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A tragedy of the horizons? An intertemporal perspective on public support for carbon taxes

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ABSTRACT

Most collective dilemmas—that is, situations in which private interests contrast with collective interests—have an embedded intertemporal component in that they often imply that the rewards from defection are immediate but the rewards from cooperation are delayed and often accrue to people in the future. This also applies to carbon taxes since they imply additional individual costs for benefits which will mostly be enjoyed by future generations, which undermines their political support. In an experiment on a representative sample of 1000 United States adults, we presented individuals with twelve alternative carbon tax formulations with varying start dates, temporal horizons of carbon abatement objectives and revenue uses. We find that public support is highest when individuals can pre-commit to policies that start a few years into the future and for policies that express their emission cuts objectives in more distant and ambitious terms —i.e. achieving carbon neutrality by 2050 as opposed to halving emissions by 2030. Individual temporal discounting, exogenously measured, account for large part of these preferences. These preferences are in contrast with the most efficient policy, which is the one that starts immediately and distributes equitably mitigation costs across time. We find two ways to realign preferences with it. First, the most efficient policy becomes politically feasible when the tax includes a dividend that is redistributed to citizens. Delivering an economic compensation at the same time of the individual costs of the tax neutralizes the effect of individual discounting and of the policy's temporal context on tax support. Secondly, when the price of the carbon tax is adjusted upward to compensate for the opportunity cost of delaying its introduction, individuals start trading off its delay with avoidance of tax increases.

1. Introduction

Sixty years ago, Garret Hardin connoted the term the Tragedy of the Commons to indicate that exploiting a common resource beyond its regeneration capacity provides private payoffs whereas the benefits of preserving the resource are shared (Hardin, 1968), which leads to its overexploitation. While Ostrom (1990) demonstrated that with monitoring and sanctioning systems in place the commons can be protected, the term has stayed to characterize open-access common-pool resources, such as the atmosphere or many fisheries (Libecap, 2008). But there is also a Tragedy of the Horizons hampering the protection of the commons (Gollier, 2020). The fruits from the sacrifices individuals and organizations could undertake today to protect resources will mostly be enjoyed in the very long term. This is particularly relevant in the context of natural resources preservation and to the climate commons since individuals must sacrifice current wellbeing for benefits which will mostly be enjoyed by future generations, which undermines political support in favor of climate regulation (Gollier, 2020). The temporal distribution of the environmental future benefits and of the costs it imposes naturally influences choices and the likelihood of achieving successful cooperation through individual climate mitigation efforts in real-world social dilemmas. To achieve successful cooperation in intertemporal environments, it is crucial to understand: a) the influence that the temporal context of the decision has on decision outcomes; b) the role individual time preferences and altruism play in the decision to cooperate; and c) the interplay between individual temporal preferences and the temporal context. In this paper, we focus on the public acceptability of a carbon tax and explore a new dimension in the literature: What is the temporal formulation of a carbon tax that maximizes its acceptability?

Carbon pricing is commonly regarded by economists as the most efficient and effective climate mitigation policy (either through carbon

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taxes or emission trading systems; Baranzini et al., 2017). However, most world emissions are still not affected by a carbon pricing instrument. The reluctance of politicians to adopt carbon taxes has been linked, among other things, to their unpopularity among voters, who notably perceive them as too coercive in comparison to "pull measures" such as subsidies. This paper investigates whether the temporal contextualization of carbon taxes can be adjusted to make them more popular. While seeking to optimize a policy's temporal context to the public's temporal preferences, one must not forget the temporal horizon of biophysical processes. The ambition of maintaining the temperature objective of 2°C depends on a fixed carbon budget constraint. The optimal timing to consume this remaining carbon budget in an intertemporally efficient manner has been analyzed by Gollier (2022). According to the author, the distribution of abatement costs recommended by the 5th IPCC report models shifts too much of the effort to the future, through carbon pricing proposals that start too cheap and increase too steeply. He attributes this intertemporal imbalance to the political unfeasibility of a high carbon price and to the unverifiable assumption that low mitigation technologies will be available in the future. Reportedly this causes high welfare losses. Thus, after investigating the temporal contextualization that maximizes public support, we then addressed the parallel question: what makes the most efficient policy, also politically feasible?

We undertook a hypothetical choice experiment in which a nationally representative sample of 1000 United States (US) adults voted in favor or against the introduction of alternative carbon tax designs which were characterized by different introduction dates (immediate, three or six years delay) and different temporal horizons (emission cuts are expressed either in 2030 or 2050 objectives). Additional policy attributes included revenue use, percentage of expected CO_2 emission cuts, taxation levels, and the estimated cost and revenues the tax may impose on households. To increase the salience of the experiment and its internal validity, we customized choice cards within the survey, rather than just showing average cost estimates, with ad-hoc calculations of the economic impact of the policy based on each participant's declared income and the consumption profile of the average person in her/his income quintile. We separately measured individual temporal preferences using a multi-pricelist experiment and analyzed whether or not more present-biased individuals are more likely to accept the tax in any given scenario. This allows us to disentangle the effects of temporal strategy from individual temporal preferences; for example, impatient individuals may prefer earlier rewards and to postpone sacrifices, whereas more future-oriented individuals or altruistic individuals may be more eager to commit to larger later rewards which are shared in the future between themselves and the next generations. With policy relevance in mind, we include carbon taxation prices that are deemed to be in the range of compatibility with the Paris Agreement objectives of maintaining global warming well below 2°C compared to pre-industrial levels. Additionally, we look at the impact of different temporal contextualizations on population groups that are found to be more opposed to the tax and that have at least one of the following characteristics: climate change deniers, individuals with conservative political values, individuals who distrust public institutions and who reject any personal responsibility to care for the environment.

We find that it is possible to optimize the temporal distribution of the carbon tax's costs and benefits to the public's preferences. Public support for a carbon tax increases substantially if its introduction and its associated economic costs are shifted forward by 3 and 6 years. Ceteris paribus, approval rates increase by 7 and 9 p.p. respectively, compared to when the tax is introduced immediately. Expressing the emission cuts objectives of the policy in more distant and ambitious terms —i.e. achieving carbon neutrality by 2050 as opposed to halving emissions by 2030— increases public support, however this policy attribute is statistically insignificant once other policy attributes are controlled for. This suggests it may increase support in combination with other policy attributes but not on its own. A policy that caters to the public's cost shifting preferences however comes at a future welfare loss, as the costs associated with climate mitigation increase with each year of inaction. This highlights a potential trade-off between the distribution of mitigation costs that is most efficient and the one that is most politically feasible. This contrast can however be addressed with appropriate policy design and communication. When the opportunity cost of delaying the tax is reflected within the policy proposal —i.e. the carbon price is adjusted upward to compensate for the delayed introduction— individuals start trading-off the postponement of the tax with its increased price and they no longer prefer to indefinitely postpone the tax. We also find that redistributing revenues as dividends to citizens counteracts this preference for postponing the policy, as this diminishes its immediate personal cost. More impatient individuals are less likely to support the tax and favor policies that start 6 years in the future. Receiving cash-back payments from the tax proceeds is also effective in neutralizing the negative effect of temporal preferences on tax acceptance. In line with previous research, we find that tax support decreases with its cost. Our analysis shows that tax levels compatible with a high probability of reaching the Paris' agreement climate targets —i.e. US\$80/tCO_2— become politically feasible if the tax includes cash-back payments. Promising cash-back payments to citizens is also effective in softening the opposition from citizens with conservative political views, climate-change deniers and citizens who distrust public institutions.

The rest of the paper is articulated as follows. Section 2 introduces the state of the relevant literature on intertemporal choice and on the acceptability of carbon taxes. It also provides context to legislation and public opinion on carbon taxes in the US. Section 3 describes the experimental design and how the survey and the analysis were structured. Section 4 presents the results through qualitative and econometric analyses. Section 5 summarizes our key findings and conclusions.

2. Background

2.1. Literature review

2.1.1. Intertemporal choice

The temporal dimensions of collective dilemmas and of the acceptability of carbon pricing are surprisingly unexplored.[1] Individual discount rates and a resource pool's temporal horizon have been identified as temporal dimensions that should theoretically influence cooperation in resource pool dilemmas (Hendrickx et al., 2001). However, empirical evidence to date on the influence of these factors on the likelihood of cooperation is fragmentary. Earlier research has highlighted that individual discounting correlates negatively with cooperation, suggesting that the temptation to free ride may be stronger for more impatient individuals (Mannix, 1991; Curry et al., 2008; Fehr and Leibbrandt, 2011). Research that has analyzed the influence of the temporal horizon of choice highlights that the longer people feel invested in a community, the more they will be willing to cooperate for its common good. For instance, Mannix and Loewenstein (1993) found that managers who anticipated that they would stay longer in the same role would contribute more to a public organizational fund. Additional experimental research has shown that cooperation becomes more unlikely as the gains from cooperation are shifted further away in time (Jacquet et al., 2013). Arora et al. (2012) found that when the consequences of a decision are shifted to the future—such as whether or not to donate to an investment cooperative if the payment is delayed by six months—individuals tend to show higher cooperation compared to when they

[1] We acknowledge that, while accepting to pay an environmental tax certainly implies a cooperative attitude, we cannot exclude that tax opposition may not necessarily relate to unwillingness to avert climate change. Tax opposition may be motivated by tax avoidance more in general or skepticism towards the effectiveness of carbon taxes as a mitigation strategy. To control for this possibility we calculate an index of individual trust in political institutions.

face the immediate consequences of their choices. In addition, pre-commitment mechanisms are one of the most known mechanisms to induce individuals to avoid present bias and invest in their future wellbeing both academically and in the established practice, for instance, by enrolling in saving schemes (Thaler and Benartzi, 2004; Benartzi and Thaler, 2013).

