yields a similar outcome, since the tax payment in proportion of their income is lower for agents with higher incomes. As a result, standards and carbon taxation with a labour tax cut receive lower public support than with progressive redistribution.

Finally, a carbon tax with revenues used for green spending has a relatively low support. Here the revenue of the tax is not given to households but is used to further reduce emissions. As a result, this policy scenario results in the largest wellbeing loss, in turn undermining policy support. Therefore, even though this policy could reach the mitigation targets with the lowest tax, it enjoys the lowest public support, i.e. compared to the other policy scenarios considered. These findings suggest that any carbon tax that is not associated with transfers to households is bound to face strong public resistance.

Our results are somewhat in contrast with survey-based insights showing that people tend to prefer green spending among all the potential revenue uses (e.g. Kotchen et al., 2017). This contradiction can be explained by the positive wellbeing effect of some form of green spending, such as through improved public transport or lower air pollution, which falls outside the scope of our analysis. Another explanation is that in our model agents form their opinion based on actual

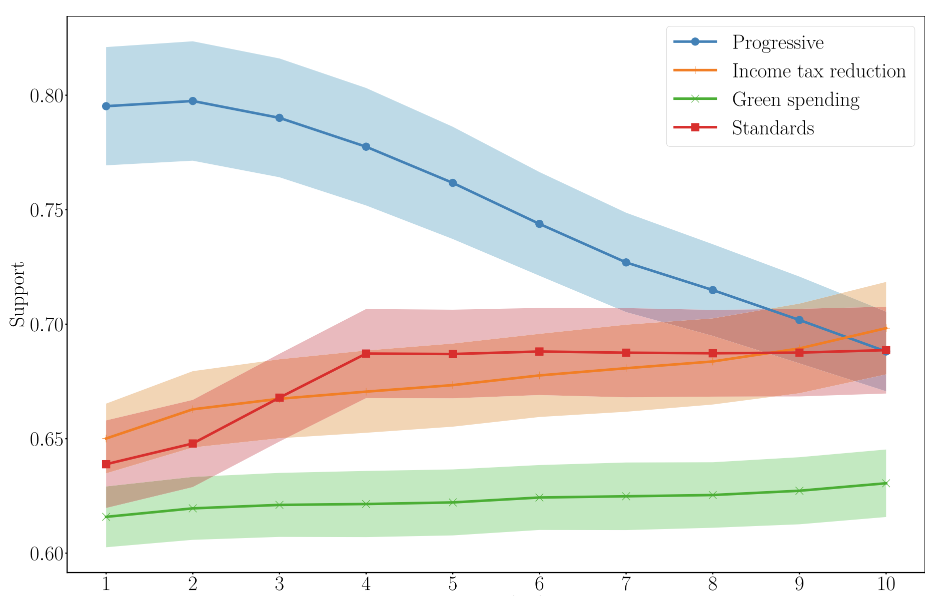
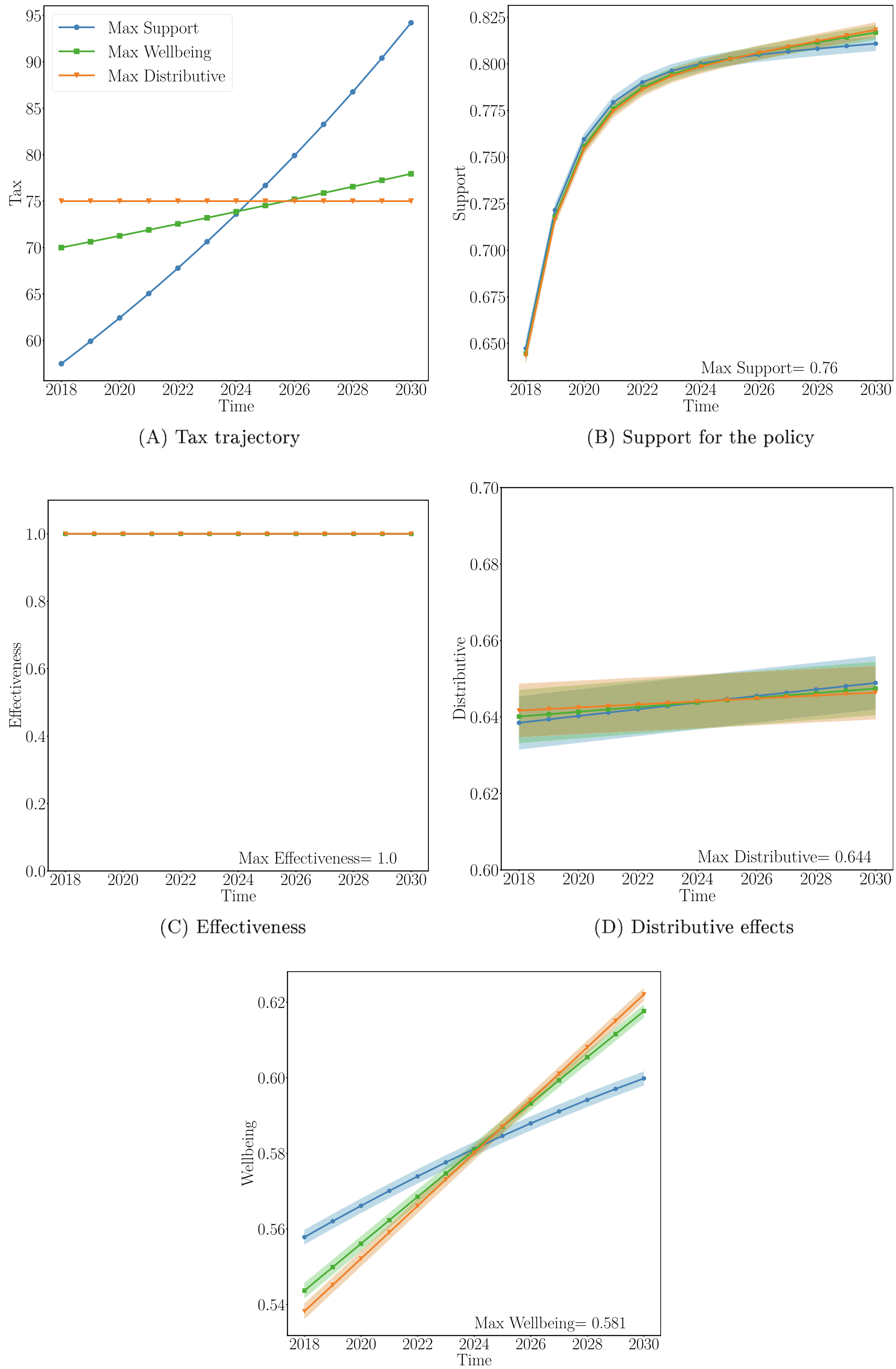


