The equity-efficiency trade-off in environmental policy: evidence from stated preferences[i]

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ABSTRACT

The design of environmental policy raises several equity issues, in particular the distribution of benefits and costs. At the same time, it has often been argued that there is a trade-off in environmental policy between equity and efficiency, which brings these issues firmly to the attention of environmental economics. In this paper we use a simple choice experiment to elicit individual preferences over equity-efficiency trade-offs in the context of two environmental problems, local air pollution and global climate change. We find that equity matters to people as much as efficiency does in the design and delivery of environmental policy.

KEYWORDS

Air pollution; allocative efficiency; climate change; choice experiment; environmental equity; polluter-pays principle

JEL CODES

A13; D61; D63; Q51; Q52; Q53; Q54

I. INTRODUCTION

The design of environmental policy raises several equity issues, in particular the distribution of the benefits and costs of policy (OECD 2004; Serret and Johnstone 2006). At the same time, the pursuit of equity objectives may be in conflict with the pursuit of altogether separate policy objectives. In particular, it has often been argued that there is a trade-off in environmental policy – as there appears to be in many other areas of public policy[ii] – between equity and economic (i.e. allocative) efficiency, which brings these equity issues firmly to the attention of environmental economics.

Where such a trade-off exists, the question arises how best to address it, but there does not seem to be a straightforward answer. One apparent solution, often relied upon in economics more generally, is to abstract from equity issues to focus on attaining allocative efficiency. But this argument rests on a number of restrictive and ultimately unrealistic assumptions about redistribution (Dréze and Stern 1987). Thus there may in general terms be a trade-off between equity and efficiency. More fundamentally, it is impossible to perfectly separate equity and efficiency considerations in welfare economics (e.g. Broome 1999; Little 1950).

Just as equity cannot be ignored, notions of what is equitable, 'fair' or 'just' appear to be intrinsically subjective (Mackie 1977). Even if they are in some way objective, it is certainly true that context matters (Wiggins 2006). Across different areas of public policy, a wide variety of distributive principles are applied (Elster 1992; Young 1994), so that it is often difficult to identify the commonalities and put them to much practical use. This suggests it is then important to know something about public preferences over the equity-efficiency trade-off. Such an approach can be supported by a number of theories in moral and political philosophy (an incomplete but nevertheless significant list includes: Habermas 1990; Hare 1971; Miller 1999; and Rawls 1971).

Thus in this paper we use a simple choice experiment to elicit individual preferences over equity-efficiency trade-offs in the context of two environmental problems of different scales: (i) the mitigation of local air pollution from traffic emissions and (ii) the mitigation of global climate change by reducing greenhouse gas emissions. We gain insights into public preferences over the key policy design issues – notably the equity-efficiency trade-off – and what factors determine the differences in these from one person to the next.

Our central conclusion is that equity matters to people as much as efficiency does in the design and delivery of environmental policy. As much as there exist popular preferences for cost-effective policies, preferences over the distribution of costs carry similar weight. In terms of the nature and direction of these distributive preferences, two key themes emerge. The first is that the polluter ought to pay for the delivery of an environmental improvement. With respect to how property rights are allocated between the polluter and the pollutee, the balance is clearly tipped towards the pollutee, such that the polluter pays. The second is that income – ability to pay – should also be considered in distributing the compliance costs of pollution-control policy.

Section two discusses examples of the equity-efficiency trade-off in environmental policy and elaborates an argument for investigating the nature of public preferences over such trade-offs using a choice experiment. Section three presents the research methodology and section four outlines our results. Section five provides a discussion.

II. EQUITY AND EFFICIENCY IN ENVIRONMENTAL POLICY

It is almost inevitable that policies and projects with environmental impacts will have distributional consequences, which we could very generally define as any relative change in a broad notion of income or wealth (i.e. including the value of environmental goods and services) between two or more individuals. There are many dimensions to these distributive effects, including income, location in space and time, and ethnicity (Serret and Johnstone 2006). In this paper, we are interested in the allocation of the opportunity cost of environmental protection. In particular, we focus on the interplay between principles guiding the allocation of cost between producers of pollution and victims of pollution, and the principle of payment in proportion to ability to pay. Moreover, we are interested in the trade-off that may well exist between these distributive principles as a whole and the overall efficiency of environmental policy.

The allocation of cost between producers of pollution and victims of pollution was classically constructed as a problem of liability and the initial allocation of property rights by Coase (1960). The polluter-pays principle (PPP) assigns property rights to the victims of pollution. It has proven to be highly influential in the drafting of environmental legislation at the national and international levels (back at least to OECD 1975). The diametric opposite of the PPP is the beneficiary-pays principle (BPP). Under this principle, the beneficiaries of an environmental improvement should pay for it. Examples of the BPP can be found in international environmental agreements, although few examples can be found in national environmental policy (Atkinson *et al*. 2000). Nevertheless, the principle that people should pay in proportion to the benefits they obtain from public-service provision is accepted and established in other areas (e.g. Young 1994). Aside from the allocation of property rights between producers and victims of pollution, one of the foremost distributive concerns in environmental policy has been that policies could be regressive, such that low-income groups pay a disproportionate share of the opportunity cost. This may in particular be true of policies that increase the cost of household energy (Johnstone and Alavalapati 1998) and in such cases burdens might also be allocated according to ability to pay. We will generally refer to this as the ability-to-pay principle.

In practice, there is much evidence to suggest that a balance is sought – that a trade-off is made – in the implementation of these principles (e.g. Bromley 1997). For example, Tobey and Smets (1996) argue that a barrier to implementation of the PPP in agricultural policy has been a desire to protect the incomes of family farms, who are the polluters in this case. Moreover, there is also much evidence to suggest that a trade-off is made between the overall efficiency of environmental policies (understood at least as cost-effectiveness) and the distribution of their benefits and costs (Goulder and Parry 2008). For example, while it is widely understood that the opportunity cost of reducing greenhouse gas emissions can be minimised by choosing a policy instrument that raises revenue to offset other taxes (i.e. a 'carbon tax' or a cap-and-trade scheme with auctioned allowances), in practice the instrument that is chosen does not tend to raise much revenue if any. Rather, polluters are excused from paying a unit charge on all their emissions, as pollution allowances are mostly allocated for free (see Ellerman and Buchner 2007, on the European Union Emissions Trading Scheme).

Yet economists have tended not to concern themselves with distributive effects. A familiar argument is that distributive effects can be ignored, because redistribution is already achieved by a complete, non-distortionary system of lump-sum taxes and transfers. But this argument rests on a number of restrictive and ultimately unrealistic assumptions about redistribution (Dréze and Stern 1987). More fundamentally, it is not possible to perfectly separate equity and efficiency considerations in welfare economics (Broome 1999; Little 1950). It is a basic result of the theory that an efficient allocation of resources is not unique. In order to make choices between competing allocations where it is impossible to make some individuals better off without making others worse off (i.e. in almost all practical instances), it is necessary to apply potential compensation tests of the Kaldor-Hicks-Scitovszky type. Not only do the results of such tests typically depend on the initial allocation of property rights[iii], they can readily be shown to exemplify an implicit social welfare function and an implicit utility function, together determining the marginal social welfare of a unit of consumption to different individuals. Put another way, one interpretation of the standard practice in separating efficiency and equity is that it merely imposes one possible implicit weighting of the costs and benefits accruing to the individuals affected by the policy. One could be forgiven for being left uneasy by the current state of practice. Even if not, pragmatism might suggest that, since distributive effects often have the capacity to command significant political attention, economics deserves to play a more constructive and active role in arbitrating the discussion (Kriström 2005).

