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THE PRISONER'S DILEMMA AND CITY-CENTRE TRAFFIC

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ABSTRACT

It is commonly asserted that such problems as inner-city traffic congestion and pollution can be understood as examples of the Prisoner's Dilemma Game (PD), but there is a dearth of empirical research that tests this assertion. 587 car owners in Oxford City were presented with three pairs of alternatives designed as traffic versions of the four outcomes of the PD, and asked to state which alternative in each pair they preferred. Only 2% of respondents showed the full set of preferences which fit the PD. Four sets of preferences accounted for 93% of responses suggesting that no single canonical game structure can represent the traffic problem. The most common set of preferences, shown by 48% of respondents fitted an "Assurance Game". The results imply that the current traffic problem may be due to lack of assurance and trust rather than raw self-interest. The public policy implications of the data are discussed.

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trust
city centre traffic

The Prisoner's Dilemma and City-Centre Traffic¹

INTRODUCTION

The literature in social science is replete with references to congestion and pollution as examples of the Prisoner's Dilemma Game.² However there is an almost complete absence of empirical research designed to test whether such a characterisation is relevant or correct. The purpose of this study is to overcome this deficit. We will take city-centre traffic as an obvious example of congestion and pollution.

It is generally recognised that while private motor transport has brought the advantages of flexibility and opportunity to those who travel by car, its growth has simultaneously inflicted the costs of congestion, pollution and road accidents upon the entire community (Bannon & Costello, 1997; Department of the Environment, Transport and the Regions, 1998; Department of Health, 1998; Royal Commission on Environmental Pollution, 1994). While some discussion has focussed on the issue of overall reduction in car use, the primary policy initiatives have so far revolved around the reduction of city-centre traffic.³ Many authors have proposed that city-centre traffic can be understood through the psychology of collective action, and more specifically as an example of a social dilemma (Platt, 1973; Cross & Guyer, 1980; Stern, 1992; Hallsworth, Black & Tolley, 1995). In a social dilemma, "It is generally more profitable for each person to maximise selfish interests but if all choose to maximise selfish interests, all are worse off than if all choose to maximise collective interests" (Komorita & Parks, 1994, p. 8). Whitelegg (1997) has suggested that people's decision to continue to drive their cars in congested and polluted cities should be

understood as the outcome of an n -person Prisoner's Dilemma Game (hereafter referred to as PD).

The PD interpretation of the traffic problem runs as follows. Start with a 2-person game.

Suppose there are two individuals a and b , and suppose that each of them makes a defection/cooperation decision (defection = drive, to be denoted as ' D '; and cooperation = not drive, to be denoted as ' C '). Assume that the payoff ranking of the outcomes of the simultaneous and independent decisions of a and b (from most desired to least) is given by:

For a : $DaCb > CaCb > DaDb > CaDb$

For b : $CaDb > CaCb > DaDb > DaCb$

It is clear that whichever strategy b chooses (D or C , i.e. drive or not-drive), a 's preferred strategy is to choose D , that is, D is a dominant strategy for a . If b does not drive, a will prefer to drive ($DaCb > CaCb$); if b drives, a will prefer to drive ($DaDb > CaDb$). Since b 's preferences are symmetric, the same argument shows that the dominant strategy for b is also to choose D , i.e. to drive. The equilibrium outcome of this game is thus $DaDb$ (non-cooperation, i.e. both choose to drive) even though both a and b rank $CaCb$ (cooperation, i.e. both choose not to drive) above $DaDb$.^{4 5} The above argument can be extended to n individuals ($n > 2$) if the preference ordering of each individual satisfies the following two requirements:

- i) It is a dominant strategy to defect, i.e. each individual is better off (prefers) driving to not driving no matter what the other individuals do.
- ii) Mutual cooperation is preferable to mutual defection, i.e. given the choice between everyone driving and everyone not driving, each individual prefers the latter to the former.

The n -player PD can be formulated as follows. Let x denote the number of players other than the individual who choose to defect ($0 \leq x \leq n-1$). For the n^{th} player, suppose:

$$C(x) = \text{Payoff from Cooperation}$$

$$D(x) = \text{Payoff from Defection}^6$$

If all n players cooperate, they each obtain a payoff of $C(0)$. Similarly, if all n players defect, they each obtain a payoff of $D(n-1)$.

The two requirements of an n -person PD, may be expressed as follows:⁷

- It is a dominant strategy to defect,

$$D(x) > C(x), \quad 0 \leq x \leq n-1$$

- Mutual cooperation is preferred to mutual defection,

$$C(0) > D(n-1)$$

FIGURE 1 ABOUT HERE

Figure 1 is a graphic representation of the n -person Prisoner's Dilemma. The $D(x)$ line shows how an individual's pay-off from defection (driving) varies with x , the number of others who defect (drive). The $C(x)$ line shows how an individual's pay-off from cooperation (not driving) varies with x , the number of others who defect (drive). However many other people do or do not drive, the $D(x)$ line is above the $C(x)$ line. The pay-off at

$C(0)$ (i.e. everyone including the individual co-operates by not driving) is higher than the payoff at $D(n-1)$ (i.e. everyone including the individual defects by driving). By an argument analogous to the 2-person case, these conditions imply an equilibrium where everyone drives (i.e. the status quo, $D(n-1)$) even though each person ranks nobody driving (i.e. a traffic-free city centre, $C(0)$) above the status quo. Thus the equilibrium point $D(n-1)$ is Pareto-inferior to the cooperation point $C(0)$.

In addition to the above general characterisation common to all n -persons PDs, Figure 1 incorporates some extra assumptions that are plausible in the context of city-centre traffic modelled as a PD:

1. $D(x)$ is substantially higher than $C(x)$ as driving is assumed always to convey the advantages of flexibility, privacy etc. irrespective of the number of others who drive. In other words, there are perceived gains to continuing to use a car, even in congested and polluted streets. This assumption is well supported by attitudinal data (Lex, 1999; RAC, 2000).
2. The $D(x)$ and $C(x)$ lines have monotonic downward slopes since it is plausible to assume that defection by others harms the individual. As the number of drivers increases, the costs of congestion and pollution increase for both drivers and non-drivers (pedestrians, cyclists and bus users).⁸

Although the PD model has been used in explaining a number of social problems (van Lange et al., 1992; Komorita & Parks, 1994; Colman, 1995), whether this model empirically fits real-life social dilemmas in general, or the city-centre traffic problem in particular, remains a

question that has rarely been tackled. Survey research shows that the public recognise the car's contribution to congestion and pollution and generally dislike congestion and pollution (Department of Environment, 1994; Lex, 1999), yet "pursue their usual, more personally convenient, air-polluting behaviour patterns" (Neidert & Linder, 1990). This mismatch between apparent preference and the negative outcome to which the individual's behaviour contributes is a feature of the Prisoner's Dilemma. However, the behavioural data (i.e. the incontestable fact that most people continue to use their cars in cities) together with the survey findings (which show people's dislike of congestion and pollution) are not sufficient to demonstrate that the traffic problem is the outcome of a PD.

To ascertain whether people's use of cars in the city centre should be construed as a PD, it is necessary to discover the rank orderings of people's preferences among the range of possible outcomes implied in the game (as outlined in the paragraphs above) and research has so far failed to address this issue. In laboratory PD games, the rank ordering of preference is dictated by the manipulation of monetary or other pay-offs. The object of these experiments then is to establish whether given these pay-offs, the equilibrium outcome predicted by the PD model does in fact result and under what conditions. Outside the laboratory, in cases such as the traffic problem, we already know people's decisions (i.e. they drive) and the collective outcome of their decisions (i.e. congestion and pollution). What we do not know, however, is the rank ordering of their preferences.

A survey is the only way in which rank orderings of preferences can be directly established. Psychologists, although long aware of the pitfalls of surveys, take the necessity of their use

for granted (Thurstone, 1931; Oppenheim, 1992). Although economists are in general less sanguine than psychologists about the usefulness of asking people questions about their preferences, they are becoming less behaviouristic than they used to be. A notable example is Sen (1973) who writes in a related context “That behaviour is a major source of information on preference can hardly be doubted, but the belief that it is the only basis of surmising about people’s preferences seems extremely questionable. While this makes a great deal of sense for studying preferences of animals, since direct communication is ruled out (unless one is Dr Dolittle), for human beings surely information need not be restricted to distant observations of choices made” (p. 257).

Van Vugt (1996) has attempted to address the question of whether the traffic problem can be understood as a PD in a series of empirical studies based on game theory. He suggests that the PD structure underlies the preferences of some people - notably those with environmental concerns. Respondents were asked whether they would drive or not, if i) the majority drove, or if ii) the majority did not drive (van Vugt, Meertens & van Lange, 1994). This design enabled van Vugt et al. (1994) to establish one of the conditions of the PD, but only for those with environmental concerns; viz. that each person has a dominant strategy. However van Vugt et al.’s (1994) design cannot establish whether the PD interpretation is correct because the respondents were not asked the critical question of how they ranked $C(0)$ vs $D(n-1)$. Van Vugt’s et al.’s (1994) work is therefore a flawed test of the PD.⁹ Furthermore, they found that the PD model did not fit the preferences of all participants, since a different group who were all commuters did not have a dominant strategy. They

chose to drive if others did not drive, but chose not to drive if others did. In other words they had preferences which corresponded to the Chicken Game.¹⁰

The current study will attempt to discover people's preference orderings by asking participants to choose between pairs of possible outcomes of a PD formulation of the traffic problem. The aim is to present each participant with scenarios that approximate to the following choices: $D(0)$ vs $C(0)$; $D(n-1)$ vs $C(0)$; and $D(n-1)$ vs $C(n-1)$.¹¹ Given that there are three paired comparisons, there are eight possible preference orderings. The only ordering that is compatible with the PD is $D(0) > C(0)$; $C(0) > D(n-1)$; and $D(n-1) > C(n-1)$. The other seven combinations will not fit the PD model. Unless a majority of the sample show the PD pattern, there would be no reasonable grounds for considering the PD as a suitable model for city-centre traffic problems.

Investigating the empirical validity of the PD is important not only to illuminate the psychology of collective decision-making but also to inform public policy. For example if the PD interpretation is correct, there is a 'democratic' argument in favour of state intervention as that would enable the achievement of a social outcome which individuals regard as superior to the one they would reach if they chose freely. Such intervention could bring about $C(0)$ (a traffic free city-centre) which is preferred by every individual to $D(n-1)$ (congestion). If the PD interpretation is incorrect and respondents actually prefer $D(n-1)$ to $C(0)$, government intervention to produce $C(0)$ would be paternalistic rather than democratic.

METHOD

1. Operationalisation of variables

A street survey was the method chosen to maximise the representativeness of the sample cost-effectively. In order to test the hypothesis that the traffic situation is a PD, it was necessary to ask people to state their preferences between options which were comprehensible, plausible and did justice to the structure of the PD. The n -person PD has many outcomes. It was decided to test the PD model by asking respondents to rank those four outcomes of an n -person PD that parallel the four outcomes of the two-person PD. A series of mini vignettes/scenarios was required to encapsulate these four outcomes. The four outcomes are: you drive/others do not drive; nobody drives; you drive/others drive; you do not drive/others do drive. The current traffic situation (i.e. you drive/others drive, $D(n-1)$, the equilibrium) will be expressed as the scenario “you and everyone else drives in the city centre”. The outcome nobody drives, $C(0)$, will be expressed as “no-one drives in the city centre”. In the remaining two outcomes there is still some driving in the city but not by everyone. In order to remain close to the logic of the PD, these two outcomes require scenarios which have “a winner” or “a loser” but eliminate any notion that being permitted to drive is justified in terms of relative merit or need. A lottery scenario was chosen as both comprehensible and suitable, since it involves distributing goods in a way which does not depend on the participants’ intrinsic qualities. For the two outcomes: you drive/others do not drive, and you do not drive/others do drive, the most straightforward expansion of the two-person PD is to select points $D(0)$, “you are the sole winner of the lottery while everyone else is a loser”, and $C(n-1)$, “you are the sole loser of the lottery while everyone else is a winner”. This was the initial operationalisation.

