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When the design of climate policy meets public acceptance: An adaptive multiplex network model

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ABSTRACT

The socio-political processes that influence the acceptance of climate policies play a crucial role in shaping mitigation strategies. In this paper, we explore the interplay between social and political dynamics and their impact on climate policy support. Using a simplified model of the social and political system, we aim to uncover ways to enhance public support for climate change mitigation measures. Several factors come into play when considering policy support, including social norms, self-efficacy, social learning, and income. By examining climate mitigation policies and accounting for shifting and inherent preferences, we shed light on how individuals contribute to processes of social change. Through simulations, we find that even minimal peer pressure has a positive and significant impact on individuals' inclination towards green behaviours, regardless of whether regressive or progressive policies are implemented. Additionally, assuming uniform self-efficacy across society leads to an overestimation of society's acceptance of green policies. Our results highlight the importance of nurturing existing skills or developing new ones. Finally, our findings reveal that regional heterogeneity matters for climate policy acceptance.

1. Introduction

The provision of a stable climate is a global public good. As such, it entails social dilemmas, the solutions to which require both cooperation and considering socio-political feedback that shape mitigation strategies (Perri et al., 2023). Climate cooperation emerges at the international level through agreements that include, among others, mitigation pledges. National and regional climate policies help climate pledges materialise and need to be accepted by individuals to ensure effective implementation (IPCC, 2018; Shukla et al., 2019; Carattini et al., 2020). Public opposition to mitigation policies has been expressed either through ousting decision-makers who make top-down decisions (Crowley, 2017; Reed et al., 2019) or through bottom-up mobilisation via social movements and demonstrations (Douenne and Fabre, 2020). Despite widespread concern about climate change, many people fail to engage in climate action (a cooperative behaviour) due to a gap between attitudes towards climate change and behaviours to mitigate it (Tjernström and Tietenberg, 2008; Kallbekken et al., 2011; Kallbekken and Sælen, 2011; Carattini et al., 2017; Klenert et al., 2018). This gap depends on both structural barriers (such as poverty, income inequality or lack of infrastructure) and individual barriers (such as social norms, perceived self-efficacy and bounded rationality).

Using a simplified model of the political and social system, and focusing on mitigation, we explore the relationship between social and political dynamics and its impact on climate policy support, aiming to uncover ways to enhance said support for climate action. To do this, we

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try to understand what drives the formation of the beliefs that are necessary for policy support by modifying the theory of planned behaviour (Ajzen, 1991; Fishbein and Ajzen, 2010) and integrating it with the literature on social network to investigate how social relations among individuals and political representative impact the support of the policy (Teodoro et al., 2021). We additionally integrate the literatures on political economy for green transition (Besley and Persson, 2022) and the one that studies the relationship between voting behaviour and norms (Ulph and Ulph, 2021; Bond et al., 2012; Muchnik et al., 2013; Levine and Mattozzi, 2020; Cole et al., 2022).

The paper builds on the theoretical literature on the political economy of environmental and climate change policies. Although this strand of the literature recognises the endogenous relationship between policy design and support for climate policy (Douenne and Fabre, 2020; Douenne and Fabre, 2022; Maestre-Andrés et al., 2019; Drews and Van den Bergh, 2016; Beiser-McGrath and Bernauer, 2019; Mattauch et al., 2020; Besley and Persson, 2022; Noeldeke et al., 2022), it does not systematically study the coevolution of policy design and support, with few exceptions (Konc et al., 2021; Konc et al., 2021; Safarzyn Ska and Van Den Bergh, 2022). To account for the social structure, the political dynamics, and the coevolution of such policy design and support, we design an agent-based model (ABM) in which a political and a social layer are represented by a multiplex network (Boguná et al., 2004; Boccaletti et al., 2014): a network that may contain multiple systems and where there may exist various types of relationships among nodes (Teodoro et al., 2021). Such network structure accounts for feedback effects within and between the social and the political layers. We additionally calibrate the ABM model with the results of a survey on citizens' attitudes and support for climate policies in Spain, one of the EU's largest greenhouse gas emitters.

Our main contribution is to shed light on the mechanisms behind the heterogeneity of individuals' climate policy support and to provide new evidence on how society understands and thinks about climate policies. The article also contributes to the literature that delves into the intricate process of citizen belief formation and perceptions and examines how these factors influence the demand for environmental regulation within political institutions (Douenne and Fabre, 2020; Carattini et al., 2017; Heine and Black, 2019; Klenert et al., 2018; Douenne and Fabre, 2022; Maestre-Andrés et al., 2019; Andre et al., 2021; Teodoro et al., 2021; Ulph and Ulph, 2021; Bond et al., 2012; Levine and Mattozzi, 2020; Drews and Van den Bergh, 2016; Cole et al., 2022; Ghesla et al., 2020). It applies innovative research methodologies such as Agent Based Model (ABM) which are better suited than representative models to capture the complexity and nuances of the coevolution of the political system and citizens' beliefs and perceptions. The literature on the use of Agent Based Model (ABM) for policy design (Noeldeke et al., 2022) and policy acceptability is starting to ramp up (Konc et al., 2021; Konc et al., 2021; Safarzyń ska and Van Den Bergh, 202,219, Savin et al., 2022) and ABM calibrated with survey represents a novel approach that enriches the literature on policy acceptability. The article addresses three key research questions: to what extent are public attitudes towards climate policies affected by social norms and self-efficacy? Do social norms and individual self-efficacy impair the efficacy of the policies? How do social and political institutions coevolve?

Our results provide valuable insights into the dynamics of public support for climate change mitigation policies. First, political leadership plays a crucial role in driving public support: when politicians fail to demonstrate interest and commitment in addressing climate change, public support for climate policy diminishes. Second, peer influence, specifically through individuals' reference groups, has a significant impact in shaping attitudes towards climate change. While individual factors like income play a role in the acceptance of mitigation policies, the influence of peers within social networks can either amplify or dampen the effect of these individual factors. This finding highlights the importance of considering social dynamics and network effects when designing communication strategies and policy interventions. Third, policies that assume all individuals possess similar capabilities have less impact than anticipated, showing the limitations of one-size-fits-all policies. Our final insight stresses the significance of accounting for regional variations in public support for climate change mitigation policies within a country. Different regions with different income levels may respond differently to specific policies, resulting in varying levels of support or opposition to climate policies. Failure to consider these regional differences can lead to polarisation and hinder the successful implementation of national mitigation policies.

The article is structured as follows: Section 2 describes the conceptual framework. Section 3 introduces the model used. Section 4 presents the key findings. Section 5 summarises and concludes.

2. Conceptual framework

The acceptance of climate policies is shaped, inter alia, by the interplay between society that demands, accepts or opposes climate policies and politicians that supply (or fail to supply) said policies. Analysing the coevolution of socio-political dynamics as regards climate policy availability, knowledge, impact, ability to act and policy acceptance is of paramount importance if we are to align climate action to the goals of the Paris Agreement, whose aim is to strengthen the response to climate change and avoid its worst impacts. A Paris-aligned response to climate change requires an unprecedented change in production, consumption and distribution processes that will not occur unless climate policies are increasingly ambitious and are actively or (at least) passively accepted by citizens. Hence, using a simplified agent- based model of the social and political system, calibrated using the results of a survey, we seek to: understand the extent to which public attitudes towards climate policies that have asymmetric impacts on the population are affected by social norms, perceived self-efficacy and place of residence; and uncover ways to strengthen public support for climate change mitigation measures, bridging the climate attitude-behaviour gap.

The analysis stems from the assumption that to find solutions to the climate global dilemma a change of behaviour of all actors in society is required. The literature on behavioural change typically faces many challenges (Bandura, 1986; Ajzen, 1991). These challenges are amplified when climate change issues are being considered, because they entail a variety of dimensions that are complex and controversial. The literature on climate action shows that a stumbling block to behavioural change is the gap between attitude and deliberated behaviour, such as engaging in mitigation and adaptation strategies (Tjernström and Tietenberg, 2008; Kallbekken et al., 2011; Kallbekken and Sælen, 2011; Carattini et al., 2017; Klenert et al., 2018). Such gap depends on both structural barriers and individuals' ones that call for an extension of the theory of planned behaviour (henceforth, TPB) (Ajzen, 1991; Fishbein and Ajzen, 2010). In fact, even if the TPB models very well the barriers at the individual level,[1] it makes strong assumptions about the nature and the interactions of the three main factors (i.e., attitudes, subjective norms, and perceived behavioural control) supporting intention to perform a change of behaviour. Among the several limitations of the TPB we consider the following two. First, it does not consider how environmental or economic factors could influence some of the determinants of a person' intention to perform a behaviour. Second, TPB does not consider whether the person has acquired the skills and resources to be successful in performing the desired behaviour, or whether that access is

[1] The TPB postulates that behaviour is motivated by one's intention to perform the behaviour. The intention is determined by three other factors: the individual's *attitude* (beliefs and values about the outcome of the behaviour) and *subjective norms* (beliefs about what other people think the person should do or general social pressure). Intention is also determined by an individual's beliefs about the presence of factors that may influence the performance of the behaviour (*perceived behavioural control*).

unequal. These limitations play a significant role in justifying people's attitudes towards supporting climate action policies.

In fact, the interaction between the personal and structural (i.e., social, environmental, and economic) spheres gives rise to two biases: the misperception of the economic effects of climate policies (Douenne and Fabre, 2022) and of effectiveness and fairness effects (Maestre-Andrés et al., 2019). A recent international survey from the OECD (Dechezleprêtre et al., 2022) affirms there are three key beliefs that are major predictors of whether people support a given climate policy: i) its perceived effectiveness in reducing emissions, ii) its perceived distributional impacts on lower-income households, iii) its perceived impact on people's own household. In the model we add those perceptions of the income effect of the policies as a fourth element in the function explaining the attitudes to support climate policy (see Fig. 1).

Yet, these perceptions or beliefs are not exogenous individual traits, but they are the result of spillover effects from structural barriers to individual ones. That is, income class and place of residence define a person's understanding of what is perceived as fair and achievable. Across income groups and places of residence, both the policy effectiveness and individuals' perceived self-efficacy[2] are socially embedded and often empirically wrong. Income and place of residence define reference groups, that in turn, delimit individuals' exposure and access to information related to green policies. In other words, heterogeneity in expectations emerges at three different stages of belief formation: information selection, information acquisition, and information processing. In this paper, we seek to unveil the drivers of the formation of beliefs that are needed for policy acceptance, and the information mechanisms supporting it. We assume that the three information mechanisms depend on global information, i.e., information coming from the chosen policy, and on local information, i.e., individuals' social reference groups. Individuals talk to their neighbours, observe the behaviour, or the economic circumstances, of no more than a sub-sample of the population, and infer the entire distribution of behaviour and beliefs from that information. If agents do not fully account for the selection process involved in the formation of the sample they observe, their inferences will be systematically biased. Andre et al. (2021) show that American citizens vastly underestimate the prevalence of climate-friendly behaviours and norms among their fellow citizens and this underestimation of climate norms is of concern because it hampers individual willingness to fight climate change.

