Ambient-Based Policy Instruments: The Role of Recommendations and Presentation

John Spraggon and Robert J. Oxoby

We explore the effects of recommended play and the presentation of payoff information on behavior in an ambient-based policy instrument experiment. Specifically, we test the effects of recommended play (via a description of marginal decision making) and a payoff table on the behavior of individuals facing an ambient-based policy instrument. We find that recommended play and the presentation of a payoff table increases the use of the socially optimal strategy, thereby increasing efficiency. These results suggest that providing decision makers with a richer description of the decision making environment significantly reduces decision error, significantly improving the efficiency of ambient-based policy instruments.

Key Words: ambient pollution instruments, recommended play, experiments

In the literature on non-point source pollution, there is mixed evidence on the ability of ambient pollution mechanisms to implement efficient outcomes. For example, while authors such as Suter, Vossler, and Poe (2009), Vossler et al. (2006), Cochard, Willinger, and Xepapadeas (2005), Alpizar, Requate, and Schram (2004), Poe et al. (2004), and Spraggon (2002, 2004a) provide experimental evidence that mechanisms based on the work of Segerson (1988) can result in the implementation of group pollution targets, this implementation occurs in an inefficient manner in terms of which polluters are reducing their emissions. Some have argued theoretically (e.g., Shortle and Horan 2001) that these mechanisms are generally less successful in reducing emissions to targets than other means and may be appropriate only in simple cases (Weersink et al. 1998).

Cabe and Herriges (1992) argue that it is fundamental for the regulator to educate the polluters as to the importance of compliance with the instrument. In this paper, we consider whether the inefficiency of these instruments in the laboratory is due to problems inherent in the instrument or problems with the manner in which participants approach these instruments. That is, we seek to determine if we can improve the ability of ambient pollution instruments to induce individuals to make socially optimal decisions by better educating the subjects about the marginal nature of optimal decision making in terms of their final payoff.

There has been a concerted effort by a number of researchers to determine the feasibility of implementing ambient-based policy instruments using controlled laboratory experiments (Suter, Vossler, and Poe 2009, Spraggon and Oxoby 2009, Oxoby and Spraggon 2008, Vossler et al. 2006, Cochard, Willinger, and Xepapadeas 2005, Alpizar, Requate, and Schram 2004, Poe et al. 2004, and Spraggon 2002, 2004a). Broadly speaking, these studies show that under a wide range of assumptions (e.g., number of polluters, heterogeneity of polluters, subject pool, and communication) these instru-

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ments can be effective at controlling the ambient level of pollution. However, these studies also suggest that in a field setting there may be significant losses in efficiency due to the inequitable distribution of emissions reduction among firms, which may have real effects on the structure of the industry [Suter, Vossler, and Poe (2009); see Giordana and Willinger (forthcoming) for a recent survey].

We hypothesize that the inability of these instruments to fully implement efficient outcomes may be due in part to their relative complexity and, more importantly, a lack of understanding among subjects regarding how these instruments affect payoff (in the lab) and profits (in the field) along the lines suggested in Chou et al. (2009). Our experiments are related to public good experiments [see Ledyard (1995) for a survey], particularly those with interior Nash equilibria (Laury and Holt 2008). This literature suggests that decisions typically fall between the equilibrium and the total endowment of the group and that decisions in dominant strategy environments are less variable than decisions in non-dominant strategy environments. Anderson, Goeree, and Holt (1998) show that this decision pattern is consistent with the quantal response decision error model and altruism. Spraggon (2004b) shows that this result extends to the ambient pollution instrument experiments as well.

To address this line of inquiry, we focus on improving the provided description of these instruments in order to highlight the incentives they create. In previous experiments, the inefficiencies observed with the implementation of exogenous targeting instruments with heterogeneous agents have been attributed to larger capacity subjects being able to use these instruments to force smaller capacity subjects out of the industry (Suter, Vossler, and Poe 2009, Spraggon 2004b).

Such deviations from predicted Nash behavior may be due to subjects not understanding the game (Chou et al. 2009), non-standard preferences [e.g., social preferences (see Spraggon 2004b)], and beliefs about other behavior [for example, Cason and Sharma (2007) and Camerer and Fehr (2006)]. The use of recommended play and alternate presentations of payoff information allows us to disentangle these causes of behavior. For example, if individuals' behaviors do not change with the provision of recommended play (as in Oxoby and McLeish 2004), this suggests that behavior is due to either preferences embodying motives beyond pure payoff maximization or beliefs about the preferences of others (Cason and Sharma 2007). On the other hand, if individuals' behaviors change based on recommendations with the presentation of payoff information (as in Chou et al. 2009, Charness, Frechette, and Kagel 2004, and Croson and Marks 2001), this suggests that decision error is affecting individuals' choices and that this added information reduces these errors.