Fig. 5. Average public support for each income decile under different uses of carbon-tax revenue. As the simulations use random numbers, we report average results ± one standard deviation over 50 runs.



(A) Tax trajectory

(B) Support for the policy

(C) Effectiveness

(D) Distributive effects

(E) Wellbeing effects

Fig. 6. Carbon tax trajectories with progressive revenue recycling, for $\delta = 0.5$ and $\gamma = 0.5$. We show only tax trajectories that receive sufficient support during the entire period and achieves the maximum average value over time for either the policy support or at least one of the policy-impact indicators (distributive effects and personal wellbeing). As the simulations use random numbers, we report average results ± one standard deviation over 50 runs.

policy impacts, while the survey reflects respondents' perception. Since households generally fail to recognize fully the systemic effects of a carbon tax on the economy as a whole, they tend to regard green spending of the tax revenues as the main way to support emission reductions (Kallbekken and Aasen, 2010). Some surveys indicate that support for standards is likely to be higher than for taxes (Rhodes et al., 2017) even though they are significantly more costly (Parry et al., 2014), which contrasts with our results. It is unlikely to be caused by a preference for non-pricing instruments over pricing instruments because the willingness to pay may be even higher for a pricing instrument than

Table 5
Support for different tax revenue uses in function of the strength of social influence, γ.

Use of carbon-tax revenue	$\gamma = 0$	$\gamma = 0.25$	$\gamma = 0.75$
Carbon tax with:			
Progressive recycling	0.82	0.76	0.74
Labour tax reduction	0.65	0.66	0.71
Green spending	0.65	0.65	0.62
Standards	0.65	0.65	0.71

Note: We refer to maximum support as the maximum average support over time achieved with the tax recycling policy.

Table 3
Parameter values

Parameter	Baseline value	Source
Number of agents	1000	
Number of periods	13	Difference between the target year 2030 and the starting year 2017
Number of social links	4000	Re-analysis of data from Maestre-Andrés et al. (2021)
Wellbeing effect weights	$\beta_1 = 0.365$; $\beta_4 = 0.008$	Re-analysis of data from Maestre-Andrés et al. (2021)
Distributional effect weights	$\beta_2 = 0.205$; $\beta_5 = -0.005$	Re-analysis of data from Maestre-Andrés et al. (2021)
Effectiveness weights	$\beta_3 = 0.511$; $\beta_6 = -0.011$	Re-analysis of data from Maestre-Andrés et al. (2021)
Weight of past opinions δ	0.5	Dreyer et al. (2015), Howe and Krosnick (2017), Douenne and Fabre (2022)
Intensity of social influence γ	0.25	Re-analysis of data from Becker et al. (2017)
Abatement cost of green spending	40 Euros per ton	Gillingham and Stock (2018)
Annual productivity growth rate	1%	OECD (2020)
Gini coefficient of income distribution	0.34	Spanish National Statistics Institute (2020)
Share of labour in production function, α	0.4	
Share of energy in production function, ζ	0.4	
Price of polluting energy, q_D	0.5	
Price of clean energy, q_C	1	
Share of polluting good in utility function, σ	0.4	
Share of clean good in utility function, η	0.2	
Share of leisure in utility function, σ	0.4	
Subsistence consumption of polluting good, $\overline{D}$	0.0031	

for standards (Aldy et al., 2012; Kotchen et al., 2017). A possible explanation is that households misperceive the costs associated with a stringent standard because they are not as salient as with pricing instruments. Given a lack of both theory and data, such perception issues are difficult to capture in the model.