The available evidence thus suggests that the default temporal setting in which the costs of cooperation are immediate, and gains are delayed undermines the possibility of cooperation. Can asking people to commit to a carbon tax that starts a few years from now increase its public support by shifting the costs it imposes to households in the future? Are individuals more likely to accept it if the gains from cooperation—in terms of future carbon emissions cuts—are expressed by a more proximal date? Do present- and future-focused individuals have similar preferences regarding the temporal distribution of the sacrifices and rewards of a carbon tax? The extent to which the temporal distribution of costs and gains can be manipulated to increase cooperation has not been systematically studied; nor are the interactions between individual time preferences and the contextual temporal setting known.

2.1.2. Carbon tax acceptance

The literature on the acceptability of carbon taxes has analyzed the impact of individual characteristics, contextual factors, and different policy designs on various geographical settings, mainly through stated preferences approaches (for a review, see Drews and van den Bergh, 2016). Common findings that are relevant to our study indicate that people tend to overestimate carbon tax costs and underestimate their environmental effects, that tax acceptability decreases with the personal costs associated with it, and that tax resistance decreases after people have gained experience with the tax (Cherry et al., 2014; Bergquist et al., 2022; Douenne and Fabre, 2022). Several studies and opinion polls have indicated a marked preference for the earmarking of revenues: individuals are more favorable to carbon taxes when revenue use is destined to finance other environmental mitigation activities, to reduce other taxes, or for redistributions in the form of cash-back payments as opposed to when the use of the revenues is not specified (Bachus et al., 2019). Support for carbon taxes also depends on the level of trust in political institutions (Savin et al., 2020) and knowledge about climate change (Douenne and Fabre, 2022).

To date, only two experiments have looked into the relationship between acceptability and the temporal context of an environmental tax. In a laboratory experiment with 218 students, Tiezzi and Xiao (2016) undertook an intertemporal market experiment based on auctions of an externality-producing good. They surveyed how support for the introduction of an environmental tax to account for the externality changed as a function of the timing of the externality. They found that environmental taxes were less likely to be approved when the externality materializes after the good that produces them has been traded and consumed. They also concluded that in real life, individuals are equally less likely to support environmental taxes when the externality they aim to reduce is not readily visible to them; for example, the benefit of consuming gasoline is experienced immediately whereas its externality, that is, pollution, accumulates over time. Bechtel et al. (2020) find experimentally that when given the option of choosing between carbon tax rates that are constant or that increase over time, individuals prefer constant rates. Our paper relates to this literature and integrates it, in that we show how political support for a carbon tax is affected by the perspective of a delayed introduction that incorporates the carbon budget constraint, through higher starting prices.

2.2. The national context in the United States

The US is a signatory of the Paris Climate Agreement and has committed to reaching net zero emissions economy-wide by 2050. In addition, it has pledged to cut its national greenhouse gas emissions by 50–52% by 2030 compared to 2005 (The White House, 2021). Different forms of carbon pricing programs have been independently adopted by 13 of its 50 States, starting with the Regional Greenhouse Gas Initiative in 2005 (which involved 11 states on the northeast coast) and followed by California's cap and trade program in 2013 and the State of Washington's Climate Commitment Act, which started in 2023 (Center for Climate and Energy Solutions, 2021).

At the federal level, five concurrent carbon pricing designs have been introduced in the 117th Congress between 2019 and the first half of 2021. They vary in terms of emissions covered, taxation level, and revenue use. The increasing presence of carbon pricing in the political debate is mirrored by an increase in public debate. Although wording differs between opinion polls, one can observe a steady increase in support for these policies. The percentage of Americans who reportedly support the introduction of a carbon tax stood at 36% in 2009 and it has gradually increased to 50% in 2016 (Puskin and Mills, 2017). The highest support has been registered in 2020, with 68% of registered voters in support of requiring fossil fuel companies to pay carbon taxes (Leiserowitz et al., 2021). In addition, Kotchen et al. (2017) analyze American households' willingness to pay for a carbon tax through a series of nationally representative surveys: they find a net increase from an average US$ 85 per year in 2011, to US$ 177 in 2016. Despite these percentages carbon taxes in the US are still controversial, and polls seemingly overestimate actual support for these policies (Anderson et al., 2023). Support for a carbon tax is a politically divisive topic, with two-thirds of Democrats in favor of it and just 30% of Republicans in support of it when the revenue use is not mentioned. The political divide, however, becomes narrower and overall support increases when tax revenues are earmarked to support further mitigation activities or to lower other taxes (to 45% of Republicans and up to 77% of Democrats; Leiserowitz et al., 2021).

Given the increasing political debate about carbon taxes and the consequent relevance and familiarity of the subject to Americans, the US offers an ideal landscape in which to test the acceptability of different carbon tax formulations. The concrete carbon tax designs to be discussed in the current US Congress enable us to replicate some key features of some of these designs. Concurrently with our core stated objective of testing the relevance of the temporal context in the acceptance of a carbon tax, this enables us to provide information on the political feasibility of some of the current policy designs in the US. Furthermore, the availability of yearly polling data on this topic allows us to make comparisons with our experimental results. While not all features of the US population may be generalizable to the rest of the world, the tendency to discount the future and hyperbolic discounting are a characteristic human trait that has been observed worldwide (Wang et al., 2016). Furthermore, temporal preferences in the US are highly proximal to the rest of the Anglo/American world but also to other cultural clusters, the German/Nordic countries, the Middle East, Asia and Eastern Europe (Wang et al., 2016). As such, the US may offer useful insights on how the temporal framing of a policy and temporal preferences could affect other contexts.

3. Methods

3.1. Experimental design

The experiment is designed as an online survey in which a nationally representative sample of the US population expresses how they would vote on a national referendum in support of the introduction of a tax on CO_2 emissions. The full survey is available in the Annex. Our survey was developed using the survey software Qualtrics and it was administered through Prolific Academic. Prolific Academic is a widely used panel for academic research that allows sampling of representative members of the US population. It has also been recommended for delivering higher quality data compared to alternative platforms (Palan and Schitter, 2018; Peer et al., 2017). The experiment aims to investigate whether support for this policy is sensitive to changes in the start year of the

Table 1
Treatments (combinations).

		Avoided CO_2 emissions			
		By 2030		By 2050	
		CB	BC	CB	BC
Policy start date	**Immediate (2021)**	1	2	7	8
	In three years (2024)	3	4	9	10
	In six years (2027)	5	6	11	12

CB=Cashback, revenues as payments to citizens, BC=Basecase, revenues to the general budget.

policy and its temporal horizon. We thus created six temporal scenarios, identified by all possible combinations between three alternative policy start dates and two alternative temporal horizons by which the CO_2 emissions cuts are expressed. These six scenarios are tested twice, once with unspecified revenue use and once with revenue use earmarked as cashback payments to constituents. The resulting 12 possible combinations define the treatment groups described in Table 1.

In summary, the proposed experiment follows a 3x2x2 factorial between subject design which identifies 12 treatments across 3 policy attributes.

i) One factor pertains to the immediacy of costs and of the eventual cashback payments (policy start date set to 2021, 2024, or 2027).
ii) One factor pertains to the immediacy with which the environmental rewards are presented (emissions abatements targets are expressed by either a 2030 or a 2050 goal).
iii) One factor pertains to whether revenue use is either unspecified (Basecase) or earmarked for redistribution (Cashback).[2]

The experiment follows a split sample design to avoid anchoring effects.[3] One respondent is assigned to just one out of the 12 combinations available. Participants answer a sequence of questions consisting of four choice tasks[4] framed within the same temporal context but with progressively increasing tax levels which are reflected not only in higher costs imposed on the average household but also in higher carbon emissions abatement targets to be achieved by the tax. To minimize sequencing effects, we disclose at the beginning of the survey the number of choice sets with which participants will be presented (Bateman et al., 2004).

3.1.1. *Internal validity and hypothetical bias*

The survey design takes several steps to ensure its internal validity. In line with the literature (see for example Carattini et al., 2019; Kotchen et al., 2017), we use a referendum format. Practitioners, including the National Oceanic and Atmospheric Administration (NOAA) panel on contingent valuation, recommend the use of this format to make the choice more realistic (Bishop and Boyle, 2019). Five studies which compared the outcome of contingent valuation surveys formulated as referenda found that they performed well in comparison to actual voting (Bishop and Boyle, 2019). As Arrow et al. (1993) observed, referenda on the provision of public goods are not uncommon, and various US states —including Massachusetts, Vermont, New Hampshire and Washington State— have cast referendums or included non-binding questions on the introduction of carbon taxes in their electoral ballots. This context also makes the study incentive compatible, meaning it is a context in which the optimal strategy for the participant is to give a true representation of her/his preferences. In particular, participants have an incentive to truthfully reflect their preferences in the survey if (a) they see the survey results as an opportunity to influence business or government actions and (b) they care about the outcomes of those actions (Carson and Groves, 2007). To recall this incentive, and similarly to Carattini et al. (2019), we informed participants that the survey results could potentially generate insights for the government with respect to the viability of adopting a CO_2 tax. We assumed that most adults care about either or both of the issues of global warming and an increase in their annual costs.

A novel feature of our survey design is that it introduced a personalized estimate of the potential cost and eventual carbon dividend payment to which the individual household would be entitled based on the income declared by the participant, the consumption profile of the average person in her/his income quintile and the tax level.[5] This design feature enabled us to elicit preferences that were based on more accurate economic expectations and, thus, were closer to predicting the actual reactions that individuals would have in real life when facing the economic consequences of the tax. To increase the policy relevance of our estimations we model the revenue distributed to individual households using as a reference an actual carbon fee and dividend policy, currently deposited in the US Congress, namely the Energy Innovation and Carbon Dividend Act of 2021 (H.R. 2307). It is the one which currently enjoys the biggest support from legislators (highest number of co-sponsors) (US Congress, 2021).