It remains for us, however, to make a case for using evidence of public preferences to inform decisions over the equity-efficiency trade-off, and for using stated-preference methods – specifically a choice experiment – to that end. Taking the more general problem first, the case for using evidence of public preferences can be made either on a positive or normative basis. The positive approach abstracts from underlying philosophical debates to simply ask how distributive problems have been resolved in reality. At the root of this approach could be the argument that notions of what is equitable, 'fair' or 'just' are fundamentally subjective in nature (Mackie 1977). This is disputed by many philosophers who believe that ethical judgements have an objective character, but even those who make this claim tend to do so with the proviso that in practice each and every distributive problem has its own context, and that any underlying objective principles of allocation can only be discovered after these numerous contextual factors are stripped away (Wiggins 2006). This, at the very least, is why empirical studies of principles of justice actually applied in different policy contexts (e.g. from allocating kidneys for transplantation to allocating college places) have uncovered substantial variation (Elster 1992; Young 1994).

The normative case does not necessarily follow from the positive one. As Hume (1739-40) famously cautioned, prescriptive statements about what *ought* to be do not necessarily follow from descriptive statements about what *is*. Nevertheless, a number of philosophical theories maintain that popularly held beliefs must be taken seriously, if the principles of justice that such theories develop are to be at once plausible and useful. "The people who are going to use them must be able to justify them to one another using only commonly accepted modes of reasoning" (Miller, 1999 p53). Thus some sort of reflective process is required, which exposes popularly held notions of what is just in any given context to general principles of justice, and this process should ultimately seek to reconcile them. Varieties of this basic idea have been put forward by, for example, Habermas (1990), Hare (1971), Miller (1999), and Rawls (1971).

We see ourselves as contributing to a wider reflective process like this, where the academic contribution includes, but is certainly not restricted to, a range of methodologies to elicit public preferences. One methodology would be to look at precedent, in the form of existing policies and social arrangements, as for instance Elster (1992) does. Economists would understand this to be a revealed-preference approach. Another is to survey in some way public opinion, which should also be familiar ground for many environmental economists, given their ever more routine use of stated-preference techniques (see, for example, Adamowicz *et al*. 1998; Alberini and Kahn 2006; Bateman *et al*. 2002; Champ *et al*. 2003). There are advantages and disadvantages to both in tackling distributive issues, which are discussed at greater length in Dietz *et al*. (2008).

In this paper, we opt for a stated-preference approach. While stated-preference methods are generally used to elicit overall willingness to pay, or to accept compensation, for a change in the provision of some environmental good, we propose a different purpose. We propose to use them to learn about preferences over competing principles of equity, and over the trade-off between equity and efficiency. The choice experiment is particularly useful in this context, because of its natural ability to model trade-offs between attributes, based on Lancaster's (1966) characteristics theory of value.

Legitimate questions can be raised of whether choice experiments are suited to the task of eliciting ethical preferences over social decisions, since they are commonly used to measure the preferences of individuals (as indeed they are in this paper), to a greater or lesser extent in a setting intended to replicate consumer choice. Sen (1970, 1992) highlighted the dichotomy between ethical preferences over social decisions on the one hand and ethical preferences over personal behaviour on the other, whereby, roughly speaking, self-interest and agent-relative ethical positions may be permissible in the latter case, but more difficult to justify in the former. This is related to concerns that individual preferences expressed as a 'consumer' may be an inappropriate guide to public-policy choices (Sagoff 1994; Vatn and Bromley 1994). In order to account for these concerns, we design a particularly simple choice experiment that emphasises the principles of justice underpinning various policies on offer. Such an essentially individual choice setting, nevertheless placed within wider and ongoing popular debate, has important analogues in real life (e.g. voting at the ballot box in elections). Future research could take further account of these issues by administering a similar choice experiment in a group setting. We return to possible weaknesses in our methodology in section five.

Little comparable research has been conducted in the environmental literature to date[iv], although there are precedents to note. Atkinson *et al*. (2000) used contingent ranking to model trade-offs between competing principles to share the compliance costs of an environmental improvement policy. However they did not explore the equity-efficiency trade-off. Similarly Saelen *et al*. (2008) use a choice experiment to estimate the curvature of a standard iso-elastic utility function for preferences over risk, inequality and time, all in the specific context of climate-change policy (also see Cameron and Gerdes 2007). This could have broad significance for a class of models in welfare economics, but is specific to climate change and in other respects addresses a narrower set of questions than those we pose here. Finally, we should note Spash's (2006) use of contingent valuation, combined with psychometric questions, to analyse how philosophical beliefs determine willingness to pay for environmental goods.

III. METHODS

We design a simple choice experiment (CE) to elicit preferences for the efficiency of environmental policy relative to equity in the allocation of compliance costs. In particular, we investigate trade-offs between four policy attributes: (i) environmental effectiveness; (ii) household compliance costs (together constituting the efficiency of the policy in terms of a benefit-cost ratio); (iii) the allocation of policy costs between households according to the PPP, BPP, or equally among all households; (iv) the allocation of policy costs according to the ability-to-pay principle, by offering low-income households some form of discount/rebate/exemption. Equity aspects of the policy are split between attributes (iii) and (iv), because we thought it worth testing whether there is an interaction between ability to pay and the other principles. For example, respondents with low socio-economic status may prefer that the polluter pays *ceteris paribus*, but only if discounts are also available to those on low incomes. However we did not find there to be any significant (two-way) interactions between policy attributes and for the sake of brevity we do not report the relevant estimates in this paper.[v] Nevertheless our experimental design had to accommodate the possibility of interaction effects, because the conventional method of drawing an orthogonal fraction from the full factorial set of possible combinations of attribute levels, which is proverbially very large indeed, only permits the estimation of main effects. In order to capture two-way interactions between policy attributes we use an 'endpoint' design (Louviere *et al*. 2000). This design is realised by first drawing an orthogonal fraction from combinations of the extreme levels of each attribute (i.e. the lowest and highest levels: the endpoints), second drawing an orthogonal fraction from the full set of attribute levels, and third combining the two fractions, eliminating repeated combinations. The result is not orthogonal, but is typically well-conditioned and efficient. For each of our two case studies, we administered two different blocks of unique choice sets.

We consider two policy case-studies: (i) local traffic-emissions policy; (ii) national climate-change mitigation policy. These cases have been selected to provide a point of contrast on the scale of the resource allocation problem, which ranges from the intragenerational and local to the intergenerational and international. We can test for the robustness of preferences across these scales. We draw our sample from an English urban area: the London Borough of Southwark. Southwark provides an ideal location, because of its diverse environmental and socio-economic geography. The borough cuts a representative swathe through London, from its Central Business District, through inner city neighbourhoods that are at once deprived and gentrifying, to wealthy suburbia. Inner city Southwark is generally characterised by poor local environmental quality, while suburban parts are much better provided in this respect.