Three pilot studies were necessary to develop acceptable versions of these scenarios. Sixty respondents were interviewed (approximately 20 for each pilot.) These interviews were conducted in the centre of Oxford by two male research assistants. On the basis of the first pilot study the vignette for $D(0)$ was reworded to suggest “a few winners” rather than “one winner” as interviewees considered the notion of one winner driving in the city centre as artificial and absurd. A “Complete Ban” replaced “no-one drives in the city centre” to represent $C(0)$ as some pilot interviewees requested an explanation of how a situation in which “no-one drives” could arise. The vignette $C(n-1)$ was reworded as a mirror image of the replacement vignette for $D(0)$ with “a few losers” (to include the respondent) and “many winners” as the notion of one loser was considered by interviewees to be, if anything, more absurd than that of one winner.

In the second pilot, however, a large number of respondents found the notion of a lottery to pick “a few losers” contrary to their understanding of what a lottery is for. Further, the juxtaposition of two different kinds of lottery in quick succession - one to pick a few winners and one to pick a few losers - confused many respondents. A wording for the analogue of $C(n-1)$ was therefore explored which was consistent with the first lottery to pick “a few winners” and “many losers” (to include the respondent). The third pilot study used this wording. Respondents did not raise any queries about the scenarios.

In none of the three pilots did the concept of city-centre present a problem. A fourth pilot study was also conducted to deal with potential conceptual problems arising from the wording of the vignettes. This is discussed in Appendix 1, section 4.

Following the pilot studies, the final scenarios chosen for use in the main study were as follows, where z represents a few defectors/drivers:

- you and a few others drive/most do not drive in the city centre as decided by a lottery – $D(z)$,
- there is a complete ban on driving in the city centre – $C(0)$,
- the traffic situation stays as it is, i.e. you and everyone else are permitted to drive in the city centre – $D(n-1)$,
- you and most others do not drive/a few do drive in the city centre as decided by a lottery – $C(z)$.

The scenarios have moved some way from the simple archetype of one winner and one loser. But they are still phrased in a way which does no violence to the common-sense assumptions of the PD. These are that people wish to be winners, prefer mutual cooperation to mutual defection, and do not wish to be losers. The phrasing in terms of few winners and many losers retains the crucial underlying concept of winners and losers.

As explained in Appendix 1, the change from a scenario phrased in terms of “one loser” - the respondent, $C(n-1)$ - to one phrased in terms of “many losers” - including the respondent, $C(z)$ - does leave a potential problem with the interpretation of one possible

result. Among the eight possible preference orderings, the only ordering that will support the PD is $D(z) > C(0)$; $C(0) > D(n-1)$; and $D(n-1) > C(z)$. Of the other seven combinations, six will show that the PD model is inapplicable to the traffic situation, but there is one combination which is uninterpretable: $D(z) > C(0)$; $C(0) > D(n-1)$; and $C(z) > D(n-1)$. This appears not to be consistent with the PD model, as $C(z)$, being a loser (among many losers), is preferred to $D(n-1)$, the Status Quo. There are however a number of reasons why someone might prefer being one of many losers to retaining the current congestion, while at the same time preferring the current congestion to being one of only a few losers or the only loser. Hence, as explained in Appendix 1, it is possible that $C(z) > D(n-1)$, but $D(n-1) > C(n-1)$. However, it is also possible that $C(z) > D(n-1)$ could indicate $C(n-1) > D(n-1)$. Consequently the preference ordering $D(z) > C(0)$; $C(0) > D(n-1)$; and $C(z) > D(n-1)$ is uninterpretable. This is unfortunate but the constraints of scenario comprehensibility and acceptability outweigh the theoretically “ideal” operationalisation of the variables. (The Results below show this not to be a problem as very few respondents chose the “uninterpretable” preference ordering.)

2. Method of main study

During May 1998, two female researchers carried out 1000 interviews in shopping areas in Oxford.¹² All interviews were conducted on weekdays. The 587 car owning respondents were asked to choose between the current traffic situation and two possible alternatives - viz. a complete ban of traffic from the city centre or a partial ban to be decided by a lottery such that only the few winners of this lottery would be allowed to drive in the city centre.

They were presented with a series of three pairs of alternatives, and had to state which of each pair they preferred.

Choice 1 There is a lottery for driving in the city centre. **You** and a few others win a ticket - so you can drive in the city centre but most other people can't.

versus Traffic is banned from the city centre completely. Neither you nor anyone else will be permitted to drive in the city centre.

Choice 2 Traffic is banned from the city centre completely. Neither you nor anyone else will be permitted to drive in the city centre.

versus The traffic situation stays as it is. You and everyone else will be permitted to drive in the city centre.

Choice 3 The traffic situation stays as it is. You and everyone else will be permitted to drive in the city centre.

versus There is a lottery for driving in the city centre. A few people win tickets – so they can drive in the city centre. But **you** and most others don't win a ticket.

The order of the three choices was varied, as was the order of the alternatives within each pair. In 50% of the questionnaires, respondents were reminded that if they could not travel into the city centre by car, they would have to walk, cycle or travel by existing public transport. All respondents were asked to indicate on a decile scale ranging from 0% to 100%, how many people in their opinion would voluntarily comply in the event of a national campaign to persuade people to stop using their cars one day in five.

Respondents were also asked how they had travelled into the city that day, and the time spent on the journey. In addition, they were asked whether any concerns they might have about the growth of traffic in Britain were due to its effect on congestion, pollution or neither. Of the sample, 48% were male, 52% were female. Ages ranged from 18-70 years; 48% were aged 35 or under.

RESULTS

The PD interpretation of the traffic problem in this study requires the following preferences :

- at Choice 1: $D(z)$ (You and a few others chosen by lottery drive; Others do not drive) is preferred to $C(0)$ (You do not drive; Others do not drive – called Complete Ban from now on);
- at Choice 2: $C(0)$ (Complete Ban) is preferred to $D(n-1)$ (You drive; Others drive – called Status Quo from now on);
- at Choice 3: $D(n-1)$ (Status Quo) is preferred to $C(z)$ (You and most others do not drive; a few others chosen by lottery do drive).

The following analysis is based on the 551 respondents who owned cars and answered all questions. Order of choice, order of option within choice and the reminder about alternative modes of transport made no difference to respondents' preferences. Table 1 shows that at Choices 2 and 3 the majority of respondents displayed PD preferences: 75% preferred Complete Ban to Status Quo, and 72% preferred the Status Quo to their not driving while a few others are permitted to drive. But they did not display PD preferences at Choice 1:

87% of people preferred a Complete Ban over their being one of the few permitted to drive in the city centre. The PD hypothesis was thus not supported.

TABLE 1 ABOUT HERE

Those few who did show a PD preference at Choice 1 were no more likely to show a PD preference at Choice 3 than those who had not shown such a preference at Choice 1 ($\chi^2 = 0.837$, $df = 1$, $p = 0.37$). In other words, people's desire to be one of the few allowed to drive at Choice 1 did not predict their dislike or fear of not being one of the few allowed to drive at Choice 3.

Respondents' preferences were related to their behaviour - viz. whether they had travelled into the city by car that morning. The key choice point in terms of behavioural prediction was Choice 3 - $D(n-1)$ vs $C(z)$. Those who preferred $D(n-1)$ (the Status Quo) to $C(z)$ (you and most others not driving while a few others are permitted to drive) were significantly more likely to have driven into the city that day ($\chi^2 = 10.49$, $df = 1$, $p = 0.001$).

The data were analysed to see the frequencies with which different possible combinations of choices were made. There are eight possible combinations of choices (see Groups 1-8, Table 2). Four of the combinations occurred rarely. Among these was the Prisoner's Dilemma sequence, found only amongst 12 of the 551 respondents (Group 5).¹³

TABLE 2 ABOUT HERE

Four combinations were comparatively common and between them accounted for 93% of the responses. These were numbered Groups 1 to 4 in descending order of numerical magnitude. Two of these groups (Groups 2 and 4) displayed a dominant strategy - in the former case not to drive, in the latter case to drive. The other two groups (Groups 1 and 3) displayed strategies which were sensitive to the behaviour of others, specifically they would drive if others did so, and would not drive if others did not.

The largest group (Group 1, $n = 264$) showed one of the sequences in which strategies were sensitive to others' behaviour. The choices for this group were Ban over You drive, $C(0)$ over $D(z)$; Ban over Status Quo, $C(0)$ over $D(n-1)$; Status Quo over You do not drive, $D(n-1)$ over $C(z)$. This series of choices suggests a preference for a ban but an unwillingness to give up driving if others carry on driving. The other combination sensitive to others' choices was Group 3 ($n = 77$) displaying the sequence Ban over You drive, $C(0)$ over $D(z)$; Status Quo over Ban, $D(n-1)$ over $C(0)$; Status Quo over You do not drive, $D(n-1)$ over $C(z)$. This combination of choices is the same as that of Group 1 except for the preference for the Status Quo over a Ban at Choice 2.

Of the two combinations which showed single dominant responses, the larger was Group 2 ($n = 128$). This group had the following rankings: Ban over You drive, $C(0)$ over $D(z)$; Ban over Status Quo, $C(0)$ over $D(n-1)$; You do not drive over Status Quo, $C(z)$ over $D(n-1)$.

This combination indicates a desire to reduce the amount of traffic even at the expense of not driving oneself. The last commonly occurring group showed a consistent preference for continuing to drive irrespective of others' behaviour (Group 4, $n = 43$). Their combination of choices was: You drive over Ban, $D(z)$ over $C(0)$; Status Quo over Ban, $D(n-1)$ over $C(0)$; Status Quo over You do not drive, $D(n-1)$ over $C(z)$.

The above four respondent groups (i.e. Groups 1 – 4) were compared for the other variables used in the study: i) age, ii) gender, iii) whether their concern about traffic was primarily due to congestion or pollution, iv) their predictions of how many people would reduce their car use in the event of a national campaign, and v) their own car use on the day on which they were interviewed.

Age and gender showed only marginal effects. Group 4 (those who preferred to continue to drive at all choice points) were more likely to be male ($\chi^2 = 6.947$, $df\ 3$, $p = 0.074$) and younger ($F = 2.451$, $df\ 3/506$, $p = 0.063$) than the other groups. There was a highly significant difference between the groups in the nature of their concerns about traffic-related pollution and congestion. Amongst the 433 respondents who indicated a clear concern about one rather than the other issue, a higher percentage of those in Groups 1 and 2 (all of whom preferred Ban over the Status Quo) were concerned about pollution ($\chi^2 = 19.094$, $df\ 3$, $p < 0.001$). When asked to predict how many people would reduce their car use, the average estimate across all participants was that 28% of people would voluntarily stop using their cars one day in five in the event of a national campaign to persuade them to do so. There was no significant difference in this estimate across the four main groups: their

predictions ranged from 25-29%, revealing uniformly pessimistic expectations about other people's willingness to renounce car use, even for as little as one day a week.

Among the sample of 551 car owners, 58% had used their cars to drive into Oxford on the day of interview. Car use showed significant differences across groups. Group 2 had made less use of their cars than the other three groups ($\chi^2 = 16.141$, $df\ 3$, $p = 0.001$).¹⁴ The other three groups did not differ from each other in car use on the interview day. They did however differ in the length of journey they had taken if they had travelled by car. Group 1 were less likely to have used the car on very short journeys (15 minutes or less) than were the other groups ($\chi^2 = 9.808$, $df\ 4$, $p < 0.05$).

In summary, the Introduction suggested that if the decisions people make about using private cars could be understood as a PD, this would be reflected in the preferences people would show between the pairs of alternatives offered. Only 12 of the 551 interviewees gave the sequence of responses that was unequivocally compatible with the PD preference ordering. However as explained in endnote 13, 10 more people displayed a preference ordering which could conceivably be compatible with the PD. Even with the addition of these respondents, the maximum number of PD respondents could only be 4% (i.e. 22/551, Group 5 plus Group 7). The PD model can therefore be rejected as an explanation of city centre traffic.

FURTHER EMPIRICAL TESTS OF THE SCENARIOS

A possible objection to the above conclusion is that the scenario $D(z)$ was not a sufficiently close proxy for $D(0)$. Pre-testing had led to the rejection of the scenario $D(0)$, an individual able to drive in the city when all others were banned (i.e. with one winner and $n-1$ losers). In pilot studies, “a few winners”, $D(z)$, instead of “one winner”, $D(0)$, was found to be a more acceptable formulation. The absence of support for the PD was, however, so striking that we felt it necessary to carry out two further small-scale tests.

