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ABSTRACT

Personal carbon allowances (PCAs) can complement current carbon pricing policies to achieve the sharp cut in emissions needed to meet the climate targets set by the Paris Agreement. While their effectiveness crucially depends on their social acceptability, there is little evidence on which specific characteristics of their design are preferred by citizens and how these preferences might differ within a society. Our study aims at eliciting preferences for a specific PCA scheme and explores their heterogeneity, using a discrete choice experiment among Belgian citizens and analyzing mixed logit and latent class models. Discrete choice experiments are a widely used tool to deliver key insights to policy design, but have rarely been used in the context of a PCA design. We find that intergenerational differences are important factors to explain citizens' willingness to accept a PCA, with younger people strongly in favour. A PCA that includes carbon price regulations and provides tailor-made advice on how to reduce carbon emissions, is more likely to be accepted. However, purchase limits for emission thresholds beyond which a tax is imposed should be carefully introduced, as we find large heterogeneity across citizens' willingness to accept this. These differences are correlated with current emission and income levels, and awareness about PCA. Our study is a first step in designing and developing a PCA, as investigating its social acceptability is a prerequisite before actual implementation.

Key policy insights

- Large intergenerational differences in the social acceptability of a PCA exist, with younger people strongly in favour.
- Carbon price regulations increase social acceptability, either through minimum and maximum prices or through a fixed price by experts.
- Provision of tailor-made advice to reduce personal carbon impact increases social acceptability.
- Introduction of purchase limits for emission thresholds, beyond which a tax is imposed, needs to be complemented by additional measures to ensure climate justice.

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Personal carbon allowances (PCA); carbon accounting; carbon emissions; social acceptability; policy instrument design; choice experiment

1. Introduction

Climate change threatens human societies and the ecosystems around them (IPCC, 2021). As the Paris Agreement aims to limit the rise in global temperature below 2°C, each country is tasked with its responsibility to achieve this common goal (United Nations, 2015). While many options exist to reduce carbon emissions, carbon pricing has become a well-recognized instrument to coordinate various actors to reduce their emissions in an economically efficient way (Stiglitz et al., 2017; Thisted & Thisted, 2020). The most common carbon pricing policies include carbon taxes and tradable permit systems, often called Emission Trading Systems (ETS)

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(Bothner, 2021; Pezzey, 2003). In 2021, these policies covered 21.5% of global greenhouse gas emissions (World Bank, 2022). However, it is argued that these carbon pricing policies are insufficient in some contexts to achieve the sharp cut in emissions required to meet the climate targets, as current carbon prices are deemed too low (Verde et al., 2020).

Personal carbon allowance[1] (PCA) is a carbon pricing policy instrument that aims to link the purchase of a good or service to its carbon footprint, thereby highlighting the personal link between citizens' consumption patterns and climate change (Fuso Nerini et al., 2021). The principle behind a PCA is that all citizens receive an equal, tradable carbon allowance, determined by the national target to reduce carbon emissions. For each purchase, the carbon equivalent is deducted from the allowance. If the allowance runs out, additional carbon units can be bought under certain conditions. Depending on its design, a PCA can be interpreted as a special form of an ETS. Unlike voluntary carbon offsetting, where consumers can choose to pay an additional fee for their carbon emissions, a PCA would be mandatory.

PCAs are argued to be more effective in changing consumers' behaviour than carbon taxes and ETSs, as they involve cognitive and social mechanisms in addition to the purely economic mechanism of assigning a carbon price (Fuso Nerini et al., 2021; Lockwood, 2010). As consumers are more aware of their individual carbon emissions, they could act more effectively on reducing them (Capstick & Lewis, 2010; Parag et al., 2011). Moreover, a recent experiment has shown that by labelling a carbon budget, PCAs can be an effective instrument to change people's consumption choices (Marek et al., 2018). In addition, by involving all citizens, a PCA could influence consumers' behaviour by changing social discourses and habits (Parag & Fawcett, 2014; Parag & Strickland, 2010). However, empirical studies that directly compare the effectiveness of PCAs against carbon taxes have found mixed evidence, thereby highlighting the importance of the specific design of the PCA in order to achieve sharper reductions in carbon emissions (e.g. Harwatt et al., 2011; Raux et al., 2015; Zanni, Bristow, & Wardman, 2013).

Despite these potential benefits, PCA schemes have never been implemented at large scale.[2] The main barriers for adoption are considered to be high implementation costs, technological constraints, and low social acceptability (Fuso Nerini et al., 2021). More recently, however, PCAs are being reconsidered, as costs associated with a worsening climate crisis are rapidly increasing, and technological advancements, such as the recent development of private carbon-counting credit cards,[3] open up new opportunities to implement a PCA (Sconfienza, 2021). Still, the social acceptability of a PCA remains crucial before it can be implemented at large scale. A recent systematic review has shown that there is no clear consensus among both researchers and policy makers on the social acceptability of PCAs (Bothner, 2021). In particular, there is little evidence on which specific characteristics of their design are preferred by citizens and how these preferences might differ within a society. Acceptability of any public policy instrument depends largely on the specific design and its characteristics, and how it is tailored towards citizens' characteristics (Ščasný et al., 2017). Key factors that influence social acceptability of climate change policies in general and PCAs in particular are their perceived fairness, which can be related to individual consequences, distributional effects and procedures, and their effectiveness in changing actual consumer behaviour (Maestre-Andrés et al., 2019).

