University of Warsaw | Faculty of Economic Sciences

Working Papers
No. 26/2023 (433)

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Warsaw 2023

UNIVERSITY OF WARSAW
FACULTY OF ECONOMIC SCIENCES
WORKING PAPERS

The impact of justice attitudes on air quality valuation: a study combining factorial survey and choice experiment data.

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Abstract: In this paper, we investigate the effect of respondents' attitudes concerning distributive justice in payments on their stated preferences for programmes reducing ambient air pollution in four cities in Poland. By combining two multi-factorial survey experiments, we propose a novel approach of incorporating justice attitudes into non-market valuation. In the first experiment – a factorial survey experiment (FSE) – we record justice attitudes towards payments. In the second experiment – a choice experiment (CE) – we elicit stated preferences for air pollution reduction programmes. As a modelling framework, we employ a hybrid choice model. The same respondents undertook both experiments in separate surveys one to two weeks apart, minimising the likelihood of biased estimates of the effect of justice attitudes on stated preferences. The results indicate a substantial effect of the justice attitude on the stated willingness to pay. The proposed approach could be used for joint modelling of justice attitudes and preferences in a wide range of fields, contributing further insights into their interactions.

Keywords: air pollution, choice experiment, distributive justice attitude, factorial survey experiment, hybrid choice model, willingness to pay

JEL codes: D63, I18, Q51, Q53

1. Introduction

Ambient air pollution is one of the major health threats worldwide (Landrigan et al. 2018; Turner et al. 2020). Every year, exposure to air pollution is estimated to cause millions of deaths and the loss of healthy years of life (WHO 2021). Most clinical studies have shown a greater impact of particulate matter (PM) air pollution than of gaseous components on human health (Hamanaka & Mutlu 2018). Almost the entire population of the world is exposed to air that exceeds the PM limits considered safe (WHO 2022). The seriousness of the problem has been acknowledged by the European Commission (EC) under its Green Deal's Zero Pollution Action Plan, which sets a 2030 goal of a minimum 55% reduction in the number of premature deaths caused by PM compared to the reference year 2005 levels (EC 2021).

Given the scale of the problem, efficiency is one of the crucial conditions for strategically selecting targeted policies to combat ambient air pollution, i.e. checking the extent to which measures improving air quality would pass a cost-benefit test. This assessment is complicated by the fact that, due to their nature as a non-market good, the benefits of air quality improvements are not fully captured by markets. In economics, however, there is a history of capturing the non-market benefits of environmental changes by using a variety of specific valuation methods (OECD 2018). For the evaluation of policy programmes aimed at improving air quality, researchers often employ stated preferences methods such as contingent valuation or choice experiment (CE) (e.g., Jin et al. 2020; Mariel et al. 2022; Tan-Soo et al. 2022; Xia et al. 2022).

The question emerges, however, as to how far corresponding measures and policies aimed at reducing air pollution are efficient while also socially acceptable. In other words: it is often not enough that technological solutions or cost-effective measures exist to tackle environmental changes, unless these measures take societal concerns into account, including aspects of distributive and participatory justice, i.e. how costs and benefits are distributed across socioeconomic groups and the extent to which citizens have a say in decision-making processes (Schlosberg 2007; Caney 2009; Bechtel & Sheve 2013). Factoring in the distributional consequences of policy measures as an aspect of policy design and evaluation, in the context of ambient air quality, has only recently gained more attention (e.g., Andor et al. 2022).

In this study, we investigate the effect of individuals' attitudes towards distributive justice in payments on their preferences for policy programmes aimed at decreasing ambient air pollution in Poland – a country with one of the highest levels of air pollution in Europe. We propose a novel approach to studying justice attitudes and preferences alike by using joint modelling. This approach combines the results of a factorial survey experiment (FSE) with those of a choice experiment. The former measures respondents' distributive justice attitudes and the latter elicits stated preferences for air quality improvements. We concentrate on distributive justice understood as an equity-focused distribution of costs, i.e. the situation when everyone makes an equal utility sacrifice at the margin (see, e.g., Granqvist & Grover 2016).

The FSE is a multifactorial experiment often used in the social sciences when examining, for example, individuals' justice concerns in relation to earnings (see, e.g., Wallander 2009; Auspurg & Hinz 2015; Treischl & Wolbring 2022). In the present study, the FSE was used to investigate respondents' justice attitudes regarding the distribution of costs across households to pay for a furnace replacement programme designed to reduce air pollution in four Polish cities. The FSE included attributes such as the distribution of investment costs across low- and high-income households, and the type of information provided regarding the programme to replace old furnaces, focusing on distributive justice attitudes regarding investment costs. Respondents answered several vignettes (described situations/projects) regarding such furnace replacement programmes, where effects of attribute levels can be singled out based on an experimental design, and they were asked their opinion about the degree of fairness or unfairness in each of these programmes. A key aspect of the vignette survey was whether those who are wealthier (i.e. households with higher incomes) should pay more than those who have fewer financial resources. This is in line with 'ability to pay' as well as equity as a distributive justice principle (see Granqvist & Grover 2016; Schlosberg 2007), implying that wealthier people should cover a greater proportion of the costs involved in preventing air pollution.

The objective of the CE was to elicit individuals' preferences for implementing public policies that can mitigate environmental health risks via air pollution reduction. The design of the CE closely followed the study by Jin et al. (2020), including attributes of premature deaths prevented, non-fatal cases prevented, the number of years needed for the policy to have an effect and annual costs for each household.