The first test was designed simply to investigate the possible effect of the scenario $D(z)$ used in the survey. It is possible that some of those who preferred $C(0)$, a Complete Ban, to $D(z)$, being one of few winners, might still have preferred $D(0)$, being the only winner, to $C(0)$. Respondents were therefore asked to state their preference between being one of few winners and being the only winner of the lottery. Such a test will check the downward slope of the defection line. Ninety per cent said they would prefer to be one of a few, i.e. $D(z) > D(0)$. Assuming transitivity, it is therefore possible to infer that a respondent with preference $C(0) > D(z)$ would also have had the preference $C(0) > D(0)$. This test, in conjunction with the pilot studies, provides reassurance that the results of the main study can be trusted. The apparent lack of support for the PD was genuine.

Given that people in the main study seemed unwilling to be one of a few winners, a second small-scale test was designed to ascertain how large the group of winners would have to be for the average person to prefer being a winner (i.e. a driver) to being a loser. Fifty respondents were asked to choose whether they wished to be a winner or a loser in a series

of lottery outcomes. Half the respondents were unwilling to accept the privilege of driving unless 30% or more of other drivers were also allowed to drive. The results of this small-scale study supported the main study. Very few respondents showed PD responses (i.e. electing to be a winner in circumstances in which they would be the only winner). Sampling over a greater range of lottery outcomes in no way increased the support for the PD model of the traffic problem. (Fuller details of these two studies are given in Appendix 2.)

DISCUSSION

Is the traffic problem a PD ?

It appears that the PD does not provide an adequate conceptualisation of the traffic problem. While most of the interviewees showed PD preferences at Choices 2 and 3, i.e. they preferred a Complete Ban over the Status Quo, and the Status Quo over “a few drive but you are not one of them”, a majority of these respondents deviated from PD preferences at Choice 1. Only 72 out of 551 (13%) chose being one of the few allowed to continue driving in the city over a Complete Ban. A great majority should have made this choice had they been guided by the self-interest motive implicit in a PD interpretation of people’s continued reliance on the car. The hypothesis that decisions that affect the traffic problem can be understood as a PD was therefore decisively rejected.

Is there a game which fits the traffic problem better?

The current data strongly suggest that no single game structure underlies the traffic problem. Van Vugt (1996) has already suggested this possibility. In our data, there were four distinct sequences of choices which characterised the four main groups, accounting for 93% of the

respondents. This is an important finding in itself as the application of any one simple game model to social dilemmas, such as car use, assumes that everyone or nearly everyone has the same preference ordering.

The most common sequence of preferences in our data, exhibited by the 264/551 (48%) respondents constituting Group 1, was Complete Ban over being one of the few allowed to drive; Complete Ban over Status Quo; and Status Quo over not being one of the few allowed to drive. This set of choices fits the preferences that characterise the “Assurance Game” (sometimes called the “Trust Game”) one of whose main features is that people do not display a single dominant strategy: their strategies are dependent on others’ behaviour. Members of Group 1 elected not to drive if others did not drive, but to drive if others did, as in the Assurance Game (AG).¹⁵ (See Figure 2 for a version of the Assurance Game.)

In the Assurance Game the most preferred outcome for each individual is cooperation by all, but this outcome will only be reached if each individual is assured that others will also cooperate. Sen (1967) introduced the term Assurance Game and carefully distinguished it from the PD as a model for collective decision making.¹⁶ In the Assurance Game, the best strategy in the event of others cooperating is cooperation, but the best strategy is non-cooperation if others do not cooperate. Expectations concerning others’ behaviour are therefore critical. The AG has two equilibria, the cooperative and the non-cooperative, of which the former is preferred by each individual to the latter. The PD has a unique non-cooperative equilibrium that is ranked lower in individual preference orderings than the non-equilibrium cooperative outcome.¹⁷

The idea that people would behave cooperatively if they felt assured that everyone else, or a sufficiently large number of other people would also do so, has been suggested by Whitelegg(1997) in his discussion of the transport crisis. He asserts that the majority are in favour of traffic reduction and an environmentally friendly transport policy but they are suffering from ‘pluralistic ignorance’ (Darley & Latane, 1968) as they do not realise that their view is so widely shared. From this set of assumptions arises Whitelegg’s concept of ‘critical mass’: the notion that bringing to people’s notice the fact that many others share their strong preference for traffic reduction will lead to voluntary cooperative behaviour.¹⁸ However, as reported in the Results, our interviewees were very pessimistic about others’ willingness to reduce their car use voluntarily in response to a government campaign, believing that less than a third of them would do so.

The preferences of Groups 2, 3 and 4

As pointed out in the Results, the choices of people in Group 3 (77/551) were dependent on the behaviour of others, i.e. they did not have a dominant strategy.¹⁹ The choices of Group 3 were structurally like those of Group 1 in that both preference orderings, if held by all, would lead to the same two equilibria. The difference between Group 1 and Group 3 was the ranking of Complete Ban vs Status Quo. While Group 1 preferred a Complete Ban to the Status Quo, Group 3 preferred the converse. In other words, people in Group 3 were behaviourally indistinguishable from those in Group 1 in that they wished to drive if others did, and did not wish to drive if others did not. Attitudinally, however, the two

groups were quite distinct, as Group 3 preferred retention of the Status Quo to a Complete Ban, while the converse was true for Group 1.²⁰

The other two main groups had dominant strategies. Group 2 (128/551) had a dominant strategy not to drive. They exhibited preferences that are consonant with a “green” outlook.²¹ This outlook was also manifest in their behaviour as this group had by far the lowest rate of car use on that day’s journey into Oxford.²² Group 4 (43/551) had a dominant strategy which showed in a preference for continuing to drive at every choice point.²³ In the sense that the preferences of Groups 2 and 4 were unaffected by the behaviour of others, they were structurally comparable to the PD sequence. Nevertheless there were also important differences. The “green” preferences of Group 2 differed from PD preferences in that they had a different dominant strategy, i.e. at each choice point they preferred the “not drive” option. The “driver” preferences of Group 4 displayed the PD dominant strategy (viz. drive rather than not-drive), but unlike the PD group they preferred the Status Quo over a Complete Ban.²⁴

A discussion of possible limitations

1. The scenarios revisited

We have already discussed and eliminated potential difficulties created by the wording of the scenarios in terms of few winners and many losers, in testing whether the traffic problem is a PD (see Appendix 1). The same difficulties must still be addressed in relation to whether the traffic problem is an AG. As explained in Appendix 3, the phrasing of $C(z)$ in terms of “many losers” could conceivably have led respondents who really had Chicken Game

preferences to state a preference for $D(n-1)$, the Status Quo, over $C(z)$ while still preferring to be the only person not driving when everyone else was driving, $C(n-1)$ over $D(n-1)$.

The fourth pilot study however showed that almost everyone preferred being one of many losers to being the sole loser. So it is extremely unlikely that the number of respondents categorised as AG was artificially inflated in this way. It is in fact more likely that the number categorised as AG is an underestimate because some respondents may have been classified as Green when they actually had AG preferences. In other words they expressed a preference for $C(z)$ over $D(n-1)$ when they might not have felt a similar preference for $C(n-1)$ over $D(n-1)$. (See Appendix 3 for fuller discussion of these issues.)

2. Were respondents truthful?

One conclusion of this study is that people's preference orderings are not similar enough to be captured by any single canonical game structure. The game structure which captures the preference orderings of the largest proportion of car owners is the Assurance Game. The Prisoner's Dilemma Game, in contrast, fitted the preferences of only 2% of the respondents. Our interpretation of these findings is that respondents are dismayed at the prospect of being losers rather than greedy to be winners in the traffic situation.

It might be argued that the failure to find a PD pattern of preferences was due to the fact that interviewees were likely to be too embarrassed to select the self-interested option at Choice

1. Such an argument rests on the assumption that self-presentation would influence responses in a research interview. Any concern of the respondents with making a good impression should however have been minimal, as the interviews were anonymous and

conducted *en passant* in a public place, and the interviewers had no identifiable connection with any interest group. The force of the criticism is further weakened by the evidence of the preference that people expressed at Choice 3. Despite the fact that 75% of respondents said that they favoured a reduction in traffic in the city at Choice 2, only 28% stated at Choice 3 that they were willing to lose the right to drive (the idealistic and altruistic option). Had self-presentation been an over-riding motive during the interview, this latter number would have been much higher.

The above criticism of interview data implies that people do not say what they really think for reasons such as embarrassment. In fact embarrassment is important precisely because in real life it influences people's actions as well as their words. During the interview a large number of respondents stated that they would not like to win the right to drive as depicted in Choice 1 because winning such a privilege, even in a lottery, would make them feel both embarrassed and uncomfortable.²⁵ The results of the second small-scale study carried out after the main study bore this out since most respondents were unwilling to be winners unless thirty per cent or more of drivers were also winners. In contemplating being amongst a few winners respondents in both studies were worried by the "unfairness" of the outcome and/or feared the social resentment and ostracism they might suffer. Thus the interviews strengthen our belief that respondents replied truthfully in stating their preference at Choice 1.

Galluci and Perugini (2000) state that "Mainstream economics is still reluctant to adopt concern for other's outcomes as a motivational source ... [However] ... Some experimental economists have recognized ... the importance of incorporating the other's outcome into

individual preferences”.²⁶ Our data reinforce the worth of this orientation amongst experimental economists. In fact, this perspective has a long history. At the end of the nineteenth century German and Austrian economists hotly debated the influence of factors other than self-interest on economic decisions.²⁷

The detailed wording and conceptualisation of the scenarios for the $D(0)$ and $C(n-1)$ options could have affected respondents’ willingness to state relatively selfish preferences. The scenarios presented respondents with a lottery that they had already won, $D(z)$, or lost, $C(z)$. If fear of envy deterred respondents from choosing $D(z)$ it is possible that the notion of a repeated lottery (in which players have the chance of a different outcome on a later occasion) rather than a one-off lottery might have increased the number of respondents prepared to select the $D(z)$ option. However, the issue is not clear-cut: while the envy factor would be reduced in a repeated lottery, the value of the prize (driving for an indefinite rather than a shorter period in uncongested streets) would also be diminished. Indeed, the choice of a one-off lottery over a repeated lottery can be defended on the very ground that the latter would reduce the surface pay-off differentials implied in the archetypal PD.

IMPLICATIONS

1. Explanation of the traffic problem

The fact that the interviewees’ patterns of choices fell into four main groups indicates that the traffic problem cannot be understood as the collective outcome of any single set of preferences. But it is possible to provide an informal account of how the various preferences might interact to produce the current traffic problem. Because 10% of car

owners (Drivers and PD) have a dominant strategy to drive, they will drive regardless of what others will do. A further 14% (group 3) prefer the Status Quo to a Complete Ban which suggests that they will be happy to continue to drive even on congested roads. Further, since these 14% will drive if others do, it is likely that even a small number of persistent drivers will be sufficient to lead them to take to their cars. So, 24% of car owners will continue to use their cars. Although the largest single group - the 48% in the AG - prefers a Complete Ban to the Status Quo, they are nevertheless unwilling to give up driving if others (and indeed only a few others) are still driving. Hence they too will probably use their cars if the 24% already discussed use theirs. Only Group 2, the Greens, will make the non-contingent choice not to drive, and they represent a small minority. This means that even though three quarters of car owners prefer a Complete Ban to the Status Quo, the fact that the majority of them are unwilling to give up driving if others continue to drive results in the current traffic problem.

2. Public policy

We now address the policy implications of our findings. The study was directed at testing whether people have PD preferences and found that they did not. It found that a near-majority (48%) of car-owners have AG preferences. But the respondents were far from uniform in their preferences: 50% of them had preferences other than PD or AG. The relevance of these mixed preferences is examined in due course.

It seems appropriate to begin by contrasting the public policy implications of AG and PD preferences. This discussion deals with three questions: Is there a case for state

intervention? If there is, what form should it take? Would intervention pose problems of implementation?