Since the carbon tax with progressive revenue recycling performs best on public support, we consider it in more detail. Fig. 6 shows the tax trajectories for the policy designs which score best on the distinct impact indicators or maximize policy support, while ensuring that emissions stay within the carbon budget and public support for each trajectory in any period exceeds the support threshold of 50%.

The increase rate that maximizes personal wellbeing is relatively low. This slow growth of the tax rate is driven by economic growth, as households due to increasing consumption pollute more and should then be subject to a higher absolute tax in order to stay within the carbon budget. This tax trajectory, however, does not achieve a public support as high as a policy with lower initial tax and a steeper increase (Fig. 6). The explanation is that households are resistant to change their opinion about a policy and do not fully update their opinion about a policy every time new evidence about its effects arrives (see Eq. 15). A policy starting with a lower tax gathers more public support early on and can exploit this support in later periods due to the path dependence of opinions.

4.2. The role of opinion stability and social influence

In our model, the public support for the policy depends on its direct impacts on households and on opinion dynamics. We discuss two mechanisms that affect the aggregate support for climate policy, namely opinion stability and social influence.

Fig. 4 shows that when opinions of agents are more stable, tax trajectories that maximize public support and personal wellbeing differ. The more resistant the opinions of agents are to change (i.e. the higher is δ), the steeper is the tax trajectory that maximizes policy support. The reason is that a lower initial tax gathers more support early on, which translates into higher support later because of stable opinions. Hence, due to opinion dynamics, welfare-maximizing policies are not necessarily the ones gathering largest public support.

Social interaction also has an effect on the support for the carbon tax. Richer agents tend to have more influence in the social network. Therefore, if a policy is beneficial to them, they are able to influence their connections to get support for it. Schemes of revenue recycling which favour low-income agents count on less support the higher is the social influence exerted by rich agents. On the other hand, when the latter benefit from the revenue use, stronger social influence increases the support for the climate policy (Table 5). The effect is stronger for rich households with right-wing political orientation, as they put more weight on their personal wellbeing effects than left-wing households (see Table 3 in Section 3). Fig. 7.

4.3. The role of income inequality

Income inequality influences public support for climate policies through two main channels. On the one hand, higher income inequality implies that the distribution of consumption of the high-carbon good changes: more agents are close to their subsistence level of consumption and agents with the highest income are responsible for a higher share of total emissions. As a result, a carbon tax with progressive recycling has better distributional – and wellbeing – effects, because it benefits the bulk of the population (and similarly regressive policies have worse distributional effects). Over time, this increases the public support for climate policies with positive distributional effects.

On the other hand, higher income inequality means that wealthier agents have a stronger influence on the opinions of other agents. This stems from the empirically motivated assumption that social influence increases with income. As stated above, with high income inequality, a carbon tax with progressive recycling benefits a larger number of agents but negatively affects high-income earners. Depending on the strength of social influence, they are able to convince other agents that progressive policies do not merit support, which drives down the public support for climate policies with positive distributional effects.

The link between income inequality and public support for different climate policies is ambiguous, and strongly depends on the capacity of the wealthiest agents to influence the implementation of policies (Gilens and Page, 2014). Fig. 8 shows that for high income inequality and strength of social influence, regressive policies gather the largest public support. When people have different weights to influence political feasibility, a minority of individuals can block a policy that would be beneficial to the majority. It shows that calculating direct effects of climate policies is not sufficient to assess public support. The addition of other mechanisms that increase the power of certain groups could reverse the positive feedback loop between stringency and public support. For instance, companies or people who dislike climate policy could