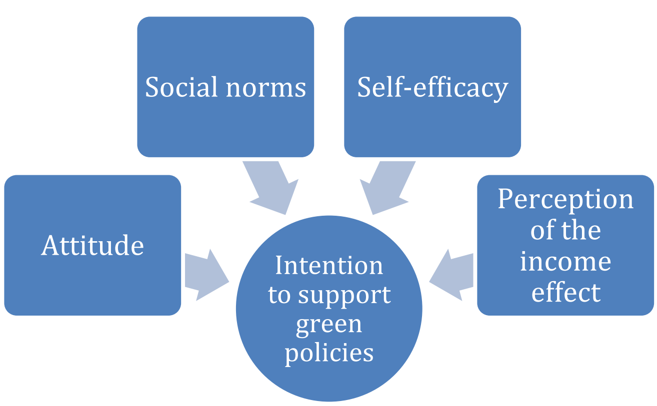

Fig. 1. Conceptual framework of Intention' formation. Model explaining individual's intention of supporting green policies, based on an extension of the theory of planned behaviour. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

To account for such biased inference, we assume that individuals' support for green policies depends on their attitude towards the policy, on the social norms governing their reference groups (Ulph and Ulph, 2021; Konc et al., 2021; Nyborg et al., 2006; Allcott and Mullainathan, 2010; Allcott, 2011; Allcott and Rogers, 2014; Bolsen et al., 2014; Dasgupta et al., 2016; Nyborg et al., 2016; Allcott and Kessler, 2019; Andor et al., 2020; Szekely et al., 2021), on their perceives behavioural control (La Barbera and Ajzen, 2020; Fishbein and Ajzen, 2010; Bandura, 1997; Ajzen, 1991) and on the perceived income effect of the policy (as seen in Fig. 1). We assume that individuals' perception of self-efficacy is the belief that they have material and cognitive capacity and control to understand the consequences of the policy and implement the new behaviour defined by the policy. We assume, moreover, that self-efficacy depends on the reference income class as sustained by the literature (Ghesla et al., 2020; Hertwig and Grüne-Yanoff, 2017): i.e., that the higher the economic resources the higher the perception of self-efficacy. Distinctively according to La Barbera and Ajzen (2020), we do not study the interaction between social norms and self-efficacy on the intention of supporting green policy. We test whether moving from the assumption of homogeneous self-efficacy to one of heterogeneity influences the level of support and the type of green policy.

Teodoro et al. (2021) show that social ties can increase learning about others' climate change perception, but it highlights that such learning is dependent of the complexity and multidimensionality of the ties. And those studies that employ social network analysis (SNA) frameworks and tools should account for this complexity. Unlike Fishbein and Ajzen (2010) and Ajzen (1991) we model social norms considering both their structural and functional aspects. The structural aspect of social norms is represented by citizens' reference group (Bicchieri, 2005). Social networks are highly stratified by socioeconomic class: people tend to befriend others with similar incomes. The existence of reference group leads to the phenomenon of homophily, that is the tendency of actors that share a specific similarity to interact more closely, and hence to influence one another, compared to actors that do not (McPherson et al., 2001; Boguná et al., 2004; Currarini et al., 2009): i.e., high (low) income individuals are more likely to interact with each other than with people outside of their income class. Biased perceptions on the cost and benefit of mitigation policies not only exist as consequences of reference groups based on income level but also due to their place of residence, especially when regional inequality is high (Susskind et al., 2022; Duarte et al., 2022). Hence, in our model individuals interact locally according to their income class and their residential area. As for the functional aspect, we integrate the literature that studies the relationship between voting behaviour and norms (Ulph and Ulph, 2021; Bond et al., 2012; Muchnik et al., 2013; Levine and Mattozzi, 2020; Cole et al., 2022) and we include social norm as an ingredient that shapes individuals' decision to support green policies, i.e., social norms make the decision to support to be conditional to what individuals' neighbours themselves support. It is important to study the two features of social norms, i.e., the structural and functional ones, because they concur in the creation of erroneous public perceptions of the effectiveness of a policy and hence impair its acceptance (Ulph and Ulph, 2021; Konc et al., 2021; Cole et al., 2022; Baranzini and Carattini, 2017; Alló and Loureiro, 2014; Greif and Kingston, 2011; Greif and Laitin, 2004; North et al., 1990; Ostrom and Basurto, 2011; Drews and Van den Bergh, 2016; Luís et al., 2018; Teodoro et al., 2021).

At the same time, the relationship between social norms and policy acceptance is not univocal. As showed by Benabou and Tirole (2011), laws can also serve as a means of conveying information about social values and norms, particularly in situations where there is uncertainty or a misunderstanding about the prevailing social norm: the attitude-behaviour gap associated with mitigation policy support falls into such case. In a society in which political parties show interest in mitigation policy or, in general, in their citizens' priorities, the general attitudes of citizen towards mitigation policy (or any other policy) become positive, while when political parties' agenda results far from the constituents'

[2] In TPB self-efficacy is the perceived control over the behaviour (Ajzen, 2010; Bandura, 1997).

needs, their support for the agenda weakens (Murray and Rivers, 2015; McCright et al., 2014; Stadelmann-Steffen, 2011).

Therefore, building on recent research that highlights the potentially productive role of social norms in fostering climate action (Nyborg et al., 2006; Allcott and Mullainathan, 2010; Allcott, 2011; Allcott and Rogers, 2014; Bolsen et al., 2014; Dasgupta et al., 2016; Nyborg et al., 2016; Allcott and Kessler, 2019; Andor et al., 2020; Szekely et al., 2021), on the literature of social cognitive theory (Bandura, 1997) and of planned behaviour (Ajzen, 1991; Fishbein and Ajzen, 2010), and, lastly, on the theory of multiplex networks (Boguná et al., 2004; Boccaletti et al., 2014) we present an evolutionary model that uses the agent-based methodology (ABM) to describe an artificial Spanish society accounting for different types of bounded-rational agents whose preferences for mitigation policies span several domains, such as economic, social, political, and subjective ones.

In our model both citizens and political institutions interact. Citizens, which are considered as consumers and voters, interact with each other via a peer pressure mechanism, while the interaction between political institution and citizens occurs on the one hand via political endorsement (linking citizens to politicians) and on the other hand via accountability[3] process (linking politicians to citizens). We test different policy scenarios, from regressive (e.g., carbon tax whose tax proceeds are earmarked to specific emission reduction projects) to progressive (e.g., carbon tax with a social cushion compensation scheme) ones in order to study the effect that they have on agents' policy support (Baranzini and Carattini, 2017; Drews and Van den Bergh, 2016; Heine and Black, 2019). Finally, we calibrate the model by using data from the Elcano Royal Institute survey evaluating Spaniards' support for elements, instruments and institutions of a Climate Change and Energy Transition Law (Fig. 2).

Within this framework, we address three key research questions: (1) To what extent are public attitudes towards climate policies affected by social norms and self-efficacy? (2) Do social norms and individual self-efficacy impair the efficacy of the policies? (3) How do social and political institutions coevolve?

3. The model

We consider a population of agents interacting in a fixed social network. The agents are of two types: citizens and elected representatives that occupy seats on the regional parliaments. The agents are located on a multiplex network having two layers that we call social and political layers, see Fig. 3.

Citizens only belong to the social layer and political seats are located on the political layer. A generic agent k has a set of neighbours or connections η_k^l for each layer, $l \in \{P, S\}$, (i.e., P = political and S = social). Hence the set of all connections within layers is formed by $\eta_k^l = \left(\eta_j^P, \eta_i^S\right)$, where η_{ji}^P is the set of connections between the seats in the political layer, while η_i^S is the set of neighbours that citizens have on the social layer.

We implement a model where both citizens and political institutions interact. Citizens interact with each other via a peer pressure mechanism, while the interaction between political institution and citizens occurs on the one hand via political endorsement (linking citizens to politicians) and on the other hand via an accountability process (linking politicians to citizens). The tool that allows us to connect the two layers, the political and the social one, is called a multiplex network (Boguná et al., 2004; Boccaletti et al., 2014). Moreover, we implement a double dividend approach to mitigation policy that considers both environmental and economic effects of the taxation but in a political economy fashion (Kallbekken et al., 2011; Kallbekken and Sælen, 2011; Cole et al., 2022; Ghesla et al., 2020; Besley and Persson, 2022): that is, we investigate whether different policies and their perceived effect on population provide insights on public acceptance of mitigation policies.

3.1. Social layer

Agents in the social layers are endowed with an initial opinion about the propensity to support a green policy, α_i. We consider two components of propensity: personal $\alpha_{i,t} \in [0,1]$ and social $\overline{\alpha_{i,t}}$. The personal green propensity represents the individual's socio-psychological factor, climate change perception and policy perception. Where if $\alpha_{i,t} = 1$,the agents fully support the green policy proposed by the political layer, whereas $\alpha_{i,t} = 0$ means completely opposed to a green policy. The social component of propensity, $\overline{\alpha_{i,t}}$, is based on social learning of the average behaviour of the neighbours. Through a process of observation and opinion dynamics agents learn about others' behaviour, internalising it as a local social norm, and updating their $\alpha_{i,t}$. Yet, peer pressure is not the only mechanism through which agents update their behaviour. The type of policy decided in the political layer influences $\alpha_{i,t}$ via the perceived income effect generated by it. Furthermore, also the self-efficacy influences $\alpha_{i,t}$. Agents update their opinion according to the following equation:

$$\alpha_{i,t+1} = \begin{cases} \gamma\left[(1-\sigma)\alpha_{i,t} + \sigma\overline{\alpha_{i,t}}\right], & \text{during peer effect stage} \\ \alpha_{i,t} + r_{p,y}\left[\alpha_{i,t}\left(1-\alpha_{i,t}\right)\right]\beta_i, & \text{during policy stage} \end{cases} \tag{1}$$

where $\gamma = [0.99, 0.999]$ is the natural degree of decay of the opinion if not sustained by the presence of a policy; $\sigma_{i,t} \in (0,1)$ measures agent's sensitivity to peer pressure and $(1-\sigma)$ is agents' adherence to their own opinion. Note that if $\sigma_{i,t} = 0$ then the agents exhibit standard fixed preferences. If social interactions reinforce support for the green policy, we say that said policy (e.g., a green tax) has a positive social multiplier. $r_{p,y}$ measures the perceived income effect generated by a specific policy implemented according to the income class y_i and β_i measures agents' self-efficacy. Agents' income class, $y_i = [H, MH, M, ML, L]$,[4] are identified according to the position that they have in the quartile distribution. It is the variable used to create the interaction network. In the model we allow agents to be affected by the policy in different ways according to their income effect $r_{p,y}$, where p= policy and y= income class.

The distribution of α among the agents follows a uniform distribution. The rationale behind the construction of alpha follows, partially, Drews and Van den Bergh (2016) which reviews the factors influencing public support for climate policies. The authors identify three major factors: social – psychological factors affecting climate change perception, perception of climate policy and its design, and contextual factors. We have revised the data from Real Instituto Elcano survey (Lázaro-Touza et al., 2019) according to the three factors mentioned above. The data set covers only two dimensions (i.e., the first and the third). Yet, the main variables selected to build α belong mainly to the first factor, i.e., the social – psychological factors and climate change perception. In the questionnaire such factor can be summarized with the following variables: first, the environmental worldview (i.e., measured by Dunlap et al., 2000, New Ecological Paradigm, NEP), second the variable Beliefs about the existence of climate change (i.e., beliefs about the existence and the human causation of climate change), and third the self-assessed Knowledge about climate change (i.e., self-rated knowledge). According to the data the two previous variables are distributed uniformly among the citizens of the survey, considering regional distribution, while income distribution affects only the Knowledge variable (see Fig. S1 in the supplementary figures). Regional distribution is one of the variables

[3] Standard models of accountability predict that voters will lower their support for the incumbent political actor when (s)he underperforms with respect to the needs and desires of its constituents and the policies are effective towards the mitigation goals.