The case for state intervention

With the PD, laissez-faire leads to market failure: the Nash equilibrium (the “Status Quo”) is Pareto-inefficient. Each individual choosing freely ends up in a situation which is less desirable from his or her standpoint than the cooperative outcome. State intervention (e.g. in the form of a traffic-ban) would be Pareto-improving, i.e. would make each individual better off.

With the AG too, there is a clear case for state intervention but the argument is more complex. The AG has two possible equilibria, the cooperative and the non-cooperative. The former is Pareto-optimal and it is arguable that it would be achieved spontaneously. If everybody believed that everyone else had unchanging AG preferences, and trusted that everyone would act on them, individuals would act cooperatively and the cooperative solution would be achieved without coercion. In this vein Sen (1967) argued in explaining the AG model (in a discussion of the optimum savings problem) that, “To get out of the problem all that is necessary is that each individual is assured that the others are doing the ‘right’ thing, and then it is in one’s own interest also to do the ‘right’ thing. No enforcement is necessary.” (p 122). Whitelegg (1997) argues along similar lines in the traffic context. He thinks that there is a role for state intervention but only to promote people’s understanding of each other’s views.²⁸

The conclusions from this line of thinking are over-optimistic for a number of reasons. Even if everyone shared the ideal of traffic reduction, and AG preferences were almost universal, people might not believe this to be the case (cf. Whitelegg, 1997). Secondly, people who start with AG preferences and act co-operatively may get discouraged when they see others behaving non-cooperatively.²⁹

It follows from the above that it is unrealistic to assume people would spontaneously gravitate away from the non-cooperative towards the cooperative equilibrium. There is therefore a case for state intervention as in the PD. As in the PD, intervention would not be paternalistic. It would be designed to give people what they want but cannot achieve through decentralised decision making.³⁰

The form of state intervention

Given that there is a case for state intervention, what form should it take? With the PD, a traffic ban would be Pareto-superior to the equilibrium outcome (the Status Quo). But there is a more subtle implication of the PD model that underlies much economic thinking on this topic.

The cooperative solution (traffic ban) is Pareto-superior to laissez-faire but it is not necessarily Pareto-optimal. In the two-person PD, the cooperative outcome is Pareto-optimal only if

$$2C(0) > C(1) + D(0).$$

If this condition were not met, a mix of cooperation and defection would be Pareto-optimal.

The n -player extension of the above condition is

$$nC(0) > xD(x-1) + (n-x)C(x), \quad \forall x \in \{1, 2, \dots, n\}.$$

If the n -person PD were an accurate representation of city-centre traffic, it is entirely possible, indeed likely, that this condition would not hold, especially if, as surveys suggest, the perceived benefits of driving are high enough that the $D(x)$ curve lies well above the $C(x)$ curve for much of its length. If the condition does not hold, public intervention should aim to move people from the non-cooperative outcome to the appropriate mix of cooperation and defection. If people only care about *ex ante* utility, the mix could be achieved by a one-off lottery that gives an appropriate number of people the right to drive. More reasonably, if *ex post* utility is what people seek to maximise, a repeated lottery that results in each person driving some of the time would be an attractive solution. This solution is approximated in some countries where in certain towns there are schemes to permit people to drive only on specified days of the week (Matsoukis, 1985; Button, 1998). It is however well-known that such schemes are subject to considerable evasion.

Economists' usual prescription for inner-city congestion and pollution is not a traffic ban but a tax on vehicle use that reduces traffic to the point where the marginal social benefit from driving equals its marginal social cost. The model underlying this reasoning is consonant with the n -person PD. If individuals had identical tastes and wealth, a tax set at the appropriate level would lead to the optimum reduction in traffic by inducing each person to drive less (the analogue in this case to an appropriate mix of cooperation and defection). Of course, in the real world, tastes and wealth differ which means that such taxes affect people

differentially. In this case, the optimality of the tax can only be argued on the assumption, frequently made in economic analysis, that “income distribution can be separately looked after”, i.e. that efficiency and distribution can be treated independently.

With the PD, a traffic ban would constitute an improvement over laissez-faire but it is unlikely to be Pareto-optimal. Pareto optimality would probably require a tax on vehicle use. The AG is crucially different in this respect. The case for a tax that produces “an appropriate mix of cooperation and defection” collapses if people have AG preferences. In the AG, the cooperative equilibrium is unambiguously Pareto-optimal, so a traffic ban is the optimal policy.³¹ Moreover, since the cooperative outcome is at the top of people’s preferences, it has no problematic distributive implications even if tastes and wealth differ (unlike a ban or tax in the PD).³²

The implementation of state intervention

In the PD, unilateral defection is the dominant strategy for each individual, so there would be an ever-present tendency to free ride and evade after public intervention is in place. A ban or a tax would thus be expensive to monitor and to police. If people had AG preferences, government intervention (in this case a traffic ban) could work more effectively, and at lower cost. Once the ban was established, there would be no tendency to free-ride or defect, so enforcement would not be expensive.

Intervention when there are heterogeneous preferences

The fact that 52% of the car-owning sample have non-AG preferences greatly complicates the choice of public policy. The crucial fact to concentrate on is that 71% of our car-owning respondents have a traffic ban at the top of their preference rankings.³³ In addition, 85% of the non-car-owning respondents who were interviewed in the survey ranked a Complete Ban above other possible options. A traffic ban would give 80% of people their first choice. This does involve over-riding the wishes of the remainder. The extent to which the latter dislike a ban varies. Only “drivers” (group 4) have a Complete ban at the bottom of their preference order and they represent only 4.5% of the total sample (i.e. including both those who do and do not own cars).

The fact that a car-free city centre would provide more than four-fifths of people what they want most, provides a democratic argument for a traffic ban when there are heterogeneous patterns of preferences. It is hard to say anything more precise about public policy without making detailed and debatable assumptions about individual and social utility functions.

If a traffic ban is agreed to be desirable, implementation would not be a difficult problem, given the distribution of preferences in our sample. Groups 1 and 2 would welcome a ban and Group 3 would acquiesce in it. This leaves only 10% of car owners (principally Group 4 – Drivers) who would strongly want to beat the ban. Even so, policing the ban will have to continue to prevent an erosion of assurance required by Groups 1 and 3.

There is no reason to suppose that the survey results are not applicable to many cities with definable city-centres. In particular, the preponderance of AG and Green preferences

accords with the visible success of many interventions to ban traffic from the centres of many European cities (Uhlig, 1979; Hass-Klau, 1990).³⁴ Moreover, as Hass-Klau & Dowland (1994) state in their detailed report about the introduction of traffic exclusion in the German town of Luneburg, one of the most important lessons was that “momentum has to be established by doing it quickly ... a slow and cautious pace does not ... lead to consensus but ... gives the critics endless opportunities to prevent anything from happening at all.” (p. 47).

3. Game theory and social dilemmas.

Impressed by the elegance of the PD theory, social policy theorists have too casually assumed that the PD provides an adequate analogy for real-world social dilemmas, such as the traffic problem or, more recently, panic-buying of fuel (Hallsworth & Tolley, 2000). Many critics of experimental games have, of course, pointed out their lack of “ecological validity” (e.g. Argyle, 1991). Furthermore, n -person dilemmas, where n is large, have a degree of complexity which makes them irreducible to the simplicity of two-person games. Even the game theorist Rapoport (1970) argued against generalisation from laboratory games, believing that “the events in the laboratory and those of the cosmos do not have the same laws”. In our view, the danger is not so much in the transfer of ideas from the laboratory but in the untested generalisation of these ideas.

The current research has strongly suggested that the traffic situation is not to be understood as a PD or indeed as any single game. Using a survey technique to address a pressing social dilemma has allowed us to illuminate some of the different considerations that inform

individuals' decisions about driving. This is an excellent example of the point made by Pruitt and Kimmel (1977) that game-theorist laboratory experimenters have much to learn from the non-laboratory world.

CONCLUSIONS

The current study, conducted in an applied as distinct from an artificial laboratory setting, has enabled us to conclude that the PD is definitely not the appropriate model to explain city centre traffic congestion and pollution. A better model is the AG. It is fear of being a loser rather than desire to be a winner that motivated many of the interviewees to keep on driving. Indeed, they were afraid of the possible negative consequences associated with success and feared that winning the right to drive might lead to envy and resentment. Traffic congestion and pollution are likely to be less a matter of people pursuing their selfish interests and more a matter of their lack of assurance and trust in others.

Our study also suggests two more general conclusions: i) The fascination of the PD, whether in laboratory experiments or in economic and social theory, may have blinded people to other possible game theoretic explanations of social phenomena, ii) Lack of social cooperation may be due to lack of trust in others rather than raw self interest, a line of thought that has significant implications for social and economic policy.

TABLE 1

The number and percentage of respondents who chose the alternatives offered at choice points 1 – 3.

<i>Number and percentage of respondents who chose each alternative (N=551)</i>		
<u>Choice 1</u>		
$D(z)$	72 13%	<i>There is a lottery for driving in the city centre. You and a few others win a ticket - so you can drive in the city centre but most other people can't.</i>
$C(0)$	479 87%	<i>Traffic is banned from the city centre completely. Neither you nor anyone else will be permitted to drive in the city centre.</i>
<u>Choice 2</u>		
$C(0)$	414 75%	<i>Traffic is banned from the city centre completely. Neither you nor anyone else will be permitted to drive in the city centre.</i>
$D(n-1)$	137 25%	<i>The traffic situation stays as it is. You and everyone else will be permitted to drive in the city centre.</i>
<u>Choice 3</u>		
$D(n-1)$	396 72%	<i>The traffic situation stays as it is. You and everyone else will be permitted to drive in the city centre.</i>
$C(z)$	155 28%	<i>There is a lottery for driving in the city centre. A few people win tickets – so they can drive in the city centre. But you and most others don't win a ticket.</i>

TABLE 2

Choices offered to and made by respondents.

	Choice 1	Choice 2	Choice 3	N	%	Designation
	<u>You drive/ Ban $D(z)/C(0)$</u>	<u>Ban/ Status Quo $C(0)/D(n-1)$</u>	<u>Status Quo/ You do not drive $D(n-1)/C(z)$</u>			
<hr/>						
Group						
1	Ban/Drive $C(0) > D(z)$	Ban/SQ $C(0) > D(n-1)$	SQ/Not drive $D(n-1) > C(z)$	264	47.9%	assurance
2	Ban/Drive $C(0) > D(z)$	Ban/SQ $C(0) > D(n-1)$	Not drive/SQ $C(z) > D(n-1)$	128	23.2%	green
3	Ban/Drive $C(0) > D(z)$	SQ/Ban $D(n-1) > C(0)$	SQ/Not drive $D(n-1) > C(z)$	77	14.0%	group 3
4	Drive/Ban $D(z) > C(0)$	SQ/Ban $D(n-1) > C(0)$	SQ/Not drive $D(n-1) > C(z)$	43	7.8%	drivers
5	Drive/Ban $D(z) > C(0)$	Ban/SQ $C(0) > D(n-1)$	SQ/Not drive $D(n-1) > C(z)$	12	2.2%	PD
6	Ban/Drive $C(0) > D(z)$	SQ/Ban $D(n-1) > C(0)$	Not drive/SQ $C(z) > D(n-1)$	10	1.8%	group 6
7	Drive/Ban $D(z) > C(0)$	Ban/SQ $C(0) > D(n-1)$	Not drive/SQ $C(z) > D(n-1)$	10	1.8%	chicken/PD
8	Drive/Ban $D(z) > C(0)$	SQ/Ban $D(n-1) > C(0)$	Not drive/SQ $C(z) > D(n-1)$	7	1.3%	group 8
<hr/>						
All	Ban/Drive 479/72 87%/13% $C(0)/D(z)$	Ban/SQ 414/137 75%/25% $C(0)/D(n-1)$	SQ/Not drive 396/155 72%/28% $D(n-1)/C(z)$	551		

N.B.	Drive (<u>You</u> are one of the few who drive/Others do not)	$D(z)$
	Not drive (<u>You do not</u> drive/A few others do drive)	$C(z)$
	Status Quo (All drive as now)	$D(n-1)$
	Complete Ban (No-one permitted to drive)	$C(0)$

APPENDIX 1: Theoretical implications of the scenarios

Implications of the chosen wording for PD interpretations of responses.