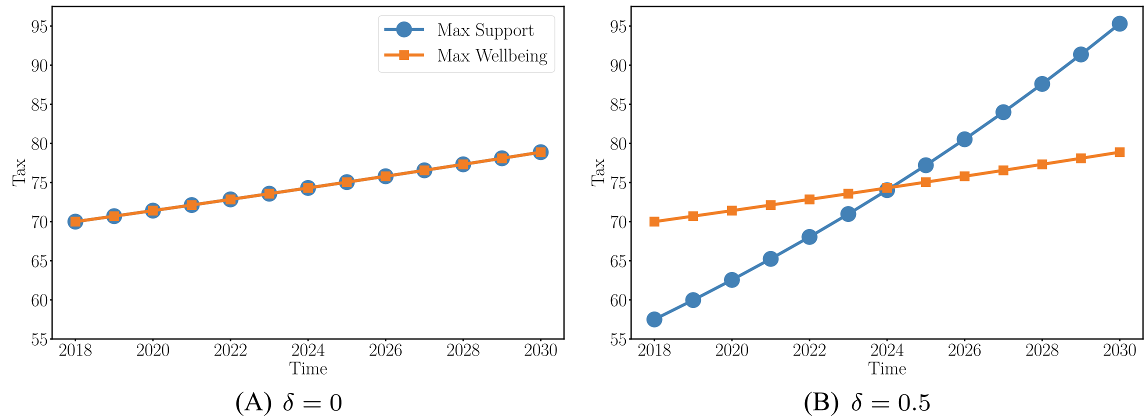


Fig. 7. Carbon tax trajectories maximizing support and wellbeing for two values of δ reflecting distinct resistance to opinion change. Results pertain to progressive revenue recycling option.

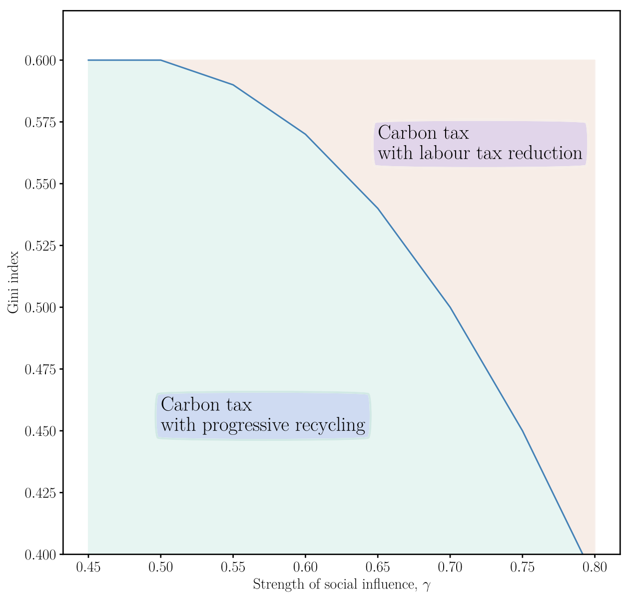


Fig. 8. Policy enjoying maximum public support as a function of the Gini index of the income distribution and the strength of social influence, γ. For combinations of Gini index and γ below the blue curve, a carbon tax with progressive recycling gathers most public support. For combinations above the curve, a carbon tax with a carbon tax with labour tax reduction, i.e. regressive recycling, gathers most public support. To aid interpretation of the Gini index values, note that South Africa has a Gini index around 0.60, China around 0.44, the United States around 0.41, Japan around 0.32, and the European Union around 0.30 (World Bank, 2020; Eurostat, 2020).

engage in lobbying action and have a direct influence on policy decisions (Isley et al., 2015). In this case, increasing the stringency of climate policy might create more resistance, despite having positive effects for most people.

5. Conclusions

Traditionally, models of climate policy focus on efficiency. We designed a model to identify carbon taxes and performance standards that are both effective and acceptable. This was motivated by substantial evidence that public support for climate policy is critical to its implementation. We developed an innovative model consisting of three modules – for policy design, calculation of impacts, and derivation of public support. We assessed trajectories of performance standards and carbon taxation under three distinct revenue uses that fulfil the requirements of effectiveness and acceptability, and identified the one enjoying the highest average public support.

We find that carbon taxation generates more public support than performance standards and that transfers to households are key to ensuring maximum support for climate policy. Progressive redistribution is the most supported revenue-recycling policy because of its positive wellbeing effects for the majority of the population. Social influence helps gathering public support for policies that are favourable to well-connected individuals. This is detrimental for transfers aimed at low-income households because these tend to exert less social influence. Agents' tendency to resist opinion change translates into higher public support for a tax trajectory with a lower initial tax that increases fast in later periods. This suggests that a carbon tax is best designed in a way to win considerable public support early on, which can then be exploited in later periods. Finally, income inequality has a double-edged effect on public support. On the one hand, higher income inequality generally increases public support for progressive policies because of their positive distributional effects for a large share of the population. On the other hand, social influence of the richest agents increases with income inequality, meaning that support for policies that are detrimental to them, such as progressive policies, decreases.

There are several avenues for further research. First, more attention is needed to understand the relation between policy impacts and public support. In particular, longitudinal data of public support for carbon taxes and other instruments could provide valuable information, notably if it would allow measuring the change in public support before and after an increase in the stringency of climate policy. The role of income as a factor co-determining the perception of policies also merits further analysis. Because our results are sensitive to parameters in the policy opinion module, conducting similar surveys in countries other than Spain would contribute to robustness of the results. Second, instead of focusing on a single policy instrument, such as a carbon tax or a performance standard, one could adapt our model to deal with a policy mix involving several instruments, which more realistically captures the reality of climate policy. Third, our framework could also be applied to non-climate policies for which effectiveness and public support are essential, such as taxes on alcohol, tobacco and food (Reynolds et al., 2019) or road pricing (Schade and Schlag, 2003). Fourth, while here we focused on citizen support, one could extend the framework with additional mechanisms underlying political feasibility, such as lobbying by firms and NGOs. Finally, further assumptions regarding policy support can be explored. For instance, one could assume that incomplete information due to media framing or the social network creates a biased perception of policy impacts. In this case information policies correcting the misperceptions could be studied as complementary instrument next to more traditional climate policies.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.gloenvcha.2022.102528.