Local traffic-emissions control

Local air pollution[vi] gives rise to a number of external costs, the most significant of which in an urban area are human health effects, namely morbidity and mortality caused by chronic and acute exposure. These particularly affect the elderly, infants and those with existing respiratory and/or cardio-vascular conditions. Annual concentrations of nitrogen dioxide (NO_2) and 24-hour average concentrations of fine particles (PM_{10}) exceed UK limits in parts of Southwark, specifically central and inner parts (Southwark Council 2002). Annual concentrations of NO_2 are also above national limits along major roads in suburban parts of the borough. The majority of all NO_2 and PM_{10} emissions generated within Southwark come from road traffic sources (54% and 76% respectively: Southwark Council 2002). Hence our choice experiment investigates trade-offs between efficiency and competing principles of equity in allocating the costs of a hypothetical traffic-emissions policy to improve local air quality. Respondents are introduced to the concept of a London Low Emissions Zone (hereafter LEZ). The LEZ is an area-based regulation, cordoning off the whole of metropolitan or Greater London from access by vehicles exceeding specified emissions limits. The LEZ was at the proposal stage at the time of undertaking the survey (2004-5), and is now in operation (since the beginning of 2008).

Respondents are told that, if implemented, the LEZ will increase health and life expectancy for some Londoners, especially infants, the elderly and those with existing respiratory and cardio-vascular problems. However, the exact design of the LEZ is yet to be determined and in the choice experiment respondents are asked to make trade-offs reflecting their preferred policy design. They face five choice sets altogether, each offering three policy options and a fourth 'no choice' option not to implement the policy at all. Each policy is described in terms of four attributes, which are summarised along with their levels in table 1.

TABLE ONE HERE

The question of who ought to shoulder the financial burden of the policy is divided into two attributes. The first, which addresses preferences over rights allocation, is called 'who pays?' and is offered at three levels: either (i) households in central London (within travel zones 1 and 2) pay, because air quality improves most there[vii] (i.e. the BPP); (ii) motorists pay (i.e. the PPP); or (iii) all

London households pay the same (equal shares). The second is a two-level attribute representing the existence of discounts for those on low incomes (i.e. ability to pay) and is either (i) yes or (ii) no. Nine cost levels are offered in the CE, from a low of £10 per year to a high of £134 per year. The range of costs represents available estimates of what the LEZ will actually cost to implement and run (including administration costs), depending on the scope of the scheme, its stringency and the monitoring and enforcement methods employed (AEA Technology Environment 2003). A sample choice set is presented in figure 1.

FIGURE ONE HERE

National climate-change mitigation

The climate-change issue spans a much larger spatial and temporal scale than local air pollution, which makes its mitigation a useful test of whether public preferences over the equity-efficiency trade-off in pollution-control policy are robust to changes in the nature of the externality. The issue of anthropogenic climate change continues to be controversial, and it is certainly true that the connection between greenhouse gas emissions and warming is not proved beyond all doubt. There are four key features of climate change, which also make it an interesting and controversial issue from the perspective of equity. The first is that there are large disparities in per-capita greenhouse gas emissions worldwide, which are proportional to economic development. The second is that, since greenhouse gases are long-lived in the atmosphere and the climate system in turn takes time to respond to radiative forcing, cumulative historical emissions are expected to have a significant bearing on current and future climate change (assuming of course the link is there), while any impacts of anthropogenic climate change will primarily fall on future generations. The third is that the impacts of a changing climate will be unequally distributed in space as well as time. The fourth is that vulnerability to climate change further depends on resources to adapt, which are again proportional to economic development. In these respects, survey respondents find themselves embedded in a multigenerational, international resource-allocation problem.

We consider a multi-sectoral domestic programme of greenhouse gas emissions cuts, which carries with it an opportunity cost. Such a programme ostensibly exists in the UK in the shape of the Climate Change Programme (last updated in DEFRA 2006). The issues the national policy-maker must resolve are in fact very similar to those of local traffic-emissions control, with the crucial exception that any benefits from the policy intervention will not accrue for many years and are likely to be greatest outside the UK (e.g. in low-latitude regions of the world). Respondents are informed about these key features of climate change. There are five choice sets altogether, each offering three alternative programmes and a fourth 'no choice' option. Each programme is described in terms of four attributes, which are summarised along with their levels in table 2.

TABLE TWO HERE

Once again, the question of who ought to shoulder the financial burden of the programme is divided into two attributes. The first is called 'who pays?' and is this time offered at two levels: either (i) all households pay the same (equal shares) or (ii) households pay according to how many greenhouse gas emissions they are responsible for (the PPP). We do not offer respondents the BPP, since its application would require a complex mechanism to transfer costs to the future. The second is a two-level attribute representing the offer of discounts to low-income households (ability to pay) and is either (i) yes or (ii) no. The payment vehicle for the programme is a general increase in living costs. Nine cost levels are offered in the CE, from a low of £30 per year to a high of £225 per year, based on estimates of the increase in UK household spending that might be brought about by policies to meet various emissions reduction targets (e.g. Enkvist *et al*. 2007). A sample choice set is presented in figure 2.

FIGURE TWO HERE

Discrete-choice analysis

The choices respondents make are estimated on the basis of the random utility model, where utility depends on observable attributes of the alternative and respondent, as well as unobservable attributes that are captured in an error term. The popular conditional or fixed-parameters logit model (McFadden 1974: hereafter the FPL model) of repeated choices is obtained by assuming that the error term for each respondent and choice alternative is independently, identically distributed (iid) extreme value. However, the assumption is strong. First, the FPL model is restricted to assuming proportional substitution between alternatives in a choice set: independence from irrelevant alternatives (IIA). Second, it cannot account for unobserved taste variation between respondents. Third, it treats the choices a single respondent makes in repeated choice sets as independent, whereas in all likelihood they will be correlated.

All three of these assumptions can be relaxed by using a mixed or random-parameters logit model (RPL: McFadden and Train 2000), whereby parameter coefficients on choice attributes are allowed to vary randomly across respondents. The challenge facing the analyst is then to correctly specify the probability or mixing distribution for each parameter. It is most common to use the analytically simple normal distribution, but its unbounded and symmetrical properties can pose problems in estimating coefficients that should theoretically be uni-directional. A relevant example is the personal cost of complying with an environmental improvement policy. Rational economic behaviour would anticipate that utility is decreasing in price (i.e. the cost coefficient should be negative) once all correlated factors have been stripped away (e.g. 'prestige' effects in car purchases). However, by virtue of superimposing an unbounded and symmetrical distribution on the data, the normal distribution can *de facto* give rise to individuals who supposedly prefer higher prices. Accordingly we use triangular mixing distributions, which can be asymmetric, for the environmental effectiveness attribute and for the cost attribute, while we use normal distributions for the burden-sharing attributes.