The wording was as follows:

- $D(z)$: There is a lottery for driving in the city centre. **You** and a few others win a ticket - so you can drive in the city centre but most other people can't.
- $C(0)$: Traffic is banned from the city centre completely. Neither you nor anyone else will be permitted to drive in the city centre.
- $D(n-1)$: The traffic situation stays as it is. You and everyone else will be permitted to drive in the city centre.
- $C(z)$: There is a lottery for driving in the city centre. A few people win tickets – so they can drive in the city centre. But **you** and most others don't win a ticket.

The above wording of the winner/loser scenarios results in their moving from extreme positions (see Figure A.1). Whereas $D(0)$ is at the highest extremity of the defection line, phrasing the $D(0)$ scenario in terms of a few winners rather than just one winner moves its location to $D(z)$, where z indicates “a few” defectors/drivers. $D(z)$ remains above $C(0)$ even after this shift as a consequence of the assumption that the pay-off to the individual from driving remains very high while only a few others drive. Similarly, whereas $C(n-1)$ is at the lowest extremity of the cooperation line, phrasing the scenario in terms of many losers moves its location to $C(z)$. As drawn, $D(n-1)$ remains above $C(z)$ even after this large shift. In other words, the figure is drawn on the assumption that the benefits to the individual of driving in a congested city centre not only outweigh the benefits of not driving in the same circumstances but also outweigh the benefits of not driving even if there has been a significant reduction in the number of drivers.

The main study, utilizing these scenarios, unambiguously tests the class of n -person PD models which incorporate these assumptions. It is however necessary to recognise potential difficulties associated with the final wording of the scenarios as a test of the PD model in its full generality. The difficulties that arise at Choice points 1 and 3 can be grouped under four headings:

At Choice 1:

1. Does $C(0) > D(z)$ imply $C(0) > D(0)$?
2. Does $D(z) > C(0)$ imply $D(0) > C(0)$?

At Choice 2:

3. Does $C(z) > D(n-1)$ imply $C(n-1) > D(n-1)$?
4. Does $D(n-1) > C(z)$ imply $D(n-1) > C(n-1)$?

1. Does $C(0) > D(z)$ imply $C(0) > D(0)$?

Given the assumptions on which Figure 1 and Figure A.1 were based, $C(0) > D(z)$ implies $C(0) > D(0)$. In Figure A.2 the $C(x)$ and $D(x)$ lines are drawn as in the earlier two figures. Now suppose that the cooperation line is not $C(x)$ but $C\phi(x)$ so that $C\phi(0)$ is very close to $D(0)$. In that case, we could have $C\phi(0) > D(z)$ but $D(0) > C\phi(0)$. We would then wrongly reject the PD at the first choice point. But it seems reasonable to rule out the possibility of $D(x)$ and $C(x)$ being very close by assumption 1 (page 4) which we regard as highly plausible. It follows from this assumption that $D(0)$ and $C(0)$ are far apart, i.e. for an individual with PD preferences, the payoff from driving greatly exceeds the payoff from not driving when no one else drives.

The same problem could arise in a different way. Suppose the cooperation line remains $C(x)$ but the defection line is $D\phi(x)$ with a steep downward slope. We could now have $C(0) > D\phi(z)$ but $D(0) > C(0)$. Again we could be misled into rejecting the PD model. We rule this out by the assumption, which we regard as eminently plausible, that for individuals with PD preferences the payoff from driving does not decline steeply if there are only a few other drivers. In summary we are assuming that the defection and cooperation lines are sufficiently far apart at $D(0)$ and $C(0)$, and that the defection line does not slope steeply downwards between $D(0)$ and $D(z)$.

Bringing the above considerations together, what we are asserting is that it would be most unlikely that an individual with PD preferences would prefer a Complete Ban over being “one of the few permitted to drive in the city centre”, but nevertheless prefer being the “only one permitted to drive in the city centre” over a Complete Ban. Therefore we are confident that the wording of the $D(z)$ scenario is suitable.

2. Does $D(z) > C(0)$ imply $D(0) > C(0)$?

If the defection line is downward sloping as would seem plausible for an individual with PD preferences, $D(z) > C(0)$ clearly implies $D(0) > C(0)$. It seems highly implausible that the defection line for a person with PD preferences could be upward sloping. If, however, a case could be made out that the defection line slopes upward between $D(0)$ and $D(z)$, $D(z) > C(0)$ does not imply $D(0) > C(0)$. This would make the $D(z) > C(0)$ preference uninterpretable. The results of the main study will show that this is not a problem since only 13% of respondents prefer $D(z)$ to $C(0)$.

3. Does $C(z) > D(n-1)$ imply $C(n-1) > D(n-1)$?

In Figure A.1 the $D(x)$ and $C(x)$ lines were drawn sufficiently far apart so that $D(n-1) > C(z)$, and therefore by the assumption of a downward sloping $C(x)$ curve,

$D(n-1) > C(n-1)$. Suppose the $D(x)$ and $C(x)$ lines are drawn closer together as in Figure A.3. We now have $C(z) > D(n-1)$ though $D(n-1) > C(n-1)$. We would then wrongly reject the PD at this choice point. Note, however, that if the cooperation line was in fact $C(x)$ with a flatter slope, we have $C(z) > D(n-1)$ and $C(n-1) > D(n-1)$ i.e. we would correctly reject the PD at this choice point. Since we do not know the true shape of the $C(x)$ line, $C(z) > D(n-1)$ is uninterpretable as a test of PD preferences.

4. Does $D(n-1) > C(z)$ imply $D(n-1) > C(n-1)$?

If the cooperation line is downward sloping, as would seem plausible for an individual with PD preferences, $D(n-1) > C(z)$ does imply $D(n-1) > C(n-1)$. If however the cooperation line slopes upwards in the range $C(z)$ to $C(n-1)$, $D(n-1) > C(z)$ does not imply $D(n-1) > C(n-1)$. The preference $D(n-1) > C(z)$ would then be uninterpretable. It is theoretically possible that the cooperation line is not monotonically downward sloping but slopes upward as x becomes larger. Van Vugt et al.'s (1994) Chicken Game interpretation of the traffic problem alerts us to this possibility. See Figure A.4.

In Figure A4, by construction, $D(0) > D(z) > C(0)$, and $C(0) > D(n-1)$. At the third choice point $D(n-1) > C(z)$, but $C(n-1)$ could be $>$ or $<$ $D(n-1)$ depending on whether the cooperation line from $C(z)$ to $C(n-1)$ is taken to be bold or dotted. Thus $D(n-1) > C(z)$ would be uninterpretable as it is compatible with the underlying game being Chicken or PD depending on whether $C(n-1)$ is above or below $D(n-1)$ respectively.

To investigate whether our study is subject to this problem, we conducted a fourth pilot to ascertain the slope of the cooperation line between $x = z$ and $x = n-1$. Sixty six respondents, who were all car drivers, were asked to state which of two options they preferred. There were three pairs of options in total, but each respondent was asked about only one of the pairs. Two of the three pairs used the scenario to be used in the survey - viz. being one of many people not permitted to drive in the city centre (i.e. one of many losers), when some people could continue to drive (i.e. there were a few winners). This was offered as an option in comparison either to being one of a few losers or to being the only loser. For completeness, one third of the respondents were asked to state their preference between being the only loser and being one of a few losers.

Among the respondents, 85% preferred being one of many losers to being one of a few losers, while 96% preferred being one of many to being the only loser. Furthermore, 91% respondents preferred the idea of being one of few losers to being the only loser. In other words, the more losers (and fewer winners) there were, the more content the respondents were to be losers. We therefore conclude that the cooperation line slopes downward as in Figures A.1 to A.3 and that the interpretation problem discussed immediately above cannot arise. Note that the results of this pilot also throw further doubt on van Vugt et al.'s (1994) interpretation of the traffic problem as a Chicken Game.

The conclusion from these tests and the preceding arguments can be stated as follows. In the survey respondents will be asked to make choices between three pairs of alternatives: $D(z)$ vs $C(0)$; $C(0)$ vs $D(n-1)$; and $D(n-1)$ vs $C(z)$. Given that there are these three choice points, there are eight possible combinations of preference. The only preference

ordering that will support the PD is $D(z) > C(0)$; $C(0) > D(n-1)$; and $D(n-1) > C(z)$. Of the other seven combinations, six will show that the PD model is inapplicable to the traffic situation. The seventh (viz. $D(z) > C(0)$; $C(0) > D(n-1)$; and $C(z) > D(n-1)$) will be uninterpretable for reasons given above.

In summary this survey will enable us unambiguously to test the class of n -person PD models as depicted in Figure A.1. As for the remaining class of n -person PDs:

- i) There are some n -person PDs that we have argued are implausible in the case of the traffic problem (see 1. and 2. above);
- ii) There are some n -person PDs that we have shown empirically in pilot 4 to be inapplicable to the traffic problem (see 4. above);
- iii) There are some n -person PDs which the main study can neither confirm nor reject (see 3. above). If our results show that this class of n -person PDs is large, further empirical work will be necessary. (In fact, in our survey, this class turned out to be very small.)

APPENDIX 2: Post-survey empirical tests of the scenarios

Test 1

Method

Thirty respondents (car drivers with demographic characteristics similar to the original sample) were asked whether they preferred a Complete Ban, $C(0)$, to the Status Quo, $D(n-1)$ in the city centre (as previously phrased). They were also asked to state which of two options they preferred. One option was the scenario used in the survey, viz. being one of few lottery winners – $D(z)$, and the other option was a scenario phrased exactly as $D(0)$ – being the only winner. The order of these tasks was varied.

Results

Ninety per cent of respondents said they would prefer to be one of a number of winners rather than the only winner, i.e. $D(z)$ was preferred to $D(0)$. Since it was found in Test 1 and in the main study that $C(0)$, a Complete Ban, was overwhelmingly preferred to $D(z)$, it follows, assuming transitivity, that the formulation of the scenario as $D(0)$ (one winner) instead of $D(z)$ (few winners) would have produced still less support for a PD interpretation of the traffic problem.

Discussion

If $D(z) > D(0)$, the implication is that $D(x)$ is not monotonically downward sloping, specifically that the $D(x)$ curve is upward sloping between $D(0)$ and $D(z)$, though it must eventually slope downwards since by the PD hypothesis, $D(0) > D(n-1)$. In this case it is possible that we could have $D(z) > C(0)$; $C(0) > D(n-1)$; and $D(n-1) > C(z) > C(n-1)$ even though $C(0) > D(0)$. In other words, it is possible that we may misclassify some people as having PD preferences, though they in fact have Group 1 preferences. This bias would strengthen our results as it would reduce the size of the PD group and increase the size of Group 1.

Test 2

Method

Fifty respondents (car drivers with demographic characteristics similar to the original sample) were asked, as in the first small-scale study, whether they preferred a Complete Ban, $C(0)$, to the Status Quo, $D(n-1)$, in the city centre (as previously phrased). They were also asked to envisage a lottery for driving in the city centre with a variable number of winners and losers. They were asked to choose whether they would wish to be a winner or a loser at a series of 11 lottery outcomes. The order of tasks was varied. The lottery outcomes ranged from ‘one winner and everyone else a loser’ to ‘one loser with everyone else a winner’. The intermediate points were expressed as winner/loser percentages, viz. 1/99, 5/95, 15/85, 30/70, 50/50, 70/30, 85/15, 95/5, 99/1. This way of testing the representation of the model shown in Figure 1 allows investigation of many more points on the graph than in the pairs of scenarios used in the main study.

Results

Eighty two per cent (41/50) of respondents preferred a Complete Ban to the Status Quo, i.e. a preference in line with the PD. Only three of these gave the full PD response (i.e. electing to be a winner in circumstances in which they would be the only winner). Sixty per cent (30/50 of the sample) preferred a Complete Ban to the Status Quo and only chose to be a winner as long as they were not the only winner. Furthermore, 57% of this group (17/30) only chose to be a winner provided at least 30% of others were also winners. Altogether 25 of the 50 respondents chose to be a winner and have the right to drive only if at least 30% were also winners.