Our study contributes to this re-emerging policy and scientific debate by investigating the social acceptability of a PCA among Belgian citizens. We use a discrete choice experiment (DCE) to elicit citizens' preferences and willingness to accept a PCA, thereby accounting for different PCA designs and heterogeneity across citizens. While DCEs have been widely used to investigate preferences for other carbon pricing policies, our study is one of the first to use a DCE to analyze social acceptability of a PCA.[4] This method allows us to investigate how the specific design of a PCA is linked to its acceptability, and how these preferences might differ within a society, thereby addressing important research gaps in the current policy and scientific debates. In line with the theoretical arguments for a PCA, we are particularly interested in citizens' preferences for the cognitive

[1]Also referred to as personal carbon trading schemes.
[2]Some small-scale experiments have been implemented in e.g. Canada, Australia, China, and Finland (Guzman & Clapp, 2017; Hendry, 2019; Tan et al., 2019; Kuokkanen et al., 2020).
[3]An example is the consortium of the Swedish firm Doconomy and MasterCard.
[4]To our knowledge, only Bristow et al. (2010) have used a DCE to analyze the social acceptability of a PCA.

and social mechanisms, including the carbon price setting, purchasing limits on carbon units, and offering of personal advice on how to reduce carbon emissions.

2. Methods

DCEs are stated preference methods that are conceptually based on Lancaster's economic theory of value, meaning that consumers' utility or satisfaction from one good is derived from the attributes or properties of the goods, rather than from the good itself (Lancaster, 1966). A DCE introduces respondents to a hypothetical good or context and asks them to state, several times, their preferred scenario between several scenarios, each characterized by attributes that take on different levels. DCEs are therefore particularly useful to elicit preferences for prospective market goods, non-market goods, or policies which have not yet been implemented, like PCAs (Louviere et al., 2000). Combined with surveys, DCEs are relatively cheap tools to analyze the social acceptability of hypothetical policies.

2.1. Determining a hypothetical PCA

PCAs can be set up in many different ways, as they can vary substantially in terms of scope of emissions covered and allocation of carbon units to individuals and households (Fawcett, 2010; Fawcett & Parag, 2010). While a DCE reveals how citizens' preferences might change for specific attributes of a PCA, we need to first determine a 'baseline' PCA and how this would hypothetically function. We explain below how we define the scope and allocation of the PCA in our study.

First, our PCA would cover all private carbon emissions related to fossil fuels and cement, including transportation, housing and heating. We deliberately focus on fossil fuels, because their CO_2 emissions are easily measured from the amount of carbon initially present in these fuels and because they are responsible for 64% of worldwide emissions in CO_2 equivalents (IPCC, 2021). This focus on fossil fuel carbon emissions is in line with other studies envisaging PCAs with a large scope (Fuso Nerini et al., 2021; Sconfienza, 2021; Wadud & Chintakayala, 2019; Woerdman & Bolderdijk, 2017).

Second, our PCA allocates to all citizens an equal amount of free carbon units of 1.2 tons of CO_2 per year per person to be used for private expenditures. This corresponds to the emission level that is needed to reach the targets as set by the Paris Agreement. In addition, states would be responsible for emissions related to public goods and services (e.g. education, health, defence, waste management, public infrastructure). We assume that these emissions will gradually phase out by 2050 to be in line with the Paris Agreement. To compare, annual consumption-based emissions for the Belgian population were estimated at 15 tons per capita in 2019, so the PCA implies a substantial reduction in carbon emissions (Global Carbon Project, 2021). If a person requires additional carbon units, these have to be purchased at a certain price level from the government. Our PCA stipulates that the government should spend 50% of the revenues generated by the sale of these extra units to finance the energy transition and the remaining 50% to assist energy-poor households, as highlighted by Chamberlin et al. (2014).

In order for our PCA to work, we assume that carbon accounting rules are harmonized across firms to verify the coherence of the carbon unit flows. This means that each firm keeps records of its internal carbon flow, thereby assigning carbon footprints to each good and service. Another assumption relates to the scale; while preferences of Belgian citizens are elicited, the PCA would be implemented at the EU level to ensure fair competition between member states.

2.2. Design of the DCE

A major step when designing a DCE is the selection of the attributes and the levels. Among possible attributes that could enter the design of a PCA, we determined four attributes taking on two to six levels, based on the PCA literature and on discussions with climatologists, carbon accounting experts and climate policy makers (Table 1).