A further alternative that obviates the shortcomings of the FPL model in a somewhat different way to the RPL model is a latent-class model (e.g. Greene and Hensher 2003: hereafter an LCM). In this paper we make use of all three models. In an LCM, the sample is divided into a finite number of groups or classes. Preferences can vary considerably between classes, but preferences within classes are assumed to be identical. Membership of any given class is probabilistic and is a function of the respondent's characteristics. Thus the LCM is naturally suited to research questions that seek to estimate choice probabilities conditional on well-defined features of the population. LCMs are less flexible than RPL models, because they use a discrete distribution to approximate the underlying continuous distribution of the parameter coefficient, but on the other hand they do not require strong assumptions about the shape of the mixing distribution. Unfortunately the number of classes in an LCM cannot be identified when the maximum likelihood of the model is estimated, so it depends on judgement. Familiar information criteria, including the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC)[viii], can be used to aid model selection. Loosely speaking, both work by quantifying the trade-off between precision and complexity as the number of parameters (classes) in the model is increased, insofar as a decreasing log-likelihood is offset against a 'penalty' that is increasing in the number of model parameters. The lower the AIC and BIC, the better. The BIC penalises an increase in parameters more stiffly. However these criteria have been found to respectively overestimate and underestimate the number of preference classes in certain circumstances and so it is not a simple question of minimising either (Leroux 1992; McLachlan and Peel 2000). In addition, the usefulness of the results vis-à-vis interpretation gradually decreases as the number of classes increases. Therefore the analyst's own judgement needs to be used alongside the results of information testing with both the AIC and BIC.

Data collection

We prepared for the choice-experiment survey by conducting eight focus groups in all, which were convened between March and June 2004. Groups were drawn from four communities within the case-study area and each met twice. On the first meeting the group discussed the mitigation of local air pollution from traffic and on the second meeting it discussed the mitigation of global climate change. This ensured that perceptions could be compared between environmental issues with the greatest validity. In order to examine how preferences might vary across communities differentiated by local environmental quality on the one hand and socio-economic status on the other, we identified four communities that populated a 2*2 matrix of, respectively, low environmental quality and low socio-economic status, high environmental quality and low socio-economic status, low environmental quality and high socio-economic status, and high environmental quality and high socio-economic status. Qualitative results from this part of the research are discussed in Dietz and Atkinson (2005).

A pilot stated-preference survey was conducted in September 2004, in which each questionnaire was sent to around 250 Southwark households; 40-50 returns were obtained on each issue. The main survey was administered in February 2005, also by post. In both, a stratified cluster sampling procedure (Henry 1990) was used to select Southwark households across the socio-economic spectrum on a probabilistic basis, where the cluster unit was a Census Output Area (mean = 125 households) and was stratified based on an indicator of socio-economic status: 'selected household characteristics'[ix]. A systematic random sample of Output Areas (clusters) was then taken and every household within each selected Output Area was sent a questionnaire.

A total of1245 households were posted a questionnaire on traffic emissions policy; 231 responded, giving a final response rate of 19.3%. The appendix compares summary statistics for the survey sample to available statistics for the population of Southwark and of England. In general, the survey sample is fairly representative of Southwark's population, with some exceptions. First, the number of households without a car is slightly under-represented. Second, the pattern of economic activity in the survey sample appears marginally biased towards those in full-time employment and towards retirees, at the expense of students and the unemployed in particular. Third, the number of households living in social rented accommodation is over-represented.

A total of 1200 households were posted a questionnaire on national climate-change mitigation; 237 responded, giving a final response rate of exactly 20%. The appendix compares summary statistics for the survey sample to available statistics for Southwark's population and for the national population. In general, the sample is again a reasonable representation of Southwark's population, with the exception of differences in car-ownership, economic activity, and tenure. In addition, the proportion of active members of an environmental organisation in the survey sample looks particularly high in this case, although there are no equivalent population data against which a comparison can be made.

IV. RESULTS

Main effects

Table 3 presents FPL and RPL estimates for both case studies. Here and in the majority of our further analysis, we code environmental effectiveness as an ordinal-level variable, so as to permit estimation of the full set of dummy variables describing how compliance costs are shared. But we shall also make some use of a dummy coding of environmental effectiveness, in order to obtain more information about the marginal utility of improvements in environmental quality relative to the marginal utility of changes in the distribution of compliance costs, but at the expense of dropping a dummy variable to avoid perfect collinearity.

There are statistically significant coefficients associated with all four policy attributes, a result that is robust both to the choice of case study and discrete-choice model. Hence it is immediately apparent that there are trade-offs between efficiency (the ratio of environmental effectiveness to cost) and equity (the allocation of rights between the polluter and pollutee, and the ability-to-pay principle). Some mixture of policy criteria is most preferred. The coefficient on environmental effectiveness is positive and significant at the 1% level, indicating as expected that respondents prefer improvements in air quality and reductions in greenhouse gas emissions respectively. Taken together, the coefficients on the rights-allocation attribute demonstrate a strong preference for polluters to pay. The coefficient on the PPP dummy variable is positive and significant at the 1% level. The coefficient on equal shares is insignificant in national climate-change mitigation, while in local traffic-emissions control it is insignificant when estimated with FPL, but negative and significant at the 5% level when estimated with RPL. The coefficient on the beneficiary-pays principle, which is offered to respondents to the local traffic-emissions control survey, is insignificant in the FPL model, but is negative and significant at the 1% level in the RPL model. Ability to pay is positive and significant at the 1% level, offering evidence that respondents also prefer policies that offer relief to those on low incomes, while the cost attribute is negative and significant at the 1% level.

TABLE THREE HERE

We examined the validity of the IIA assumption that the FPL model makes, using the test devised by Hausman and McFadden (1984). The FPL model estimated on the full set of choice options (policies A to C and the status-quo option D) is compared to its counterpart estimated after one particular option is omitted (e.g. policy A). If IIA holds, the two sets of estimates should not be significantly different. In local traffic-emissions control, the null hypothesis that IIA holds is rejected in three out of four cases at the 10% level or lower. In national climate-change mitigation, it is rejected in two cases out of four at 5% significance.[x] There is hence some evidence to indicate that the IIA assumption is inappropriate. Moreover, explanatory power improves vastly with use of the RPL model.

In order to gain more information about the trade-offs respondents make between environmental effectiveness and burden-sharing criteria, we compare implicit prices[xi] in table 4, focusing on estimates from the RPL model. On this occasion environmental effectiveness is coded as a set of dummy variables[xii], with separate dummies for a medium improvement and for a high improvement.[xiii] In addition, the cost attribute is treated as non-random to enable straightforward interpretation of implicit prices.

TABLE FOUR HERE

By calculating implicit prices for the PPP and ability to pay, it is possible to show that value is attached not only to positive environmental outcomes, but also to a desirable distribution of compliance costs. The average implicit price of a policy that achieves a medium improvement in air quality is £84.52 per year, compared to £152.79 for a policy that achieves a high improvement. A policy that compels motorists to pay is valued at £96.93, while a policy that offers discounts to those on low incomes is valued at £37.65. Inspection of the standard errors on the implicit prices shows that the marginal valuation of a highly effective policy is significantly greater than that of a policy implementing the PPP, but the marginal valuation of a policy of medium environmental effectiveness is not significantly different to that of a policy implementing the PPP. A significantly lower implicit price is attached to a policy implementing the ability-to-pay principle.