[4] H=High, MH = medium-high, M = medium, ML = medium-low, L = low

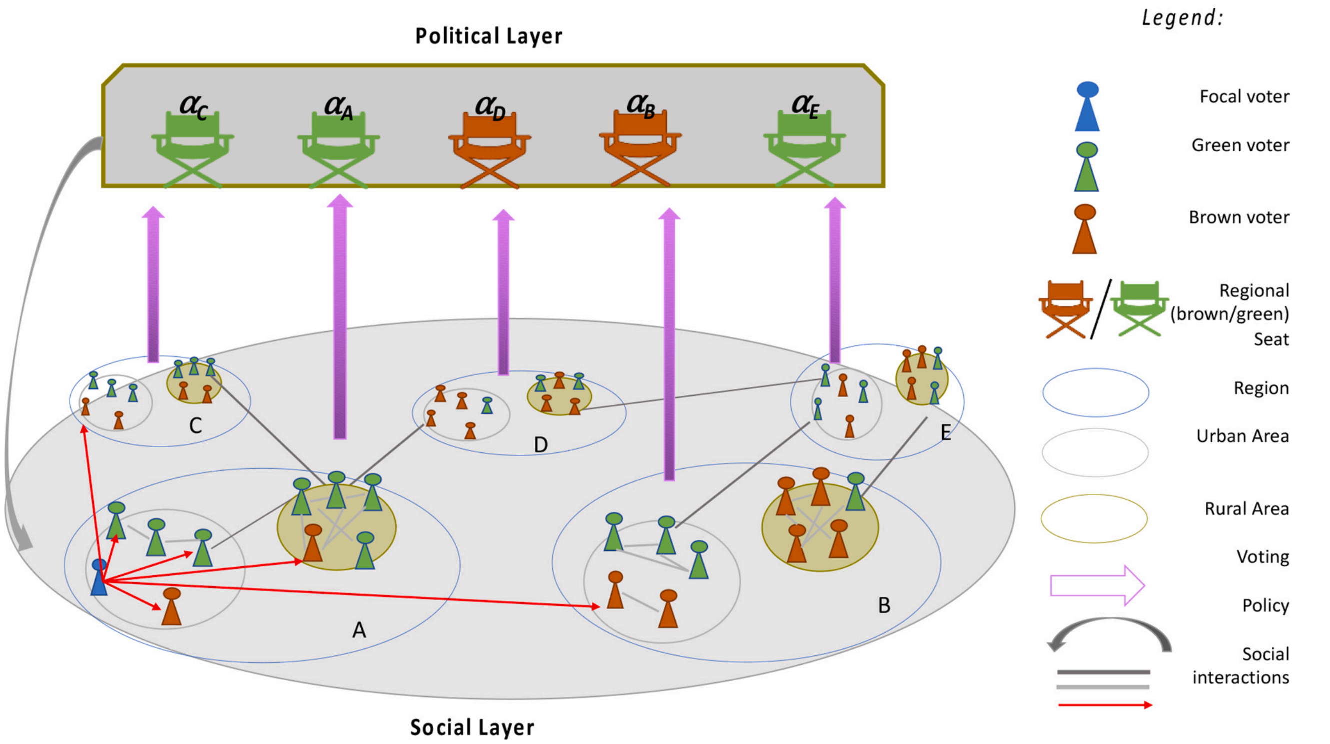

Fig. 2. The Model Dynamics. The Social Layer is composed by the citizens distributed across regions and urban and rural areas. The interaction at the social level occurs through a probabilistic function that associates a higher probability of interaction between a resident of an urban area might interact with people residing in the same urban area or other regions' urban area, and a lower probability that the former resident might interact with people living in non-urban areas. For example: the focal voter (the blue voter) resides in the urban area of region A but interacts with people from the same urban area and from the non-urban area of the same region, as well as with people of other region's (e.g., B and C) urban area. Each region will support green or brown policies according to the propensity of their population (e.g., region A has most green supporters). Such support determines the colour of the regional seats associated with that region; for example, the seats associated with region A will be mainly green. The Political Layer is composed by the regional seats. The seats (or set of seats per region) decide, following a probabilistic function based on majority rules, which policy will be implemented. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

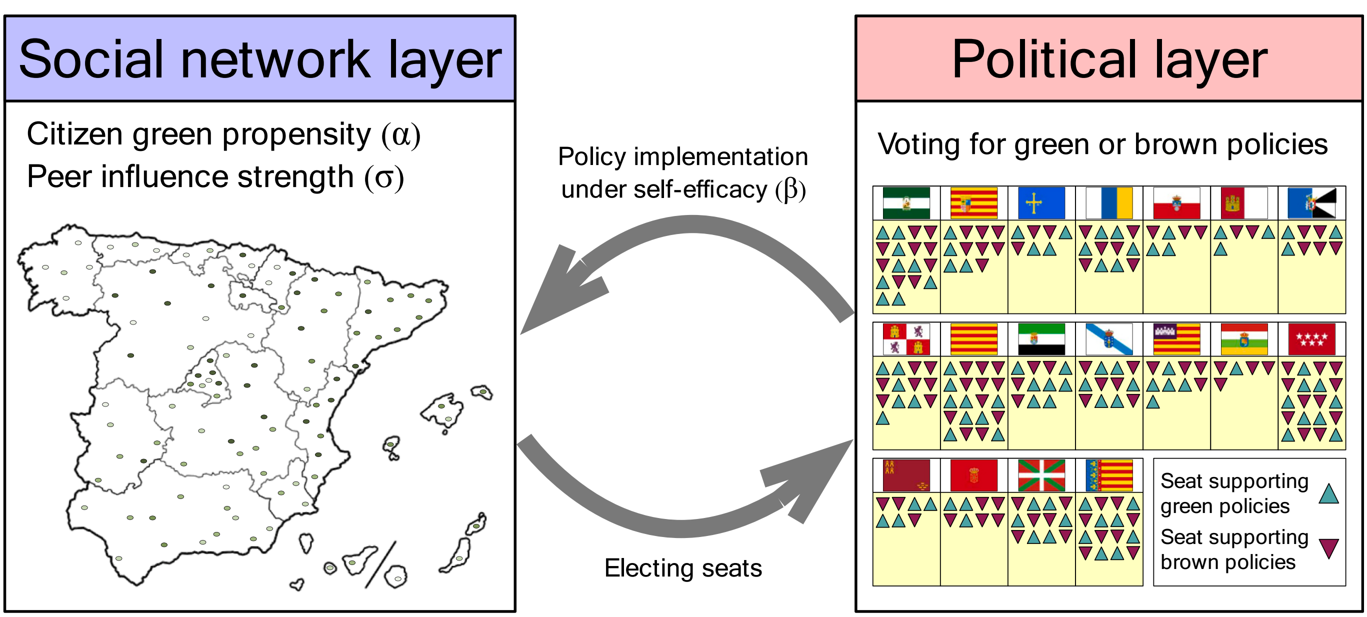

Fig. 3. The sketch of the model dynamics. The map of Spain (on the left) represents the social network layer in which citizen interactions within and across the 18 regions (on the right) take place. Within the social network layer, the dynamics of social learning and pressure take place. Citizens elect their respective regional political seats. The political layer represents the number and the colour of seat per autonomous region. On this layer the seats vote for green or brown policy to be adopted. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

considered in the set of contextual factors by Drews and Van den Bergh (2016); but given that their relationship with the socio-psychological factor is uniform, we have decided to keep them out of the construction of α but to give them a major role in the network structure.

Agents' self-efficacy perception, $\beta_{i,t} \in (0,1)$, is the belief that they have material and cognitive capacity and control to understand the consequences of the policy and implement the new behaviour defined by the policy. Agents' self-efficacy will be implemented as follows:

$$\beta_i = \begin{cases} \in (0,1), & \text{heterogeneous self} - \text{efficacy} \\ 1, & \text{homogeneous self} - \text{efficacy} \end{cases} \tag{2}$$

$\beta = 1$ represents a population with full and equal self-efficacy whereas a population with heterogeneous self-efficacy has β decreasing as the income class decreases. β_i represents another instance of agents' inertia. Inertia emerges not only because of increasing returns to conformity but also because of the way in which individual self-views evolve. If most members of the population do not believe in their abilities to change the status quo they are more likely to unquestionably follow the standing behavioural rule. Then, citizens may counterbalance the policy effect with their perception of self-efficacy. The two variables selected to build β are: on the one hand, the *Perception of being able to consume less energy* and, on the other hand, the *Perception that by changing consumption behaviour* individuals can help climate change mitigation. According to the data the two variables are, on average, very high for all income classes and regional communities but, while the two perceptions show independence from the regional community, their association with income is not univocal (see Fig. S2 in the supplementary figures). Thus, as suggested by the literature (Ghesla et al., 2020; Hertwig and Grüne-Yanoff, 2017), in the model we investigate what happens to the degree of policy support, when we move from an assumption of homogeneity to one of heterogeneity. Hence, we model two scenarios: the first scenario represents β homogeneous for all income levels; the second scenario shows a self-efficacy dependent on the income classes.

In summary, every citizen's decision to vote for green policy is linked to four motivations: their attitudes regarding voting for a green policy, their perception of the income effect of the policy, their susceptibility to local descriptive norms, and their self-efficacy. On this social layer, two different dynamics take place: the social learning dynamics and the seat election. The seats are assigned through probabilistic rule per community. At the community level, we compute the α_c of the community and we associate the number of seats. E.g., if Andalusia, from the simulated data, has an average $\alpha_c = 0.4$, hence the 40% of its seats (7 out of 18 seats), on average, will be green-friendly.

3.2. Political layer

The population of the political layer belongs to the 17 Spanish communities and the two autonomous cities of Ceuta and Melilla; its size per community is calibrated according to the actual regional distribution (i.e., each community has a total number of seats in its parliament but the colour of the seats changes according to Araujo, 2011). Each seat s is based on the community political views α_c and is characterized by a binary political view $\alpha_s \in [G, B]$ that will determine the choice of the policy (either green, G, or brown, B), and the number of voters (i.e. links) $n_{s,t}$ (that depends on the number of people sharing the same political view). We refrain from using political party affiliation in defining the seat because as reported in the analysis from Sociedad Espanola de Ornitologías, SEO (2018) the main political parties in Spain do not differ in terms of supporting a climate law for Spain. The parties differ however in their climate policy instruments of choice and in the design of policy pathways towards green transitioning: a government-centred pathway represented by the left-wing party (i.e., PSOE), a market-centred pathway represented by the right-wing party (i.e., PP) and a grassroots pathway represented by left-wing populism (i.e., Unidas Podemos). There are for sure other political parties in Spain with interesting energy worldviews to analyse, but it could be argued that the selected ones are overall representative of the energy transition policy space (Caldés et al., 2019). In the model, we indirectly account for political parties by proposing five different scenarios of policy that represent and extend the three policy pathways mentioned before.

Within the political layer, two main dynamics occur: policy decision and implementation. The policy decision dynamics is based on seat competition which is related to the number of links connected to each seat, e.g., if $\alpha_s = 20\%$, which means that the 20% of the total seats are Green, the green policy will be adopted 20% of the time on average. Even though this dynamic could seem very simple, it still bears important features for the goal of the model. In fact, the model does not aim at studying the best characteristics or the evolution of political parties' coalition for the design of green policy. It rather pursues the goal of showing that policy design is highly connected to strong (or weak) support from citizens. Usually, the literature separates the political and social layers in the analysis of policy support and design or considers one of the two layers exogenous and given. Here instead we model the feedback across levels by connecting them endogenously and by giving a more complex representation. In the policy implementation dynamics, the seats decide the income effects of the policy, $r_{p,y}$. In fact, each policy (whether green or brown), when implemented, has a different income effect on population (it is biased towards the green policy effect):

$$r_{p,y} = \begin{cases} > 0, & \text{if Green policy is adopted} \\ 0, & \text{if Brown policy is adopted} \end{cases} \tag{3}$$

where y is the vector for the income class and $p = [G, B]$ the two policies. For each income class the policy will have an effect, for example, $r_{G,y} = [90\%; 75\%; 50\%; 25\%; 10\%]$ is a Green policy that has a decreasing positive effect on all the classes and a null effect on the low income class; this is an example of a highly regressive policy. Through this step we are modelling the trust mechanism (or accountability process): the politicians decide over a specific policy that will be the signal of trust to send back to their constituents. A government is considered accountable when both the political process meets the needs and desires of its constituents, and when the policies are effective in delivering mitigation goals. Once the policy is decided its effects will affect citizens' opinion for the next time step (a reverse trust mechanism) as shown in the eq. (1) of the evolution of α.