To the best of our knowledge, the current study is the first to link justice attitudes and stated preferences, both obtained in multifactorial survey experiments, in a joint model based on a hybrid choice model (HCM) framework. Our approach has two main advantages. Firstly, most research in non-market valuation that includes attitudes has used single survey items or an item battery comprising several items as measures. In contrast, FSEs have the advantage of an underlying experimental design that can separate the effects of distributive justice dimensions: distribution of costs for example. Furthermore, as the situations described (the vignettes) vary in multiple aspects and respondents must make trade-offs in the FSE, socially desirable response behaviour is less likely (Auspurg et al. 2015). Therefore, the FSE approach offers a more robust measurement of (justice) attitudes than the use of standard survey items. Secondly, (justice) attitudes are latent constructs that cannot be directly observed.

To account for the latency of attitudes, the HCM (Ben-Akiva et al. 2002) has been increasingly applied in the literature. HCMs frequently combine data from a CE with attitudinal indicator variables, using a structural equation model integrating latent variables associated with the indicator variables into the choice model (e.g., Hoyos et al. 2015; Zawojska et al. 2019; Strazzera et al. 2022). While we follow this line of research, the present study is the first to combine an FSE recording justice attitudes and a CE recording stated preferences in a HCM framework, thereby providing a more in-depth analysis of the relationship between justice attitudes and stated environmental preferences. This follows recent attempts to combine CEs with other experimental, multi-factorial data, in particular data from best-worst scaling (B-W) experiments (Balbontin et al. 2015; Song et al. 2020).

Another unique feature of our research is that the FSE and the CE were presented to the same individuals but at separate points in time: the two survey waves were conducted one to two weeks apart from each other. Previous research suggests that if attitudes and preferences are measured in the same survey, the question order can affect the results (e.g., Liebe et al. 2016). Our two-wave approach thus avoids this issue and allows for stronger causal inferences (also by excluding the possibility of reverse causality, see Kroesen et al. 2017).

Furthermore, it must be noted that we measure the justice attitude and stated preferences in the same general context, i.e. air pollution reduction, but not in relation to exactly the same environmental programme. This approach increases the explanatory power of attitudes from a theoretical point of view. Measuring attitudes and preferences at the same level of specificity – by referring to exactly the same environmental programme, for example, and/or including it in the same experimental design such as CE – increases the strength of empirical correlations; from a theoretical point of view, however, more robust results are achieved by showing that environmental attitudes in one context explain preferences in another context (see, e.g., Liebe, 2010).

Combining distributive justice attitudes (FSE) and stated preferences (CE) in a joint statistical model, we expect individuals with strong distributive justice attitudes on supporting lower-income households in environmental programmes to be less cost-sensitive than those with weaker attitudes. Research on environmental justice suggests a strong prevalence of an equity-driven and ability-to-pay distributive justice attitude (e.g., Schlosberg 2007; Granqvist & Grover 2016), and those with stronger attitudes are assumed to be willing to bear greater costs for providing environmental goods that also benefit others in society (bearing in mind that some are more affected by the negative outcomes of air pollution than others). If this holds true, then willingness to pay (WTP) for air quality improvement programmes is positively associated with a distributive justice attitude referring to equity and ability to pay.

The remainder of the article is structured as follows. Section 2 explains the empirical modelling approach focusing on the FSE and CE method, along with survey implementation, including FSE and CE design. Section 3 presents the joint modelling approach of combining FSE and CE data. The results are described in section 4, followed by a discussion and conclusions in section 5.

2. Empirical approach

2.1. The FSE and CE methods

The FSE is a multifactorial survey experiment that originated in sociological research in the 1950s (Rossi 1979; Wallander 2009; Auspurg & Hinz 2015). FSEs have frequently been used to study justice/fairness concerns; for example, regarding fair wages, social norms and political action (Jasso & Rossi 1977; Jasso & Opp 1997; Auspurg et al. 2017). In FSEs, respondents are presented with one or more descriptions of a situation (also policy programmes) that differ in a discrete number of attributes or factors, and are asked to evaluate each situation according to criteria such as fairness. Based on the experimental variation in the situational attributes presented, an FSE can uncover causal effects of single situational dimensions on the outcome being investigated. Fractional factorial designs are commonly used in FSE studies; outcomes such as perceived fairness are typically assessed on rating scales, where scales with approximately 11 scale points are recommended (Auspurg & Hinz 2015, 69). It is common to present vignettes as text, whereas FSEs can also be presented in tabular form; studies have suggested that the presentation format does not significantly affect FSEs' results (Sauer et al. 2020).

FSEs have advantages over measuring justice attitudes using standard survey items or item batteries. Due to the systematic variation of the attributes presented in vignettes, the FSE experimental setup compels respondents to make trade-offs, from which it is possible to separate the effects of single situational dimensions. The causal influence of each attribute on perceived fairness can thus be determined, and socially desirable response behaviour is less likely (Auspurg et al. 2015). In comparison to standard surveys, FSEs are also better suited for investigating the context specificity of justice attitudes. FSEs seek to uncover how individual judgement varies when considering a range of situational factors, which is far more difficult to implement when using standard survey items. In environmental research, FSEs have been used to capture fairness concerns and the importance of distributive and participatory justice; for example, related to the expansion of renewable energies (Liebe et al. 2017), the acceptance of airport expansion scenarios (Liebe et al. 2020) and landowners' acceptance of turbines (Parkins et al. 2022).

In a CE, respondents choose, often repeatedly, a preferred option between at least two mutually exclusive alternatives varying in attribute levels (Mariel et al. 2021). Like FSEs, CEs can be used to estimate and separate the effects of multiple attributes on an outcome of concern, as both rely on an experimental design that allocates attribute levels to, in the case of the FSEs, specified circumstances or, in the case of CEs, alternatives. Generally, both FSE and CE present respondents with a series of situations or choice tasks in a survey, generating a type of panel data. One of the main differences in these approaches is the response format. FSEs use a rating scale to record respondents' assessment, and the endpoints of the rating scale are often anchored by words suitable to the measurement context. If justice is the objective, wordings could be 'completely unfair' and 'completely fair'. In contrast, CEs ask respondents to select a preferred alternative from a set of mutually exclusive options, mirroring the concept of preferences, as respondents are asked to choose between options. In this regard, CEs have a clear behavioural foundation in economic theory rooted in random utility theory (McFadden 1974).