Respondents to the national climate-change mitigation survey place an average marginal value of £184.04 per year on a policy that offers a medium cut in greenhouse gas emissions, £395.04 on a policy that offers a big cut, £255.88 on a policy that charges households in proportion to their emissions and £168.70 on a policy that offers discounts to low-income households. The corresponding standard errors indicate that while the implicit price of a big cut is significantly greater than that of implementation of the PPP, the implicit price of implementation of the PPP is itself significantly greater than that of a medium cut. Indeed, the implicit price of a medium cut is not significantly different to that of a policy implementing the ability-to-pay principle.

Determinants of preferences

Having established a pattern of trade-offs on aggregate, the sensitivity of estimates to particular respondent characteristics and attitudes is now tested. In the RPL models, almost all of the standard deviations estimated for the policy attributes are highly significant (see table 3), indicating preference heterogeneity. We are especially interested in posing the question of whether respondent preferences reflect self-interest. In previous qualitative research, we found from focus group discussions that perceptions of the equitability of traffic-emissions control policies including the LEZ depended in some measure on the balance of personal benefits and costs on offer (Dietz and Atkinson 2005).

Because respondent characteristics and attitudes are invariant within each respondent's set of choices, they can only be included through additional two-way interactions with the relevant policy attributes. We test four hypotheses:

1. Respondents who report themselves to be 'very concerned' about air pollution or climate change are systematically more likely to choose policies that offer greater environmental effectiveness. In the case of climate-change mitigation, this is not an expression of self-interest in a narrow sense, since the benefits of the policy will accrue in the far-off future.[xiv] Instead, it is perhaps more appropriate to view this interaction as a construct-validity test of whether respondent choices reflect their self-reported attitudes. We represent respondents 'very concerned' about air pollution or climate change in the respective surveys with a dummy variable that takes 1 if the respondent reports being 'very concerned' and 0 otherwise[xv];
2. Polluters will avoid alternatives that allocate costs based on the PPP. In the case of local traffic-emissions control, the hypothesis is that heavy motorists do not choose policies where the motorist has to pay. In the case of national climate-change mitigation, respondents who imagine themselves to be responsible for a greater-than-average share of greenhouse gas emissions would have a preference against the PPP. However, unlike local traffic emissions, this is a difficult aspect to model, because respondents may lack firm expectations about their own contribution to climate change, including greenhouse gas

emissions generated through domestic space heating, embodied in other consumer purchases etc. The only available proxy for greenhouse gas emissions in the survey is motoring habits. Focus group discussions indicated that participants were able to connect vehicle emissions with climate change, even if they sometimes lacked an appropriate causal view of the sources of carbon dioxide more generally. We capture heavy motorists with a dummy variable that takes 1 if the respondent's household drives its heaviest-used car more than 10,000 miles per year and 0 otherwise[xvi];

3. Respondents to the local traffic-emissions control survey living in central London will have a negative preference for the BPP, because they are told in the survey that they would have to pay most of the policy costs under this regime. We specify a dummy variable taking 1 if the respondent lives in central London (transport zones 1 and 2) and 0 if s/he lives beyond;
4. Respondents with low socio-economic status systematically choose policies that offer discounts to low-income households and/or cost less. We use a proxy for socio-economic status, specifying a dummy variable taking 1 if the respondent lives in social-rented accommodation and 0 otherwise.[xvii]

Table 5 presents RPL estimates, where the interaction effects enter as fixed coefficients. In both case studies, the interaction effect between environmental effectiveness and respondents 'very concerned' about air pollution/climate change is positive and significant, in line with expectations. In local traffic-emissions control, it is significant at the 1% level, whereas in national climate-change mitigation, it is significant at the 5% level. In local traffic-emissions control, the interaction between the PPP and heavy motoring is negative and significant at the 10% level, offering weak evidence that polluters systematically avoid options in which they would be required to shoulder a heavier financial burden. In national climate-change mitigation, the same interaction is correctly signed but is insignificant, which could reflect the fact that, as discussed, motoring habits are a poorer proxy for household greenhouse gas emissions.

TABLE FIVE HERE

The interaction between the BPP and living in central London is insignificant. The interaction between the ability-to-pay principle and our proxy for socio-economic status is positive and significant at the 10% level in national climate-change mitigation, offering some weak evidence that those on low incomes prefer policies that provide financial relief to such households. However in the case of local traffic-emissions control the interaction effect is insignificant. Finally, the interaction between socio-economic status and the price attribute is negative and significant at the 1% level in local traffic-emissions control, but although correctly signed it is insignificant in national climate-change mitigation.

An LCM can account for preference heterogeneity in a similar fashion to the RPL model (based on a discrete rather than continuous mixing distribution), but it is additionally a natural choice of model to probe for the existence of particular groups of homogeneous preferences in the data. We estimate an LCM for both case studies, re-testing the above four hypotheses on the determinants of preferences by allowing attitudinal and socio-economic variables describing (i) environmental concern, (ii) motoring habits, (iii) residence in respect of the LEZ and (iv) socio-economic status to determine class membership. Tables 6 and 7 report estimates for local traffic emissions-control and national climate-change mitigation respectively. The top halves of the tables give the class-dependent coefficient estimates on the policy attributes. The bottom halves of the tables give the coefficients of the class-membership function, which tests our four hypotheses from above. These class-membership coefficients are normalised to zero for the third class, so the remaining coefficients for classes one and two are interpreted as probabilities of membership of these classes relative to class three.

We present estimates of a three-class model for both case studies. As with the RPL models, moving from one class to two (i.e. from an FPL model to an LCM) improves model fit hugely. Increasing the number of classes beyond two continues to increase model fit (i.e. log-likelihood and pseudo r-squared), but by smaller increments. According to the AIC, information improves in both case studies as the number of classes increases to four. The BIC, which penalises an increase in the number of classes more stiffly, suggests two classes in both cases.[xviii] However inspection of the parameter estimates with two and three classes suggests that the three-class model will provide more useful information in both cases.

TABLE SIX HERE

In local traffic-emissions control, the estimates identify three intriguingly different classes of respondent. We might call class one the 'socially concerned environmentalist'. Members of this class are strongly focused on environmental effectiveness, the coefficient on which is positive and significant at the 1% level. Not only is this class concerned with improving air quality, it also exhibits a strong preference to put the ability-to-pay principle into operation (positive and significant at the 1% level). But it is less focused on the allocation of rights, where the only significant dummy variable is that on the BPP (negative and significant at the 5% level). The cost attribute is negative and significant at the 1% level.

The second class of respondent wants the polluter to pay. The coefficient on the PPP is positive and significant at the 1% level, while the coefficient on the BPP is negative and significant at the

1% level. Thus respondents would derive considerable utility from a transfer of property rights from polluter to pollutee. The coefficient on environmental effectiveness is positive and significant at the 5% level, while the cost coefficient is in fact positive and significant at the 10% level.