Concerns about internal validity also guided the number of choice options shown in each choice set. In similar, related studies, some researchers have chosen to include three or more choice alternatives as a way to maximize the amount of information gathered from a small sample; that is, to elicit both the likelihood that a policy would be accepted against the status quo and the relative preference between different policy alternatives. In contrast, we chose to present participants with just two choice options—the status quo and one policy alternative—for three reasons:

a) According to the mechanism design theory by Gibbard (1973) and Satterthwaite (1975), only binary response formats can be incentive compatible and thus induce participants to realistically represent their choices.[6]
b) The number of alternative options included in a choice set has been found to affect answers in several convergent validity studies (see a review in Weng et al., 2021). Measured willingness to pay in contingent valuation surveys and response rates vary depending on whether respondents reply to a binary-choice question in which one option is the status quo and the alternative is the introduction of an environmental policy; or they reply to a multiple-choice question

[2] In this paper we include only two of the potential revenue uses discussed in the literature: revenue which is conferred back to the State's general budget and revenue which is redistributed to citizens. Preferences for the different types of revenue recycling schemes have been extensively addressed in the literature (Drews & Van den Bergh, 2015; Dechezleprêtre et al., 2022; Carattini et al., 2019; Douenne and Fabre, 2022). In this experiment we choose to restrict the uses of revenues to just two of the available alternatives to contain the already high number of treatments.

[3] Anchoring effects refer to the possibility that cognitive processes may be biased by the first pieces of information displayed to individuals. Exposing the same respondent to several temporal frames in a sequential order, would have potentially introduced an influence of the first temporal contextualization on the following choice sets.

[4] Based on Louviere et al. (2000) who recommend not to exceed choices to 4 questions.

[5] Similarly, Douenne and Fabre (2022) calculated the estimated economic impact on each household, however their approach differs from ours in that rather than communicating the specific amounts to respondents, they inform each household that they may have an 80% chance of losing (or winning) from the policy based on their own estimations.

[6] For example, when participants are presented with more policy alternatives, they may infer that there is uncertainty about the cost of a given policy, and they may be induced not to reveal their true preferences (e.g. they may try to induce the government to supply the good at the lowest price, even if their actual willingness to pay was higher than they indicate) (Carson and Groves, 2007).

format in which status quo and a number $n > 1$ of alternative policies are considered. Recent empirical (Weng et al., 2021) and theoretical (Carson and Groves, 2007) studies and the NOAA panel on contingent valuation recommend a binary elicitation format to reduce anchoring and other sources of bias typical of multiple-choice questions (Arrow et al., 1993).

c) A survey that reproposes the choice elicitation method of the context it wants to mimic is more relatable to participants, and their results should be more realistic and credible (Carson and Groves, 2007). Since actual referenda use a binary format, it seems logical to reproduce it in our survey.

We, therefore, expect the binary elicitation format to be the one that records stated preferences which are closer to real-world choices. To further minimize the risk of hypothetical bias and in accordance with best practices, we added a follow-up question after the experiment, asking respondents to rate how certain they were of their responses as a measure of the questions' internal validity (Johannesson et al., 1999; Brouwer et al., 2010). We also gave respondents the possibility to answer "Don't Know" to the experimental choices. This enables us to calibrate the analysis towards greater accuracy.

Prior to the survey, we provided a simple introduction of the link between the use of fossil fuels, CO_2 emissions, and global warming as well as an explanation of how a carbon tax could address the problem. We also reminded participants of the expected temperature increase in the US should global greenhouse gas emissions continue on the current path, and we informed them of the national commitment the US government has made to decrease its emission trajectory. This introduction reflects the information that would likely be included in a referendum and mirrors similar surveys in the literature. Following the NOAA's recommendations, we also reminded individuals of their budget constraints and of expenses they may have to forego to pay for the policy's costs. This helps participants putting the policy's costs in relation to their actual income, thereby potentially reducing hypothetical bias (Bishop and Boyle, 2019).

3.1.2. Policy attributes

Table 2 summarizes the policy attributes used to describe the tax and their consequences on the different scenarios. Each attribute has several levels, and attributes are interlinked with each other. We considered three different *Policy Start Dates* with three years in between them, 2021 (immediate), 2024, and 2027. By including three-year delays, we modeled for a date which is far enough in the future in the constituents' minds yet still possibly within a government's electoral mandate. By including a 6-year delay scenario, we evaluated the possibility for a government to introduce a tax that will only be effective in the next political mandate.

We defined *Tax Levels* expressed in US\$/tCO_2 that are either below or within the price range that is considered necessary to reach the Paris Treaty objectives of staying within 1.5–2°C of global warming by the end of this century. The estimation of the tax levels needed to achieve these scenarios has been the subject of several modeling exercises. These exercises have estimations that vary widely and depend on a variety of factors—such as different baseline assumptions and a wide range of pessimist/optimist expectations regarding technological improvements and policy contexts. In defining taxation levels for the experiment, we relied on the Stiglitz-Stern review of existing carbon price estimates and, in line with their analysis, we considered the explicit carbon price consistent with Paris temperature targets to be between US\$40–80/tCO_2 by 2020 and US\$50–100/tCO_2 by 2030 (High-Level Commission on Carbon Prices, 2017). We also included a tax equal to US\$15/tCO_2, which is the taxation level proposed in the Energy and Dividend Act bill. More specifically, we considered a carbon tax at US\$ 15, 40, 60, and 80 per tCO_2 for policies starting in 2021. We considered that the range in the level of taxation so defined should be the most relevant for policymakers. Estimates of tax levels compatible with global temperature scenarios are usually calculated using 2020 as a baseline and they then gradually increase. The Energy and Dividend Act bill is also set to increase the tax by a minimum of US\$10 per year. For the scenarios in which the tax introduction is delayed to 2024 or 2027, the starting tax level is higher to account for this planned yearly increase and is further augmented to make up for the years of missed emissions cuts and, consequently, a narrower carbon budget. More specifically, we increased the planned starting fee by 3.9 p.p. for every year of delay.[7] The resulting tax fees for the delayed scenarios are reported in Table 2. In order to reduce the cognitive burden on participants, we decided against displaying tax levels on the choice cards, since such information is anyway reflected in the personalized costs and revenue estimates. A similar approach was followed by Douenne and Fabre (2022) and Dechezleprêtre et al. (2022). At the start of the survey, participants were required to insert their household annual income, and this information was used to compute in real time the estimated cost and revenue that the participant would likely face in real life as a consequence of the tax through a method further detailed below.

Table 2
Policy attributes and levels.

Attributes	Status Quo	Levels
1. Policy start date	never	2021, 2024, 2027
2. Tax level *(not shown on choice cards)*	0 US \$/tCO_2	Tax levels for policy start in 2021: 15, 40, 60, 80 US\$/tCO_2 (three are compatible with the Paris Agreement objectives, although with differing degrees of probability, and one is potentially below). Tax levels adjusted for policy start delayed to 2024: 50, 67, 75, 100 US \$/tCO_2 Tax levels adjusted for policy start delayed to 2027: 62, 93, 123, 130 US \$/tCO_2
3. Cost of the tax for the household	0 US \$/year	The value is calculated within the survey and it depends on the tax level and the household income declared by the participant. It ranges between 0.01 and 1400 US\$/year.
4. Revenue of the tax for the household *(Cashback condition only)*	0 US \$/year	The value is calculated within the survey and it depends on the tax level and the household income declared by the participant. It ranges between 0.07 and 773 US\$/year.
5. % decrease in national emissions *(compared to 2005 levels)*	• 14% (2030) • 25% (2050)	Depends on the tax level and the temporal horizon considered: • 20–75% (2030) • 60–130% (2050)
6. Temporal horizon by which emissions cuts are expressed	2030, 2050	2030, 2050

Cost of the tax to households. Our computations of the costs and revenues to specific households are based on a study (Ummel, 2016) which focused on the distributional implications on American households of

[7] This estimate is based on Furman et al. (2015), who conducted a meta-analysis of 16 integrated climate mitigation models and found that, on average, a decade of delay in the implementation of climate mitigation policy reflects in an average increase in abatement costs by 39%. An alternative estimate by the Brookings Institute finds that delaying the introduction of a carbon tax at US\$ 15 in the US economy would require on average a total increase in the tax by nearly 9% per year of delay to achieve the same cumulative emissions were the tax to start immediately (Mckibbin et al., 2014). We intentionally used the most conservative estimate to detect whether even small tax adjustments would affect support for the tax.

the previously mentioned Carbon Dividend Act.[8] Using a simulation of household-level effects (from the American Community Survey and the Consumer Expenditure Survey) and input–output data from the Bureau of Economic Analysis, the study calculated the yearly financial impact that a US\$15/tCO_2 tax would have on the average American family in each income quintile. We used this study as a benchmark to generate within the survey a personalized estimate of cost implications for each participant, using a) his/her household income, b) the average consumption of people in the same income quintile, and c) the tax level considered on the choice card.[9] The expected personalized impact of the policy as shown in the choice card is thus based on the consumption patterns and characteristics of the average representative household of the participant's income quintile, adjusted for her/his income. The costs assigned to each tax level were internally consistent—higher tax levels corresponded to higher costs to the household.[10] The same study also defined the *potential revenues* that would be redistributed to families based on their income quintile. We thus used these calculations to compute the cashback revenue to which the participant household could potentially be entitled in the Cashback condition. The range of values of the costs and revenues from the tax are included in Table 2.

We then described the common benefits each policy alternative supposedly delivers in terms of *Percentage Change in the National CO_2 Emissions* with respect to 2005 levels.[11] These emissions reduction objectives were estimated based on the tax level and were expressed under different *Temporal Horizons*—that is, the emission change that could be reached by either 2030 or by 2050. To associate tax levels with their potential to reduce emissions we retrieved data on the absolute values by which US CO_2 emissions should decrease compatibly with different global warming scenarios. These data were taken from the Climate Action Tracker (2021), which also includes estimates of national emission paths under current scenarios.[12] For the purpose of our survey design we associate their range of projections progressively, by matching increasing tax levels with increasing emission cuts,[13] while keeping the Stiglitz-Stern estimate as a benchmark (the explicit carbon price consistent with Paris temperature targets) (High-Level Commission on Carbon Prices, 2017).