Table 1. Attributes and levels of attributes

Attribute	Explanation	Attribute levels
Price level	Price per ton of CO_2 emissions that people would pay to buy extra carbon units	• 10 € / ton • 20 € / ton • 50 € / ton • 100 € / ton • 200 € / ton • 500 € / ton
Price regulation	Mechanism to determine the carbon price, thereby affecting its volatility	• Free market price resulting from supply and demand • Market price controls with minimum and maximum price • Price fixed by experts with regular revisions
Reduction advice	The personal carbon allowance comprises a dashboard giving tailor-made advice to reduce carbon emissions	• No advice • Advice
Purchase limit	The personal carbon allowance is implemented with an annual purchase limit. Should an individual exceed the limit, a tax needs to be paid	• No limit • Light limit of 27 ton/year per person • Strong limit of 15 ton/year per person

The first attribute, price level, is defined as the price per ton of CO_2 emissions that people would pay to buy additional carbon units besides the standard monthly allowance.[5] The price takes six levels of 10, 20, 50, 100, 200 and 500 €/ton. The range of these values is derived from a study investigating the level of carbon prices compatible with the limitation of global warming to 2°C under different Shared Socioeconomic Pathways (SSP) scenarios (Guivarch & Rogelj, 2017). We found similar price levels in another DCE study investigating the social acceptability of a PCA (Bristow et al., 2010). This attribute influences social acceptability as it entails an additional cost for individuals, which can be perceived as fair or unfair (Maestre-Andrés et al., 2019).

The second attribute, price volatility, is selected to investigate citizens' preferences for the setting of carbon price. The attribute consists of three levels: (i) a free-market price resulting from supply and demand with potential high price volatility; (ii) market price controls using minimum and maximum prices, resulting in a medium level of volatility and (iii) a fixed price determined by an independent group of experts, leading to a low level of volatility. This attribute is inspired by the studies of Perino and Willner (2017) and Knopf et al. (2018), who investigate different ETS designs and how they could be complemented by price-based control measures, such as a floor price. Unregulated carbon prices, which are commonly observed in various ETSs, have typically been associated with less social acceptability because of their lower perceived fairness related to individual consequences and distributional effects (Maestre-Andrés et al., 2019).

The third attribute, advice on reductions, is selected to assess to which extent respondents are interested by tailor-made advice for emission reduction that they would receive through the use of their PCA. The attribute takes on two levels: whether or not the respondent receives information on how to substitute carbon-intensive goods by showing alternatives of carbon-extensive goods. We chose this attribute to elicit the importance of the awareness impact channel on changing consumers' behaviour, which is often put forward as one of the main reasons why a PCA might be more effective than a simple carbon tax (Capstick & Lewis, 2010; Parag

[5]In theory, it is possible that citizens do not use all of their carbon units and can hence re-sell. However, in our sample this was the case for only 3.6% of the respondents.

et al., 2011). It is inspired by the recent development of applications that track citizens' emissions (Kuokkanen et al., 2020). Some of them, like Cogo or Carbo, offer personalized advice to reduce carbon emissions.

The fourth attribute, purchase limit, is selected to analyze the preferences of respondents towards emission thresholds beyond which individuals should be taxed in addition to the carbon price. The attribute takes on three levels: (i) no limit; (ii) light limit (annual emissions threshold at 27 tons of CO_2) and (iii) strong limit (annual emissions threshold at 15 tons of CO_2). These thresholds are based on the current emission levels of the Belgian population. If an individual exceeds the limit, a tax needs to be paid for each extra carbon unit he/she purchases. This purchase limit is in line with the model proposed by Burgess (2016), who argues that a higher usage would be necessary before purchase of top-ups is allowed. Research has shown that some might prefer having a limitation on carbon unit purchase, because they want to avoid massive carbon emissions by others (or themselves, provided that other higher emitters are also constrained) (Bristow et al., 2010). This refers directly to consideration of fairness. Others could interpret a purchase limit as an unacceptable constraint on their freedom, a judgment in terms of procedural fairness.

A next step in the design of a DCE is to select those combinations of alternatives with specific attribute levels that yield the most information when respondents make their choices. Using Ngene software, we generated a D-efficient design of 18 choice cards, which were divided in three blocks so each respondent should only evaluate six choice cards. The survey was set up in such a way so an equal number of respondents was allocated to each block. Each choice card contains three alternatives: two PCA scenarios and one opt-out alternative, meaning that the respondent does not accept any of the proposed scenarios. The cards were always shown in a random order to avoid possible order and starting point effects.