References

Aldy, J.E., Kotchen, M.J., Leiserowitz, A.A., 2012. Willingness to pay and political support for a US national clean energy standard. Nat. Clim. Change 2, 596–599. https://doi.org/10.1038/nclimate1527.

Allcott, H., 2011. Social norms and energy conservation. J. Public Econ. 95, 1082–1095. https://doi.org/10.1016/j.jpubeco.2011.03.003.

Anderson, B., Böhmelt, T., Ward, H., 2017. Public opinion and environmental policy output: a cross-national analysis of energy policies in Europe. Environ. Res. Lett. 12, 114011 https://doi.org/10.1088/1748-9326/aa8f80.

Aubert, D., Chiroleu-Assouline, M., 2019. Environmental tax reform and income distribution with imperfect heterogeneous labour markets. Eur. Econ. Rev. 116, 60–82. https://doi.org/10.1016/j.euroecorev.2019.03.006.

Büchs, M., Schnepf, S.V., 2013. Who emits most? Associations between socio-economic factors and UK households' home energy, transport, indirect and total CO2 emissions. Ecol. Econ. 90, 114–123. https://doi.org/10.1016/j.ecolecon.2013.03.007.

Bechtel, M.M., Scheve, K.F., van Lieshout, E., 2020. Constant carbon pricing increases support for climate action compared to ramping up costs over time. Nat. Clim. Change 1–6. https://doi.org/10.1038/s41558-020-00914-6.

Becker, J., Brackbill, D., Centola, D., 2017. Network dynamics of social influence in the wisdom of crowds. Proc. Natl. Acad. Sci. U.S.A. 114, E5070–E5076. https://doi.org/10.1073/pnas.1615978114.

Beiser-McGrath, L.F., Bernauer, T., 2019. Could revenue recycling make effective carbon taxation politically feasible? Sci. Adv. 5, eaax3323. https://doi.org/10.1126/sciadv.aax3323.

van den Bergh, J.C.J.M., Savin, I., Drews, S., 2019. Evolution of opinions in the growth-vs-environment debate: Extended replicator dynamics. Futures 109, 84–100. https://doi.org/10.1016/j.futures.2019.02.024.

Bergquist, P., Mildenberger, M., Stokes, L.C., 2020. Combining climate, economic, and social policy builds public support for climate action in the US. Environ. Res. Lett. 15, 054019 https://doi.org/10.1088/1748-9326/ab81c1.

Berthe, A., Elie, L., 2015. Mechanisms explaining the impact of economic inequality on environmental deterioration. Ecol. Econ. 116, 191–200. https://doi.org/10.1016/j.ecolecon.2015.04.026.

Bénabou, R., Tirole, J., 2006. Incentives and Prosocial Behavior. Am. Econ. Rev. 96, 1652–1678. https://doi.org/10.1257/aer.96.5.1652.

Bond, R.M., Fariss, C.J., Jones, J.J., Kramer, A.D.I., Marlow, C., Settle, J.E., Fowler, J.H., 2012. A 61-million-person experiment in social influence and political mobilization. Nature 489, 295–298. https://doi.org/10.1038/nature11421.

Bowles, S., 1998. Endogenous preferences: The cultural consequences of markets and other economic institutions. J. Econ. Lit. 36, 75–111.

Braha, D., Aguiar, M.A.M.d., 2017. Voting contagion: Modeling and analysis of a century of U.S. presidential elections. PLOS ONE 12, e0177970. doi:10.1371/journal.pone.0177970.

Carattini, S., Baranzini, A., Thalmann, P., Varone, F., Vöhringer, F., 2017. Green Taxes in a Post-Paris World: Are Millions of Nays Inevitable? Environ. Resour. Econ. 68, 97–128. https://doi.org/10.1007/s10640-017-0133-8.

Carattini, S., Carvalho, M., Fankhauser, S., 2018. Overcoming public resistance to carbon taxes. WIRES Clim. Change 9, e531. https://doi.org/10.1002/wcc.531.

Carlsson, F., Kataria, M., Krupnick, A., Lampi, E., Löfgren, s., Qin, P., Sterner, T., Yang, X., 2021. The climate decade: Changing attitudes on three continents. J. Environ. Econ. Manage. 107, 102426. doi:10.1016/j.jeem.2021.102426.

Castro, J., Drews, S., Exadaktylos, F., Foramitti, J., Klein, F., Konc, T., Savin, I., Bergh, J. v.d., 2020. A review of agent-based modeling of climate-energy policy. WIRES Clim. Change 11, e647. doi:10.1002/wcc.647.