[8] We choose this study, since it is, at time writing, the only impact assessment of the distributive implications of the Carbon Dividend Act. Although the study was commissioned by Climate Citizens Lobby (CCL), who advocate for the policy, we have no reason to assume there was a conflict of interest, since the report was undertaken by an independent researcher at the University of Pennsylvania and who has no other linkage to CCL.

[9] More specifically, we multiplied the participant income by the average % income loss that corresponds to her/his income quintile (as estimated by Ummel, 2016) and divided the amount by US\$15 to obtain the cost to that specific household of each US\$1 of carbon tax; we then multiplied such amount by the tax level considered on the choice card. These estimates give individuals an idea of the potential impact that such a policy would have on an average representative households in their income range, adjusted for their actual declared income. An alternative approach, could have been to generate estimates based on participants' estimated household energy and travelling expenditures (Douenne and Fabre, 2022).

[10] This in contrast to other studies that let policy attributes vary independently (e.g. allowing for combinations where lower tax levels have higher cost implications as in Alberini et al., 2018).

[11] Year 2005 was chosen as baseline since it is the year by which US nationally-determined pledges are expressed.

[12] The Climate Action Tracker estimates national emission pathways and whether they align with the Paris Agreement long-term temperature objectives by using a carbon-cycle/climate model (MAGICC6). The methodology of the model is described in Meinshausen et al. (2009, 2011) and Rogelj et al. (2012).

[13] Within this experiment we merely use a broad range of existing projections as reference points to see how likely these scenarios are to influence participants' preferences. The probability of occurrence of each emission abatement scenario, or the assumptions they are derived from is not the focus of this exercise.

Fig. 1 includes screenshots of how the survey looked like for an individual assigned to the Basecase condition (a) and Cashback condition (b). The introductory wording of our survey was partly borrowed from the National Surveys on Energy and Environment (2016) and from Carattini et al. (2019) and adapted to meet our ends.

3.2. Post-experiment survey

3.2.1. Individual time preferences

We used a common approach in the literature to elicit individual time preferences which consisted of a multi-pricelist choice task as in Andersen et al. (2006) and Coller and Williams (1999). Respondents repeatedly chose between a smaller–sooner (option A) and a larger–later payment (option B), as shown in Fig. 2. The more immediate payment was set to US\$500 immediately, whereas the latter reward was US\$500 + X, available in 1 year. X is a positive number that increases with each iteration. The iterated choices are organized in increasing order as typically done in the time preference literature. X is calculated using an annual rate of return between 5 and 50% on the principal and the magnitude of the rewards match those typically used in intertemporal choice experiments (Andersen et al., 2006). Interest is compounded monthly based on major US bank's business practices. The point at which individuals switch from choosing the more immediate payoff to preferring the future income identifies the individual's discount rate. Falk et al. (2018) show that this intertemporal choice task is an accurate predictor of time discounting, even when the choices are hypothetical. To increase the precision of our estimates, we discarded inconsistent responses from our final sample (i.e. respondents repeatedly switching between the sooner and the later amounts as the later reward increased).

3.2.2. Additional data

In addition, we recorded data on:

i Income
ii Education level
iii Political identity
iv Area classification: Rural, town, metropolitan
v Environmental values
vi Climate change beliefs
vii Social expectations regarding other's willingness to pay for the environment
viii Self-assessed level of selfishness/altruism on a 1–5 scale
ix Trust in political institutions: 0–10 index based on expressed trust towards the US Congress, the US Federal Government, and politicians.

The following sociodemographic information on participants was already available from Prolific: age, sex, nationality, current country of residence/state of US residence, country of birth, employment status, and student status. We enriched our dataset by collecting information on the US states that had a carbon pricing scheme in place at the time of the survey.

3.3. Data and descriptive statistics

We fielded our survey between July 29 and August 4, 2021, on Prolific Academic. Our sampling was restricted to US residents aged 18 or older. Remuneration for participation in the survey was an amount proportional to the time spent on the survey paid at US minimum wage. Median completion time was five minutes, with 75% of respondents completing the survey in three–nine minutes. A total of 1092 respondents participated in our survey, and 1013 (92.8%) completed it to the end. Of these, 13 (1.3%) were excluded from the analysis for failing attention checks, thus leaving us with 1000 individuals who formed our final survey sample. They replied to four experimental choice sets, thus generating a total of 4000 observations. While random assignment of

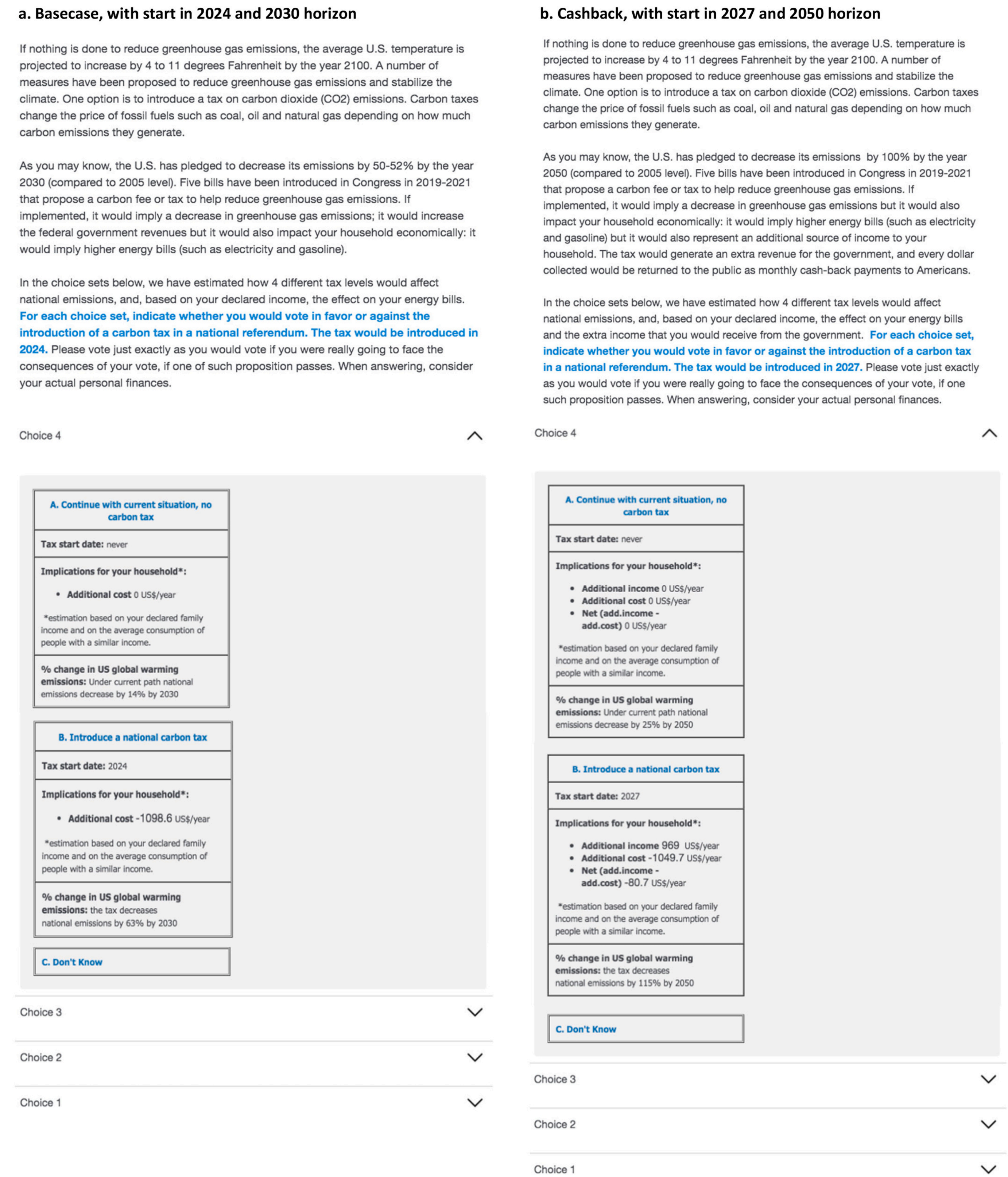

Fig. 1. Introduction to the experiment and examples of choice task.

participants across treatments should lead to homogenous groups, we calculated descriptive variables of the sample by group to ensure that the groups were balanced (Table 3).

The distribution of age, educational attainments, and individual discount rate were homogenous across groups as shown by the *p*-values of the ANOVA test of equal variances (for the continuous variables) and the *p*-value of the Kruskal-Wallis test (for the ordinal variables). We detected slight imbalances in the re-partition of individuals across gender, ethnicity, income, and political partisanship. These imbalances were accounted for in the econometric analysis through control

Please take a look at the table below. Notice that as you go down the table one option is fixed while the other changes. In each row of the table, please indicate your preference between option A and option B.

1.	Option A. Receive $500 today.	Option B. Receive $525 in 12 months.
2.	Option A. Receive $500 today.	Option B. Receive $552 in 12 months.
3.	Option A. Receive $500 today.	Option B. Receive $580 in 12 months.
4.	Option A. Receive $500 today.	Option B. Receive $609 in 12 months.
5.	Option A. Receive $500 today.	Option B. Receive $640 in 12 months.
6.	Option A. Receive $500 today.	Option B. Receive $672 in 12 months.
7.	Option A. Receive $500 today.	Option B. Receive $705 in 12 months.
8.	Option A. Receive $500 today.	Option B. Receive $741 in 12 months.
9.	Option A. Receive $500 today.	Option B. Receive $777 in 12 months.
10.	Option A. Receive $500 today.	Option B. Receive $816 in 12 months.

Fig. 2. Intertemporal choice task.

Table 3
Main descriptive statistics of the sample by treatment group.