The third class of respondent is broadly the 'cost minimiser'. The cost coefficient is negative and significant at the 1% level, while the ability-to-pay principle is positive and significant at the 10% level. The coefficient on environmental effectiveness is insignificant (though correctly signed), while in terms of rights allocation respondents have a positive preference for equal shares of the financial costs of air quality improvements at the 5% level. Thus this class appears to be primarily concerned with a low and equal share of the cost of the policy, which appears to derive at least in part from a lack of sympathy with its environmental aims.

The coefficients on class membership tend towards confirming two of our hypotheses, consistent with our earlier analysis using an RPL model with interaction effects. First, respondents who are very concerned about air pollution are statistically likely to be members of class one, the 'socially concerned environmentalists'. Second, respondents with low socio-economic status are statistically likely to belong to the class of 'cost minimisers'. Again, motoring habits and residence in central London do not determine class membership.

TABLE SEVEN HERE

In national climate-change mitigation, table 7 shows that we can immediately single out a class of respondents (two), which invariably selects the status-quo option. The coefficients on environmental effectiveness, ability to pay and cost are insignificant. The coefficients on the PPP and equal shares are both negative and significant at the 5% and 1% levels respectively. Since these are the only two levels of the rights-allocation attribute, this indicates that the status-quo option is strongly preferred.[xix]

The remaining respondents are divided into two more subtly different classes. Class one again looks like 'socially concerned environmentalists'. For one, the coefficient on environmental effectiveness is large and positive, compared to a cost coefficient that is only significant (and negative) at the 10% level. For another, the coefficient on ability to pay is positive and significant at the 1% level. But, unlike the local traffic-emissions case, this class also prefers policies that allocate rights according to the PPP, which is positive and significant at the 5% level. The preferences of the third class appear to be based to a greater extent on what is perceived to be an equitable (as opposed to effective) policy, as the coefficient on the PPP is positive and significant at the 1% level, alongside ability to pay. The coefficient on environmental effectiveness is also positive and significant at the 1% level, but it is small in comparison with the PPP. The cost coefficient is negative and significant at the 1% level. The class-membership function demonstrates that none of our posited socio-economic or attitudinal variables determine membership of these three classes.

V. DISCUSSION AND CONCLUSIONS

Equity and efficiency are often competing criteria in the design and delivery of environmental policy (Goulder and Parry 2008), and equity is itself a contested concept, including numerous competing principles of distribution. If policy makers are to be supported in establishing where the balance should lie between these competing criteria and principles, a task for research is to elicit public preferences over the various trade-offs. We do not suggest that it is the only such task, but we do consider it to be one useful source of evidence.

Our results broadly suggest that equity in the distribution of compliance costs matters to people *as much as* efficiency does in the design of pollution-control policy. In our choice models, the estimated coefficients on policy attributes representing the distribution of compliance costs between households are highly significant, as well as the estimated coefficients on the effectiveness of policy and its cost (together efficiency). With respect to preferences over competing principles of distribution, we find strong support for the PPP as the appropriate allocation of property rights between polluters and victims of pollution. However, we also find a preference for the allocation of policy costs in proportion to ability to pay. Like Atkinson *et al*. (2000), we thus find there is "an apparent willingness to trade off between the principle which guides property right allocation and that for income distribution" (p1804). All of these results are robust both to the choice of case study and discrete-choice model.

The random-parameters logit model suggests that there is considerable heterogeneity in respondent preferences, and the latent-class model draws out some interesting differences, isolating a class of respondent in both case studies who is seemingly concerned at once with the effectiveness of the policy and that it should not disproportionately impact upon low-income households (the 'socially concerned environmentalist'). Especially in the case of local traffic-emissions control, the latent-class model also isolates a class of respondent seemingly focused above all on implementing the PPP. While the evidence for this is weaker in the case of national climate-change mitigation, there is nevertheless a class of respondent for whom distribution is relatively more important than efficiency. Neither the latent-class specification nor the estimation of interaction effects between policy attributes and respondent characteristics in the RPL model uncovers strong evidence that self-interest governs equity preferences.

This last result could in fact be of considerable importance to the method as a whole, since, as section two indicated, the normative philosophical argument for basing public policy on popular preferences rests in some measure on the capacity to elicit distributive judgements that do not simply reflect self-interest. However, in previous qualitative research, also in the London Borough of Southwark, we found stronger within-subject evidence that expressed preferences for equity did correspond with the personal balance of costs and benefits accruing from a policy change (Dietz and Atkinson 2005). The weaker results we find in the current paper could be due to identification problems, especially since our proxies for polluters and beneficiaries are themselves rather weak. Alternatively, it could be that respondents accept the 'fairness' of the principle to guide allocation of property rights between polluters and pollutees, while at the same time seeking to minimise their own burden through the cost attribute. More research would seem warranted on the theme of self-interest.

The policy implications of our research can be separated into weak and strong categories. A weak interpretation of our research, which confirms numerous anecdotal experiences, is simply that policies, somewhat irrespective of how efficient they are, may not be politically possible if they are perceived to be regressive and/or to 'let the polluter get away with it'. The strong interpretation of our research is of course that policy design *should* reflect the preference structure we have elicited. In this respect, public preferences do not support making efficiency the only goal of policy, at the expense of equity. This also has implications for economic analysis and appraisal, suggesting that distributional analysis should be a central component. This is a further indication that the debate about the use of distributional weights in cost-benefit analysis cannot easily be waylaid (Pearce 2005). Yet there is a major caveat here. We would interpret our results as being significant wherever a trade-off exists in environmental policy that cannot be eliminated. In many cases, however, trade-offs can be reduced by intelligent use of a portfolio of policies. To give a counterexample, policies to reduce household use of energy that increase prices while at the same time giving a financial rebate to low-income households are likely to be less efficient than policies that provide relief to such households by, for example, subsidising energy efficient appliances. Thus our results should be considered across a portfolio of policies, where there may in some cases be opportunities to reduce the equity-efficiency trade-off.

There are methodological issues that we have not had an opportunity to explore within the confines of a single research project. Perhaps the most important of these has already been noted above. It is the question of whether our survey has been able to elicit the appropriate class of preference for the purpose of arbitrating between competing social arrangements (Sagoff 1994; Sen 1970, 1992; Vatn and Bromley 1994). In this context it would be worthwhile to exploit methodologies recently developed in stated-preference research to elicit preferences in a discursive, small-group environment (e.g. Brown *et al*. 1995; Kenyon *et al*. 2001), as well as methodologies that provide greater insight into the thought processes followed by respondents (Ryan *et al*. 2002).

Appendix. Summary statistics for the survey samples compared to Southwark and national population.