2.2. Implementation of the two-wave survey

The two-wave survey with the FSE (first wave) and the CE (second wave) was conducted in December 2021 and January 2022. The sample included residents from four cities in Poland, each with approximately 500,000 inhabitants. The average income level of populations in the chosen cities was similar. This selection process resulted in respondents from Gdańsk, Katowice, Łódź and Wrocław. Two of these cities, Gdańsk and Wrocław, had lower air pollution levels than average pollution levels in Polish cities in recent years, whereas the other two cities, Katowice and Łódź, had above average pollution levels. The sampling procedure was a quota sampling representative, in terms of gender, age and education level, for an urban population in Poland.

The FSE (first wave) and CE (second wave) were conducted by a polling agency inviting members of a web-based panel. Those who had finished the FSE were invited to take part in the CE, which followed on two weeks later. Between 78% and 90%, varying across the four cities, of those who completed the interview in the first wave also finished the second wave. In total, 1,139 completed both surveys. In the final sample, the respondents' median age was 44 (the 2020 median age in urban areas of Poland was 45 for women and 41 for men; GUS 2022). Of the respondents, 52% were women, which is slightly below (approximately 1 percentage point) the overall proportion in the Polish urban population (GUS 2022). Regarding education, people with a higher level of education were overrepresented (51% compared to the 40% national level; GUS 2022). The mean net monthly household income of respondents was 8,200 zł (approximately 1,800 Euro), which is about 30% above the national average (GUS 2021; GUS 2023). The questionnaires were constructed by consulting experts in public health matters and were pre-tested with people from the general public, followed by a pilot survey with 80 respondents. The pilot results were used for the final survey design and questionnaire refinement. Respondents were asked to complete the questionnaire on personal computers or tablets as neither the vignettes nor the choice sets were fully visible on a standard smartphone.

2.3. FSE–distributive justice

The first-wave questionnaire (FSE) included four sections. In the first section, we collected information regarding each respondent's household structure and health status, with a focus on respiratory and heart system diseases. The second section introduced respondents to the air pollution problem in Poland, discussing the main sources of PM pollution (so-called low emission), the process of smog formation and information about diseases caused by air pollution. The third section was the core of the FSE, in which we informed respondents that some measures had already been taken to reduce air pollution in Polish cities, but these actions could be further modified to increase effectiveness. Respondents were then presented with three main potential activities that could be implemented in the city where they live; these schemes included: old coal furnace replacement in private and communal housing,[1] imposing fines for burning inappropriate fuel (low-quality coal, wet wood and other fuels such as municipal waste), and publicising information about smog episodes in the respondents' cities via various media. These activities were described in the vignettes presented, using different levels of attributes. With regard to distributive justice, the share of investment costs for residents and the proposed size of fines varied across income groups. Respondents were asked to assess the acceptance, perceived fairness and support of the proposed programme in each vignette, using 11-point Likert scales. Respondents' socioeconomic data were collected in the fourth and final section of the FSE. Table 1 presents detailed information about the attributes used in the FSE and their levels.

Table 1. Attributes and attribute levels used in the FSE.

Attribute		***Attribute levels***
Contribution to investment cost: private houses	average- and high-income group (HI); low-income group (LI)	{100%; 100%}, {100%; 50%}, {100%; 0%}, {50%; 50%}, {50%; 0%}, {0%; 0%}
Contribution to investment cost: communal houses		100%, 50%, 0%
Period		1 year, 3 years, 5 years
Fines	average- and high-income group (HI); low-income group (LI)	{1000 zł; 1000 zł}, {1000 zł; 500 zł}, {1000 zł; 0 zł}, {500 zł; 500 zł}, {500 zł; 0 zł}, {0 zł; 0 zł}
Information		no additional information, mobile phones, all TV information programmes

Note: 1 Euro = 4.6 zł.

As underlying experimental design, we employed an orthogonal design with two-way interactions (fold-over design) for the vignettes. This design has the advantage of attributes

[1] In Poland, in communal housing, flats are owned by the local authority (Polish: gmina), which sets criteria for applicants (usually income-related) and allocates homes accordingly, as a particular form of social assistance.

varying independently from one another within and across vignettes, resulting in 72 vignettes (with perfect orthogonality and level balance). Each respondent was presented with six vignettes, which were randomly drawn from this set without replacement. Figure 1 presents a vignette example.

PRIVATE HOUSES

- *The cost of replacing furnaces will be **50%** financed by **the MUNICIPALITY from local taxes** and **50%** by **the HOUSEOWNERS** if their household income is on or **ABOVE the AVERAGE** level in Poland.*
- *The cost of replacing furnaces will be **100%** financed by **the MUNICIPALITY from local taxes** if houseowners' household income is **BELOW** the average level in Poland.*

COMMUNAL HOUSING

- *The cost of replacing furnaces will be **50%** financed by **the MUNICIPALITY from local taxes** and **50%** by **the HOUSE RESIDENTS**.*

PERIOD

- *The furnaces will be replaced **within 5 years**.*

FINES

- *If household income is on or **ABOVE** the **AVERAGE LEVEL** in Poland, those who use inappropriate fuel until the furnace replacement **will be fined 1000 zł** for each occurrence*
- *People with a **LOWER** household income than the average in Poland **will be fined 500 zł**.*

INFORMATION

- *Information about **smog** episodes in Poland will be **sent on MOBILE PHONES**.*

How FAIR or UNFAIR do you think this project would be in its current form?