	TREATMENTS												*p*-value from F test	FINAL SAMPLE	US POPULATION
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)			
Variables	**2021/ 2030 Cashback**	**2021/ 2030 Basecase**	**2024/ 2030 Cashback**	**2024/ 2030 Basecase**	**2027/ 2030 Cashback**	**2027/ 2030 Basecase**	**2021/ 2050 Cashback**	**2021/ 2050 Basecase**	**2024/ 2050 Cashback**	**2024/ 2050 Basecase**	**2027/ 2050 Cashback**	**2027/ 2050 Basecase**			
Mean age	46.0 (0.882)	43.6 (0.882)	43.8 (0.942)	45.3 (0.938)	46.3 (0.995)	43.3 (0.890)	42.1 (0.901)	43.3 (0.921)	45.2 (0.922)	43.9 (0.838)	45.3 (0.853)	43.2 (0.903)	0.459	44.3 (0.261)	46.9[a] (0.905)
Female (%)	49%	49%	65%	52%	51%	45%	50%	52%	49%	53%	48%	49%	0.004	51%	51%[a]
Ethnicity (White/ non-Hispanic)	72%	66%	72%	75%	76%	73%	62%	74%	80%	70%	77%	72%	0.006	72%	72%[a]
Median Household Income	$66,338	$67,692	$68,338	$64,648	$64,994	$56,044	$65,939	$63,063	$55,874	$70,645	$66,494	$64,753	0.062	$65,330	$65,712[a]
Education (bachelor's and higher)	61%	60%	55%	53%	61%	64%	58%	69%	60%	52%	62%	55%	0.991	59%	48%[b]
Individual Discount Rate (mean on a scale 1–11)	5.44 (0.198)	5.58 (0.180)	5.62 (0.193)	5.62 (0.195)	5.27 (0.187)	6.21 (0.205)	5.57 (0.206)	4.97 (0.187)	5.59 (0.201)	4.71 (0.187)	5.78 (0.188)	5.76 (0.205)	0.137	5.51 (0.056)	NA
Identifies with the Republican party (%)	16%	34%	16%	25%	26%	22%	21%	29%	14%	18%	23%	23%	0.000	22%	24%[c]
N. participants	80	82	81	85	80	86	84	80	85	83	86	88	NA	1000	NA

[a] National gender, age, ethnicity, and income data came from the US Census Bureau (2021).
[b] Educational attainment data for Americans aged 25–64 came from the OECD (2021).
[c] The percentage of Americans considering themselves Republicans is the June 2021 figure from Gallup Consulting (2021).

variables. To show the comparability of our sample to the US national population, we included statistics in Table 3 on American households using the latest data from the US Census Bureau (2021), the OECD (2021), and Gallup Consulting (2021). Despite minor differences in average age (44.3 vs. 46.9), political partisanship (22% vs. 24% identifying as Republicans), and educational attainment (59% vs. 48% with at least a bachelor's degree[14]), our sample matches well the average US household.

3.4. Analysis

To establish the determinants of the support for the tax, we estimated logit regressions of the form:

$$Y_{(i,c)} = F\Big(PolicyTemporalSetting_{(p)}, PolicyCost\&Revenues_{(i,p,t)}, PolicyRevenueUse_{(r)}, IndividualCharacteristic_{(i)}, StateLevelControls_{(s)}\Big) \quad (1)$$

The response variable $Y_{(i,c)}$ records whether the individual *(i)* voted in favor of the carbon tax design contained in one of the four choice sets *(c)* to which he/she was exposed. It is modeled as a function of:

a) one of the six temporal settings of the policy design (*p*);
b) the costs and the revenues that the policy eventually imposes on the household, calculated based on the individual (*i*)'s household income, the policy temporal setting *(p),* and the four tax baseline levels *(t)*;
c) the policy's use of revenues *(r)* as either cashback payments or payments to the general federal budget;
d) personal characteristics of individual *(i)*, including political and environmental beliefs, personal discount rate, and demographic data; and
e) state level controls (*s*), including whether the state in which individual *(i)* lives has already initiated a carbon pricing scheme.

Controls d) and e) increase the precision of our estimates and correct for the slight sociodemographic imbalances observed between groups.

4. Results

4.1. The temporal distribution of carbon taxes' costs and rewards that increase their public acceptance

We start with a graphical representation of our key results. The variable of interest is the percentage of participants voting in favor of the introduction of the carbon tax over the total number of respondents. In the Annex we report the percentage of "Yes" votes over the total after excluding participants who voted "Don't Know". Below we re-evaluate the results by coding "Don't know" answers as "No", which provides a more conservative estimate of carbon tax support.[15] There are clear, statistically significant variations in the acceptance rates, across policy attributes and groups. The proportion of yes votes ranged between 55.5% and 70%, depending on treatment group (F: 3.71, Pr > F = 0.000). These percentages are in line with the latest available opinion polls that registered approval rates of 50% (five years earlier in 2016) or 67% (Puskin and Mills, 2017; Leiserowitz et al., 2021), although we acknowledge that similarly to such polls, survey experiments may overestimate support.

[14] The percentage of Americans with minimum a bachelor degree comes from the OECD and it is possibly an underestimate since it refers to 2019, while the rate of Americans with a university degree keeps growing year on year and is likely to be higher for 2021.

[15] "Don't Know" answers averaged 7% of the total across treatments.

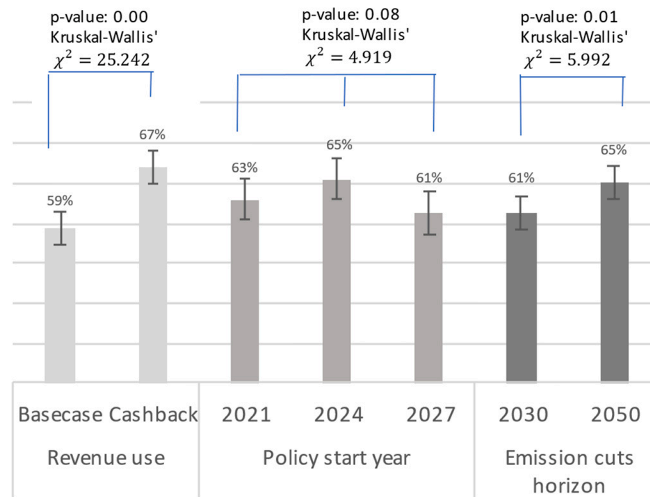

Fig. 3. Percentage of yes votes by treatment attribute.
Source: own computations based on experimental data. Error bars are calculated on the basis of 95% confidence intervals.

As shown in Fig. 3, we find the biggest difference in acceptance rates across revenue use. Predictably, tax acceptance is higher when revenue use is channeled back to citizens in the form of cashback payments, reaching 67% on average (Kruskal-Wallis' $X^2(1) = 25.242$, *p*-value = 0.00). When revenues are simply conferred to the federal government budget, yes votes reach 59% on average. The tax approval rates appear to be highest for the scenarios that introduce the tax in 2024 following a 3-year delay as compared to the immediate introduction and the 6-year delay scenario (Kruskal-Wallis' $X^2(2) = 4.919$, *p*-value = 0.08). In our design, delaying the introduction of the tax implies a higher tax rate and hence higher cost implications for the average household proportionate to the length of the delay. This was intentionally done to reflect the fact that delaying the start of a carbon tax would need to be compensated with higher starting fees to still reach the Paris Agreement global warming mitigation objectives. Presumably due to the effect of individual discounting of future outcomes,[16] participants were more likely to commit to a carbon tax if delayed by 3 years, despite the slight cost increase it would bring about for their households. However, it appears that the cost increase in the 2027 scenario is big enough to more than offset the effect of individual discounting and any potential increase in yes votes that could have been brought about by a further delayed introduction. Expressing the emission reduction achieved by the tax by different temporal horizons had a statistically significant effect on acceptance rates: on average, the 2050 horizon achieved a higher consensus of 65% compared to 61% for scenarios in which 2030 emissions abatement objectives were mentioned (Kruskal-Wallis' $X^2(1) = 5.992$, *p*-value = 0.01). Constituents saw the tax more favorably when it was framed in a longer-term horizon with more ambitious environmental objectives. In light of the slight socio-demographic unbalances observed between treatment groups, we computed average treatment effects (ATEs) using the propensity score matching method as robustness check. After including the four variables which showed unbalances and additional socio-demographic controls, ATEs calculated through this method were statistically significant: i) introducing the policy

[16] The fees and associated household costs were intentionally undiscounted for three reasons. First the acceptable objective rate of discounting to apply to future outcomes is highly controversial; second, the concept of discounting is too complex to explain to laypeople and third, we wanted to let individuals to apply their own discount rate. Since we measure individual discount rates exogenously after the experiment, we are able to use our estimated individual discount rates to disentangle the effect of individual discounting, temporal setting and tax level.

Table 4
Regression output (Marginal effects).