Variable		Local traffic-emissions survey sample	Climate change survey sample	Southwark population	English population
Size		231	237	244860	49138831
Number of cars per households	0	42.1% (93)	40.2% (94)	51.9%	26.8%
	1	45.3% (100)	50.4% (118)	38.7%	43.7%
	2+	12.7% (28)	9.4% (22)	9.4%	29.5%
Is the household's heaviest used car driven over 10,000 miles per year?	Yes	6.5% (15)	6.8% (16)	-	-
	No	93.5% (216)	93.3% (221)	-	-
Sex	Males	46.5% (107)	46.2% (108)	48.9%	48.7%
	Females	53.5% (123)	53.9% (126)	51.1%	51.3%
Age (years)	16 to 20	2.2% (5)	1.7% (4)	7.7%	6.2%
	21 to 30	16.1% (37)	22.9% (54)	25.4%	12.9%
	31 to 40	29.1% (67)	27.1% (64)	25.6%	15.6%
	41 to 50	20.9% (48)	17.0% (40)	15.0%	13.1%
	51 to 60	17% (39)	14.0% (33)	9.9%	12.2%
	61+	14.8% (34)	17.3% (41)	16.4%	19.8%
Children living at home	Yes	30.4% (66)	-	27.5%	40.8%
	No	69.6% (151)	-	72.5%	59.2%
Economic activity	Full-time employed	56.1% (128)	57.9% (136)	46.8%	47.3%
	Part-time employed	13.2% (30)	11.5% (27)	9.3%	13.7%
	Retired	13.6% (31)	15.8% (37)	8.0%	13.5%
	Student	4.8% (11)	5.1% (12)	13.3%	7.3%
	Unemployed	3.5% (8)	3.8% (9)	6.2%	3.3%
	Looking after the home	4.8% (11)	3.4% (8)	6.2%	6.5%
	Unable to work due to sickness or disability	3.5% (8)	1.7% (4)	5.3%	5.3%
	Other	0.4% (1)	0.9% (2)	5.0%	3.1%
Housing tenure	Social rented	27.1% (62)	23.4% (55)	53.5%	19.3%
	Private rented	20.5% (47)	25.1% (59)	13.5%	8.8%
	Owned	52.4% (120)	51.5% (121)	31.4%	68.7%
Membership of an environmental organisation (e.g. Worldwide Fund for Nature)	Yes	7.1% (16)	10.3% (24)	-	-
	No	92.9% (209)	89.7% (209)	-	-
Number of respondents living in zones 1 and 2 (i.e. central London)	In zones 1 and 2	95.2% (220)	-	-	-
	Outside	4.8% (11)	-	-	-
Very worried about air pollution/climate change	Yes	92 (41.4%)	99 (43.4%)	-	-
	No	130 (58.6%)	129 (56.6%)	-	-

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Table 1.
Attributes and attribute levels.

Attribute	Levels
Improvement in air quality	Low Medium High
Average annual cost to a London household (£)	10; 25; 39; 54; 70; 87; 104; 119; 134
Who pays?	1. All London households pay the same (equal shares); 2. Households in central London (within travel zones 1 and 2) pay, because air quality improves the most for them (BPP); 3. Motorists pay (PPP)
Discounts for those on low incomes	No Yes

Table 2.
Attributes and attribute levels.

Attribute	Levels
Commitment to the future – cut in GHG emissions	Small Moderate Big
Average cost to a British household (£)	30; 57; 81; 105; 128; 153; 176; 200; 225
Who pays?	1. To share the costs, all households pay the same; 2. Households pay according to how many emissions they are responsible for
Discounts for low-income households	No Yes

Table 3.
FPL and RPL estimates of preferences for policy attributes (standard errors in parenthesis).

Variable	Local traffic-emissions control			National climate-change mitigation		
	FPL	RPL		FPL	RPL	
		Mean	Std. deviation		Mean	Std. deviation
Environmental effectiveness	0.641***	1.301***	2.989***	1.030***	1.926***	4.221***
	(0.058)	(0.157)	(0.444)	(0.058)	(0.195)	(0.439)
Rights allocation – PPP	0.938***	1.681***	2.690***	1.388***	2.959***	1.746***
	(0.103)	(0.310)	(0.270)	(0.213)	(0.417)	(0.376)
Rights allocation – equal shares	0.061	-0.447**	1.332***	0.001	0.652	0.816*
	(0.097)	(0.200)	(0.318)	(0.191)	(0.409)	(0.480)
Rights allocation – BPP	-0.093	-1.532***	1.834***	-	-	-
	(0.085)	(0.225)	(0.264)			
Ability to pay	0.273***	0.532***	1.113***	0.957***	1.597***	1.427***
	(0.089)	(0.175)	(0.295)	(0.094)	(0.185)	(0.218)
Cost	-0.007***	-0.018***	0.049***	-0.005***	-0.011***	0.033***
	(0.001)	(0.003)	(0.010)	(0.001)	(0.002)	(0.005)
Number of respondents/ observations	231/ 4620	231/ 4620		237/ 4740	237/ 4740	
Log-likelihood	-1401.192	-1083.480		-1119.162	-918.094	
Pseudo R^2	0.09	0.29		0.30	0.43	

* Significant at 10%, ** at 5%, *** at 1%

Table 4.
Implicit prices of attributes using RPL estimates (standard errors in parenthesis).

Difference between attribute levels	Local traffic-emissions control	National climate-change mitigation
Medium improvement	£84.52 (17.00)***	£184.04 (27.00)***
High improvement	£152.79 (20.92)***	£395.04 (49.19)
Rights allocation – PPP	£96.93 (17.15)***	£255.88 (36.40)***
Rights allocation – equal shares	£2.60 (15.27)	-£22.87 (30.96)
Rights allocation – BPP	-£34.26 (18.77)*	-
Ability to pay	£37.65 (12.63)***	£168.70 (24.20)***

* Significant at 10%, ** at 5%, *** at 1%

Table 5.
Sensitivity to respondent characteristics and attitudes (standard errors in parenthesis).

Variable	Local traffic-emissions control		National climate-change mitigation	
	Mean	Std. deviation	Mean	Std. deviation
Environmental effectiveness	0.900***	3.674***	1.736***	4.655***
	(0.179)	(0.469)	(0.232)	(0.455)
Rights allocation – PPP	1.942***	3.441***	3.163***	0.950*
	(0.686)	(0.369)	(0.444)	(0.456)
Rights allocation – equal shares	-0.122	1.576***	0.753*	1.453***
	(0.653)	(0.308)	(0.430)	(0.346)
Rights allocation – BPP	-2.314***	2.158***	-	-
	(0.671)	(0.348)		
Ability to pay	0.550**	1.350***	1.523***	1.260***
	(0.219)	(0.266)	(0.198)	(0.302)
Cost	-0.018***	0.066***	-0.013***	0.036***
	(0.003)	(0.009)	(0.002)	(0.005)
Environmental effectiveness*very concerned	1.025***	-	0.604**	-
	(0.283)		(0.253)	
PPP*heavy motoring	-1.224*	-	-0.161	-
	(0.749)		(0.619)	
BPP*lives in central London	1.048	-	-	-
	(1.285)			
Ability to pay*low socio-economic status	-0.186	-	0.660*	-
	(0.409)		(0.388)	
Cost*low socio-economic status	-0.018***	-	-0.004	-
	(0.005)		(0.003)	
Number of respondents/observations	231/ 4620		237/ 4740	
Log-likelihood	-1010.836		-868.429	
Pseudo R^2	0.31		0.44	

* Significant at 10%, ** at 5%, *** at 1%

Table 6.