Please tick on the following scale.

Very unfair	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	***Very fair***
	0	1	2	3	4	5	6	7	8	9	10	

Fig. 1. Example of a vignette used in the FSE.[2]

[2] Apart from the fairness assessment after each vignette, we asked the following additional questions (with responses indicated on an 11-point Likert scale): *How ACCEPTABLE is such a programme for you? How likely*

2.4. *Choice experiment – preferences*

The design of the CE, implemented in the survey's second-wave, was based on the study by Jin et al. (2020), which aimed to elicit a willingness to pay (WTP) for the public provision of health risk reduction measures via air quality improvements. The CE questionnaire was divided into three sections. In the first section, respondents were reminded of the information about PM air pollution they had received in the FSE part. Additionally, information on the number of annual premature deaths in Poland caused by these pollutants in comparison to the numbers of premature deaths due to other causes, including road accidents, was provided. The second section contained the choice tasks. Each choice set presented two air pollution reduction programmes and the status quo (SQ) option. The programmes presented in choice sets differed on the extent of mortality risk reduction in the respondent's city, morbidity risk reduction, the number of years before the proposed policy would have an effect and cost of the programme per household (in the form of an increase in local taxes). The programmes were to last for 5 years. The final section collected information about the respondent's lifestyle, including recreational activities, quality of life and perceived health status. Table 2 presents information on the description of attributes used in the CE.

Table 2. Attributes and attribute levels used in the CE.

Attribute	Description	Attribute levels
Mortality	Premature deaths prevented per year per 100,000 people	0 (SQ), 10, 20, 30, 40, 50
Morbidity	Non-fatal cases prevented per year per 100,000 people	0 (SQ), 100, 200, 300, 400, 500
Period	Number of years before policy will have an effect	0 (SQ), 1, 3, 5
Cost	Annual cost of programme per household in zł (local tax increase)	25, 50, 100, 300, 500, 800

Note: 1 Euro = 4.6 zł. SQ stands for status quo.

For the CE, we used a Bayesian D-efficient design as the underlying experimental design (Rose & Bliemer 2009; Mariel et al. 2021), taking priors from the pilot study. The D-efficiency

would you be to sign a petition IN FAVOUR of this project in its current form? How likely would you be to sign a petition AGAINST this project in its current form?

criterion for the multinomial logit model was selected for optimisation. To allow for uncertainty regarding the prior values, 1,000 Sobol draws were taken from uniform distributions for each parameter prior (ChoiceMetrics 2021). The final design included 36 choice sets. In the survey, each respondent was presented with eight randomly drawn choice sets from the 36 sets, and drawn sets were not replaced. Figure 2 presents an example of a choice set.

	Option A	**Option B**	**No programme (status quo)**
Prevented **PREMATURE DEATHS** per year in your city per 100,000 people	**10 fewer deaths** per 100,000 people	**40 fewer deaths** per 100,000 people	Same number of **deaths** as today
Prevented **NON-FATAL CASES** per year in your city per 100,000 people	**200 fewer cases** per 100,000 people	**100 fewer cases** per 100,000 people	Same number of **cases** as today
NUMBER OF YEARS before policy has an effect	**5** years	**3** years	-
ANNUAL COST per **household**	**50** zł	**300** zł	**0** zł
MY CHOICE	☐	☐	☐

Fig. 2. The choice set example.

3. Hybrid choice modelling approach

In the HCM, we used answers from the FSE as measurement equations to identify a latent variable, which is linked with individuals' utility function in the CE model. Our specification was tailored to our specific case study, as the vignettes in the FSE were also described by the attributes of a policy scenario (consider Table 1), which needed to be accounted for in the model. In contrast, the usual HCM specification employs an item battery for the measurement equations. An overview of the model structure is presented in Figure 3. The FSE and CE parts of the model are linked by the common latent factor denoted as *Distributive Justice* attitude. In the CE model it enters through the marginal utilities for each attribute, whereas in the FSE model it enters as an interaction with the *Equity* variable (see Figure 3).