2.3. Data collection

We implemented an online survey addressed to French-speaking Belgians based on voluntary participation, which was completed by 278 respondents. We diffused the survey through various channels, including mailing lists of various organizations and social media. The survey comprised two main parts. First, general data about the respondents was collected, including questions about socio-economic characteristics of the respondents, their EU climate policy knowledge, and their awareness about PCAs. In addition, a simplified table (Table S1 in Supplementary Material) was presented to respondents for self-evaluation of their current carbon emission level. We based this on an existing online estimator targeted to French citizens,[6] and adapted this to the Belgian context. We simplified the estimation to not overburden the respondents. Five domains that are considered to be most important for carbon emissions were included: (i) transportation during holidays; (ii) daily transportation; (iii) type of housing and heating; (iv) housing surface per person and (v) income level – as income is a main determinant of carbon emission levels (Ivanova et al., 2017). Respondents indicated for each domain the scenario that best reflected their situation, choosing between five different options. After filling in the table, they had to select the emission category that best reflected their overall emission level. This category was then converted into an estimated emission level, taking the value of 3, 9, 15, 21 or 27 ton of CO_2 per person per year using the information from the online simulator. We need to stress that this emission level is an approximate estimation and should not be interpreted as people's actual emission level. Still, this estimation reflects general trends for low-, medium- and high-emitters, and can therefore be used by the respondent to further interpret the DCE.

Second, the PCA was introduced and explained. The exact information provided to the respondents is presented in the Supplementary Material. Next, the concept of the DCE was presented, with all the attributes carefully explained. To make the attribute of carbon price more tangible, we presented the corresponding monthly cost for each emission level. For example, people who selected emission category A as overall emission level (corresponding to 3 ton of CO_2 per person per year) would not have to purchase additional carbon units, as this is covered by the personal allowance and the public emissions managed by the government. In contrast, people who selected emission category E (corresponding to 27 ton of CO_2 per person per year) would have to purchase additional carbon units of 2 ton of CO_2 per month. Depending on the carbon price, their mean

[6]'Nos GEStes Climat' simulator, available on: https://nosgestesclimat.fr/.

monthly expenditures on additional carbon units could range between 20€ and 1,000€. A cheap talk script was used to remind respondents to fill in the DCE as truthfully as possible.[7] Then, the respondents filled in the six choice cards of the DCE, followed by some questions if the respondents had ignored attributes when making their choices to reveal possible cases of stated attribute non-attendance. The total number of observations is therefore equal to 5004, which corresponds to 278 (number of respondents) multiplied by six (each respondent filling in six choice cards) and three (each choice card consisting of three alternatives).

Respondent characteristics are summarized in Table S2 in Supplementary Material. The average respondent age is 31 years old and nearly half of the respondents identified their gender as female. About 18% of respondents live in the Brussels-Capital Region. The education level comprises three main groups: 26% hold a secondary school certificate, 30% have a bachelor's degree and 42% have a master's degree. Nearly half of the sample (46%) is enrolled as a student. We need to stress that our sample is not representative of the French-speaking Belgian population, as the respondents tend to be younger, higher-educated, or are still enrolled as a student, and are more likely to live in Brussels.

2.4. Econometric analysis

DCEs are analyzed based on random utility theory, which assumes that utility consists of a deterministic and a stochastic (random) component (Manski, 1977; McFadden, 1974). The utility derived from alternative i by respondent n can be described as follows:

$$U_{in} = V_{in}(X_i, S_n) + \epsilon_{in} \tag{1}$$

In Equation (1), U_{in} represents the total utility of respondent n when he/she chooses alternative i. V_{in} is the deterministic part of utility and ϵ_{in} the random part (i.e. the error term), which is not observed. The deterministic part of utility depends on the attributes of the alternative (X_i) and on characteristics of the respondent (S_n). The uncertainty associated with the utility function makes it impossible to determine the total utility function. However, we can observe which alternative is chosen. Assuming utility maximizing behaviour, the probability that an alternative i is preferred over j among J alternatives, is equal to the probability that the utility of i is larger than j. This can be expressed as:

$$P_{in} = P(U_{in} \geq U_{jn}) = P(V_{in} + \epsilon_{in} \geq V_{jn} + \epsilon_{jn}) \; \forall j \in [1, \ldots, J] \; and \; i \neq j \tag{2}$$

Because the random component of utility is not observed, assumptions are needed to develop operational choice models (Louviere et al., 2000). In our analysis, we use two types of choice models to analyze preferences and identify sources of preference heterogeneity. First, we use a Mixed Logit (MXL) model, which relaxes the Independence of Irrelevant Alternatives (IIA) assumption and allows for preferences to be different across respondents by estimating a density function around the random coefficients. The presence of preference heterogeneity is indicated by the standard deviations associated with the estimated coefficients. We assume that the distribution of the price attribute is fixed and the other attributes are random, as we expect substantial preference heterogeneity for the latter but an overall dislike for a higher buying price (in line with theory and other empirical studies).