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Logit	Logit If vote cert.> 3[c]		Logit	Logit	Logit	Logit If vote cert.>3[c]	Logit	Logit If Basecase	Logit If Cashback	Logit If Net ≥0	Logit If Net < 0
Policy characteristics												
Policy Start 2024 (dummy)	0.073*** (0.019)	0.059* (0.071)		0.040 (0.257)		0.054 (0.116)	0.052 (0.146)	0.065 (0.308)	0.129** (0.021)	0.001 (0.986)	0.062 (0.329)	0.056 (0.201)
Policy Start 2027 (dummy)	0.092*** (0.005)	0.075** (0.028)		0.100*** (0.005)		0.129*** (0.000)	0.130*** (0.000)	0.040 (0.562)	0.223*** (0.000)	0.089 (0.117)	0.143 (0.059)	0.164*** (0.001)
Horizon 2030 (dummy)	−0.037 (0.152)	−0.031 (0.239)	−0.038 (0.135)	−0.027 (0.342)		−0.034 (0.236)	−0.023 (0.437)	−0.089* (0.100)	−0.047 (0.287)	−0.033 (0.386)	−0.056 (0.313)	−0.037 (0.307)
Revenue as cashback (dummy)	0.077*** (0.003)	0.077*** (0.004)		0.057** (0.044)		0.084*** (0.003)	0.085*** (0.004)	0.097* (0.076)				
Hh Cost			−0.00005*** (0.013)									
Hh Revenue			0.00006* (0.077)									
Tax level	−0.002*** (0.000)	−0.002*** (0.000)		−0.002*** (0.000)		−0.002*** (0.000)	−0.003*** (0.000)	−0.003*** (0.000)	−0.004*** (0.000)	−0.001*** (0.000)	−0.001** (0.023)	−0.003** (0.000)
Individual characteristics												
Intertemporal disc. rate (0–10 scale)					−0.007* (0.062)	−0.008* (0.062)	−0.006 (0.173)	−0.017** (0.053)	−0.009 (0.187)	−0.005 (0.411)	−0.00002 (0.998)	−0.010* (0.073)
*2024 Start								−0.002 (0.830)				
*2027 Start								0.016* (0.102)				
*2030 Horizon								0.010 (0.216)				
*Cashback								−0.001 (0.873)				
Republican Party (dummy)				−0.439*** (0.000)	−0.300*** (0.000)	−0.297*** (0.000)	−0.292*** (0.000)	−0.299*** (0.000)	−0.305*** (0.000)	−0.274*** (0.000)	−0.449*** (0.000)	−0.283*** (0.000)
Income				−1.63 e^{-07} (0.614)	−7.84 e^{-07}** (0.020)	−7.75 e^{-07}** (0.024)	−1.26 e^{-06}*** (0.001)	−7.97 e^{-07}** (0.022)	−1.12 e^{-06}** (0.038)	−7.77 e^{-07}* (0.074)	3.06e^{-07} (0.832)	−7.35e^{-07}* (0.102)
NoRespEnvironment (dummy)					−0.112* (0.074)	−0.109* (0.077)	−0.085 (0.204)	−0.110* (0.070)				
Selfishness (dummy)					−0.192*** (0.000)	−0.196*** (0.000)	−0.189*** (0.000)	−0.194*** (0.000)	−0.174*** (0.000)	−0.217*** (0.000)	−0.285*** (0.000)	−0.173*** (0.000)
No social norm (dummy)					−0.124 *** (0.000)	−0.131 *** (0.000)	−0.155*** (0.000)	−0.133*** (0.000)	−0.140 *** (0.001)	−0.111 *** (0.009)	−0.093 (0.114)	−0.152 (0.114)
Political trust (1–10 scale)					0.031*** (0.000)	0.030*** (0.000)	0.031 *** (0.000)	0.030*** (0.000)	0.040*** (0.000)	0.023*** (0.017)	0.028** (0.047)	0.040*** (0.000)
Clim. change denial (dummy)					−0.414 *** (0.000)	−0.423 *** (0.000)	−0.498 *** (0.000)	−0.428 *** (0.000)	−0.619*** (0.000)	−0.387*** (0.006)	−0.514 (0.211)	−0.510*** (0.000)
Demographic controls												
Age					−0.004*** (0.000)	−0.004*** (0.000)	−0.005*** (0.000)	−0.004*** (0.000)	−0.007*** (0.000)	−0.003** (0.026)	−0.004** (0.029)	−0.006*** (0.00)
Female (dummy)				0.047* (0.096)	0.028 (0.358)	0.028 (0.361)	0.057* (0.082)	0.027 (0.383)	0.028 (0.520)	0.060 (0.181)	0.023 (0.706)	0.041 (0.273)

(*continued on next page*)

Table 4 (*continued*)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Logit	Logit If vote cert.> 3[c]		Logit	Logit	Logit	Logit If vote cert.>3[c]	Logit	Logit If Basecase	Logit If Cashback	Logit If Net ≥0	Logit If Net < 0
Unemployed (dummy)					−0.004	0.008	−0.015	0.014	0.072	0.035	0.065	−0.012
					(0.937)	(0.880)	(0.796)	(0.789)	(0.358)	(0.631)	(0.528)	(0.850)
Educ.: min. bachelor's degree (dummy)					0.002	0.001	0.018	0.003	0.022	0.002	0.109*	−0.024
					(0.936)	(0.971)	(0.596)	(0.924)	(0.654)	(0.995)	(0.091)	(0.538)
Rural (dummy)					−0.072	−0.070	−0.062	−0.072	−0.149**	−0.039	0.056	−0.129**
					(0.163)	(0.174)	(0.261)	(0.155)	(0.035)	(0.614)	(0.654)	(0.034)
Ethnicity and nationality	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
State level controls												
State level carbon tax				0.053*								
				(0.086)								
State of residence	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y
Observations	4000	3568	4000	3660[b]	3844	3844	3420	3844	1936	1888	1136	2664
Pseudo R^2	0.014	0.014	0.005	0.121	0.187	0.201	0.235	0.204	0.240	0.222	0.303	0.212
***p*-value F test**	0.000	0.000	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes. * Significant at <0.10, ** significant at <0.05, *** significant at <0.01. Values reported are Marginal Effects at the Means MEM, *p*-values in parentheses. Errors are clustered at the individual level.
[a] *p*-value F test nearly statistically significant at 0.11.
[b] Fewer observations due to missing data on US state of residence. [c] Individuals rated the certainty of their votes on a scale from 1 to 7, from very uncertain to very certain.

immediately and expressing emission objective by the 2030 horizon decreased acceptance rates (respectively, ATE = −0.303, $p = 0.000$; and ATE = −0.034, $p = 0.042$). Including cashback payments increased support (ATE = 0.048, $p = 0.003$). These differences in approval rates are a sign that the temporal setting of a tax in terms of its start date and the temporal horizon by which its emission reduction targets are expressed have an influence on its political acceptance. In line with the above results, the treatment group that gathers the highest acceptance corresponds to a carbon tax that redistributes its revenues to constituents, that starts three years in the future and with emission reduction objectives expressed by 2050. Nearly half of all survey participants (48%) voted in favor of the policy for all tax levels; 18% always voted against, and 2% always responded "Don't know". The remaining participants changed their support in function of the tax level, usually switching from "Don't know" to "No", from "Yes" to "No" or from "Yes" to "Don't Know" as the tax level increased.

Table 4 reports our regression estimations of marginal effects. We use logit models with clustered standard errors at the individual level (to account for the fact that repeated responses from the same individuals are not independent). Our dependent variable is a binary 0–1 dummy capturing whether individuals replied in favor of introducing the tax. The model shows the effect of individual and policy attributes on the likelihood that individuals would vote in favor of a national referendum on the introduction of a carbon tax. Prior to running the regressions we crosschecked for potential multicollinearity among the explanatory variables, by examining bivariate correlations, the Variance Inflation Factors (VIF) and tolerance levels. Across all covariates simultaneously included in the regressions, VIF and tolerance levels fall well below 10 and well above 0.10, respectively, thus ruling out multicollinearity concerns. The first four covariates are dummy variables identifying the treatments. We find that asking individuals to pre-commit to a carbon tax that starts 3 or 6 years in the future increases acceptance by 7 p.p. and 9 p.p., respectively, compared to introducing it immediately, when the effect of the cost of the tax on households is controlled (column 1). This suggests that individuals would have a preference for postponing the policy as long as possible, if the policy's cost were unaffected by this delay, and it confirms our earlier interpretation of more people voting in favor of policy designs starting in 2024 compared to 2027. The promise of cashback payments increases acceptance by nearly 7 p.p. These estimations are statistically significant at the 99% confidence level. We do not find a statistically significant effect of expressing environmental objectives for 2030 versus 2050 on policy support. This policy attribute seems to be ineffective on its own, once other policy attributes and tax levels are accounted for. As an additional robustness check, we repeated the same regression by excluding individuals that expressed some degree of uncertainty regarding their votes (column 2). The estimations confirm the results from the previous regression both in terms of statistical significance and signs. As expected, and in line with the literature (Sælen and Kallbekken, 2011; Gevrek and Uyduranoglu, 2015), approval decreases with tax rates and the associated additional cost that a tax imposes on households (column 3).[17] Predictably, tax acceptance increases with each additional US$ of revenue from the cashback payments.

In column 4, we addressed the slight gender, income, ethnicity, and political imbalances observed across treatment groups. The addition of these control variables left our previous results unchanged. We included a dummy variable which captures whether or not living in a state that has already adopted carbon pricing in some form positively affects individual acceptance rates; the coefficient is statistically significant at the

[17] As mentioned in the methods section, cashback payments and household costs are calculated based on the participant's declared income. For this reason, we substitute household cost and revenues from the tax with tax level due to their high correlation with income. For the same reason we excluded the Policy Start dummies in this regression.

99% confidence level, and it has a positive sign.[18]

Column 5 focuses on the individual level characteristics affecting choice. When we conjoin individual characteristics and policy attributes in the same regression (column 6), our aforementioned findings are confirmed in terms of statistical significance and signs. Amongst the individual level characteristics that affect choices the most, we find that denial of the occurrence of climate change reduces the probability to approve it by 42 p.p. People who identify with the Republican Party are 20 p.p. less likely to vote in its favor (these estimates are statistically significant with negative signs). Income negatively correlates with tax acceptance, potentially reflecting the fact that individuals with a higher income incur higher cost increases in absolute terms and receive smaller cashback payments. However, this finding may also reflect other income-related characteristics, such as preferences for redistribution. We also find that individual beliefs concerning the environment and society in general affect choice. Individuals who decline any personal responsibility to care for the environment, or those who think that others would not pay a price to protect the environment are less likely to vote for the tax. As a measure of pro-social orientation, we asked participants whether they thought that one should focus on his/her own life and not bother too much with helping others. People who agreed with this statement were 30 p.p. less likely to approve of the tax. In line with previous findings in the literature (Umit and Schaffer, 2020), we find that our index measuring trust in institutions on a 0–10 scale positively correlates with tax approval. The more an individual trusts the federal government, the US Congress, and politicians, the more likely she/he is to avail of carbon pricing at the federal level. By looking at demographic characteristics, we find that carbon tax support decreases with age. We did not find a statistically significant effect of unemployment or of education.[19] We find some evidence that females are more likely to be in favor of a carbon tax, however this result was not always statistically significant across regressions. Repeating the regression on the subset of participants who were highly certain of their choices does not change these results (column 7). We compute interaction terms between the policy's temporal attributes and revenue use, and between all policy attributes and the net economic impact of the tax on participants. The estimated effects are not statistically significant and are thus not reported here. However, when we run split regressions separating participants in the Basecase and Cashback condition (columns 9 and 10), we find that the temporal attributes of the policy lose relevance. In addition, separating individuals who expect a net loss from the tax, compared to those who do not, we find that the effect of temporal frame and individual discounting is only statistically significant for the former (columns 11 and 12). In addition, we find that expectations about the economic effects of the tax are highly relevant for individuals living in rural areas: when they do not expect to receive a dividend or when they expect a net loss, they are less likely to vote in its favor by 15 and 13 p.p. respectively. Conversely, including cash-back transfers effectively counters opposition from rural areas. It is possible that people living in rural areas anticipate that the cost imposed on them by the tax may actually be higher than the ad-hoc figures included in the choice cards, owing to longer commuting distances and fossil fuel consumption connected to rural living. This is in line with Umit and Schaffer (2020), who found that individuals who are more dependent on energy are more averse to carbon taxes.