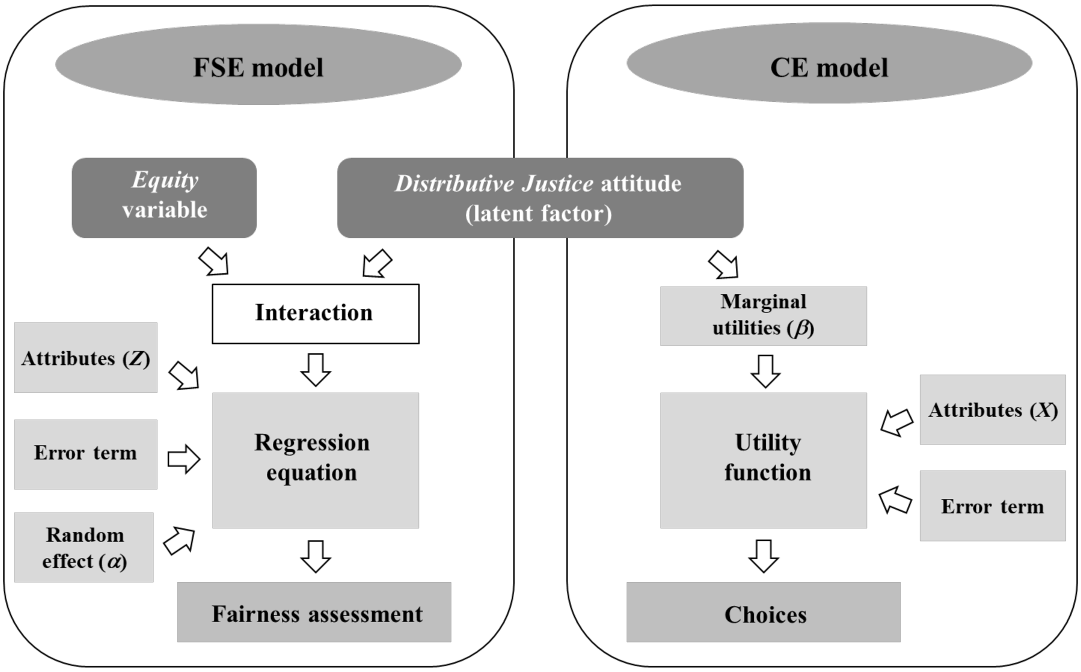

Fig. 3. Visual representation of the hybrid choice model structure.

The *Equity* variable in the FSE model indicates the egalitarian justice approach (more equity-focused) in which the wealthier individuals should pay more than the less wealthy ones. The *Equity* variable is constructed as a difference in the proposed contribution levels for investments to reduce air pollution between low-income, average and high-income households (the rest of the costs are covered via subsidy from municipalities – see Figure 1). The *Equity* variable always took nonnegative values because the low-income group of households was always offered the same or higher subsidy for furnace replacement compared with the average and high-income group in our FSE design (Table 3).

Table 3. Construction of the *Equity* variable.

Variable: *Equity* (difference in contribution between LI and HI)	Contribution level for investments in private housing dependent on household income
0	100% (LI) – 100% (HI); 50% (LI) – 50% (HI); 0% (LI) – 0% (HI)
0.5	50% (HI) – 50% (LI); 100% (HI) – 50% (LI)
1	100% (HI) – 0% (LI)

Note: HI and LI stand for the average and high-income group and the low-income group, respectively.

We start the formal description of the model with the CE component. Specifically, we assume that the utility that individual *i* derives from choosing alternative *j* in choice task *t* is as follows:

$$U_{ijt} = \beta_i X_{ijt} + \varepsilon_{ijt}. \tag{1}$$

where $\mathbf{X}_{ijt}$ is a vector of the attributes in the CE (see Table 2), as well as the alternative specific constant for the status quo alternative (*ASC_SQ*). β_i is a vector of random parameters, which we can interpret as marginal utilities. Finally, ε_{ijt} is a stochastic component, assumed to follow an i.i.d. type I extreme value distribution with constant variance.

We allow for preference heterogeneity in equation (1) by using a mixed logit (MXL) specification, in which we assume that $\beta_i = [\beta_i^N, \beta_i^{LN}]$ consists of random parameters that are normally distributed (β_i^N) and random parameters that follow log-normal distribution (β_i^{LN}). The choice of a specific distribution for a given attribute was based on model fit to data. Furthermore, we assume that these coefficients are affected by the latent variable, denoted as LV_i. More precisely, the functional form is assumed to be as follows:

$$\begin{cases} \beta_i^N = \mu_N + \alpha_N LV_\mathrm{i} + \sigma_N \xi_i^N \\ \beta_i^{LN} = exp(\mu_{LN} + \alpha_{LN} LV_\mathrm{i} + \sigma_{LN} \xi_i^{LN}) \end{cases} \tag{2}$$

where □, α and σ are coefficients to be estimated and ξ represents unobserved stochastic terms following a standard normal distribution, which allow for modelling of unobserved heterogeneity. Note that for random parameters that have log-normal distribution, μ_{LN} does not have an absolute interpretation; for example, the negative sign (or lack of significance) does not mean that the average marginal utility is negative (not significant).

Given that the choice component of the hybrid model follows a MXL specification, we refer to our model as a hybrid mixed logit (HMXL). The (conditional) probability of choosing alternative *j* is then obtained using a standard multinomial logit formula (where y_{it} denotes an alternative that individual *i* has selected in the choice situation *t*) as follows:

$$P(y_{it} | \xi_i, LV_i) = \frac{exp\left(\beta_i X_{i y_{it} t}\right)}{\sum_l exp\left(\beta_i X_{ilt}\right)}. \tag{3}$$

The second part of our hybrid model is the FSE component, in which the dependent variable is a fairness assessment of a given policy scenario (vignette) using an 11-point rating scale. We follow the usual approach in the FSE literature, wherein the dependent variable is treated as continuous and modelled with the linear specification. Specifically, we assume that answers for the *k*th vignette presented to the respondent are a linear function of the vignette's attributes and the error term η_{ik}:

$$F_{ik} = \alpha_i + LV_i Equity_{ik} + \boldsymbol{\theta}\boldsymbol{Z}_{ik} + \delta\eta_{ik}. \tag{4}$$

The FSE component in (4) is linked with the CE component in (1) by the latent factor LV_i, which we interpret as an attitude toward *Distributive Justice*. The latent factor in (4) is interacted with the $Equity_{ik}$ attribute and can be interpreted as individual-specific marginal effect for it. Intuitively, if the level of LV_i is high for the given individual, then the $Equity_{ik}$ of a given policy option strongly affects their fairness assessment. For example, policies in which affluent and less wealthy people have to bear identical costs for that policy will be deemed as less fair than policies in which people with fewer funds available pay less than wealthy people. On the other hand, if the LV_i (*Distributive Justice* attitude) has a low level for a given individual, then the $Equity_{ik}$ will not have much of an effect on the fairness assessment. We assume that the latent variable follows a normal distribution in the population, $LV_i \sim N\,(\mu_{LV}, \sigma_{LV})$, with parameters μ_{LV} and σ_{LV} to be estimated.