3.3. Policy scenarios

Regarding climate change there are large asymmetries between those whose behaviour needs to change the most and those who suffer the most if a change does not occur. Environmental taxes are usually perceived as regressive (Maestre-Andrés et al., 2019; Dechezleprêtre et al., 2022; Alvarez, 2019; IMF, 2019; Estrada and Santabárbara, 2021) as they are considered to produce higher negative externalities for middle and low-income classes, regardless of their market or government-based nature.

In this paper we analyse market-based policies, and different policy scenarios are presented and studied. The different scenarios are represented by different values in $r_{p,y}$which represent different effects for each income class. We model the different scenarios as follows:

A uniform intervention is a policy that has the same effects on all the income class regardless their capacity to absorb the externalities of the policy. Example of uniform policy would be a carbon tax whose proceeds are delved to general Government revenue or to reduce deficit, or to a lump sum redistributive tool. All the income classes are impacted with the same levy and the proceeds will be applied, randomly, to all their needs.

$$\text{Uniform green policy}: r_{p,y} = [50\%; 50\%; 50\%; 50\%; 50\%]$$

A regressive intervention is a policy that produces larger costs (or minimum gains) on low-income classes. An example of such policy could be a carbon tax in which the tax proceeds are earmarked to specific emission reduction projects such as direct public investment in low-carbon technologies and infrastructure and subsidies and price guarantees to make low-carbon energy sources more abundant and cheaper, and R&D subsidies to spur innovation; a reduction to corporate income tax; transfers to firms that are particularly affected or tax cuts for firms.

$$\text{Regressive green policy}: r_{p,y} = [90\%; 75\%; 50\%; 25\%; 10\%]$$

A progressive policy is an intervention in which compensation to the poor or most needy people is designed. With this policy the high-income classes receive less gain than the rest of the population. An illustration of such policy could be a carbon tax with compensation via social cushioning, or equal pre-capital rebate to all taxpayers. Other examples could be carbon tax associated with payment for those whose electricity bill is a relatively higher percentage of income conditional upon improving adaptation of the house.

$$\text{Progressive green policy} := r_{p,y} = [10\%; 25\%; 50\%; 75\%; 90\%]$$

The bimodal policy affects positively both the lowest and the highest classes. It aims to help society to transition towards a carbon free economy by making the low-carbon option technologically and commercially available, via R&D subsidies to spur innovation, applying tax cuts to firms that are particularly affected, along with subsidies to promote the deployment of the low carbon option (e.g. renewables), while increasing fairness via a social cushion or lump sum transfer. This type of policy tries to reduce the negative social impact but not at the expense of macro variables like competitiveness.

$$\text{Bimodal green policy}: r_{p,y} = [80\%; 40\%; 10\%; 40\%; 80\%]$$

The middle-class carbon tax policy affects positively the middle class. It aims at spending more on reform for reforming the labour market like a payroll tax cut or a social security contribution that could reduce labour costs and increase employment, and in turn, raise the household income.

$$\text{Middle class green policy}: r_{p,y} = [20\%; 60\%; 90\%; 60\%; 20\%]$$

A summary of the main variables of the model is shown in Table 1.

3.4. Network structure

The social network layer includes 10,000 nodes, representing citizens from the 18 regions of Spain divided into five different social income classes. The political layer includes 200 nodes, representing the seats from the 18 regional governments. The distributions of citizens and seats we have implemented in the model are reported in Table 2. The links between citizens are created using the stochastic block network model (Holland et al., 1983) tuning connection probabilities between citizens to have an average individual node degree of about 4, as suggested by the literature (Hu and Wang, 2009)[5]. As we model the emergence of norms, we are interested in physical social networks (i.e., a neighborhood, workplace network or friendship network). Many empirical social networks of these types exhibit two common characteristics (Amaral et al., 2000; Jin et al., 2001; Handcock et al., 2017): (i) high clustering, meaning that there is a high probability for two peers of an agent to be connected, and (ii) low average path length, meaning that any two agents are connected through a low number of links. A stochastic block model has both characteristics. In the stochastic block model we implemented it is more likely to interact with citizens belonging to the same social income class and region. This is the way we implement homophily[6] (high likelihood of imitating the strategies of agents similar to oneself) and reference groups that are the structural aspect of social norms. For example, if agents i and j are from Madrid and they are both rich, their interaction is more likely to occur than the one with agent *k* that is neither from Madrid nor rich. The motivation behind such specification is to represent how social norms are formed via local interactions. Agents' preferences for a specific policy depend on their learning about what other people in their neighborhood do or say. Local interactions allow people to see the world, forge their opinion and, in turn, modulate both their preferences regarding policy support and their assessment of policy effectiveness. We decided to report results having a relatively low average degree, i.e., 4, since opinion dynamics, such as that related to peer pressure about political opinions, happens among few strong connections between peers. The network structure is static. However, a new network structure having similar characteristics is created at the beginning of each new simulation.

Table 1
Table of the Model's Parameter.

Parameter	Values	Definition
1. α_i	$\in [0,1]$	Green propensity
2. β	$\in (0,1]$	Self-efficacy
3. σ	$\in (0,1)$	Peer-pressure
4. $r_{p,y}$	≥ 0	Income policy effect
5. N_c	10000	Citizens' population size
6. N_s	200	Seats' numerosity
7. y_i	$[H, MH, M, ML, L]$	Agent's income class

3.5. Simulation parameters

The initial input data come from a survey designed by the Elcano Royal Institute that has collected information on 1000 Spanish adults (≥18 years old) through interviews conducted over the phone. The data come from stratified sampling by Autonomous Communities, applying sex and age quotas proportional to the distribution of the population in Spain, proportional to the distribution of the population in each of the strata. The distribution of agents in the social layer per community follows the Spanish demographical data while income class distributions follow the survey data from Elcano. The distribution of seats, per community, follows the political data from Araujo (2011), while the colour distribution, per community, depends on the survey data. The original number of seats is 1258. In the model it is normalized to 200 seats. Simulations were run with 10,000 individuals and 200 political seats. Different scenarios were considered to analyse the role of different policies and their interaction with income classes and different levels of redistribution of the revenue from a carbon tax. The strength of social influence (σ) determines how the propensity of agents, α_i, react to changes in propensity in their social network. To study the role of peer pressure or social norms on the evolution of α and on the stability of a green policy we focused on four values of σ: $\sigma = 0$ (absence of peer pressure), $\sigma = 0.25$ (low peer pressure), $\sigma = 0.5$ (strong peer pressure), $\sigma = 1$ (extreme peer pressure). For the social layer, we generated undirected networks of $10,000$ agents with approximately $20,000$ links, which results in a mean degree of 4 (Hu and Wang, 2009). The analysis unfolds as follows. First, we run six policy scenarios (one for no green

[5] The degree of an agent is its number of peers in the network. A mean degree of 4 implies a very low social network density in line with empirical estimates by, e.g., Hu and Wang (2009) and a very sparse social interactions matrix.

[6] The idea behind the concept of homophily is that people's personal networks are homogeneous regarding many sociodemographic, behavioural, and intrapersonal characteristics. Homophily is the mechanism through which people make sense of the surrounding social worlds. Homophily creates a cognitive window that has powerful implications on people's information collection and access, on their attitudes and the interactions they experience.

Table 2
Calibration Table. In the last five columns we report the number of nodes by region and social income class we implemented in the model. These numbers follow the percentages (%) per income class from the data of the survey carried out by the Royal Elcano Institute. The number of citizens per region is proportional to the actual population of Spain in 2022 (see column Population 2022). On the other hand, the number of seats is fixed to 200 and their distribution by region is proportional to the actual number of seats (see column Seats 2022) in the 18 governments of the autonomous communities and cities.

	Region (2022)	Seats (2022)	Population (2022)	Model seats	Model citizens	Elcano	H (%)	HM (%)	M (%)	ML (%)	L (%)	H	HM	M	ML	L
1	Andalucia	109	8,379,248	17	1794	170	2	11	27	34	24	52	200	496	612	432
2	Aragon	67	1,307,984	11	280	25	4	16	48	16	16	11	44	134	44	44
3	Asturias	45	1,028,135	7	220	19	10	21	21	15	31	23	46	46	34	69
4	Baleares	59	1,128,139	9	241	21	9	28	14	33	14	22	69	34	80	34
5	Canarias	70	2,126,779	11	455	34	0	5	29	38	26	0	26	133	174	120
6	Cantabria	35	580,067	6	124	12	0	16	33	16	33	0	20	41	20	41
7	Castilla-Mancha	33	2,025,510	5	433	52	0	13	25	38	23	0	58	108	166	100
8	Castilla-Leon	81	2,407,650	13	515	62	3	4	24	43	24	16	24	124	224	124
9	Catalunya	135	7,596,131	21	1626	163	6	19	31	34	9	99	309	508	558	149
10	Valencia	99	4,959,243	16	1061	108	4	10	24	37	24	49	108	255	393	255
11	Extremadura	65	1,072,059	10	229	19	0	0	36	36	26	0	0	84	84	60
12	Galicia	75	2,700,970	12	578	55	3	10	25	34	25	21	63	147	199	147
13	Rioja	33	315,371	5	67	6	0	0	0	50	50	0	0	0	33	33
14	Madrid	132	6,576,009	21	1408	138	4	19	33	23	18	61	275	469	336	265
15	Murcia	45	1,477,946	7	316	27	0	14	22	37	25	0	46	70	117	82
16	Navarra	50	647,219	8	138	13	0	15	53	30	0	0	21	74	42	0
17	Vasco	75	2,198,657	12	470	44	11	11	31	27	18	53	53	149	128	85
18	Ceuta-Melilla	50	171,452	8	36	3	33	33	0	0	33	12	12	0	0	12
	TOTAL	1258	46,698,569	200	10,000	971	5	14	26	30	23	423	1381	2880	3253	2060

policy, and the five green policy scenarios) with full self-efficacy, (i.e, when $\beta = 1$). We compare, for a specific policy, the consequence of peer effect on the global evolution of agents' support for green policies. Second, we compare the six policy scenarios and their support by looking at different revenue distribution strategies. The support for specific policies is driven by both income effects linked to each specific policy and peer effects. At the same time, we study how the design and support for each policy influence the final number of green seats. Finally, we show the effect of self-efficacy on the overall system evolution. The model has been developed by relying on the agent-based approach (Epstein, 2012; Farmer and Foley, 2009), because it allows to fully consider the heterogeneity of our consumer/worker agents, their boundedly rational updating behaviour, and the complex interactions among the networks that compose the artificial economy under investigation, without imposing any analytical restriction, as the traditional approach to economics requires (Fontana, 2010; D'Orazio, 2019; Stiglitz, 2018).

We report average results over 100 runs for each combination of parameters. Replications of identical policy combinations generally varied only slightly – due to stochasticity – underpinning high robustness of the results. The considered time span for the simulations is 1000 steps, for a total of 10 seat elections. We begin the simulation with the election of political seats, which are re-elected every ten implemented policies. Between the implementation of each policy 10 peer influence steps are implemented. The code can be found at https://doi.org/10.5281/zenodo.6780132.

4. Results

In what follows we consider five different policy scenarios plus a baseline scenario where no green policy is implemented: uniform (same effects on all the income classes), regressive (larger costs on low-income classes), progressive (larger costs on high-income classes), bimodal (affects positively both the lowest and the highest classes) and middle (affects positively the middle class).

Fig. 4 represents the six scenarios that explain why the evolution of people's support for mitigation policy needs to be studied through models that consider both economic incentives and peer influence. We report the average level of green propensity among citizens (green bars for the five social income classes: red bar for the population average) together with the average number of green seats at the end of the simulation (blue bar).