4.2. The effect of intertemporal discounting on tax acceptance

Individual 1-year discount rates correlate negatively with policy approval, the estimated effect is statistically significant with negative sign (columns 5,6,8). Ceteris paribus, impatient individuals are less likely to vote in favor of the tax, presumably because by placing less importance on the future, they are less inclined to accept additional short-term costs for the long-term preservation of the climate. The relationship between individual support of environmental preservation policies and temporal preferences is well documented in the literature (Fehr and Leibbrandt, 2011; Bruderer Enzler, 2015). Once we control for individual discount rates in our regressions, the effect of dealying the policy' start to 2024 loses statistical significance, corroborating our earlier intuition that individual's preference to postpone the policy by three years is entirely explained by individual discounting. In Column 8 we include interaction effects between individual discount rates and the four dummy variables identifying other policy attributes. We find a statistically significant interaction between individual discount rates and policy start date. The positive sign indicates that the effect of individual discounting on policy acceptance is attenuated when the tax starts 6-years later. This result could be interpreted as an indication of hyperbolic discounting, with participants discounting farther outcomes at declining rates. It supports the idea that impatient individuals, while generally more opposed to the introduction of a carbon tax, may lower their resistance, if they had a chance to pre-commit to a policy that starts later in time. This is in line with the literature highlighting that people with hyperbolic discounting have a desire for pre-commitment mechanisms (Ashraf et al., 2006). As mentioned earlier, the effect of discounting on policy choice seems to depend on the expected economic effect of the policy: only households that expect to be negatively impacted from the policy seem to discount the future benefits that the carbon tax may bring. Negative time preferences seemingly do not activate when individuals expect a neutral or positive impact of the policy on their income. This is possibly a sign that when the carbon tax is attached to a private economic compensation which is delivered at the same time, individuals do not perceive the choice situation as one involving an intertemporal tradeoff.

4.3. The political feasibility of a Paris Agreement's objective-compatible tax

Fig. 4 depicts the percentage of yes votes by taxation level. Each individual voted the same carbon tax design four times (as defined by start of the policy, temporal emission horizon, and revenue use), with only variations in the taxation level (and the associated costs, revenues, and emission cuts). The four baseline tax levels voted upon were 15, 40, 60, and 80 US$. These rates were adjusted proportionally to the delay with which the policy was introduced for individuals in the 2024 and 2027 delay conditions. As the Figure shows, acceptance is highest in the first choice set when the tax rate and the cost implications for households are lowest and it gradually decreases as the costs increase. Qualitative analysis of the sentences written by participants to explain their choices in the pilot phase confirms that for some there is a switch point at which the cost of the tax simply becomes too high to the individual either in relation to his/her income, the policy's environmental objectives, or both. It should be noted that in the Basecase condition, individuals are predictably more sensitive to tax increases, and the percentage of yes votes decreases more markedly in this condition, whereas it appears to be more stable for participants that receive dividends. This shows that in a carbon tax policy with a cashback program, individuals would potentially accept a level of taxation that would be politically unfeasible in the absence of this revenue redistribution.

[18] Additional regressions not reported here included controls for the emission abatement objectives of each design. The coefficients are statistically significant and have a negative sign, while the coefficients for household costs lose significance. This is clearly due to multicollinearity between the cost of the tax and the amount of emissions it promises to abate. As per our experimental design the percentage of emissions that a carbon tax design can achieve depends on the tax level and consequently, a tax that pursues more ambitious environmental objectives also translates into a higher cost for households.

[19] Beyond the dummy variable for people with at least a bachelor degree which is included in the regressions we also tested as alternative measure an educational attainment scale from 1 to 10 and a dummy variable for people who currently are students. They also did not give any statistically significant result.

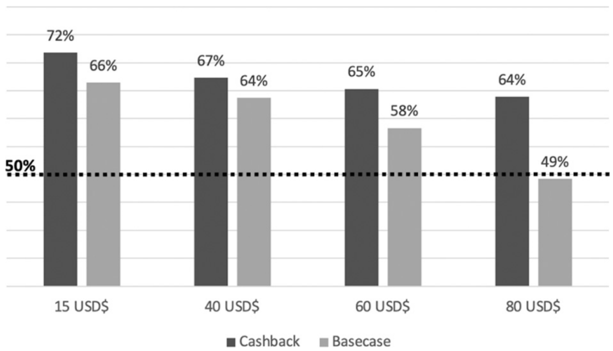

Fig. 4. Percentage of yes votes by taxation level, Cashback versus Basecase.
Source: own computations based on experimental data. Taxation levels shown in labels are baseline levels, that are adjusted upward for the delayed scenarios.

In particular, the fourth choice set which corresponds to the tax level that has the highest probability of reaching the Paris global warming objectives falls short of the majority approval in the Basecase condition with 49% of yes votes, while it appears to be politically feasible in the Cashback condition. Fig. 5 shows the temporal treatment that maximizes the percentage of yes votes by focusing only on the fourth choice. The figure shows that if we focus on taxation levels consistent with Paris global temperature objectives, but we do not want to earmark revenues, then the ideal policy horizon that maximizes acceptability is the 2024/2050 horizon.

4.4. Political relevance analysis

There are pools of participants that are significantly more likely to be against a carbon tax. Even though they may constitute a minority, they may still represent a politically relevant group. It is thus of interest to understand whether or not there is a temporal framing of a carbon tax that can persuade them. As noted earlier, among the analyzed individual characteristics, the primary ones that negatively affect tax acceptance are: a) the belief that climate change is not currently happening; b) political identification with the Republican Party; c) distrust in institutions; and d) refusal to ascribe to personal responsibility for protecting the environment.

Fig. 6.a–d shows the marginal effects of policy attributes (policy start in 2024 or 2027, 2030 as emission horizon, and Cashback) for each additional unit increase in the climate belief scale, political scale, trust index, and environmental responsibility scale (calculated based on the equation in column 6, Table 4). The highlighted areas in the graphs correspond to individuals that match the four characteristics just described. Across the four groups, inclusion in the Cashback group and in the treatment group in which the tax starts in 2027, followed by a tax design that starts in 2024, have the biggest impact on the probability of approving the tax, and these effects are statistically significant. These effects are positive for any value of the four scales under consideration; they are strongest for individuals identifying as Republicans, people with low trust in public institutions, and people who deny any personal environmental responsibility. On the contrary, these treatments are not as effective on individuals who do not recognize that climate change is occurring. These graphs indicate that one of these policy features or a combination thereof may help to persuade a potentially politically relevant section of the American population to approve a carbon tax.

5. Conclusions

The literature on intertemporal choice and cooperation tells us that cooperation is less likely to arise in a scenario in which costs are immediately imposed for rewards that are shared and will occur further in the future. This is the standard temporal context of a carbon tax which imposes from its beginning costs on a constituency for environmental benefits that accumulate slowly and will only be tangible in the distant future. The intertemporal dimension of carbon taxes and its effect on public acceptability has not been previously studied. This is the first paper to explore whether the temporal contextualization of carbon taxes can be designed in a way that increases their popularity. In particular, we analyzed whether asking people to pre-commit to a carbon tax that starts a few years from now increases its public support and whether individuals prefer that its target emission cuts are expressed by a more proximal or distant date. This is also the first study to analyze whether individual temporal preferences affect the acceptability of carbon taxes.

We find that it is possible to design carbon taxes that optimize the temporality of its costs and benefits to the public's preferences. Ceteris paribus, individuals are more likely to commit to a carbon tax if the economic costs it imposes on households can be slightly shifted to the future (by postponing the start of the policy by a few years). This is possibly due to individual discounting as individuals typically discount future costs. A key caveat to this finding is that temporal preferences are dynamic and potentially inconsistent, as people who claims to be in

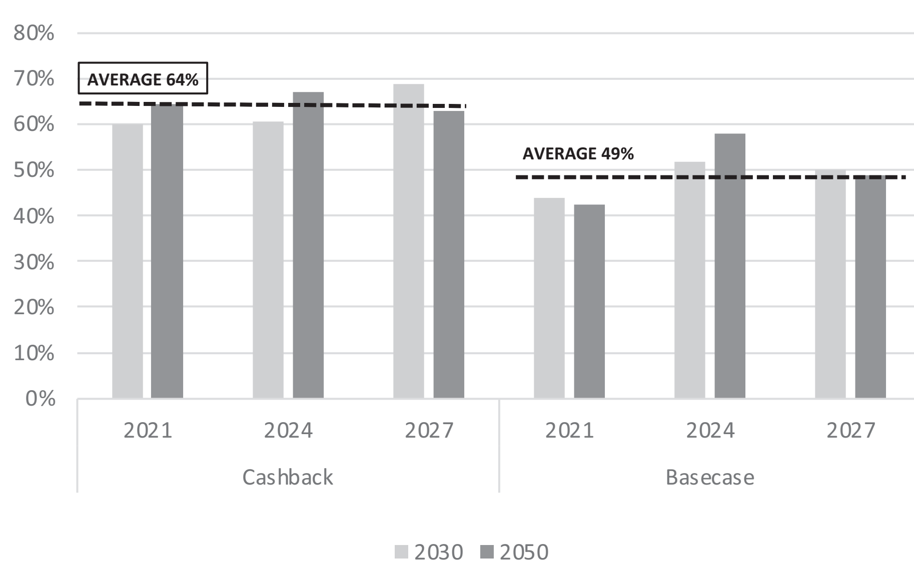

Fig. 5. Percentage of yes votes by treatment group, taxation baseline 80 USD$.
Source: own computations based on experimental data.