Additionally, α_i in (4) is an individual-specific random effect (following normal distribution), accounting for the panel nature of the FSE data. $\mathbf{Z}_{ik}$ is a vector of attributes other than $Equity_{ik}$ with fixed coefficients $\boldsymbol{\theta}$, measuring their impact on the dependent variable. Finally, η_{ik} is an error term following standard normal distribution, with parameter δ modelling its standard deviation. Given the normal distribution of the error term, the probability of choosing F_{ik} on the Likert scale is obtained by the probability distribution function of normal distribution

$$P(F_{ik}|LV_i, \alpha_i) = \varphi\left(\frac{F_{ik}-\alpha_i-LV_i Equity_{ik}-\boldsymbol{\theta}\boldsymbol{Z}_{ik}}{\delta}\right). \tag{5}$$

Combining equations (3) and (5), the overall formula for the likelihood function is given by

$$L_i = \int \prod_t P(y_{it}|\boldsymbol{\xi}_i, LV_i) \prod_k P(F_{ik}|LV_i, \alpha_i)\, f(LV_i, \alpha_i)\, g(\boldsymbol{\xi}_i) dLV_i d\alpha_i d\boldsymbol{\xi}_i. \tag{6}$$

Because random parameters, random effect, and latent factor are unobserved, they must be integrated out to obtain unconditional probability. In equation (6), $f(LV_i, \alpha_i)$ denotes the probability distribution function of the latent factor and the random effect in the FSE part of the model, whereas $g(\xi_i)$ denotes the probability distribution function of random parameters in the CE part of the model. As the multi-dimensional integral in equation (6) cannot be expressed with an analytical formula, we employ maximum simulated likelihood techniques, using 1,000 scrambled Sobol draws (Czajkowski & Budziński 2019).

4. Results

4.1. FSE model

The FSE was modelled using a random effects regression, in which the dependent variable was the level of perceived fairness of the situations presented in the vignettes (indicated on the 11-point Likert scale where higher values indicated higher levels of perceived fairness). Note that we solely used responses to the fairness assessment in this study.[3] The results of the FSE model are presented in Table 4.

Table 4. Results of the HMXL – the FSE model.

Dependent variable: *Fairness assessment*	**Means**			**Standard deviations**		
var.	coef.		st.err.	coef.		st.err.
Constant (random effect)	4.505	***	0.145	1.733	***	0.046
Period	0.001		0.020	-		-
Contribution: Private housing_HI (50%)	0.289	***	0.089	-		-
Contribution: Private housing_HI (100%)	-0.655	***	0.082	-		-
Contribution: Communal housing	-0.905	***	0.077	-		-
Fines (HI = 500zł, LI = 0zł)	0.216	*	0.118	-		-
Fines (HI = 500zł, LI = 500zł)	0.806	***	0.105	-		-
Fines (HI = 1000zł, LI = 0zł)	0.103		0.107	-		-
Fines (HI = 1000zł, LI = 500zł)	0.674	***	0.102	-		-
Fines (HI = 1000zł, LI = 1000zł)	0.962	***	0.101	-		-
Smog information (TV)	0.358	***	0.076	-		-
Smog information (mobile phone)	0.321	***	0.074	-		-
	Distributive justice attitude					
Equity	0.468	***	0.100	0.946	***	0.145

Note: ***, ** and * indicate 1%, 5% and 10% significance levels, respectively. Private housing HI and Private housing_LI stand for the average- and high-income group and the low-income group of private homeowners, respectively. In the case of communal housing, we assumed that residents belong to the LI group.

[3] We found that assessments regarding fairness and programme's acceptance are strongly correlated.

With regard to the main objectives of our study, the measurement equations show that the latent variable captures intrinsic attitudes regarding distributive justice in payments. The *Distributive Justice* attitude is on average positive and significant, indicating that individuals assessed vignettes on average as fairer when the contribution of higher-income households to furnace replacement was higher than the contribution of less wealthy households. In other words, we find that on average there is a positive link between *Equity* and individuals' assessment of the policy fairness. Nonetheless, *Distributive Justice* attitude also has a significant and relatively large standard deviation, indicating some heterogeneity – the weight attached to *Equity* variable varies between individuals. This variation allows us to link two parts of the HCM model (FSE and CE) for later assessment of how *Distributive Justice* attitude affects individuals' preferences (consider Table 5 below).

Additionally, the findings in Table 4 suggest that the fairness assessment of situations presented in vignettes is positively associated with a contribution of 50% by higher-income households, compared with 0% (i.e. full amount paid by the government), and negatively associated with contributions of 100%. Thus, the more affluent residents are expected to contribute a substantial share, a higher percentage of the costs than the less well-off, yet they are not expected to carry the full burden. Furthermore, fairness assessments are negatively associated with higher contributions by residents of communal housing, who typically belong to lower-income groups.

Apart from the distributive justice in payments, which is the focus of our analysis, the FSE component also refers to several other aspects of justice. Table 4 indicates that for higher- and lower-income households alike, fairness assessments are positively and significantly associated with implementing fines for using inappropriate fuel. Furthermore, the effect sizes suggest that respondents perceived the imposition of equal fines as most fair, regardless of income group/level; therefore, fairness assessments are positively linked to redistribution across socioeconomic groups in relation to subsidies, but not (or less so) in relation to fines. Information provision is an important aspect of participatory justice, and results in the FSE suggest that fairness assessments are positively affected by information provision via TV and mobile phones, with similar effect sizes.