Discussion

The predominant response in both the main and smaller studies was (i) to prefer a Complete Ban to the Status Quo, and in the second smaller study, (ii) to wish to have the right to drive only if a substantial number of other people did so too.

Because of the greater range of points which can be investigated, the second smaller study's way of testing the model is in some ways, more satisfactory than the scenario method. Such an approach, however, would have been unsuitable for the main study for at least two reasons. Tversky and Kahneman (1973) have demonstrated that people are prone to a variety of errors when dealing with percentages. Secondly, a series of questions of this kind runs the risk of alienating potential respondents as they find the task repetitive or suspect they are being tricked into some kind of reasoning task. This problem is particularly acute in roadside interviews.

APPENDIX 3: Possible misclassification of respondents

Table 2 shows the eight possible combinations of preference resulting from the three choices offered. We are confident that we have not underestimated the number of respondents with PD preferences for the following reasons: Groups 3,4,6 and 8 could not have PD preferences as they unambiguously failed the PD test by preferring the current traffic situation to a Complete Ban, $D(n-1) > C(0)$. Groups 1, 2, 3 and 6 fail the PD test at the first choice point, since they preferred $C(0)$ to $D(z)$. Not only is it a plausible assumption that this implies $C(0) > D(0)$, but this was confirmed by post-survey test 1. This leaves Groups 5 and 7. Group 5 is the PD group, because the PD tests were satisfied at all three choice points. Group 7 is problematic. It satisfies the PD tests at the first two choice points. However, as explained in Appendix 1, $C(z) > D(n-1)$ is ambiguous as regards the relative ranking of $D(n-1)$ and $C(n-1)$. The preferences of Group 7 were therefore compatible with both the PD and Chicken Games. In the survey this problem turned out to be of little empirical quantitative significance. Even if all the respondents with the Group 7 ranking were included in the PD category, the latter would only account for 4% of respondents.

The potential difficulties with regard to misclassification must also be addressed in relation to whether the traffic problem is an AG. If the cooperation line were not monotonically downward sloping, it would be possible that some respondents were misclassified as AG when in fact their preferences corresponded to the Chicken Game. In other words it would be possible for people to prefer the Status Quo, $D(n-1)$, to being one of many losers, $C(z)$, and nevertheless prefer being the sole loser, $C(n-1)$, to the Status Quo, $D(n-1)$. But it has already been shown in pilot study 4 that this is not so (see Appendix 1). The co-operation line is downward sloping in the relevant range. This downward slope also rules out the possibility that some “greens” may have been misclassified as AG.

There remains the further possibility that some people may have been misclassified as “green” when they had AG preferences. This could be the case given the wording of the scenarios and a monotonically downward sloping cooperation line. The minority of respondents (28%) who accepted being losers at Choice 3 might have been even less numerous had the wording been different (i.e. a scenario where the respondent was still a loser but amongst fewer losers). These respondents may have been attracted to the $C(z)$ option precisely because it permitted so few to drive. It is possible that the attraction of some of these respondents to $C(z)$ was not due to a dominant strategy not to drive. This leads to the conclusion that some of the group labelled “green” may actually have had the contingent strategy which typifies the assurance group. This would mean that assurance preferences typified over 50% of the sample.

It is also conceivable that some respondents classified as “greens” might in reality have had Chicken Game preferences, since $C(0) > D(z)$ could in principle allow $D(0) > C(0)$. But post-survey test 1 has ruled this out by showing that $D(z) > D(0)$ (see Appendix 2).

Using the pilot and post-survey tests, it is possible to consider in this exhaustive way whether respondents may have been misclassified for each of the remaining groups. But the

low numbers of respondents in these groups renders presentation of this material unnecessary. The only other significant misclassification that could occur on account of the scenarios is that some respondents identified as “drivers” may belong to Group 3.

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END NOTES

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² “The Tragedy of the Commons” is another model commonly used to explain these phenomena. But this ‘tragedy’ itself is generally modelled as an n -person PD. For example, see Dawes, Delay & Chaplin (1974) who model the decision to pollute as an n -person PD.

³ It is generally assumed by planners and others concerned with the environment, that for most towns or cities, the concept of the “city-centre” is unproblematic (Royal Commission on Environmental Pollution, 1994; Hass-Klau, 1990). For complex conurbations, such as London or Los Angeles, the matter may not be so clear-cut as such cities are multi-centred.

⁴ In this paragraph and in the rest of this paper, ‘equilibrium’ is used as a short-hand for ‘Nash equilibrium’, viz. a situation in which each player is in his/her preferred position given the choices of the other players. The PD has one equilibrium and it is not ‘Pareto-optimal’. A Pareto-optimal situation is defined as one in which one player cannot improve his/her position without worsening that of another player. In the PD, the equilibrium is $DaDb$. The non-equilibrium position $CaCb$ is Pareto-superior to $DaDb$, but it may or not be Pareto-optimal. See endnote 29.

⁵ Throughout this paper we employ the terms “cooperative” and “non-cooperative” in their everyday sense. Of course, these terms also refer to alternative modes of game theoretic analysis as defined by Von Neumann & Morgenstern (1944). It should be emphasised that our analysis is purely “non-cooperative” in its technical meaning. Reference to cooperative outcomes or equilibria does not imply that binding agreements are available.

⁶ C or D denotes the strategy of the individual, and notation within brackets refers to the number of others who defect (drive). The $C(x)$ and $D(x)$ notation is used to refer to payoff or outcome depending on context.

⁷ The two key features of the two-person PD would be as follows in the new notation:

- It is a dominant strategy to defect, so that

$$D(0) > C(0), \text{ and } D(1) > C(1)$$

- Mutual cooperation is preferred to mutual defection, so that

$$C(0) > D(1)$$

From each player's point of view, the ranking of the four outcomes would be:

$$D(0) > C(0) > D(1) > C(1).$$

The cooperative outcome is $C(0)$, and the equilibrium outcome is $D(1)$.

⁸ The general PD model does not require that the $D(x)$ and $C(x)$ lines be monotonically downward sloping. But the relative positions of $D(0)$, $C(0)$, $D(n-1)$ and $C(n-1)$ imply that these lines must eventually slope down. Note that we have drawn the $D(x)$ and the $C(x)$ lines as parallel straight lines, but that is purely for convenience. (For a discussion of the general PD model see Appendix 1.)

⁹ Van Vugt (1996) found that respondents with environmental concerns (mainly students) had a dominant strategy not to drive. To infer that their preferences were of the PD rather than "green" variety, van Vugt would have had to show that they preferred congestion, $D(n-1)$, to traffic-free streets, $C(0)$!!

¹⁰ The model that van Vugt (1996) considered to have high explanatory value in describing the behaviour of commuters was the "Chicken Game" ($D(0) > C(0) > C(n-1) > D(n-1)$). In this game, players do not have dominant strategies and their decisions are dependent on others' behaviour. This is prototypically seen as a two-person game in which two motorists are driving head-on towards each other down a single-track road. In this case, mutual defection (i.e. both continuing to drive) will result in

the worst possible outcome of a collision. Van Vugt et al. (1994) tested this model. Their study is vulnerable to the criticism that commuters were led to the given responses as they were presented with scenarios that i) contained ideal conditions for the use of public transport (i.e. living 2-3 minutes walk from a station at either end of the journey to work), and ii) suggested that if everyone else drove it would be quicker to travel by public transport, but that if everyone else went by public transport it would be quicker to drive. The demand characteristics of these scenarios would appear to be overwhelming. It is important to note again that van Vugt et al. (1994) did not ask the critical question whether $C(0)$ is preferred to $D(n-1)$. Thus van Vugt et al. (1994) could not reliably establish that the commuter respondents had Chicken Game preferences. Furthermore, the Chicken Game cannot provide a plausible explanation for the traffic problem as it implies that drivers concerned about congestion only use their cars because they think others will not do so, and change to public transport when they perceive others using their cars. If this were the case, continuous traffic congestion should not arise.

¹¹ To get a PD ordering of preferences of four outcomes from the 3 choices, we need to assume transitivity, i.e. if x is preferred to y and y is preferred to z , x is preferred to z . This is surely an innocuous enough assumption if the chain of transitive reasoning is short. Transitivity of preference is assumed throughout this paper.

¹² The interviews were conducted prior to the pedestrianisation of parts of Oxford city-centre in 1999.

¹³ Group 7 showed the preference ordering $D(z)$ over $C(0)$; $C(0)$ over $D(n-1)$; and $C(z)$ over $D(n-1)$. The most straightforward interpretation of this sequence is that it is the Chicken Game. However, as already explained in Appendix 1, under some interpretations, it is possible to argue that the phrasing of $C(z)$ in terms of few winners and many losers implies that a preference for $C(z)$ over $D(n-1)$ is not necessarily incompatible with the PD model. On this interpretation, Group 7 could therefore be regarded as ambiguously belonging to the PD group. This however does not create any great improvement in support for the PD model as the addition of the 10 Group 7 respondents would only increase the overall

percentage of PD answers to 4%. Thus the uninterpretability problem alluded to in the Method and Appendix 1 was of little quantitative significance.

¹⁴ This difference simply echoes the trend noted above that those who chose the option of not being one of the few allowed to continue driving in the city at Choice 3 ($C(z) > D(n-1)$) were significantly less likely to have driven into the city that day. This choice characterises Group 2 and none of the other three major groups.

¹⁵ Group 1 made the following choices in the survey (see Table 2):

$$C(0) > D(z); C(0) > D(n-1); D(n-1) > C(z)$$

Assuming transitivity, these choices are compatible with 3 complete orderings of the 4 outcomes.

$$C(0) > D(z) > D(n-1) > C(z)$$

$$C(0) > D(n-1) > D(z) > C(z)$$

$$C(0) > D(n-1) > C(z) > D(z)$$

All these orderings are consistent with the AG on the assumption, justified in Appendix 1, that $D(z)$ and $C(z)$ are good proxies for $D(0)$ and $C(n-1)$.

¹⁶ Van Vugt (1996) mentioned the “Trust Game” as a possible model for decision-making about car use, but surprisingly did not test it.

¹⁷ The PD has one equilibrium, $D(n-1)$, which is not Pareto-optimal. The AG has two equilibria, $C(0)$ and $D(n-1)$, one of which - viz. $C(0)$ - is Pareto-optimal.

¹⁸ Whitelegg (1997) labels the traffic problem as a PD. But his description of motorists’ decisions, emphasising that people do not have a dominant strategy, suggests that he should have classified it as an AG.

¹⁹ Group 3 made the following choices in the survey (see Table 2):

$$C(0) > D(z); D(n-1) > C(0); D(n-1) > C(z)$$

Assuming transitivity, these choices are compatible with 3 complete orderings of the 4 outcomes. On the assumption, justified in Appendix 1, that $D(z)$ and $C(z)$ are good proxies for $D(0)$ and $C(n-1)$, all these orderings are consistent with the logic of an AG, except that the Status Quo is preferred to a Complete Ban.

²⁰ In game theoretic terms, these two games have the same equilibria, viz. $C(0)$ and $D(n-1)$, but with the reverse Pareto ranking.

²¹ The survey results yield the following choices for Group 2 (see Table 2):

$$C(0) > D(z); C(0) > D(n-1); C(z) > D(n-1)$$

Assuming transitivity, these choices are compatible with 5 complete orderings of the 4 outcomes. On the assumption, justified in Appendix 1, that $D(z)$ and $C(z)$ are good proxies for $D(0)$ and $C(n-1)$, all these orderings show a dominant strategy not to drive. This reflects a green mentality with varying degrees of self-regard and regard for others.

²² It is possible that the Group 2 figure may underestimate those in the population with green preferences since at least some of the non-car owners in our sample may be ex-car owners who have given up their car for “green” reasons.

²³ Group 4 made the following choices in the survey (see Table 2):

$$D(z) > C(0); D(n-1) > C(0); D(n-1) > C(z)$$

Assuming transitivity, these choices are compatible with 5 complete orderings of the 4 outcomes. On the assumption, justified in Appendix 1, that $D(z)$ and $C(z)$ are good proxies for $D(0)$ and $C(n-1)$, all these orderings show a dominant strategy to drive. This indicates that Group 4 respondents are “committed drivers” with libertarian attitudes of varying degrees of strength.