4.1. The feedback effect between political engagement and voters' acceptance

Fig. 4a shows the effect that a brown policy alone (e.g., subsidising fossil fuels) has on the evolution of people's green propensity. Whenever the political network does not show any interest in promoting mitigation policy, the strength of green propensity dissipates, at any level of peer pressure, and the political green seats practically disappear in all simulations. In other words, what we observe is a coevolution of social and political institutions. Even if all the citizens were motivated to change and were aware that such change is necessary, no one would act alone (Olson, 1965; Ostrom, 2000) unless enforced by a legal power that functions as a catalyst (Székely et al., 2018; Lipari and Andrighetto, 2021). If, instead, the political layer starts showing an interest in mitigation policy - from Fig. 4b to Fig. 4f - the evolution of α and the number of seats sustaining the green policy start to rise.

4.2. Social norms, income effect and inequality

Figs. 4b to 4f also show how much the peer effect modulates the income effect. Whenever the peer effect is null, the response to the policy is driven only by the individual propensity and the income effect relative to the policy. Our results show that when peer pressure, via social learning, increases its weight, then the single income effect starts to lose its power and the social effect increases the average propensity non-linearly. In most of the scenarios, the peer effect already has an impact for a low level of peer pressure (i.e., $\sigma = 0.25$). In scenarios presented in Fig. 4c, d, and e, the highest average propensity to support a green policy is reached when $\sigma = 0.25$ while it slightly decreases for higher levels of peer effect.

Indeed, the fact that agents share information, and interact, and by this interaction, they form common knowledge that has an impact on the evolution and level of final green propensity. For uniform policy, see Fig. 4(b), for different levels of peer pressure, the average green propensity oscillates around 0.6, with slightly higher levels when peer effect is mild or strong. For the rest of the panels, the highest level of final green propensity is achieved for a low level of peer pressure.

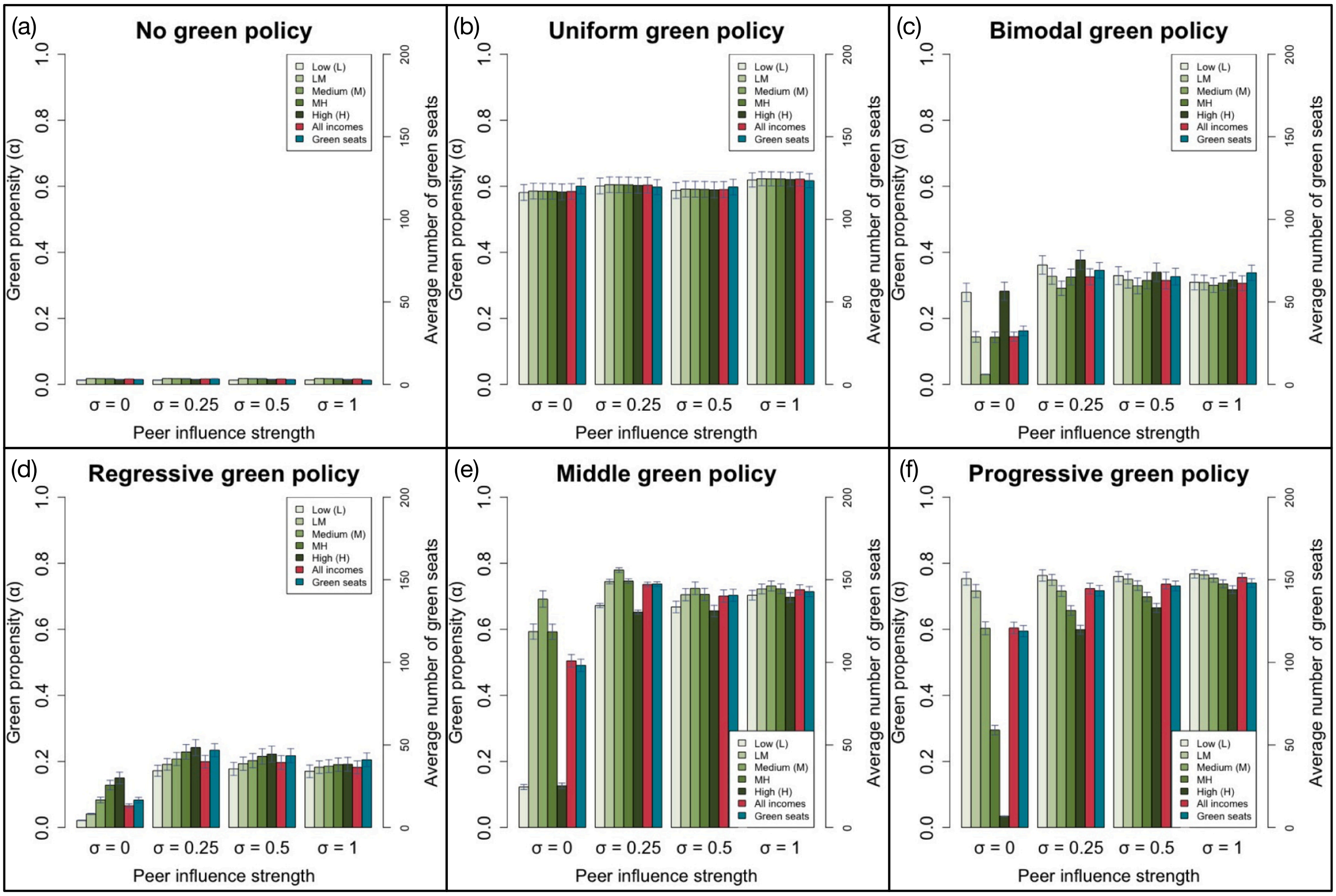

Fig. 4. The effect of green policies and peer influence on citizens' green propensity, α, and on the number of green seats. Each panel represents the final average level of α and the final number of green seats for each policy implementation and for different degree of peer influence. When σ = 0 peer pressure is absent, for σ = 0.25 agents are exposed to low peer pressure, when σ = 0.5 pressure from neighbours is mild, and when σ = 1 neighbours' influence is pervasive. Averages and standard errors are reported. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Finally, people's attitudes towards mitigation policy are negatively affected by inequality and in accordance with the literature, see (Kallbekken and Sælen, 2011; Brannlund and Persson, 2012; Carattini et al., 2017), the scenarios that received more support (i.e. the acceptance rate is higher) were those in which the distribution of revenue is either uniform or progressive towards the poorer or more vulnerable members of society (i.e. scenarios with a green policy aimed at reducing the impacts on the middle-income and lower income classes). On the other hand, it is also interesting to note how the peer effect modulates the income effect when progressive and middle class green policies are implemented. The two policies are designed to meet the needs of low- and middle-income classes, according to the fair and needy principles of redistributing the revenues. Hence, high-income classes are impacted less positively than the others, and indeed the green propensity α of such classes is very small when agents are not exposed to peer pressure. Yet, when the peer effect kicks in the α for the high-income classes also increases.

4.3. Effect of self-efficacy

In our model self-efficacy β is introduced during the policy stage. When a new policy is implemented, that is the time in which people need to change their behaviour and update their beliefs about their capability to act. If their capability to act is scant (i.e., self-efficacy tends to zero) the acceptance of the green policy will fall. This is the result that we see in Fig. 5 when we compare the effect of all the policies in a population with full and equal self-efficacy efficacy ($\beta = 1$), see Fig. 5 (a), against a population with heterogeneous self-efficacy (β decreases as the income class decreases), see Fig. 5 (b). Fig. 5(a) shows the evolution of α in all the policies when self-efficacy is the same for the entire population, as results reported in Fig. 4. We can see that the type of policy affects both the initial level and the evolution of individual's support for green solutions. Hence, the across policy analysis shows that highly progressive policies (i.e., policies that support low-income classes) and the uniform ones (i.e. policies that impact equally all income classes) start off with a higher initial α and are more able to maintain that higher support across income classes. Furthermore, the effect of peer pressure across the policy is different. For middle and progressive policies, a very low level of peer pressure (i.e. $\sigma = 0.1$) is needed to boost acceptance; for uniform policy the impact of peer pressure is not determinant in modulating the level of acceptance as well as in the no-green policy scenario; finally, in the bimodal and regressive scenarios peer pressure must be higher (i.e. $\sigma = 0.3$) to increase acceptance of green policies.

Fig. 5b shows the evolution of the green propensity α in all the policies when self-efficacy is heterogeneous across income classes. Heterogeneity in β is modelled taking into consideration that as we go down the social ladder, from high-income to low-income classes, the competences of individuals decrease. This assumption is motivated by the tendency observed in the empirical results reported in Fig. S2b of the supplementary figures. The effect of heterogeneous self-efficacy does not have an impact on the ordering of policies, i.e., middle and progressive green policies are still higher than their more regressive counterparts, but the initial level of α and subsequently its evolution are, across all policies, lower than the scenario in which β is full across

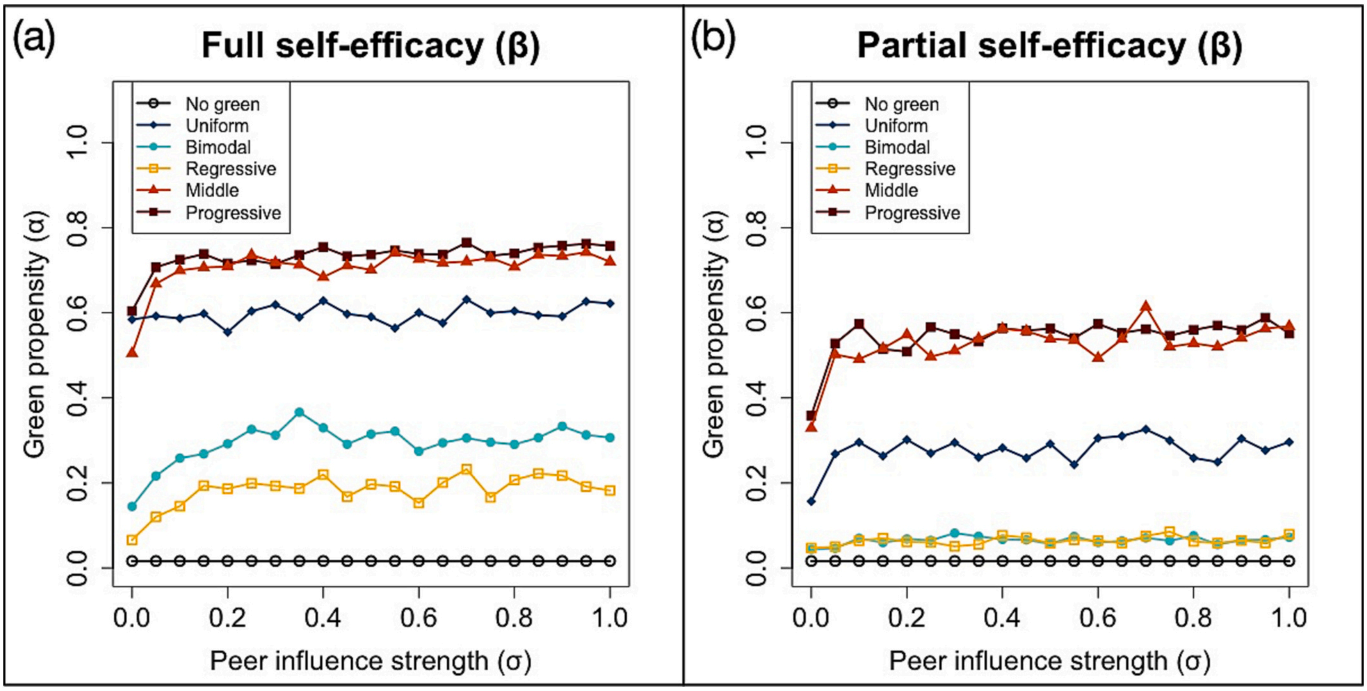

Fig. 5. *Effect of self-efficacy on green propensity for all policies and peer influence.* The figure shows the evolution of green propensity for each policy scenario, at different levels of σ, in the two cases where self-efficacy is considered the same for all income classes (a) and where β is decreasing as the income classes decreases (b). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

income classes. In Fig. 5b the effect of regressive and bimodal policies is that green propensity drops even further. Moreover, there are differences between the two figures also among regressive and uniform policies. First, the middle and progressive policies in Fig. 5b start with almost the same initial level of α, while in Fig. 5a it is not the case. As the peer pressure increases, the sudden increase of α, in both policies, seems to be larger when β is heterogeneous than when it is homogeneous. Second, the gap between the two more regressive policies and the uniform policy is larger when β is heterogeneous. This result is very important because if a uniform policy is designed on the assumption that all agents have the same capabilities and that its impact is not very different from the efficacy of regressive or middle policies, the efficacy of the uniform policy is overestimated with respect to the real scenario in which β is heterogeneous. The final level of α with no peer pressure ($\sigma = 0$) undergoes a drop in all the three policies (uniform, middle and progressive). More specifically for the middle and regressive policies the drop is of about 0.2 points. But, in the case of the uniform policy, the reduction is even higher (the drop is of >0.4 points). Hence, the assumption of a homogeneous self-efficacy, that assumes people would understand perfectly all the features of a policy, would lead to wrong estimations of final acceptance.