Second, we use a Latent Class (LC) model, which assumes that respondents can be divided into different classes or segments, each one being characterized by a unique preference pattern. Homogenous preferences and independent and identically distributed error terms can be assumed within each of these classes, while preferences differ across the classes. The number of classes is established by comparing the log likelihood and the Akaike's and Bayesian information criterion. We find that the incremental improvement in these parameters is highest in a model with three classes compared to models with two or four classes. Models with more than four classes are not considered, because class sizes would be too small. To explore preference heterogeneity, we specify a membership function, including the variables of age, emission level (i.e. high emitter of 27 t/year), income level (i.e. low income of less than 2.000€/month), and whether the respondent has heard

[7]The following cheap talk script was used in French: '*Sur les six cartes suivantes, veuillez faire votre choix entre les trois options proposées. Assurez-vous de choisir tel que vous le feriez si l'option choisie devenait réelle pour vous.*'

about a PCA before the DCE. These variables are chosen based on an LC model without membership function, in which we compared differences across classes. Overall, our results do not differ substantially according to the specification of the membership function, as the main conclusions remain valid.

In addition, we perform two robustness checks. First, we analyze an unrestricted Generalized Multinomial Logit (GMNL) model to control for scale heterogeneity, which may arise if choices of respondents are not consistent across the different choice cards. Second, we use the stated attribute non-attendance (ANA) information collected in the survey to correct for possible bias if respondents did not consider all attributes when choosing between the alternatives. Following Scarpa et al. (2013), we analyze a new MXL model in which we set the coefficients to zero for those attributes that respondents ignored. In the sample, 32.7% of the respondents claims to have ignored at least one attribute: 16.2% ignored the attribute of price level, 28.4% ignored the attribute of price regulation, 24.5% ignored the attribute of reduction advice and 9.4% ignored the attribute of purchase limits.

All the attributes' parameters as well as an alternative specific constant (ASC) are included in the model. The ASC captures the (dis)utility associated with the opt-out option (i.e. not accepting any of the PCA alternatives). The ASC is set to one in case of the opt-out option and zero in case of the two PCA alternatives, meaning that a negative coefficient indicates an overall preference to accept the PCA presented in the DCE. In the sample, 24 people have always opted out (8.6%) and 211 never opted out (75.9%). We do not know whether those 24 people are 'protest bidders' (i.e. not interested in the DCE and therefore always selecting opt-out) or whether they are genuinely against the PCA in our DCE. Our results for the attribute preferences are robust to whether these respondents are in- or excluded from the sample. The price attribute is specified as a continuous variable[8] while all the other categorical attributes are coded using dummy coding for ease of interpretation.[9]

A final step in our analysis is the estimation of the willingness to accept (WTA) for different PCA attributes. WTA is expressed in monetary terms and is derived from the marginal rate of substitution between the price level attribute and another attribute, holding all else constant (Louviere et al., 2000). We derive WTA values in WTA space, placing distributional assumptions directly on the WTA and price coefficients (Train & Weeks, 2005). WTA indicates the carbon price that respondents are willing to accept if the level of attribute studied is included in the PCA. A higher WTA for a specific attribute level is thus associated with a higher social acceptability of a PCA that bases its design on these preferences. In other words, people are prepared to accept a PCA with a higher carbon price if they perceive the policy to be more effective and fairer. This interpretation is a bit subtler than the more straightforward interpretation of DCEs that evaluate consumer preferences for private goods and services, which states their willingness to pay for their own consumption. Moreover, we use the WTA values to compare preferences across latent classes, as direct comparison of estimated coefficients is not allowed (Louviere et al., 2000). Hence, we rather interpret them in a relative way and refrain from interpreting them in an absolute way.

3. Results

Table 2 presents the results from the MXL model (our base model), the GMNL model (which corrects for scale heterogeneity) and the MXL stated ANA model (which corrects for possible bias related to ANA). The associated WTA estimates are presented in Figure 1. The three models report coefficients and standard deviations that are similar in sign and significance level, without statistically significant differences in WTA estimates, indicating that the MXL model is robust to scale heterogeneity and stated ANA. Therefore, we continue our discussion based on the MXL model. The ASC is significantly negative, meaning that the utility associated by the opt-out option is negative on average. This indicates that respondents prefer generally to accept the PCA that is presented in the DCE. Moreover, they prefer a PCA with a lower carbon unit price, which is regulated by a floor and ceiling price or determined by experts rather than a free-market price, which offers tailor-made

[8]Given the jumps in the price levels, we also tested a model in which price was specified as a discrete variable, but this did not change the main results.

[9]We estimated the model using effects coding as well and did not find a significantly different coefficient for the ASC.

Table 2. Mixed logit model estimates compared to estimates from generalized multinomial logit model and mixed logit model corrected for attribute non-attendance.