²⁴ If everyone had Group 2 (green) preferences the equilibrium would be $C(0)$ (i.e. a Complete Ban) and it would also be Pareto-optimal. Similarly, if everyone had Group 4 (drivers) preferences the equilibrium would be $D(n-1)$ (i.e. the Status Quo) and it would again be Pareto-optimal. In both these cases, no social dilemma is created.

²⁵ The lottery formulation was deliberately chosen to remove any suspicions of deservingness from the scenarios. If anything, the lottery increases a bias in favour of finding a PD result because on the face of it a lottery is 'fair' since everyone has an equal chance of winning. This should reduce any sense of guilt if one is a winner or resentment if one is a loser.

²⁶ Some might argue that it is possible to differentiate people's "raw" (self-interested) preferences from their modification due to social factors. This implies a model in which people initially make a raw decision and only subsequently make a socially influenced decision. Within psychology there is much debate and research about whether decision-making is serial or parallel. There is no *a priori* reason to assume that decision-making about car use is serial. Nor is there any reason to assume that, if the decision process were serial, consideration of self-interest would come first. It is perfectly conceivable that some people might be sufficiently concerned about their social status, respectability or "face" that their first consideration would be the range of socially acceptable alternative courses of action open to them. Only subsequently would they make the supposedly "raw" self-interested choice from among this set. It is at least equally probable that social and self-interested concerns interact with each other in people's consideration of a given option. One should not of course assume that social concerns are necessarily moral or unselfish, but they may be either or both.

It is important not to take for granted the idea that there is a privileged set of "raw" self-interested preferences which have priority in decision-making. When this idea is taken for granted as an article of faith it becomes unfalsifiable.

²⁷ Schmoller and the German historical economists enjoyed a lengthy period of dominance in German economic thought between the 1870s and the early years of the twentieth century. They “objected to the *a priori* deductive or theoretical approach of classical economics, and demanded in its place an *a posteriori* inductive or empirical approach. They accused the classicists of atomism and economic egoism – of basing their analyses upon the acts of individual economic agents in abstraction ... from anything but narrow self-interest – and called instead for due acknowledgement of the force of the organic structures of community (*Gemeinschaft*) ... and the complexes of social and individual interests ... which impinge upon economic action” (Bryant, 1985, pp 59-60).

²⁸ This view gains some empirical support from two distinct areas of research in experimental social psychology. In laboratory studies of repeated trial PDs, it is commonly found that cooperation is increased if participants can communicate (Deutsch, 1958). Experimental studies of groups have also shown that a vocal minority who support an innovative point of view for which the majority already feel some sympathy can lead the whole group to change its behaviour (Moscovici, 1980; Mugny, 1982). This change seems to depend on the majority’s recognising that most other people do in fact share their sympathy for this view (Clark & Maass, 1990).

²⁹ Moreover, as Williams (1995) has warned, it would be unwise to draw non-interventionist conclusions from an AG model of social dilemmas because the necessary conditions for communication and social influence are not easily found in large, complex societies. Furthermore, even though the phenomenon of minority influence is attractive to those of a liberal persuasion, psychological research has repeatedly shown that majority influence tends to be far stronger (Latane & Wolf, 1981). This implies that communication of shared attitudes will not be sufficient, and that even a willingness to change on the part of a few people will not initiate a general change.

³⁰ This is in complete contrast to, say, the imposition of a traffic ban if people had a preference to continue driving come what may as some of our respondents (Group 4) did. In such circumstances,

state intervention would be designed to produce paternalistically an outcome valued by the government with no concern for individual preferences.

³¹ It could be argued that the cooperative outcome could be reproduced by a tax that reduces driving sufficiently to create the assurance that is needed for everyone not to drive, which is in any case their first preference. In equilibrium, the revenue from the tax would be zero and the desired result would be produced more directly by a ban.

³² The AG model provides some insight into why public opinion is often strongly opposed to the use of pricing (DoE, 1994; Lex 1999, RAC, 2000). Those with AG preferences would willingly give up driving if they are assured that others will not drive, but feel aggrieved if others drive and in those circumstances wish to drive themselves. Therefore if there is an intervention which allows some people to drive and denies this right to others, it will be unpopular and resisted. Individuals may have AG preferences because they are committed to equality of access to roads, or merely because they fear others' envy. Of relevance here is Jones' (1998) suggestion that in Britain "The urban road network (unlike motorways) is implicitly viewed as a general purpose public space which all are free to share ... it represents one of a diminishing number of situations where people are treated equally." (p. 269)

³³ The 71% is comprised of 48% AG and 23% Greens. It is logically possible that some of our Greens preferred $C(z)$ to $C(0)$ while preferring $C(0)$ to both $D(z)$ and $D(n-1)$. (see endnote 21). But such masochistic preferences are psychologically highly unlikely.

³⁴ This follows a long tradition: the ancient Romans also adopted extreme measures for traffic reduction by banning most categories of vehicle from the city centre during daylight hours.