Clayton, S., 2018. The Role of Perceived Justice, Political Ideology, and Individual or Collective Framing in Support for Environmental Policies. Soc. Just. Res. 31, 219–237. https://doi.org/10.1007/s11211-018-0303-z.

Criqui, P., Jaccard, M., Sterner, T., 2019. Carbon Taxation: A Tale of Three Countries. Sustainability 11, 6280. https://doi.org/10.3390/su11226280.

Crowley, K., 2017. Up and down with climate politics 2013–2016: the repeal of carbon pricing in Australia. WIRES Clim. Change 8, e458. https://doi.org/10.1002/wcc.458.

Cruz, S.M., 2017. The relationships of political ideology and party affiliation with environmental concern: A meta-analysis. J. Environ. Psychol. 53, 81–91. https://doi.org/10.1016/j.jenvp.2017.06.010.

Douenne, T., Fabre, A., 2022. Yellow vests, pessimistic beliefs, and carbon tax aversion. Am. Econ. J-Econ. Policy 14, 81–110. https://doi.org/10.1257/pol.20200092.

Douenne, T., Fabre, A., 2020. French attitudes on climate change, carbon taxation and other climate policies. Ecol. Econ. 169, 106496 https://doi.org/10.1016/j.ecolecon.2019.106496.

Drews, S., van den Bergh, J.C.J.M., 2016. What explains public support for climate policies? A review of empirical and experimental studies. Clim. Policy 16, 855–876. https://doi.org/10.1080/14693062.2015.1058240.

Dreyer, S.J., Walker, I., 2013. Acceptance and Support of the Australian Carbon Policy. Soc. Just. Res. 26, 343–362. https://doi.org/10.1007/s11211-013-0191-1.

Dreyer, S.J., Walker, I., McCoy, S.K., Teisl, M.F., 2015. Australians' views on carbon pricing before and after the 2013 federal election. Nat. Clim. Change 5, 1064–1067. url:https://www.nature.com/articles/nclimate2756, doi:10.1038/nclimate2756. number: 12 Publisher: Nature Publishing Group.

Elster, J., 1989. Social Norms and Economic Theory. J. Econ. Perspect. 3, 99–117. https://doi.org/10.1257/jep.3.4.99.

Eurostat, 2020. Gini Index. url: https://appsso.eurostat.ec.europa.eu/nui/show.do?lang=en&dataset=ilc_di12.

Fafchamps, M., Gubert, F., 2007. The formation of risk sharing networks. J. Dev. Econ. 83, 326–350. https://doi.org/10.1016/j.jdeveco.2006.05.005.

Gilens, M., Page, B.I., 2014. Testing Theories of American Politics: Elites, Interest Groups, and Average Citizens. Perspect. Polit. 12, 564–581. https://doi.org/10.1017/S1537592714001595.

Gillingham, K., Stock, J.H., 2018. The Cost of Reducing Greenhouse Gas Emissions. J. Econ. Perspect. 32, 53–72. https://doi.org/10.1257/jep.32.4.53.

Goulder, L.H., 2020. Timing is everything: how economists can better address the urgency of stronger climate policy. Rev. Env. Econ. Policy 14, 143–156. https://doi.org/10.1093/reep/rez014.

Goulder, L.H., Hafstead, M., Kim, G., Long, X., 2019. Impacts of a carbon tax across US household income groups: What are the equity-efficiency trade-offs? J. Public Econ. 175, 44–64. https://doi.org/10.1016/j.jpubeco.2019.04.002.

Goulder, L.H., Hafstead, M.A.C., Williams III, R.C., 2016. General Equilibrium Impacts of a Federal Clean Energy Standard. Am. Econ. J-Econ. Policy 8, 186–218. https://doi.org/10.1257/pol.20140011.

Grainger, C.A., Kolstad, C.D., 2010. Who Pays a Price on Carbon? Environ. Resour. Econ. 46, 359–376. https://doi.org/10.1007/s10640-010-9345-x.

Hall, J.W., Lempert, R.J., Keller, K., Hackbarth, A., Mijere, C., McInerney, D.J., 2012. Robust Climate Policies Under Uncertainty: A Comparison of Robust Decision Making and Info-Gap Methods. Risk Anal. 32, 1657–1672. https://doi.org/10.1111/j.1539-6924.2012.01802.x.

Hänsel, M.C., Drupp, M.A., Johansson, D.J.A., Nesje, F., Azar, C., Freeman, M.C., Groom, B., Sterner, T., 2020. Climate economics support for the UN climate targets. Nat. Clim. Change 10, 781–789. https://doi.org/10.1038/s41558-020-0833-x.

Hoff, K., Stiglitz, J.E., 2016. Striving for balance in economics: Towards a theory of the social determination of behavior. J. Econ. Behav. Organ. 126, 25–57. https://doi.org/10.1016/j.jebo.2016.01.005.