	MXL (uncorrelated)				GMNL (unrestricted)				MXL (corrected for ANA)			
	Mean Coef. [a] (se)[b]		SD[c] Coef. (se)		Mean Coef. [a] (se)[b]		SD[c] Coef. (se)		Mean Coef. (se)		**SD Coef. (se)**	
ASC[d]	−4.337	***	5.342	***	−4.352	***	5.206	***	−4.478	***	5.388	***
	(0.755)		(0.729)		(0.925)		(0.883)		(0.763)		(0.692)	
Carbon unit price (€/ton)	−0.003	***			−0.003	***			−0.003	***		
	(0.000)				(0.000)				(0.000)			
Market price controls	0.591	***	−0.039		0.606	***	0.107		0.757	***	−0.150	
	(0.110)		(0.276)		(0.129)		(0.269)		(0.131)		(0.510)	
Price fixed by experts	0.553	***	0.004		0.554	***	−0.111		0.750	***	0.365	
	(0.110)		(0.392)		(0.118)		(0.362)		(0.137)		(0.365)	
Advice offered	1.019	***	0.948	***	1.067	***	1.016	***	1.373	***	1.065	***
	(0.111)		(0.140)		(0.162)		(0.166)		(0.147)		(0.169)	
Annual limit: 27t	0.661	***	0.714	***	0.670	***	0.713	***	0.715	***	0.824	***
	(0.115)		(0.219)		(0.126)		(0.198)		(0.130)		(0.227)	
Annual limit: 15t	0.375	***	1.361	***	0.394	***	1.420	***	0.340	**	1.560	***
	(0.134)		(0.193)		(0.149)		(0.232)		(0.152)		(0.220)	
Tau coefficient					0.239							
					(0.355)							

* $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.
[a]Coefficient; [b]Standard error; [c]Standard deviation; [d]Alternative Specific Constant.
All models contain 5004 observations. The log likelihood of the models are respectively −1203.5, −1202 and −1162.6.

advice, and which stipulates an emission threshold above which additional carbon purchases are taxed. However, standard deviations are significant for all the attributes and ASC, except for price volatility. This means that our sample is characterized by a substantial preference heterogeneity.

Table 3 shows the results of the LC model with three different classes, each having a distinct preference pattern, with the associated WTA estimates presented in Figure 1. The major difference between the first and second class (representing 44% and 40% of the sample respectively) and the third class (representing 16%) is that the former prefer, on average, to accept a PCA while the latter does not, as is shown by the negative ASC for the first and second class, and a positive ASC for the third class. In addition, the first class shows a higher WTA for price regulation and they are strongly in favour of limitations beyond which emissions are taxed. This is in contrast to the second class who strongly dislikes these limitations and who needs to be compensated if such

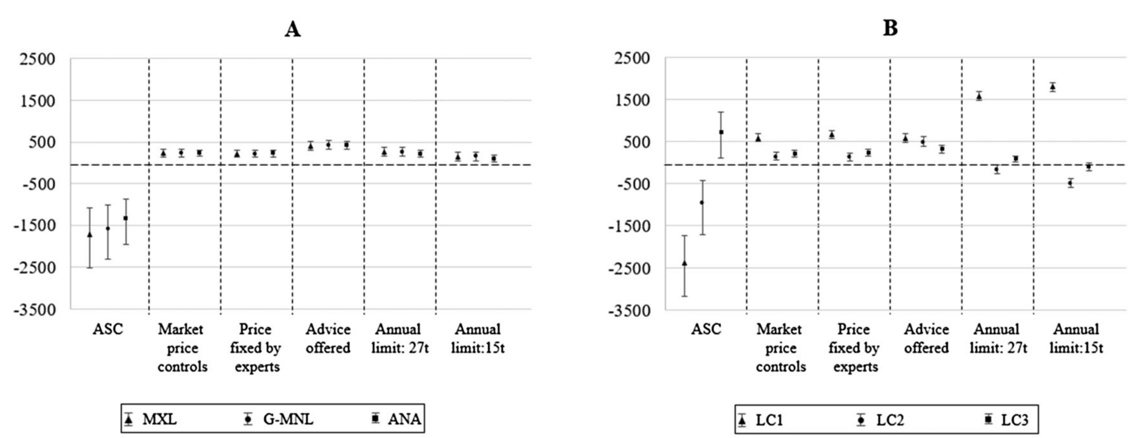

Figure 1. Willingness-to-accept estimates in €/ton with 95% confidence intervals. (A) Mixed logit model (MXL) and robustness checks of Generalized Multinomial logit model (G-MNL) and MXL corrected for Stated Attribute Non-Attendance (ANA), derived from regressions presented in Table 2. (B) Latent Class model (LC) for three classes, derived from regressions presented in Table 3.