Three-class model of preferences for local traffic-emissions control policy (standard errors in parenthesis)

Variable	Class 1	Class 2	Class 3
		Utility function	
Environmental	1.503***	0.306**	0.313
effectiveness	(0.168)	(0.149)	(0.221)
Rights allocation – PPP	-0.983	1.853***	0.416
	(0.963)	(0.254)	(0.335)
Rights allocation – equal	-1.530	-0.209	0.968**
shares	(0.975)	(0.263)	(0.396)
Rights allocation – BPP	-2.032**	-0.719***	-0.016
	(0.947)	(0.195)	(0.235)
Ability to pay	0.984***	0.016	0.580*
	(0.191)	(0.196)	(0.316)
Cost	-0.015***	0.005*	-0.026***
	(0.003)	(0.003)	(0.007)
		Class membership function	
Constant	-0.721	0.888	-
	(1.228)	(0.807)	
Very concerned	0.932**	-0.000	-
	(0.375)	(0.000)	
Heavy motoring	-0.954	-0.374	-
	(0.775)	(0.875)	
Lives in central London	1.061	-0.308	-
	(1.217)	(0.781)	
Low socio-economic	-0.600	-1.269***	-
status	(0.468)	(0.468)	
Number of respondents/observations	231/ 4620		
Log-likelihood	-1084.209		
Pseudo R^2	0.29		

* Significant at 10%, ** at 5%, *** at 1%

Table 7.
Three-class model of preferences for national climate-change mitigation policy (standard errors in parenthesis)

Variable	Class 1	Class 2	Class 3
	Utility function		
Environmental effectiveness	1.440***	-0.126	0.458***
	(0.086)	(0.247)	(0.104)
Rights allocation – PPP	1.184**	-1.622**	3.088***
	(0.490)	(0.731)	(0.330)
Rights allocation – equal shares	0.661	-2.268***	2.192***
	(0.452)	(0.759)	(0.353)
Ability to pay	1.143***	-0.255	1.271***
	(0.133)	(0.483)	(0.154)
Cost	-0.002*	-0.02	-0.018***
	(0.001)	(0.003)	(0.002)
	Class membership function		
Constant	1.257***	-1.111**	-
	(0.381)	(0.445)	
Very concerned	-0.155	-0.141	-
	(0.436)	(0.436)	
Heavy motoring	-0.100	-6.772	-
	(0.930)	(29.745)	
Low socio-economic status	-0.447	-0.455	-
	(0.478)	(0.479)	
Number of respondents/observations	237/ 4740		
Log-likelihood	-899.500		
Pseudo R^2	0.44		

* Significant at 10%, ** at 5%, *** at 1%

Figure 1.

Example choice set for local traffic-emissions control.

6. Which of these schemes do you prefer?				
	Scheme **A**	Scheme **B**	Scheme **C**	**D**
Improvement in air quality	Low	High	High	Leave things as they are
Average cost to a London household	£39 per year	£54 per year	£54 per year	
Who pays?	To share the costs, all London households pay the same.	Motorists pay, because they are the ones polluting.	To share the costs, all London households pay the same.	
Discount for the poor?	No	Yes	No	
Tick one box →	☐	☐	☐	☐

Figure 2.

Example choice set for national climate-change mitigation.

7. Which of these three schemes do you prefer?				
	Scheme **A**	Scheme **B**	Scheme **C**	**D**
Commitment - cut in gases	Big	Big	Medium	Do nothing more
Average cost to a British household	£105 per year	£30 per year	£176 per year	
Who pays?	To share the costs, everyone pays the same.	People who are responsible for making more gases pay more.	People who are responsible for making more gases pay more.	
Discount for the poor?	Yes	No	Yes	
Tick one box →	☐	☐	☐	☐

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[ii] For example, a social security system that reduces poverty may at the same time reduce incentives to work (*viz.* unemployment benefits) or to save (*viz.* a state pension).

[iii] That is, willingness to pay is not equal to willingness to accept compensation (Kriström 2005). Also see, for example, Kahneman *et al*. (1990) on the effect of ownership on preferences over gains and losses.

[iv] There has been some research on the equity-efficiency trade-off in health economics (e.g. Dolan 1998; Dolan and Robinson 2001).

[v] The estimates can be obtained from the corresponding author on request.

[vi] Local air pollution comprises a large number of chemical elements and compounds with potentially harmful properties: e.g. oxides of nitrogen (NO_x); sulphur dioxide (SO_2); fine particles (PM_{10}); lead (Pb); carbon monoxide (CO) and ozone (O_3).

[vii] This is essentially an arbitrary construct, but enables participants to easily imagine how costs might be allocated under the BPP. In addition, one can test whether preferences are sensitive to where respondents live in relation to transport zones 1 and 2 (i.e. self-interest: see below).

[viii] $AIC=-2\ln L+2\kappa$, where κ is the number of parameters estimated in the model. $BIC=-2\ln L+\kappa\ln(n)$, where n is the number of observations.

[ix] Selected Household Characteristics is a comparatively comprehensive indicator of socio-economic status/deprivation that classifies households (1/0) based on four criteria:

1. *Employment*: whether any member of the household aged 16-74 who is not a full-time student is either unemployed or permanently sick;
2. *Education*: whether no member of the household aged 16 to pensionable age has at least 5 GCSEs (the English secondary school qualification for those aged 16) at grade A-C or equivalent AND no member of the household aged 16-18 is in full-time education;
3. *Health and disability*: whether any member of the household self-reports general health as being 'not good' in the year before Census OR has a limiting long term illness;
4. *Housing*: whether the household's accommodation is either overcrowded, OR is in a shared dwelling, OR does not have sole use of bath/shower and toilet, OR has no central heating.

[x] Estimates can be obtained from the corresponding author on request.

[xi] The implicit price of any attribute is the ratio of the (negative of the) coefficient on that attribute and the coefficient on the cost attribute. It is an estimate of the marginal change in welfare for a change in a particular attribute.

[xii] For the sake of brevity we do not report the full set of estimates for the models in which *environmental effectiveness* is coded as a set of dummy variables. Estimates can be obtained from the corresponding author on request.

[xiii] Doing so also creates a dummy-variable trap, which is obviated by dropping a dummy variable elsewhere in the model. After testing, we opted to drop the dummy variable representing a low improvement in environmental quality, since it had the lowest explanatory power of all the dummy variables implicated in the trap (p-values of 0.718 and 0.995 in the cases of local traffic-emissions control and national climate-change mitigation respectively).

[xiv] Respondents are told that the benefits of emission reductions will begin to accrue in about thirty years' time.

[xv] The response categories offered were 'very concerned', 'quite concerned', 'not very concerned' and 'not at all concerned'.
[xvi] This accounts for the fact that, although many households own cars, they may seldom use them, especially in urban areas. Therefore a simple count of the number of cars a household runs may be a misleading indicator of motoring habits. The 10,000 miles cut-off reflects the answer categories offered.
[xvii] There are well-known difficulties with eliciting individual or household income in surveys, especially in the UK. Given that our survey was administered by mail shot, there was a particular risk that the inclusion of an explicit question about income would further reduce the response rate.
[xviii] Estimates can be obtained from the corresponding author on request.
[xix] To confirm this finding, we re-ran the three-class model, dropping equal shares and adding a dummy variable for the status quo. This dummy variable was positive and significant at the 1% level, while none of the other explanatory variables, including the PPP, were significant.