Howe, L.C., Krosnick, J.A., 2017. Attitude strength. Annu. Rev. psychol. 68, 327–351.

Isley, S.C., Lempert, R.J., Popper, S.W., Vardavas, R., 2015. The effect of near-term policy choices on long-term greenhouse gas transformation pathways. Global Environ. Chang. 34, 147–158. https://doi.org/10.1016/j.gloenvcha.2015.06.008.

Jacobs, B., van der Ploeg, F., 2019. Redistribution and pollution taxes with non-linear Engel curves. J. Environ. Econ. Manag. 95, 198–226. https://doi.org/10.1016/j.jeem.2019.01.008.

Kahneman, D., Tversky, A., 1979. Prospect Theory: An Analysis of Decision under Risk. Econometrica 47, 263–291. https://doi.org/10.2307/1914185.

Kallbekken, S., Aasen, M., 2010. The demand for earmarking: Results from a focus group study. Ecol. Econ. 69, 2183–2190. https://doi.org/10.1016/j.ecolecon.2010.06.003.

Kaufman, N., Barron, A.R., Krawczyk, W., Marsters, P., McJeon, H., 2020. A near-term to net zero alternative to the social cost of carbon for setting carbon prices. Nat. Clim. Change 10, 1010–1014. https://doi.org/10.1038/s41558-020-0880-3.

Kim, J., Schmöcker, J.D., Fujii, S., Noland, R.B., 2013. Attitudes towards road pricing and environmental taxation among US and UK students. Transport. Res. A-Pol. 48, 50–62. https://doi.org/10.1016/j.tra.2012.10.005.

Klenert, D., Mattauch, L., 2016. How to make a carbon tax reform progressive: The role of subsistence consumption. Econ. Lett. 138, 100–103. https://doi.org/10.1016/j.econlet.2015.11.019.

Klenert, D., Mattauch, L., Combet, E., Edenhofer, O., Hepburn, C., Rafaty, R., Stern, N., 2018. Making carbon pricing work for citizens. Nat. Clim. Change 8, 669–677. https://doi.org/10.1038/s41558-018-0201-2.

Klenert, D., Schwerhoff, G., Edenhofer, O., Mattauch, L., 2018. Environmental Taxation, Inequality and Engel's Law: The Double Dividend of Redistribution. Environ. Resour. Econ. 71, 605–624. https://doi.org/10.1007/s10640-016-0070-y.