4.4. Regional effect

The analysis now focuses on understanding how regions can be effectively incorporated into the decision-making process driving climate policy. The discussion on the implementation of national mitigation policies cannot be done without also considering the regional differences within a country. Whenever we zoom in on regional analysis, what was valid at the national level could change. After all, income inequalities, social norms and green propensity exist not only at national level but also at a regional level and the reaction of individuals is mediated by their regional institutions and capabilities. Fig. 6 shows the regional differences under three main policies (regressive, middle, and

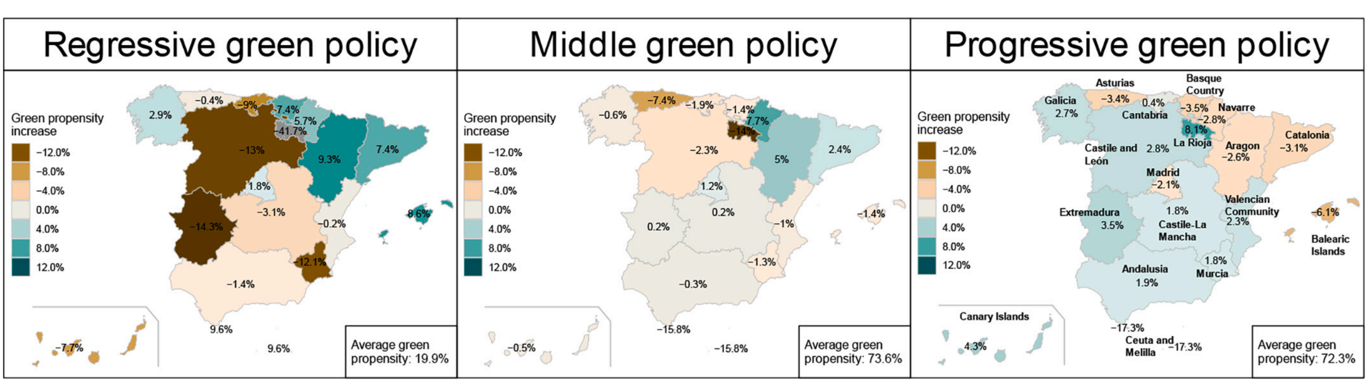

Fig. 6. *Regional green propensity variation for three main policy scenarios (*i.e., *regressive, middle, and progressive green policy).* The regional green propensity variation is computed as the normalized difference between the average regional green propensity, α_C, and the average national green propensity. Positive variations are colour coded with green while negative variations are in brown. Peer pressure (σ) was set at 0.25, but similar results were obtained for other values. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

progressive policies) and $\sigma = 0.25$. We report the normalized relative differences between the final green propensities per community and the national average green propensity. As one can see, the latter is not uniformly distributed across communities since some of them react more positively to specific policies than others. If the policy effect is more homogeneous across the communities, the final Spanish map displays a great portion of light grey areas. If the policy effect is heterogeneous across communities, then we can observe polarized scenarios.

As it happens for the individual income classes the regions which are, on average, poorer are those most negatively impacted by the regressive policy and, consequently, their final level of green propensity tends to be lower (e.g. Extremadura is the most impacted region in negative terms, with a $-14,3\%$ versus the average national level), while regressive policies benefit the regions that are richer (e.g. northern-eastern regions are greener than the others). Once we apply a more progressive policy, we can see the transitions towards maps that are greener in poorer regions. The comparison between middle and progressive policies shows further insights. We can observe that, given a similarly high level of national average green propensity around 73.6%, the two scenarios are polarized in opposite ways: richer communities (such as Navarra, Aragon and Cataluña) are above the national average when a middle green policy is implemented while the reverse scenario is observed for a progressive policy.

5. Discussion

The agent-based simulations show that the representation of decision-making in the model strongly influences the predicted existence and the acceptance rates of green policies. In what follows we present four channels through which the acceptance might be swayed. We start by presenting the role played by the political level in steering acceptance according to the intensity of green engagement of its representatives. Then, we move to address the roles played by individuals' income, cognitive abilities, and social preferences in the acceptance of a policy. Finally, we present the importance of having a regional representation of the acceptance along with the national one to single out possible bottlenecks in the development of a policy that, in turn, would reduce its efficacy.

5.1. Political engagement matters

Our first result underscores the crucial role of political leadership in driving public support for climate change mitigation policies. When politicians fail to show interest and commitment to addressing climate change, public support for the issue diminishes at any level of peer pressure, and the political green seats disappear. If, instead, the political layer starts showing an interest in mitigation policy the evolution of citizens' green propensity and the number of seats sustaining the green policy start to rise. This first result shows the importance of approaching the issue of cooperating in climate policy from the perspective of the coevolution of political and social networks (Greif and Kingston, 2011; Greif and Laitin, 2004). This result is in accordance with the literature stating that their countries' attitude drives policymakers' action. The higher the request for green policy, the higher the support for green seats and, in turn, the stronger the green propensity (Murray and Rivers, 2015).

This first result suggests that regulations are necessary tools to sustain citizens' propensity, but acceptability of the policy depends on how the regulation is designed. This highlights the need for proactive engagement (Luís et al., 2018) and advocacy from political leaders to mobilise public opinion and galvanise support for effective climate policies. International experience has shown the importance of systematic stakeholder engagement, at both national (Luís et al., 2018) and regional level (see Lennox et al., 2011 for a two case studies in New Zealand), for successful adaptation policies (Palermo and Hernandez, 2020 for a case study in various municipalities in Malaysia) and mitigation policies (Ferreira et al., 2022 for a case study in Portugal). Stakeholder engagement is considered an efficient tool to design sounding policies that reflect the need and expectation of the constituents. The importance of participation by all actors is emphasized throughout the 2030 Agenda[7] (United Nations, 2015): the engagement is so powerful that take a considerable attention in the achievement of SDG 13 (i.e., Climate Action). Stakeholder engagement serves two objectives: firstly, increasing the accountability of the policy cycle (i.e., designing policies for the needs and desires of the constituents, fostering trust between citizen and policymakers), and secondly, helping citizens to attain agency over the global climate dilemma.

An example of the first objective is offered by Ferreira et al. (2022) which explores whether in Portugal stakeholders' choices align with priority interventions, proposed solutions and expected benefits: the results shows that stakeholders can make decisions that lead to a coherent mitigation policy designed for sustainable cities. Yet, stakeholder engagement in long-term sustainable development works best if it is organised as a continuous process rather than being conducted on an ad hoc basis or through unrelated one-off engagement exercises at different points of the policy cycle. A structured process enables stakeholders as well as governments to plan ahead, to assemble evidence, reports and other material to make well-researched contributions at the appropriate time in the policy cycle. Moreover, stakeholder engagement works better if the voices heard are representative of the regional differences within the country to avoid that polarisation could hinder the successful implementation of national mitigation policies.

On the second objective, Ojala (2022) shows how collective climate change action can lead to constructive hope, i.e., hope that strengthens goal setting and decarbonization pathways. The paper shows how top-down intervention like the use optimistic messages may increase climate hope, but with varying success. Intervention focused on solution-oriented individual and collective actions is more effective than general progress messages. Action can lead to increased hope: engaged individuals often report feeling more hopeful, knowing they are not alone in addressing climate change. Stakeholder participation sessions allow citizens to activate such actionable hope at the point of performing prefigurative practice, where individuals become role models for sustainable living.

5.2. The role of peer influence and income effect on policy acceptance

As regulation coordinates actions, peer pressure coordinates intentions thanks to the effect of creating common knowledge. While individual factors like income play a role, the influence of peers within social networks can either amplify or dampen the effect of these individual factors.

Listening to peers and incorporating others' opinions in the evolution of their own opinion is a sign that social consensus is building up and, hence, social norms start influencing people's green propensity. These results are supported by the previous literature (Nyborg et al., 2006; Allcott, 2011; Bolsen et al., 2014; Allcott and Kessler, 2019; Andor et al., 2020; Szekely et al., 2021; Alló and Loureiro, 2014; Van der Linden et al., 2015). Moreover, whenever the population is strongly oriented towards green policy, their voices influence their voting choice (i.e., the number of green seats increases) and shape the support for climate change policy measures among policymakers themselves (Nilsson et al., 2004). In Fig. 4, the consequence of social learning and income effect on the final number of green seats is evident for uniform, middle and progressive policies (higher for the latter two), which results in a higher number of final green seats with respect to their regressive counterparts. This is somewhat a different result from the one in Konc et al. (2022),

[7] The Preamble highlights "a spirit of strengthened global solidarity, focused in particular on the needs of the poorest and most vulnerable and with the participation of all countries, all stakeholders and all people."

where social influence is expressed in terms of similarity of political ideology and where the social network has a free scale topology where wealthier citizens tend to be more central and influential in the social networks with harsh consequences on the support of progressive policies. The two different results highlight the importance of network structure in the evolution of policy support. Moreover, they highlight the necessity of producing more studies that aim at calibrating the network of connections of individuals.

Moreover, peer pressure has an increasing impact on the citizens' income classes not only when a policy is benefiting them. Such an increase could be determined by the homophily measure we have implemented. In our model, homophily represents the reference groups of each agent: rich citizens have a higher probability to meet other rich ones than poorer although all income classes are connected among each other. Hence, as soon as we allow peer pressure σ to increase, rich citizens will be also influenced by poorer ones and, by social learning dynamics, the high-income classes convince themselves that progressive and middle green policies benefit society, even if the policies imply higher costs (or lower benefit) for them. Then, the support for more progressive policies, that would be economically subpar for higher income classes, could be an expression of other motivations that in this paper we cannot assess, like, the warm-glow effect or preference for equity or fair distribution of the costs (Maestre-Andrés et al., 2019), or fairness perceptions of environmental green policy. Even though the reasons behind such an increase are beyond the scope of this paper, successful green policy design would benefit from capitalising on these results and adding complementary instruments, like community engagement or citizen assemblies (Luís et al., 2018; Teodoro et al., 2021), which, by using information transmission and network structure, would increase citizens' support for mitigation policies. This finding highlights the importance of considering social dynamics and network effects when designing communication strategies and policy interventions. From a policy intervention, the findings highlight, on the one hand, the importance of having a clear understanding of the social network in which people are embedded, and on the other hand, complementary policy interventions need to be designed to increase social interactions when homophily is present. For example, when reference groups and social networks are highly stratified by socioeconomic class (i.e. people tend to befriend others with similar incomes), and such structure creates biased information towards the acceptance of mitigation policy, exposing people to a larger pool of people by means of public consultation could break the vicious cycle biased perception on mitigation policy.