Table 3. Latent Class model estimates with attribute preferences and membership function

	Latent Class 1			Latent Class 2			Latent Class 3		
	Class share = 44.1%			Class share = 40.3%			Class share = 15.6%		
	Coef. [a]	Std. err. [b]		Coef.	Std. err.		Coef.	Std. err.	
Attribute preferences									
ASC[c]	−2.051	(0.531)	***	−2.603	(0.389)	***	2.569	(0.516)	***
Carbon unit price	−0.001	(0.000)	**	−0.003	(0.000)	***	−0.004	(0.001)	***
Market price controls	0.507	(0.154)	***	0.385	(0.194)	**	0.702	(0.368)	*
Price fixed by experts	0.570	(0.154)	**	0.357	(0.177)	**	0.831	(0.379)	**
Advice offered	0.502	(0.154)	***	1.331	(0.195)	***	1.118	(0.322)	***
Annual limit: 27t	1.359	(0.224)	***	−0.461	(0.218)	**	0.286	(0.383)	
Annual limit: 15t	1.557	(0.243)	***	−1.343	(0.339)	***	−0.381	(0.442)	
Membership function									
Age	−0.037	(0.015)	**	−0.031	(0.013)	**			
High emitter (27t/year)	−23.610	(7.682)	***	−0.993	(1.065)				
Low income (<2.000€/month)	−0.426	(0.489)		−1.941	(0.727)	***			
PCA awareness	1.378	(0.492)	***	0.261	(0.552)				

* $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$
[a]Coefficient; [b]Standard error; [c]Alternative Specific Constant.
The model contains 5004 observations. The log likelihood is equal to −1174.76. AIC and BIC values are respectively 2541.3 and 2518.3.

limitations are to be introduced. Another major difference is that the third class is indifferent whether additional carbon purchases above a certain threshold are taxed or not, as the coefficients for this attribute are insignificant.

In line with their distinct preference structures, the classes also differ in terms of socio-economic characteristics (membership function in Table 3). Younger respondents are more likely to belong to class 1 and 2 than class 3. Being a high-level emitter decreases the likelihood of belonging to class 1 while having a low-income level decreases the likelihood of belonging to class 2 compared to class 3. Respondents who are aware of PCAs are more likely to belong to class 1.

4. Discussion

We find major differences across citizens in the social acceptability of the PCA that we present in our study. A large proportion of the citizen sample (84%) is favourable to the PCA, but 16% would require additional incentives to accept it. Our sample is not representative of the Belgian population with an oversampling of students and younger people, who constitute the main part of people in favour of a PCA. This might suggest that the overall social acceptability of a PCA may be lower in the total population, but we are careful to draw general conclusions based on our specific sample. Still, the differences in acceptability can be largely explained by age, which demonstrates the importance of considering intergenerational differences on how to mitigate climate change. Younger people are more likely to face climate extremes and therefore demand more action from policy makers, but are also more willing to take individual action, such as participating in a PCA (Han & Ahn, 2020; Thiery et al., 2021).

It is rather difficult to compare our results with other studies investigating the acceptability of a PCA, given the differences in the specific design of the PCA presented in other studies and the representativeness of the population in the survey samples. Nevertheless, our findings are in line with a study in the United Kingdom (UK), where acceptability ranges from 17 to 80% of the population, depending on the attributes presented to respondents (Bristow et al., 2010), and with a more recent survey in China, where 75% of the interviewees agreed or strongly agreed that they would participate in a PCA (Liu, 2019). Another study shows that British citizens would prefer a PCA over the current carbon tax policy, as they have less trust in their government to operate the tax, while Swedish citizens do prefer to continue their carbon tax policy instead of introducing a PCA (Jagers et al., 2010). Comparing our results with studies on the acceptability of voluntary carbon offsetting, this seems to be lower than for our PCA. Possible reasons might be that people have less trust in these schemes because of clarity and regulation issues (Blasch & Farsi, 2014; Gössling et al., 2007; Tao et al., 2021).

Our DCE also demonstrates that the specific design of a PCA matters for improving its social acceptability. First, all respondents are in favour of a PCA in which the carbon price is regulated instead of a free market price. Whether this regulation occurs through price floors and ceilings, or through a fixed price defined by experts, matters less. This suggests that citizens tend to distrust the effectiveness and fairness of an unregulated carbon price in tackling carbon emissions, a problem commonly identified in existing ETSs (Perino & Willner, 2017; Knopf et al., 2018). In addition, citizens might be more vulnerable to large price fluctuations compared to large-scale multinationals (Woerdman & Bolderdijk, 2017).

Second, the possibility to obtain tailor-made advice on how to reduce carbon emissions is considered as a major advantage by all of the respondents. This represents an important opportunity for policy makers to increase the social acceptability of a PCA. It confirms that improving awareness about personal carbon impact can be a major channel of effect in changing consumers' behaviour, and that this cognitive effect highly complements the purely economic incentives associated with a simple carbon price policy (Capstick & Lewis, 2010; Parag et al., 2011). While there is an increasing amount of information available and accessible to consumers about the carbon emissions related to different goods and services, looking up this information seems to be too time-consuming and not user-friendly. A PCA that offers this service may meet consumers' demand for information in a more effective way.