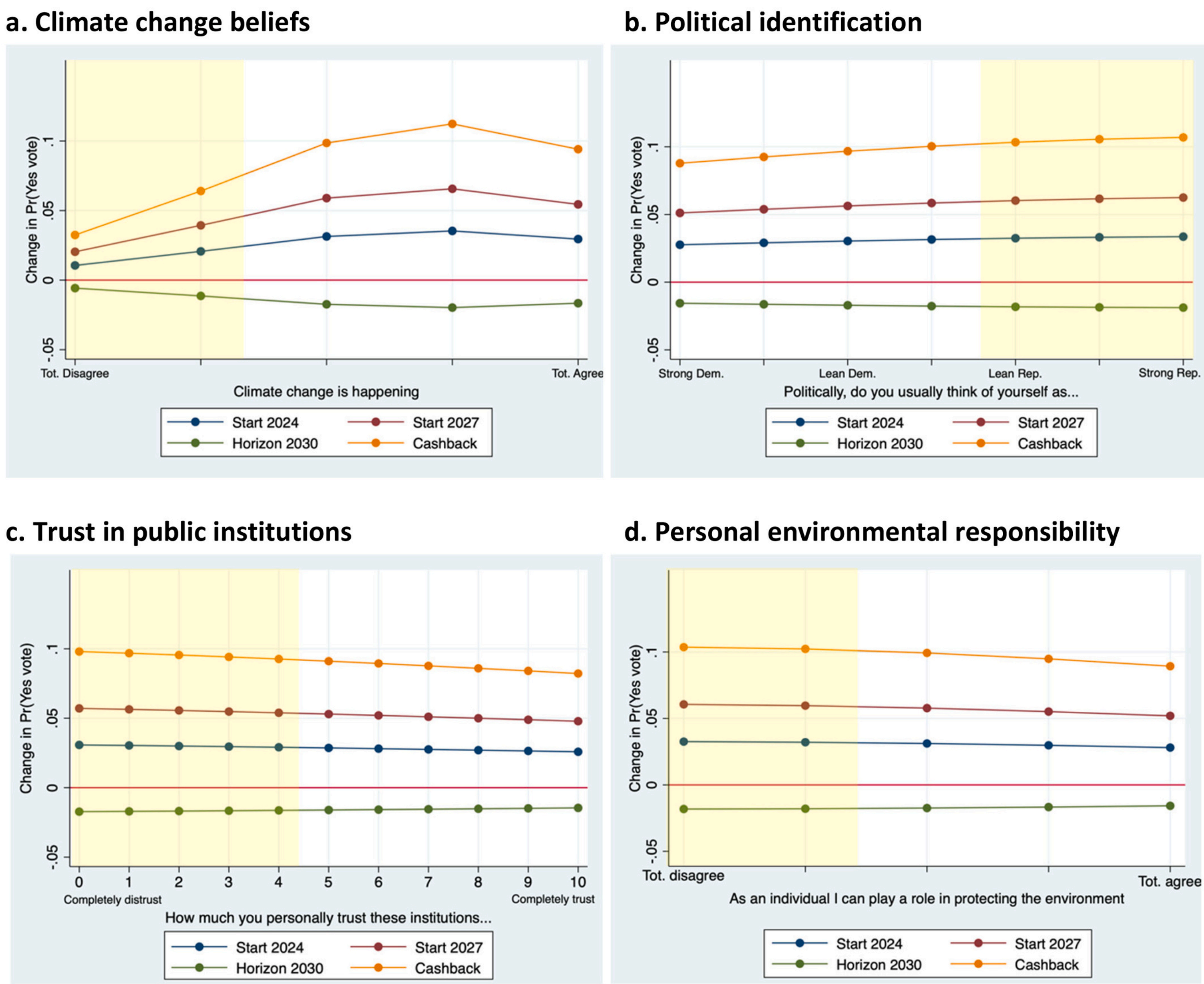

Fig. 6. Marginal effects of policy attributes on nay-sayers.
Source: own computations based on experimental data. Notes. Highlighted areas in the graphs corresponds to: a."Climate change is not happening"; b. "Identifies as Republican"; c. "Mostly distrust public institutions"; d. "Denies personal environmental responsibility".

favor of a policy that starts in three years, may actually change their mind three years from now. Clearly, the increase in popularity of a delayed policy start can be advantageous only if it comes with a pre-commitment mechanism, such as a binding popular vote through which constituents can irrevocably pre-commit to the preference they stated a few years earlier.

However, delaying the introduction of a carbon tax has clear bio-physical consequences as the carbon keeps accumulating in the atmosphere and the carbon budget that remains in order to stay within the Paris global warming objectives narrows with each year of delay. A delayed introduction would, therefore, require increasing the ambition of the tax by either adjusting its starting level or by scheduling steeper year-on-year increases. In this paper, we tested the former hypothesis, and we adjusted starting tax levels in proportion to the delay. A precise estimate of this adjustment is even more complex than estimating the taxation level required to meet the Paris objectives if the tax were to start immediately because it relies even more heavily on predictions and assumptions regarding the evolution of global emissions, the availability of low carbon technology and climate feedback loops. Attempting an exact estimation is beyond the scope of our paper, but we propose an adjusted tax level which falls within the range of plausibility, and which is intentionally an underestimate. We show that when individuals are confronted with the short-term opportunity cost that delaying the tax would potentially imply, they are not necessarily in favor of indefinitely postponing it. When the price of carbon is adjusted to take the delay into account, we see that individuals start to trade off tax postponement against the containment of costs. The exact switch point would ultimately depend upon the adjusted tax rate, individual discounting, and how the cost on households is derived, among other things. As our descriptive findings in Fig. 3 show, our conservative estimate of a tax increase which is proposed to meet the Paris objectives with a six-year delay is high enough to decrease tax approval rates as compared to 2021 and 2024. In the longer-term, such a tradeoff is likely to resolve itself, as the increased cost of mitigation for longer delays is enough to erode any additional support which might come from the appeal of shifting costs to the future.

The political message is clear: while precommitment to costs that are slightly delayed may increase the immediate political acceptance of a tax and increase the likelihood that a national referendum would pass, that increased support would be merely temporary and artificial unless the short-term opportunity costs of waiting were disclosed. Procrastinating on the approval of urgently needed carbon taxes for fear of voter opposition may not payoff in the long term, as the public opposition that politicians try to avoid today will likely increase proportionally to the length of the delay and the associated increase in mitigation costs that the policy would need to include. The higher the opportunity cost of waiting, the less likely is a delayed introduction to win any additional support. Politicians could leverage this and include the additional costs that an increased risk of waiting could pose for the climate in their carbon tax proposition and communications.

In addition, there are clear unknowns about tipping points and feedback mechanisms that imply a greater risk of catastrophic global warming events if climate mitigation policies are postponed and the concentration of CO_2 in the atmosphere becomes higher (Furman et al., 2015). Shifting a larger portion of the abatement effort to the future is also inefficient as it leads to avoidable welfare losses compared to a more balanced intertemporal distribution of efforts (Gollier, 2022). The most efficient policy is thus the policy that starts immediately as the mitigation costs increase with each year of delay. In the absence of cashback payments, or in the presence of individual economic losses, people's preference to delay the policy comes at a future welfare loss. Thus, any carbon tax proposal or postponement thereof that is passed on by the population should not only include the economic opportunity cost of waiting, but it should also mention the resulting welfare losses and the increase in long-term environmental risks.

In the short-term there is thus also a policy tradeoff, in which pre-committing to a policy that is postponed by a few years may increase its public support but worsen its efficiency and its effectiveness in averting climate catastrophe. This finding applies only to the Baseline scenario, and for individuals who expect a net loss from the tax. Beyond disclosing the opportunity costs of waiting, another effective way to counteract this preference for postponing the policy is to redistribute the tax revenues to citizens. Adding a personal gain, such as a private economic compensation, that is delivered at the same time as the individual costs of the tax leaves the temporal dimension of choice in the background; neutralizing the effect of individual discounting and of the policy's temporal context on tax support. When choice is no longer just between incurring in a private cost for the sake of a long-term shared benefit, but there is also short-term private benefit from the policy, individuals appear to no longer perceive the choice situation as one involving an intertemporal tradeoff. To maximize support for the most efficient policy, the ideal carbon tax formulation should thus contain a dividend redistribution component, at least at its introduction. This also appeals to groups of constituents that would typically oppose the tax.

Furthermore, people are more likely to favor a carbon tax if justified by more ambitious albeit more temporally distant environmental objectives; for example, climate neutrality by 2050 is a more evocative goal than merely halving carbon emissions by 2030. A limitation of our experimental design is that we included just two uses of revenues out of all available alternatives. This was done to contain the already high number of treatments. Future research could expand to other alternative revenue uses not included in the paper. It could also build on this work by looking at the effect of the timing of the cashback payments versus the timing of the increased costs that households would face on a daily basis.

Inclusion and diversity statement

We worked to ensure gender and ethnic balance in the recruitment of human subjects.

CRediT authorship contribution statement

Mariateresa Silvi: Conceptualization, Methodology, Software, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Funding acquisition. **Emilio Padilla Rosa:** Writing – review & editing, Supervision, Project administration, Funding acquisition.

The authors have nothing to disclose.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2023.106815.

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