5.3. Effective policy is tailored to heterogeneous populations

The assumption of a homogeneous self-efficacy, that assumes people would perfectly understand all the features of a policy, would induce an overestimation of the final acceptance level.

The cause of such difference in α is due to the self-efficacy effect: even though the choice of policy addresses the severity of the economic impact that a green policy creates, people's limited competence to understand (and their perceived lack of capacity to respond to) the policy impairs their capacity to take advantage of it and reduces their support (Kallbekken et al., 2011). When facing the decision of how to change their behaviour, low-income classes would abide more often by curtailment policy (e.g., turning off lights, driving less) rather than engage in more complex green decisions like investment in energy efficiency improvements or taking advantage of tax or financial benefits. Thus, the efficacy of the set of policy instruments associated with middle and progressive green policy decreases and so does the general individual's acceptance rate. Results like those depicted in Fig. 5b are consistent with the literature on boosting policy which targets competencies and capabilities rather than immediate behaviour. Hence, to increase the acceptance and efficacy of the already cited policies, the policymakers might consider designing complementary interventions aimed at increasing β by fostering existing competencies or developing new ones, such as financial and energy literacy, and enhancing deliberative capabilities (Hertwig and Grüne-Yanoff, 2017).

Thus, policies that assume all individuals possess similar capabilities have less impact than anticipated. Instead, policies tailored to the specific needs and characteristics of a heterogeneous population, particularly in terms of income disparities, are more effective. By acknowledging and addressing these differences, policymakers can develop targeted interventions that resonate with diverse segments of the population. Moreover, to increase the acceptance and the efficacy of the policies, policy complementary interventions, aimed at increasing self-efficacy, are necessary. In this research, we investigated the role of self-efficacy biased according to income class. However, as for future work, we intend to further study the distribution of self-efficacy at a regional level to identify other sources of potential heterogeneity that could affect the acceptance of the policy. Furthermore, whenever the population is strongly oriented towards green policy, their voices influence their voting choice (i.e., the number of green seats increases) and shape the support for climate change policy measures among policymakers themselves (i.e. increasing the probability of designing a green policy).

5.4. Regional heterogeneity affects acceptance

Accounting for regional variations in public support for climate change mitigation policies within a country is of paramount importance. One relevant parameter of the model is the homophily measure of individuals that creates their social network. In the model, each agent interacts with the others not only based on income level but also based on community residency. The association between individuals allows them to have, with a certain probability, connections with other agents outside their income class and community of residence, hence the display of such interaction allows an agent living in Madrid to discuss green policy with an agent living in Andalusia. Such interaction influences the evolution of the green propensity, not only at the national level and at the income class level, but it can also be measured at a regional/local level. Bearing in mind also that such intermediate level gives the policymaker a deeper understanding of impacts and an additional tool for analysis at the time of national and regional policy design. These results are a strong indication that also regional heterogeneity is a source of paramount information. Climate change is a global phenomenon with local impact. The fight against climate change cannot be won at the expense of some regions and policymakers need a deeper understanding of impacts when designing national and regional policies. According to the OECD report (Matsumoto et al., 2019) the lack of horizontal (e.g., different methods of gathering data on greenhouse gas emissions) and vertical (e.g., lack of subnational authority in energy supply, or limited access to green finance) coordination between national and subnational government reduces the possibility of the latter to reach their full mitigation potential. To solve this policy misalignment between national and subnational governments, the policymakers need to strengthen the coordination at the national and local levels by developing and implementing plans, policy tools, or localised reporting and monitoring frameworks.

Thus, policymakers must adopt a nuanced approach that considers regional contexts and engages with local stakeholders to ensure broader public acceptance and cooperation. Even though in this study we assess the effect of national policy on the regions, an interesting extension of the model should consider also regional-oriented policy. Said extension could highlight our last results that show that regional inequalities, as well as regional polarisation of social norms (for green or brown policies) are sources of information that should be accounted for and addressed when policies are designed.

6. Conclusions

The challenge posed by climate change calls for policymaking that looks at both the demand and the supply sides of mitigation through/ with a deeper understanding of the determinants and the dynamics of policy support. In the literature on climate change modelling, the socio-political processes which determine climate policy are treated as exogenous. Our main theoretical contribution is identifying the relevant feedback processes between social and political levels, that are present in a vast and interdisciplinary literature, and connecting them in a stylised model of the social and political system aimed at understanding how to achieve higher support for climate change mitigation policies. Our findings help enhance current understanding of the complexities of public opinion and provide valuable guidance for policymakers aiming to foster widespread support for climate change mitigation initiatives. Our policy contributions to practitioners and policymakers are twofold. On the one hand, the support for climate change mitigation actions depends on the coevolution of regulation, market-oriented policies, and social contexts. On the other hand, policy acceptance requires an understanding of the role that individual and regional heterogeneity play. For this reason, the design of environmental and climate policies should account for both aspects.

To reach those results, we applied our framework to green policy analysis and developed a model of political support of climate mitigation policy with socially embedded agents. The simulations demonstrate that the assumed representation for voters' decision-making significantly impacts predicted acceptance rates. Their acceptance of the policy is a function of four individual variables: individuals' intrinsic preferences for green policies, peer influence arising from their social network, their perceived self-efficacy, and the income effect of the policy. In this setting, policy acceptance and voting decisions are affected directly by the income effect and indirectly by the influence of peers. Another important element for acceptance is political engagement.

Our first result underscores the importance of modelling the feedback effects existing between political engagement and voters' support for the policy. Political leadership plays a critical role in garnering public support for climate change mitigation policies. If politicians fail to show interest and commitment in addressing climate change, public support wanes and the political representation supporting environmental policies diminishes.

Our second result reveals the importance of peer influence and networks. While individual factors such as income have an influence, the power of peers within social networks can enhance or diminish the impact of these individual factors. When the weight of peer pressure increases, via social learning through individuals' reference groups, the single-income effect starts to lose its grip and the social effect increases the average propensity to accept green policies non-linearly.

Third, the simulation highlights the limitations of one-size-fits-all approaches to climate policy. Generally, the results highlight the importance of choosing an adequate approach to represent voters' decision-making in models as a prerequisite for reliable policy recommendations. Inappropriate representation of voters' decision making can lead to over or under estimation of acceptance rates, which can mislead policymakers and even prevent them from providing the needed support. Assuming people have the same self-efficacy would lead to wrong estimations of policy acceptance. Finally, the effect of regional analysis shows that the national level of green propensity to accept green policies offers the policymaker only a partial representation of reality. It is crucial to acknowledge that different communities may respond differently to specific policies, resulting in varying levels of support or opposition to mitigation policies. Failure to consider these regional differences can lead to polarisation and hinder the successful implementation of national mitigation policies. Policies that on average seem optimal could have a reverse effect when observed at the regional level.

These results offer possible avenues for future research in three dimensions: the decision making, policy-type, and multiplex network dimensions. The decision-making dimension seems the most promising, with several possible model extensions. First, currently the initial alpha is uniformly distributed between 0 and 1. What happens if its distribution is more polarized on average or with respect to income and regions? High polarisation of initial acceptance could reduce the impact of social influence and the optimal level of σ could be higher than we found (i.e., the exposure to others' opinions should be larger). Related to the previous assumption, such polarisation is more likely to happen when social influence plays a strong role in preferences' formation. Further analysis could also be done on sigma, which now is the same for the entire population. If social learning intensity is wider, i.e., people's interaction goes beyond their geography or income class via participatory instruments, then they are exposed to a higher diversity of opinions and ideas and such exposure could increase the green propensity. On the contrary, if social learning occurs in a niche, i.e., people interact only with their neighbours, opinions become polarized preventing the emergence of a coordinated action for voting green. A third extension could collect primary data on σ by asking citizens to elicit both their social network and the degree of interaction with it. Regarding the policy-type dimension, this model could be adapted to assess the acceptability of adaptation policies. As regards the multiplex network dimension, an interesting extension would be to add an intermediate level representing either the companies or sub-national institutions.

Additional information

Accession codes. The simulation code and results to generate the figures can be found at: https://doi.org/10.5281/zenodo.6780132.

Declaration of Competing Interest

None.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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References

Ajzen, J., 1991. The theory of planned behavior. Organ. Behav. Hum. Decis. Process. 50 (179–21).
Allcott, H., 2011. Social norms and energy conservation. J. Public Econ. 95, 1082–1095.
Allcott, H., Kessler, J.B., 2019. The welfare effects of nudges: A case study of energy use social comparisons. Am. Econ. Journal: Appl. Econ. 11, 236–276.
Allcott, H., Mullainathan, S., 2010. Behavior and energy policy. Science 327, 1204–1205.
Allcott, H., Rogers, T., 2014. The short-run and long-run effects of behavioral interventions: experimental evidence from energy conservation. Am. Econ. Rev. 104, 3003–3037.
Alló, M., Loureiro, M.L., 2014. The role of social norms on preferences towards climate change policies: A meta-analysis. Energy Policy 73, 563–574.
Alvarez, M., 2019. Distributional effects of environmental taxation: an approximation with a meta-regression analysis. Econ. Analysis Policy 62, 382–401.
Amaral, L., Scala, A., Barthélémy, M., Stanley, H.E., 2000. Classes of small-world networks. Proc. Natl. Acad. Sci. 97 (21), 11149–11152.
Andor, M.A., Gerster, A., Peters, J., Schmidt, C.M., 2020. Social norms and energy conservation beyond the us. J. Environ. Econ. Manag. 103, 102351.