Third, the introduction of purchase limits in a PCA is quite a contentious issue. Especially higher-emitters, who have to buy additional carbon units if they do not change their current consumption patterns, strongly dislike an emission threshold beyond which a carbon tax is imposed. People from lower-income households are more in favour of purchase limits, which relates to a fairness principle that more effort would be asked from richer people who tend to emit more (Christis et al., 2019; Lévay et al., 2021; Sommer & Kratena, 2017). This was also found by Bristow et al. (2010) in their study on the acceptability of a PCA in the UK. It might also be the case that people who have not heard about PCAs before the DCE perceive the whole idea of a PCA as too brusque if purchase limits are included as well. This is illustrated by the higher share of respondents that already heard about PCAs among those who are in favour of purchase limits. All these factors should be considered by policy makers when introducing purchase limits, otherwise, a PCA might be deemed to reinforce climate injustice, thereby jeopardizing initiatives to reduce emissions (Sovacool et al., 2019).

Our DCE entails some limitations. As it relies on stated preferences, hypothetical bias is inherent in a DCE. It might be the case that respondents did not always select the scenario that they would also accept in real life, thereby overstating their WTA. As explained in section 2.3, we used a cheap talk script to address this hypothetical bias. While the effectiveness of a cheap talk script has been questioned before, especially for the purchase of private goods (Blumenschein et al., 2008; Moser et al., 2014), it has been documented that hypothetical bias is rather small in the demand for voluntary climate change mitigation (Uehleke & Sturm, 2017). In addition, the selection of attributes is crucial for a good design. As the PCA is already quite an abstract concept to most respondents, we purposely include only four attributes. Other attributes that might have been relevant as well are, e.g. how the government would use the revenues from selling carbon units; the initial allocation of carbon allowances; the scope of GHG emissions included for the system; how privacy would be ensured; whether excess carbon units can be extended over time and the introduction of a progressive carbon tax. To simplify the task for respondents, we specified these conditions as given under the proposed PCA (see Supplementary Material for the exact description). Future studies could investigate the importance of these attributes. Another limitation is that we did not specify the maximum and minimum price, or the tax level. It might be that respondents did not interpret this in the same way. Yet, this choice was also deliberate to make the DCE not too complex. Finally, our sample is relatively small and not representative of the Belgian population as it was based on voluntary participation in an online survey. Still, the intergenerational differences likely hold at the national level as well and can probably be extrapolated to other similar countries where young people are more concerned about the consequences of climate change. To improve the external validity of our results, our study should be repeated for different countries, preferably using large and representative samples.

5. Conclusion

This study investigates the social acceptability of a PCA, a policy tool that has recently received (renewed) attention to improve current carbon pricing policies. Contrary to more straightforward carbon taxes and ETSs, PCAs can substantially vary in their design, which largely influences their social acceptability. While this acceptability has been investigated before, there is little or mixed evidence on which specific characteristics of their design are preferred by citizens and how these preferences might differ within a society. Using a DCE among Belgian citizens and analyzing mixed logit and latent class models, we find that social acceptability highly depends on the policy design and on citizens' characteristics. Results from our sample show that intergenerational differences are important factors to explain citizens' willingness to accept a PCA, with younger people strongly in favour. If a PCA includes carbon price regulations and the provision of tailor-made advice on how to reduce carbon emissions, the social acceptability is improved among all segments within society. However, purchase limits for emission thresholds, beyond which a tax is imposed, should be carefully introduced, as we find large heterogeneity across citizens' willingness to accept this. These differences are correlated with current emission and income levels, and awareness about PCA.

Obviously, our study is a first step in designing and implementing a PCA. Other characteristics have to be considered that could explain social acceptability. We introduced a PCA with a large scope covering all emissions related to fossil fuels and cement, and that allocates an equal amount of carbon units to each citizen that is far below the current emission level of most people. This is quite an ambitious PCA, but deemed necessary if a PCA is to effectively reduce carbon emissions. Other PCAs can be different in terms of scope and allocation, thereby influencing their effectiveness but also their social acceptability. Investigating preferences for these aspects clearly entails scope for further research when developing new PCAs. In addition, a thorough evaluation of all the costs and benefits of a PCA is clearly needed as well, preferably comparing its efficiency and effectiveness to other mitigation policies, such as voluntary carbon offsetting and other carbon pricing policies. These insights are especially crucial for policy makers in countries that lag behind in their ambitions to reduce carbon emissions. Other important aspects that need to be investigated further before implementing a PCA are linked to technological and political hurdles. These need to be overcome as well, including guaranteeing citizens' privacy, correctly linking purchases to their carbon impact, and ensuring climate justice. Important steps have been made to guarantee privacy as different private carbon accounting solutions have recently been provided by banks and other consortia (e.g. Doconomy, Banx, Green-Got, Carbo and Cogo). Nevertheless, investigating social acceptability is a prerequisite before actual implementation, and our study contributes to this first major step.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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