4.2. CE model

In our HMXL, the CE and FSE models were linked through a single latent variable, which we interpreted as a *Distributive Justice* attitude. This latent variable was identified through an interaction with *Equity* in the FSE and entered the CE model as an explanatory variable for the marginal utility of each attribute (see equation (2) and Table 5). The attributes entered the model linearly, with all marginal utilities modelled as fully correlated random parameters. In this model, we assumed a normal distribution of coefficients for the *SQ_ASC* and the *Period* attribute. For the remaining attributes (i.e. *Mortality*, *Morbidity* and *Cost*), after investigating a few specifications of the model and based on the model diagnostics, we chose log-normal distributions, imposing a positive utility on the decrease in the number of premature deaths, non-fatal cases linked with the air pollution level and a positive utility of money (income). The results of the CE component, including the effect of the *Distributive Justice* attitude, are presented in Table 5.

Table 5. Results of the HMXL – the CE model.

		μ			***σ***		
var.	dist.	coef.		st. err.	coef.		st. err.
SQ_ASC	n	-7.422	***	0.419	4.715	***	0.326
Mortality/10	ln	-1.433	***	0.137	1.282	***	0.118
Morbidity/100	ln	-1.695	***	0.171	1.028	***	0.104
Period	n	-0.137	***	0.028	0.233	***	0.023
-Cost/100	ln	-0.138		0.102	2.161	***	0.066

***α* - effect of *Distributive Justice* attitude (LV)**			
var.	coef.		st. err.
SQ_ASC	-0.071		0.349
Mortality/10	-0.113		0.162
Morbidity/100	0.343	**	0.140
Period	-0.026		0.037
-Cost/100	-0.342	***	0.106

Note: ***, ** and * indicate 1%, 5% and 10% significance levels, respectively. *n* and *ln* indicate a random parameter distribution (either normal or log-normal).

The results indicate that respondents wanted air reduction programmes to be implemented. The probability of choosing a given alternative was significantly and positively influenced by the *Mortality* (i.e. the reduction, resulting from the implementation of programmes to combat air pollution, in the number of premature deaths caused by air pollution) and *Morbidity* (i.e. the reduction of non-fatal cases caused by air pollution) attributes.[4] Additionally, the coefficient for the *Period* attribute appeared to be negative and significant, indicating that respondents preferred to have a programme implemented earlier rather than later. The *Cost* attribute had a negative effect on the utility level of the given alternative, as this attribute entered the model as a negative value and the assumed distribution of a random parameter is log-normal. Relatively large and significant standard deviations indicate the presence of substantial unobserved preference heterogeneity in the model, validating the use of the random parameter specification.

The median results of respondents' WTP for mortality and morbidity reduction are presented in Table 6. The results indicate that respondents were willing to pay 3 zł to avoid one premature death per year per 100,000 people and 0.3 zł to avoid one non-fatal case per year per 100,000 people. We present median WTP in this study rather than mean WTP, as mean WTP very often becomes unrealistically high when cost coefficients are log-normally distributed. Furthermore, median WTP is generally found to be more stable than mean WTP (Bateman & Brouwer 2006). These results are consistent with the findings obtained by, among others, Yoo et al. (2008) and Jin et al. (2020), which indicate that, in air pollution valuation studies using mortality and morbidity levels, mortality per person is valued approximately 10 times higher than morbidity.

Table 6. Median WTP in zł.

	Median WTP	**Conf. Interval**	
Mortality (1 person per 100,000)	3.1	2.5	3.7
Morbidity (1 person per 100,000)	0.3	0.2	0.4
Period	7.7	5.1	10.7

Note: 1 Euro = 4.6 zł.

4.4 Linking the FSE and CE components

The impact of justice-related attitudes concerning the distribution of the costs of management actions on the stated preferences in the CE component was tested by making the marginal utilities of the CE attributes functions of the *Distributive Justice* attitude (see equation (4) and

[4] The reported coefficients relate to the underlying normal distribution. Thus, for example, the coefficient −1.4326 for *Mortality* does not mean that the effect of this attribute is negative. We could say that for $LV = 0$, the median effect is exp(−1.4326), which is positive.

Table 5). The significant and positive effect of the latent variable on the marginal utility of *Morbidity* suggests that individuals with a stronger sense of distributive justice care more about the *Morbidity* reduction. Moreover, the negative effect of distributive justice on the marginal utility of (-)*Cost* attribute indicates a lower marginal utility of income for individuals with stronger distributive justice attitudes. This translates to higher WTP for proposed changes, on average.

To facilitate the interpretation of the effect of the *Distributive Justice* attitude on respondents' valuation of air pollution reduction programmes and attributes that describe outcomes, we simulated the WTP for mortality and morbidity reductions for respondents with varying distributive justice attitudes (Fig. 4). In both cases, the WTP increases with the strength of distributive justice attitudes; however, this impact appears to be greater for *Mortality* than for *Morbidity*.