Konc, T., Savin, I., 2019. Social reinforcement with weighted interactions. Phys. Rev. E 100, 022305. https://doi.org/10.1103/PhysRevE.100.022305.
Konc, T., Savin, I., van den Bergh, J.C.J.M., 2021. The social multiplier of environmental policy: Application to carbon taxation. J. Environ. Econ. Manag. 105, 102396 https://doi.org/10.1016/j.jeem.2020.102396.
Kotchen, M.J., Turk, Z.M., Leiserowitz, A.A., 2017. Public willingness to pay for a US carbon tax and preferences for spending the revenue. Environ. Res. Lett. 12, 094012 https://doi.org/10.1088/1748-9326/aa822a.
Lachapelle, E., Paterson, M., 2013. Drivers of national climate policy. Clim. Policy 13, 547–571. https://doi.org/10.1080/14693062.2013.811333.
Levi, S., Flachsland, C., Jakob, M., 2020. Political Economy Determinants of Carbon Pricing. Global Environ. Polit. 20, 128–156. https://doi.org/10.1162/glep_a_00549.
Levine, D.K., Mattozzi, A., 2020. Voter Turnout with Peer Punishment. Am. Econ. Rev. 110, 3298–3314. https://doi.org/10.1257/aer.20170476.
Levinson, A., 2018. Energy Efficiency Standards Are More Regressive Than Energy Taxes: Theory and Evidence. J. Assoc. Environ. Resour. Econ. 6, S7–S36. https://doi.org/10.1086/701186.
Lindbeck, A., 1997. Incentives and Social Norms in Household Behavior. Am. Econ. Rev. 87, 370–377.
Maestre-Andrés, S., Drews, S., Bergh, J.v.d., 2019. Perceived fairness and public acceptability of carbon pricing: a review of the literature. Clim. Policy 19, 1186–1204. doi:10.1080/14693062.2019.1639490.
Maestre-Andrés, S., Drews, S., Savin, I., van den Bergh, J.C.J.M., 2021. Carbon tax acceptability with information provision and mixed revenue uses. Nat. Comm. Forthcoming.
Mailath, G.J., Postlewaite, A., 2010. The social context of economic decisions. J. Eur. Econ. Assoc. 1, 354–362. https://doi.org/10.1162/154247603322390991.
McCright, A.M., Dunlap, R.E., Marquart-Pyatt, S.T., 2016. Political ideology and views about climate change in the European Union. Environ. Polit. 25, 338–358. https://doi.org/10.1080/09644016.2015.1090371.
Metcalf, G.E., Stock, J.H., 2017. Integrated Assessment Models and the Social Cost of Carbon: A Review and Assessment of U.S. Experience. Rev. Environ. Econ. Policy 11, 80–99. https://doi.org/10.1093/reep/rew014.
Meunier, G., Schumacher, I., 2020. The importance of considering optimal government policy when social norms matter for the private provision of public goods. J. Public Econ. Theory 22, 630–655. https://doi.org/10.1111/jpet.12418.
Muchnik, L., Aral, S., Taylor, S.J., 2013. Social Influence Bias: A Randomized Experiment. Science 341, 647–651. https://doi.org/10.1126/science.1240466.
Murray, B., Rivers, N., 2015. British Columbia's revenue-neutral carbon tax: A review of the latest grand experiment in environmental policy. Energ. Policy 86, 674–683. https://doi.org/10.1016/j.enpol.2015.08.011.
Niamir, L., Ivanova, O., Filatova, T., 2020. Economy-wide impacts of behavioral climate change mitigation: Linking agent-based and computable general equilibrium models. Environ. Modell. Softw. 134, 104839 https://doi.org/10.1016/j.envsoft.2020.104839.
Nyborg, K., 2018. Social Norms and the Environment. Annu. Rev. Resour. Econ. 10, 405–423. https://doi.org/10.1146/annurev-resource-100517-023232.
OECD, 2020. Spain Data. url: https://data.oecd.org/spain.htm.
Oswald, Y., Owen, A., Steinberger, J.K., 2020. Large inequality in international and intranational energy footprints between income groups and across consumption categories. Nat. Energ. 5, 231–239. https://doi.org/10.1038/s41560-020-0579-8.
Pahle, M., Burtraw, D., Flachsland, C., Kelsey, N., Biber, E., Meckling, J., Edenhofer, O., Zysman, J., 2018. Sequencing to ratchet up climate policy stringency. Nat. Clim. Change 8, 861–867. https://doi.org/10.1038/s41558-018-0287-6.
Parry, I.W.H., Evans, D., Oates, W.E., 2014. Are energy efficiency standards justified? J. of Environ. Econ. Manag. 67, 104–125. https://doi.org/10.1016/j.jeem.2013.11.003.
Pizer, W.A., Sexton, S., 2019. The Distributional Impacts of Energy Taxes. Rev. Environ. Econ. Policy 13, 104–123. https://doi.org/10.1093/reep/rey021.
Quinet, A., 2019. The Value for Climate Action: A Shadow Price of Carbon for Evaluation of Investments and Public Policies. France Stratégie. Technical Report.
Ramstein, C., Dominioni, G., Ettehad, S., Lam, L., Quant, M., Zhang, J., Mark, L., Nierop, S., Berg, T., Leuschner, P., others, 2019. State and trends of carbon pricing 2019. The World Bank.
Reed, M., O'Reilly, P., Hall, J., 2019. The Economics and Politics of Carbon Taxes and Regulations: Evidence from Voting on Washington State's Initiative 732. Sustainability 11, 3667. https://doi.org/10.3390/su11133667.
Reynolds, J.P., Archer, S., Pilling, M., Kenny, M., Hollands, G.J., Marteau, T.M., 2019. Public acceptability of nudging and taxing to reduce consumption of alcohol, tobacco, and food: A population-based survey experiment. Soc. Sci. Med. 236, 112395 https://doi.org/10.1016/j.socscimed.2019.112395.
Rhodes, E., Axsen, J., Jaccard, M., 2017. Exploring citizen support for different types of climate policy. Ecol. Econ. 137, 56–69. https://doi.org/10.1016/j.ecolecon.2017.02.027.
Savin, I., Drews, S., Maestre-Andrés, S., van den Bergh, J., 2020. Public views on carbon taxation and its fairness: a computational-linguistics analysis. Climatic Change 162, 2107–2138. https://doi.org/10.1007/s10584-020-02842-y.
Schade, J., Schlag, B., 2003. Acceptability of urban transport pricing strategies. Transport. Res. F-Traf. 6, 45–61. https://doi.org/10.1016/S1369-8478(02)00046-3.
Sommer, S., Mattauch, L., Pahle, M., 2020. Supporting carbon taxes: The role of fairness. Working Paper 873. Ruhr Economic Papers. doi:10.4419/96973010.
Spanish Congress, 2019. Proposición de ley sobre cambio climático y transición energética.
Spanish National Statistics Institute, 2020. Annual salary survey. url:https://www.ine.es/dynt3/inebase/es/index.htm?padre=4564&capsel=4567.
Ulph, A., Ulph, D., 2018. Environmental policy when consumers value conformity. J. Environ. Econ. Manag. 102172 https://doi.org/10.1016/j.jeem.2018.09.001.
World Bank, 2020. Gini index. url: https://data.worldbank.org/indicator/SI.POV.GINI.