Fig. 1 n-person Prisoner's Dilemma Game

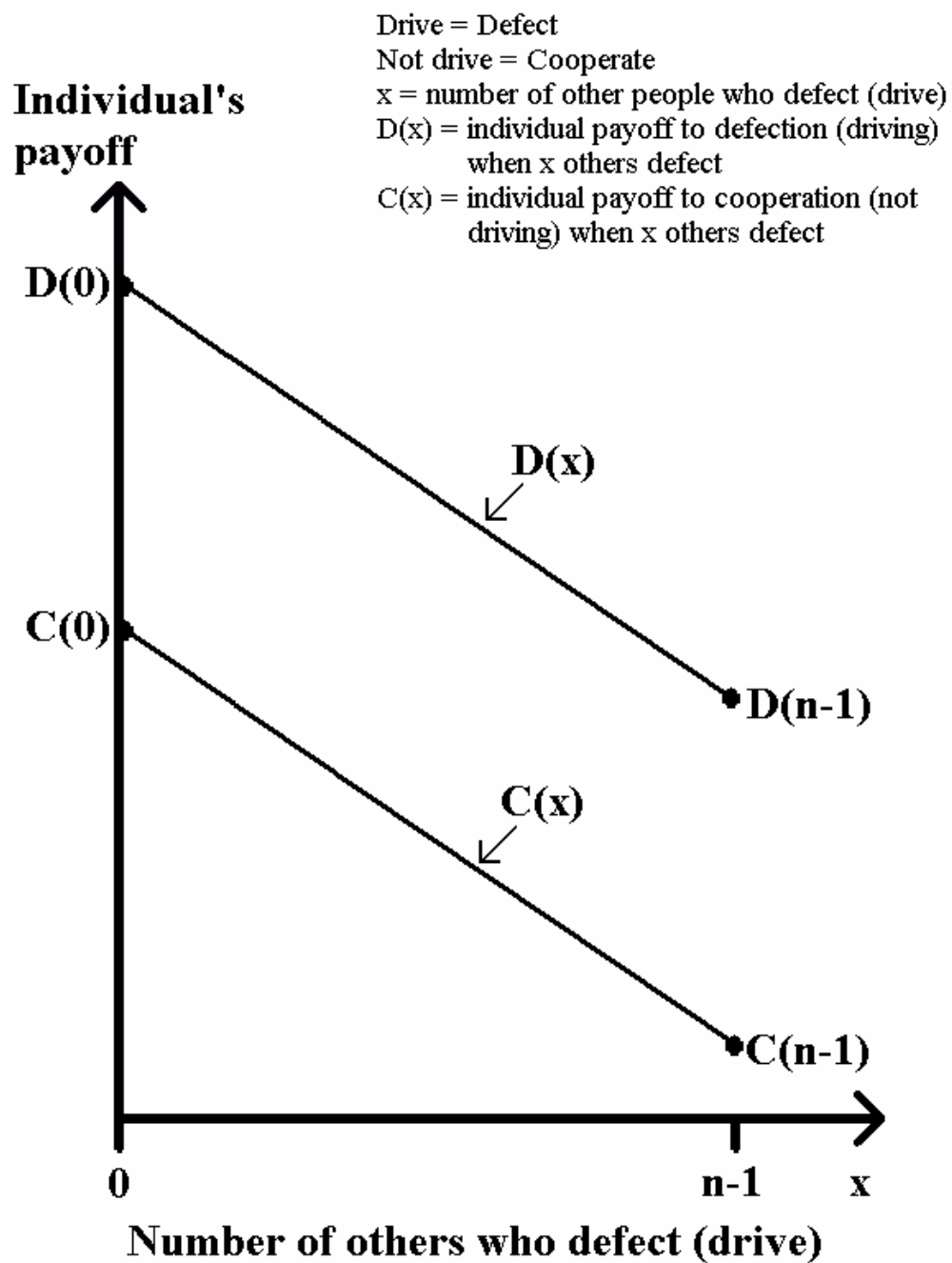


Fig. 2 Assurance Game and the Traffic Situation

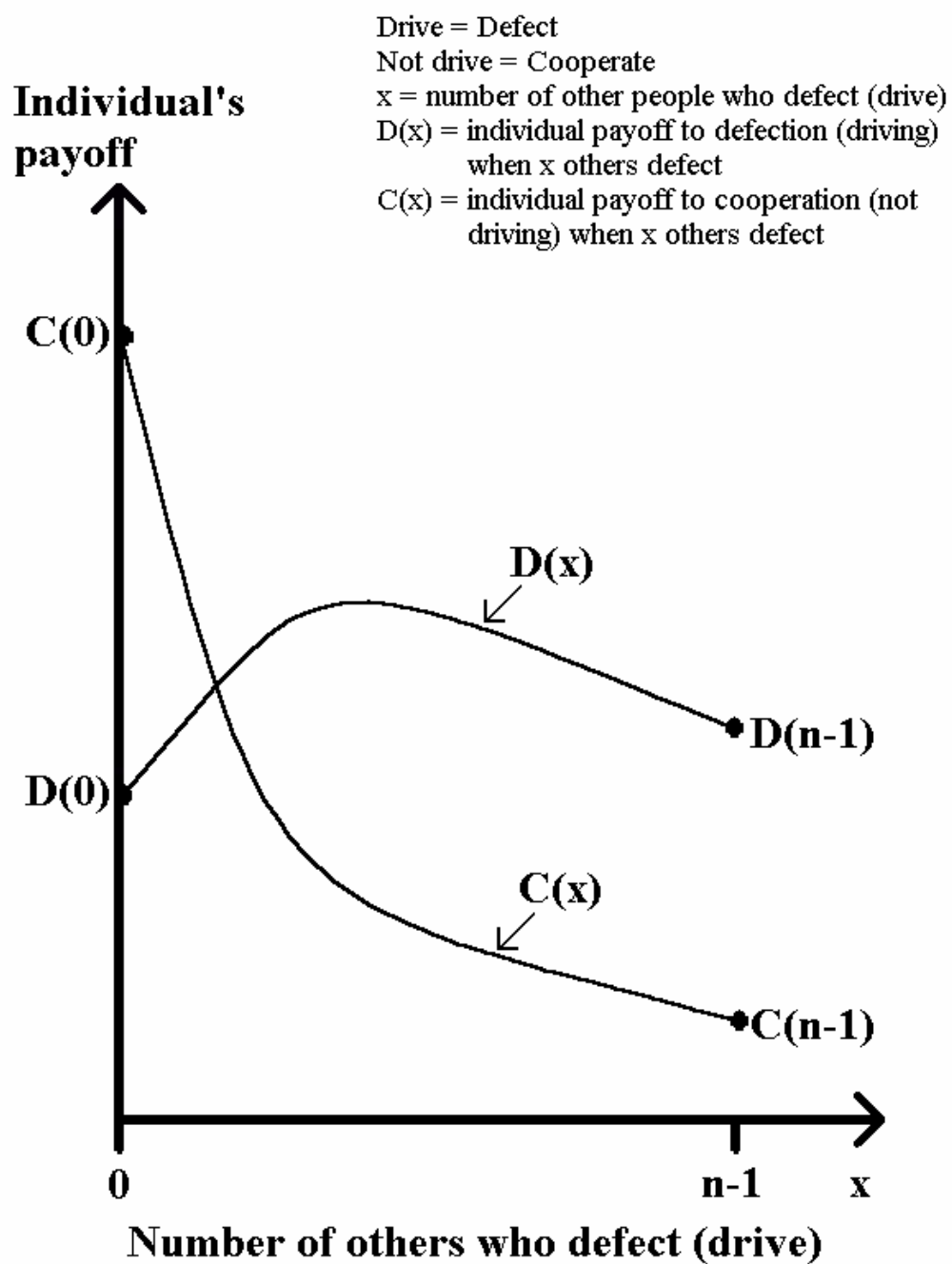


Fig. A.1 n-person Prisoner's Dilemma Game
showing positions of $D(z)$ and $C(z)$

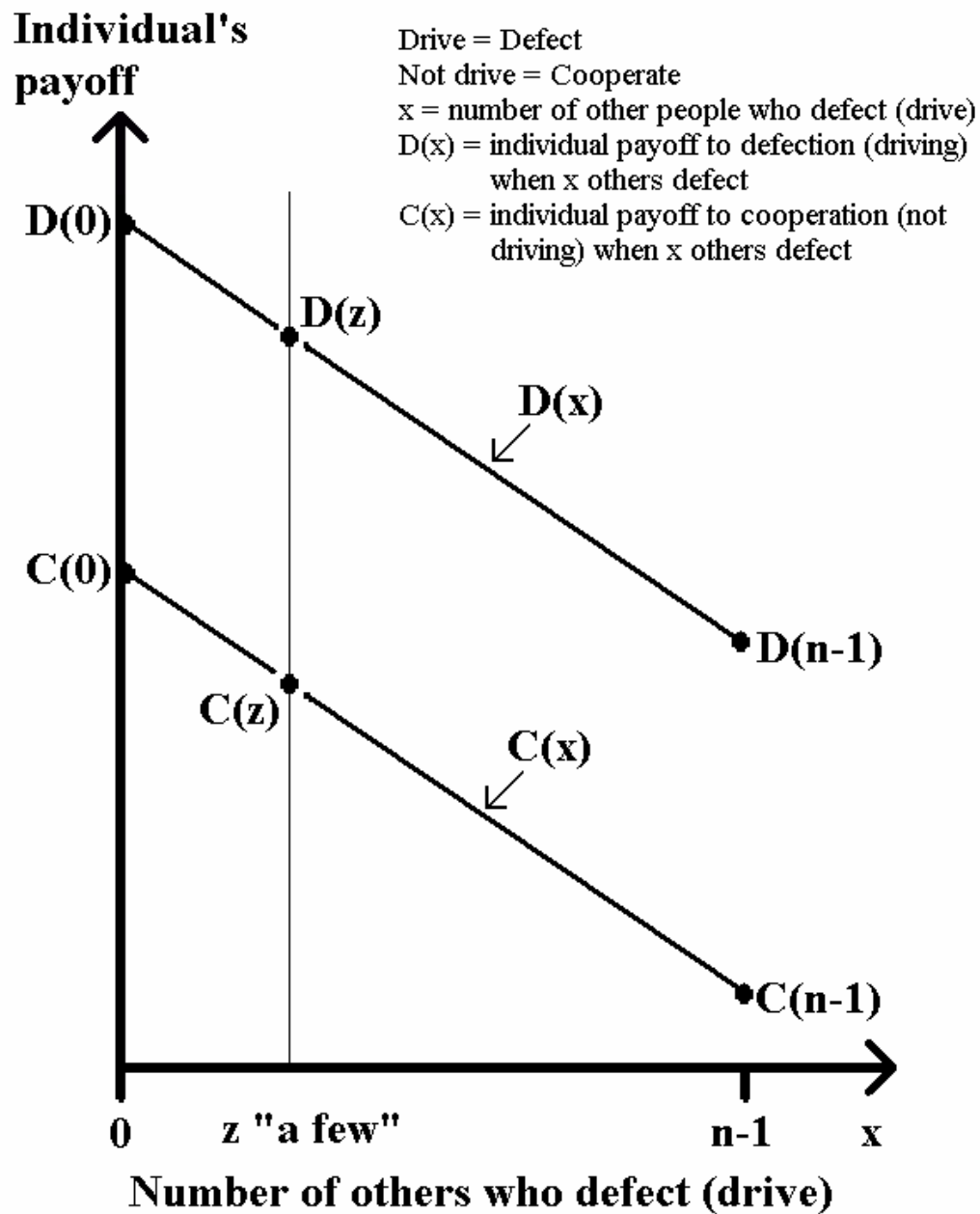


Fig. A.2 Alternative possible cooperation and defection lines relevant to Choice 1

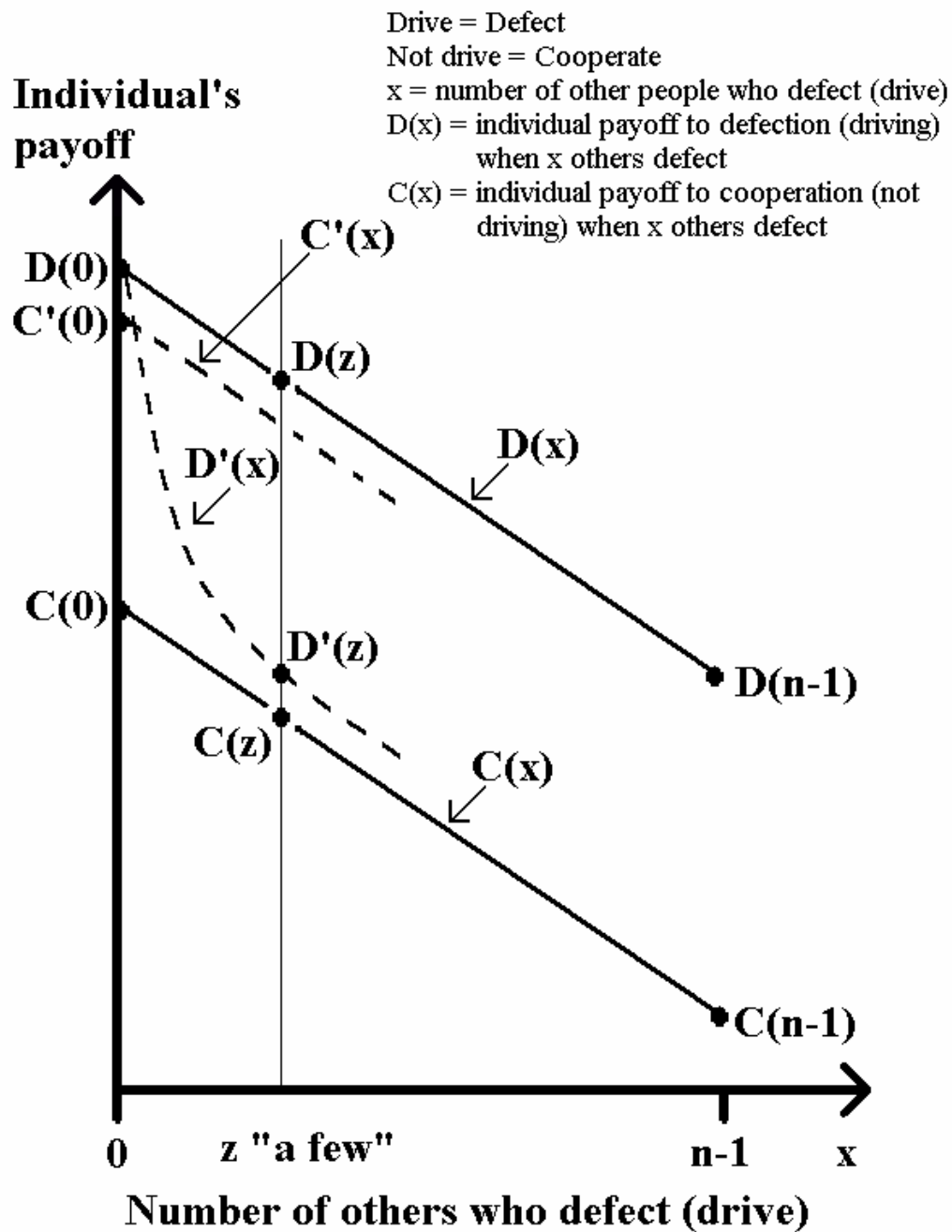


Fig. A.3

**Alternative possible cooperation
lines relevant for Choice 3**

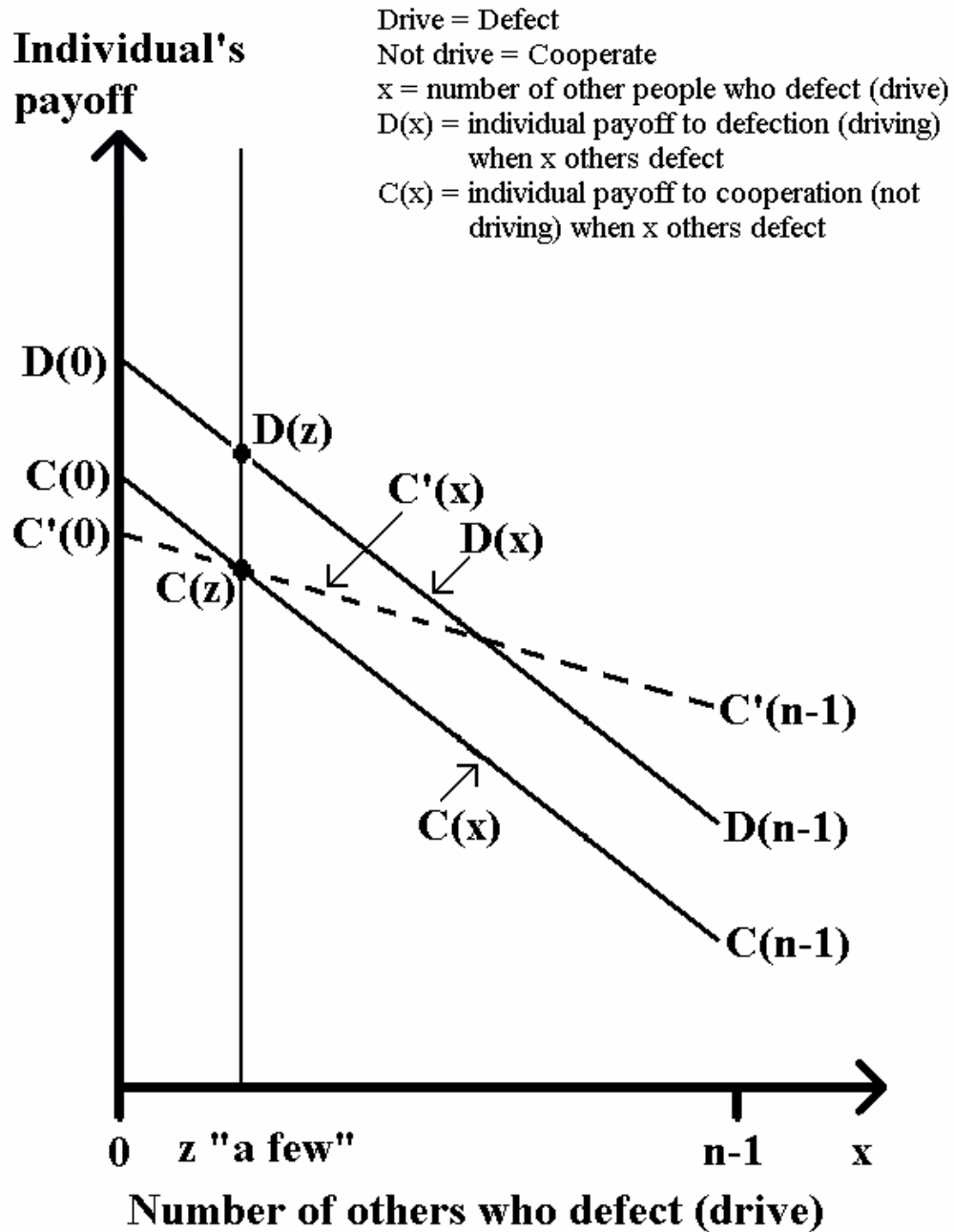


Fig. A.4 Alternative non-monotonic cooperation lines relevant for Choice 3