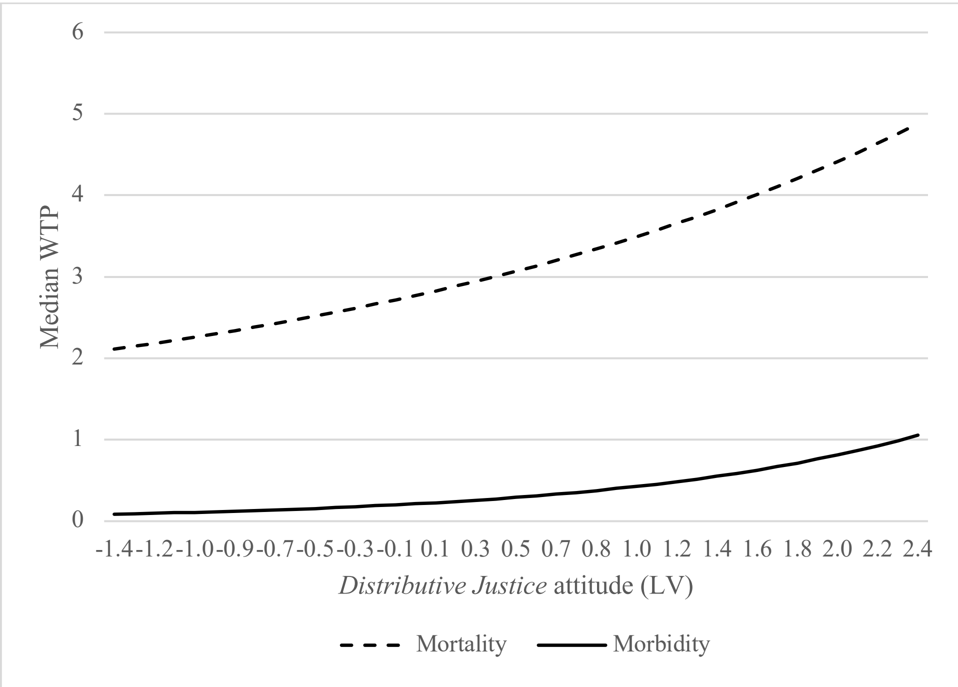

Fig. 4. Median WTP of respondents with varying intensities of *Distributive Justice* attitude (LV).

5. Conclusions and discussion

It is well documented that air pollution can severely and negatively affect individuals' health and well-being, broadly defined (Landrigan et al. 2018; Turner et al. 2020; WHO 2022). While air pollution is a problem in most countries, some are more affected than others. Poland has one of the highest pollution levels in Europe, and urgently needs policy measures to mitigate air pollution, especially in urban areas. Against this background, the present study investigates the impact of attitudes towards distributive justice in payments on preferences for programmes to reduce air pollution in four cities in Poland. For policymakers, understanding justice attitudes alongside preferences towards air quality improvements, and how the two are associated, can be crucial when proposing policy measures such as the introduction of new technologies or alternative management methods (Sovacool 2014). That accounting for the distributional aspects is essential for policy support was recently demonstrated *inter alia* by Andor et al. (2022). They investigated how exemptions for low-income households and energy-intensive companies in Germany influenced political support for charging additional costs to promote renewable energies.

As a methodological novelty, we linked the stated preferences for air pollution reduction programmes, recorded via a CE, with justice attitudes measured via an FSE. Subsequently, we constructed a hybrid choice model that modelled attitudes and preferences alike. This approach benefits from the advantages of using FSE to measure latent concepts such as distributive justice attitudes in contrast to single survey items or item batteries, and has two main benefits. Firstly, due to the systematic variation of the attributes presented in vignettes, the experimental setup of FSE compels respondents to make a trade-off, which separates effects of single situational dimensions; the causal influence of each attribute on perceived justice can thus be determined. Secondly, due to its experimental design, FSE is less prone to socially desirable response behaviour. Moreover, the same respondents faced the FSE and then the CE, with a time gap of one to two weeks between the different experiments. This design allowed us to estimate stronger causal effects of FSE-based attitudes on CE-based stated preferences.

The results reveal a substantial effect of the justice attitudes related to the distribution of the costs arising from programmes to reduce air pollution and the stated willingness to pay for those programmes. Moreover, our results suggest that individuals who prefer cost distribution to be more equity-focused derived higher utility from the morbidity reduction that results from air quality improvement, and were also less cost-sensitive compared to individuals who are less concerned about distributive justice. These findings are in line with the results presented by Andor et al. (2022), showing that policy support is substantially higher when low-income households are exempt.

Further research is needed to establish the rationale for the different effects exercised by justice attitudes on the attributes of mortality and morbidity used to describe the programmes to reduce air pollution. In the present study, we do not observe a significant effect on the former. This may be because some trade-offs are perceived by individuals as more problematic or taboo

(Chorus et al. 2018) than others. For example, in the CE, individuals had to make trade-offs between mortality and morbidity, which some respondents may have perceived as immoral. If distributive justice attitudes are associated with individuals' moral values, this could affect our results. Of course, the importance of taboo trade-offs depends on the context in which a study is conducted.

We would like to stress that the actual functional form of the HCM applied to link FSE and CE data varies depending on the specific application. The one used in the current study stems from the need to identify distributive justice attitudes. We achieve this by treating the weight that individuals assign to the equity of the policy programme in the FSE as a measure of distributive justice. This study is meant to serve as a starting point for developing comprehensive approaches for simultaneously investigating justice attitudes and stated preferences.

A next step could be to extend the model to include different types of justice concerns via additional latent variables. In this study, we assumed that eliciting justice attitudes indirectly though FSE was superior because of decreased social desirability bias and stronger causal effects. Nonetheless, in the future, a rigorous comparison could be conducted in order to evaluate the advantages of the proposed approach compared with incorporating standard item batteries concerning justice principles into a CE. Our findings also suggest heterogeneity in justice attitudes and environmental preferences, both of which might vary with individuals' socioeconomic background. In addition, it will be crucial to test the robustness of relationships between justice attitudes and environmental preferences when different environmental goods and problems are introduced. In other words, how context-specific are the effects of justice attitudes on environmental preferences in terms of the relevance of justice dimensions such as distributive and participatory justice? As our approach refers to hypothetical behaviour, future research should consider the nexus between justice attitudes and non-hypothetical behaviour; for example, by employing incentivised, real CEs.

The current study has demonstrated that it is fruitful to combine more complex sociological approaches for attitude measurement with economic approaches of stated preference analysis in order to facilitate a comprehensive examination of the bearing that social justice considerations have on environmental policy acceptance. The presented approach, combining FSE and CE, can also be employed to examine the effects of FSE-based beliefs and normative judgements on environmental preferences. We hope this study paves the way to further applications.

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