Andre, P., Boneva, T., Chopra, F., Falk, A., 2021. Fighting climate change: The role of norms, preferences, and moral values.
Araujo, J.O., 2011. Los sistemas electorales autonómicos. Generalitat de Catalunya, Departament de Governació i Relacións Institucionals.
Bandura, A., 1986. Social Foundations of Thought and Action. Prentice-Hall, Englewood Cliffs, New Jersey.
Bandura, A., 1997. Self-efficacy: toward a unifying theory of behavioral change. Psychol. Rev. 84, 191.
Baranzini, A., Carattini, S., 2017. Effectiveness, earmarking and labeling: testing the acceptability of carbon taxes with survey data. Environ. Econ. Policy Stud. 19, 197–227.
Beiser-McGrath, L.F., Bernauer, T., 2019. Could revenue recycling make effective carbon taxation politically feasible? Sci. advances 5, eaax3323.
Benabou, R., Tirole, J., 2011. Laws and Norms. Tech. Rep. National Bureau of Economic Research.
Besley, T.J., Persson, T., 2022. The Political Economics of Green Transitions.
Bicchieri, C., 2005. The Grammar of Society: The Nature and Dynamics of Social Norms. Cambridge University Press.
Boccaletti, S., et al., 2014. The structure and dynamics of multilayer networks. Phys. Rep. 544, 1–122.
Boguná, M., Pastor-Satorras, R., Díaz-Guilera, A., Arenas, A., 2004. Models of social networks based on social distance attachment. Phys. review E 70, 056122.
Bolsen, T., Leeper, T.J., Shapiro, M.A., 2014. Doing what others do: norms, science, and collective action on global warming. Am. Polit. Res. 42, 65–89.
Bond, R.M.C.J., Jones, Jason J., Di Kramer, Adam, Marlow, Cameron, Settle, Jaime, Fowler, James H., 2012. A 61-million-person experiment in social influence and political mobilization. Nature 489, 295–298.
Brannlund, R., Persson, L., 2012. To tax, or not to tax: preferences for climate policy attributes. Clim. Policy 12, 704–721.
Caldés, N., et al., 2019. Policy Pathways for spain's Energy Transition.
Carattini, S., Baranzini, A., Thalmann, P., Varone, F., Vöhringer, F., 2017. Green taxes in a post-Paris world: are millions of nays inevitable? Environ. Resource Econ. 68, 97–128.
Carattini, S., Levin, S., Tavoni, A., 2020. Cooperation in the climate commons. Rev. Environ. Econ. Policy 1.
Cole, J.C., Ehret, P.J., Sherman, D.K., Van Boven, L., 2022. Social norms explain prioritization of climate policy. Clim. Change 173, 1–21.
Crowley, K., 2017. Up and down with climate politics 2013–2016: the repeal of carbon pricing in Australia. Wiley Interdiscip. Rev. Clim. Chang. 8, e458.
Currarini, S., Jackson, M.O., Pin, P., 2009. An economic model of friendship: Homophily, minorities, and segregation. Econometrica 77, 1003–1045.
Dasgupta, P., Southerton, D., Ulph, A., Ulph, D., 2016. Consumer behaviour with environmental and social externalities: implications for analysis and policy. Environ. Resource Econ. 65, 191–226.
Dechezleprêtre, A., Fabre, A., Kruse, T., Planterose, B., Chico, A.S., Stantcheva, S., 2022. Fighting Climate Change: International Attitudes toward Climate Policies (vol. No. w30265). National Bureau of Economic Research.
D'Orazio, P., 2019. Income inequality, consumer debt, and prudential regulation: an agent-based approach to study the emergence of crises and financial instability. Econ. Model. 82, 308–331.
Douenne, T., Fabre, A., 2020. French attitudes on climate change, carbon taxation and other climate policies. Ecol. Econ. 169, 106496.
Douenne, T., Fabre, A., 2022. Yellow vests, pessimistic beliefs, and carbon tax aversion. Am. Econ. Journal: Econ. Policy 14, 81–110.
Drews, S., Van den Bergh, J.C., 2016. What explains public support for climate policies? a review of empirical and experimental studies. Clim. Policy 16, 855–876.
Duarte, R., García-Riazuelo, Á., Sáez, L.A., Sarasa, C., 2022. Economic and territorial integration of renewables in rural areas: lessons from a long-term perspective. Energy Econ. 110, 106005.
Dunlap, R.E., Van Liere, K.D., Mertig, A.G., Jones, R.E., 2000. New trends in measuring environmental attitudes: measuring endorsement of the new ecological paradigm: a revised NEP scale. J. Soc. Issues 56 (3), 425–442.
Epstein, J.M., 2012. Agent-based computational models and generative social science. In: Generative Social Science: Studies in Agent-Based Computational Modeling, 4–46. Princeton University Press.
Estrada, Á., Santabárbara, D., 2021. Recycling Carbon Tax Revenues in Spain. Environmental and Economic Assessment of Selected Green Reforms. Banco de Espana Working Paper.
Farmer, J.D., Foley, D., 2009. The economy needs agent-based modelling. Nature 460, 685–686.
Ferreira, V., Barreira, A.P., Pinto, P., Panagopoulos, T., 2022. Understanding attitudes towards the adoption of nature-based solutions and policy priorities shaped by stakeholders' awareness of climate change. Environ. Sci. Policy 131, 149–159.
Fishbein, M., Ajzen, I., 2010. Predicting and Changing Behavior: The Reasoned Action Approach. Psychology Press, New York, NY, USA.
Fontana, M., 2010. Can neoclassical economics handle complexity? The fallacy of the oil spot dynamic. J. Econ. Behav. & Organ. 76, 584–596.
Ghesla, C., Grieder, M., Schubert, R., 2020. Nudging the poor and the rich–a field study on the distributional effects of green electricity defaults. Energy Econ. 86, 104616.
Greif, A., Kingston, C., 2011. Institutions: Rules or Equilibria? In Political Economy of Institutions, Democracy and Voting, 13–43. Springer.
Greif, A., Laitin, D.D., 2004. A theory of endogenous institutional change. Am. political science review 98, 633–652.
Handcock, M.S., Raftery, A.E., Tantrum, J.M., 2017. Model-based clustering for social networks. Journal of the Royal Statistical Society: series A (statistics in society) 301–354.
Heine, D., Black, S., 2019. Benefits beyond climate: environmental tax reform. Fiscal Policies for Dev. Clim. Action 1.
Hertwig, R., Grüne-Yanoff, T., 2017. Nudging and boosting: steering or empowering good decisions. Perspectives on Psychol. Sci. 12, 973–986.
Holland, P.W., Laskey, K.B., Leinhardt, S., 1983. Stochastic blockmodels. First steps. Soc. networks 5, 109–137.
Hu, H., Wang, X., 2009. Evolution of a large online social network. Phys. Lett. A 373, 1105–1110.
IMF, 2019. Fiscal policies for Paris climate strategies–from principle to practice. IMF Policy Pap. No.
IPCC, 2018: Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield (eds.)]. In Press.
Jin, E.M., Girvan, M., Newman, M.E.J., 2001. Structure of growing social networks. Phys. Rev. E 64 (4), 046132.
Kallbekken, S., Sælen, H., 2011. Public acceptance for environmental taxes: self-interest, environmental and distributional concerns. Energy Policy 39, 2966–2973.
Kallbekken, S., Kroll, S., Cherry, T.L., 2011. Do you not like pigou, or do you not understand him? Tax aversion and revenue recycling in the lab. J. Environ. Econ. Manag. 62, 53–64.
Klenert, D., et al., 2018. Making carbon pricing work for citizens. Nat. Clim. Chang. 8, 669–677.
Konc, T., Savin, I., van den Bergh, J.C., 2021. The social multiplier of environmental policy: application to carbon taxation. J. Environ. Econ. Manag. 105, 102396.
Konc, T., Drews, S., Savin, I., van den Bergh, J.C., 2022. Co-dynamics of climate policy stringency and public support. Glob. Environ. Chang. 74, 102528.
La Barbera, F., Ajzen, I., 2020. Control interactions in the theory of planned behavior: rethinking the role of subjective norm. Eur. J. Psychol. 16 (3), 401.
Lázaro-Touza, L.E.L., González-Enríquez, C., Francés, G.E., 2019. Los Españoles ante el cambio climático: apoyo ciudadano a los elementos, instrumentos y procesos de una Ley de Cambio Climático y Transición Energética. Real Instituto Elcano.
Lennox, J., Proctor, W., Russell, S., 2011. Structuring stakeholder participation in New Zealand's water resource governance. Ecol. Econ. 70 (7), 1381–1394.
Levine, D.K., Mattozzi, A., 2020. Voter turnout with peer punishment. Am. Econ. Rev. 110, 3298–3314.
Lipari, F., Andrighetto, G., 2021. The change in social norms in the mafia's territories: the anti-racket movement of addiopizzo. J. Institutional Econ. 17, 227–242.
Luís, S., Lima, M.L., Roseta-Palma, C., Rodrigues, N., Sousa, L.P., Freitas, F., et al., 2018. Psychosocial drivers for change: understanding and promoting stakeholder engagement in local adaptation to climate change in three European Mediterranean case studies. J. Environ. Manage. 223, 165–174.
Maestre-Andrés, S., Drews, S., van den Bergh, J., 2019. Perceived fairness and public acceptability of carbon pricing: a review of the literature. Clim. Policy 19, 1186–1204.
Matsumoto, T., Allain-Dupré, D., Crook, J., Robert, A., 2019. An integrated approach to the paris climate agreement: The role of regions and cities.
Mattauch, L., Sommer, S., Pahle, M., et al., 2020. Supporting Carbon Taxes: The Role of Fairness. Tech. Rep. Institute for New Economic Thinking at the Oxford Martin School, University.
McCright, A.M., Dunlap, R.E., Xiao, C., 2014. Increasing influence of party identification on perceived scientific agreement and support for government action on climate change in the United States, 2006–12. Weather, Climate, and Society 6 (2), 194–201.
McPherson, M., Smith-Lovin, L., Cook, J.M., 2001. Birds of a feather: Homophily in social networks. Annu. Rview Sociology 415–444.
Muchnik, L., Aral, S., Taylor, S.J., 2013. Social influence bias: A randomized experiment. Science 341, 647–651.
Murray, B., Rivers, N., 2015. British columbia's revenue-neutral carbon tax: A review of the latest "grand experiment" in environmental policy. Energy Policy 86, 674–683.
Nilsson, A., von Borgstede, C., Biel, A., 2004. Willingness to accept climate change strategies: the effect of values and norms. J. environmental psychology 24, 267–277.
Noeldeke, B., Winter, E., Ntawuhiganayo, E.B., 2022. Representing human decision-making in agent-based simulation models: agroforestry adoption in rural Rwanda. Ecol. Econ. 200, 107529.
North, D.C., et al., 1990. Institutions, Institutional Change and Economic Performance. Cambridge University Press.
Nyborg, K., Howarth, R.B., Brekke, K.A., 2006. Green consumers and public policy: on socially contingent moral motivation. Resour. energy economics 28, 351–366.
Nyborg, K., et al., 2016. Social norms as solutions. Science 354, 42–43.
Ojala, M., 2022. Hope and climate-change engagement from a psychological perspective. Current opinion Psychology 101514.
Olson, M.L.J., 1965. The Logic of Collection Action: Public Goods and the Theory of Groups. Harvard University Press, Cambridge, MA.
Ostrom, E., 2000. Collective action and the evolution of social norms. J. economic perspectives 14, 137–158.
Ostrom, E., Basurto, X., 2011. Crafting analytical tools to study institutional change. J. institutional economics 7, 317–343.
Palermo, V., Hernandez, Y., 2020. Group discussions on how to implement a participatory process in climate adaptation planning: a case study in Malaysia. Ecol. Econ. 177, 106791.
Perri, S., Levin, S., Hedin, L.O., Wunderling, N., Porporato, A., 2023. Socio-political feedback on the path to net zero. One Earth 6 (6), 725–737, 16 June 2023.

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.
Safarzyn Ska, K., Van Den Bergh, J.C., 2022. Abm-iam: optimal climate policy under bounded rationality and multiple inequalities. Environ. Res. Lett. 17, 094022.
Savin, I., et al., 2022. Agent-based modeling to integrate elements from different disciplines for ambitious climate policy. Wiley Interdiscip. Rev. Clim. Change e811.
Shukla, P.R., Skea, J., Calvo Buendia, E., Masson-Delmotte, V., Pörtner, H.O., Roberts, D. C., 2019. et al. IPCC, 2019: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems.
Sociedad Espanola de Ornitologías, SEO, 2018. https://www.seo.org/wp-content/uploads/2018/10/Respuestas_LeyCC.pdf (Accessed:09/06/2023).
Stadelmann-Steffen, I., 2011. Citizens as veto players: climate change policy and the constraints of direct democracy. Environmental politics 20 (4), 485–507.
Stiglitz, J.E., 2018. Where modern macroeconomics went wrong. Oxf. Rev. Econ. Policy 34, 70–106.
Susskind, L., et al., 2022. Sources of opposition to renewable energy projects in the United States. Energy Policy 165, 112922.
Székely, Á., Nardin, L.G., Andrighetto, G., 2018. Countering protection rackets using legal and social approaches: an agent-based test. Complexity 2018.
Szekely, A., et al., 2021. Evidence from a long-term experiment that collective risks change social norms and promote cooperation. Nat. Commun. 12, 1–7.
Teodoro, J.D., Prell, C., Sun, L., 2021. Quantifying stakeholder learning in climate change adaptation across multiple relational and participatory networks. J. Environ. Manage. 278, 111508.
Tjernström, E., Tietenberg, T., 2008. Do differences in attitudes explain differences in national climate change policies? Ecol. Econ. 65, 315–324.
Ulph, A., Ulph, D., 2021. Environmental policy when consumers value conformity. J. Environ. Econ. Manag. 109, 102172.
United Nations, 2015. Transforming our World: The 2030 Agenda for Sustainable Development. United Nations, Department of Economic and Social Affairs, New York.
Van der Linden, S.L., Leiserowitz, A.A., Feinberg, G.D., Maibach, E.W., 2015. The scientific consensus on climate change as a gateway belief: experimental evidence. PloS One 10, e0118489.