In the current experiment we describe the incentives created by these instruments by emphasizing that there exists a dominant strategy where the benefit to the player from increasing his or her decision number (emission) by one unit is equal to the cost of doing so, thereby reducing decision errors and making clear the incentives provided by the instrument. We also include a payoff table to further clarify the decision making environment. This paper builds on previous work discussed in Spraggon and Oxoby (2009) and Oxoby and Spraggon (2008). Spraggon and Oxoby (2009) show that when subjects are familiar with the concepts of game theory they are much more likely to choose decisions that are consistent with the predictions of standard theory. Oxoby and Spraggon (2008) show that describing the marginal decision making nature of the problem results in significantly more compliance but does not have a significant effect on efficiency. Our procedures follow these studies by exploring whether the efficiency of two ambient pollution mechanisms can be improved when participants are provided with both information on marginal decision making and a payoff table.

The effects of a detailed presentation of the incentives created by an exogenous targeting instrument and a payoff table are striking: we observe significant changes in individuals' behavior with this information. Specifically, individuals' decisions more closely match Nash predictions on average, and we observe greater aggregate efficiency. This suggests that the deviations we observe from theoretical, wealth-maximizing decisions are due not to alternate preference specification, but rather to errors. Moreover, our results demonstrate that the careful presentation of information to users of these instruments can reduce these errors, resulting in the implementation of more efficient outcomes. This emphasizes the potential for recommendations (as in Croson and Marks 2001) and payoff tables (as in Charness, Frechette, and Kagel 2004) to guide behavior in (relatively) complex decision environments. On a broader scale, these results increase the degree of optimism regarding the efficacy of exogenous targeting instruments in the field and support the importance of education as discussed in Cabe and Herriges (1992).

Experimental Design

Our decision environment is based on the standard linear exogenous targeting instrument (e.g., Segerson 1988). In this environment, an exogenous group target is set and individuals are taxed and (potentially) subsidized when group decisions exceed or fall below this target. The tax and subsidy rates are chosen such that the mechanism implements the socially optimal outcome as a Nash equilibrium. Such instruments are often used in the study of environmental problems (non-point source pollution) and team production environments.

In our experiment participants choose decision numbers with payoffs based on a private component and a group component. The private payoff function B_n is increasing in a participant's decision number and given by

$$(1) \qquad B_n(x_n) = 25 - 0.002(x_n^{\max} - x_n)^2 ,$$

where x_n is subject n's decision number and $x_n^{\max}$ is the subject n's maximum decision number. The quadratic payoff function was chosen to ensure that the equilibrium decision was not on a boundary of the decision space.

We utilized sixteen groups of four subjects with heterogeneous participants. That is, two subjects had a maximum decision number of 100 and two subjects had a maximum decision number of 125. We refer to these different types as medium and large capacity subjects.

The group component of participants' payoffs is such that the higher the aggregate decision number (the sum of decision numbers within a group), the lower the group payoff. We investigated two instruments, both involving a tax if the aggregate decision number exceeded the target. The instrument which we refer to as the tax/subsidy instrument also subsidized participants when the aggregate decision fell below the target. The tax instrument is presented as

$$(2) \qquad T_n(X) = \begin{cases} 0.3(X - 150) & \mathit{if}\ X > 150, \\ 0 & \mathit{if}\ X \le 150. \end{cases}$$

The tax/subsidy instrument is presented as

$$(3) \qquad T_n(X) = \begin{cases} 0.3(X - 150) & \mathit{if}\ X > 150, \\ 0.3(X - 150) & \mathit{if}\ X \le 150, \end{cases}$$

where

$$X \equiv \sum_{n=1}^{N} x_n$$

is the aggregate decision number (referred to as the group total). Given a tax/subsidy rate of 0.3 and the number of subjects per group ($N = 4$), maximizing the group's payoff yields the target of 150.

Under the tax/subsidy instrument, participants' best response for any X is $x_n^* = x_n^{\max} - 75$. Under the tax instrument, a participant's best response is also $x_n^* = x_n^{\max} - 75$. However, if $X < 150$, a participant could increase her payoff by increasing her decision number to the point that $X = 150$. Since all participants share this incentive, the unique Nash equilibrium is $x_n^* = x_n^{\max} - 75$ for all participants. We refer to the outcome where participants choose $x_n^* = x_n^{\max} - 75$ as socially optimal as this solves the social planner's problem in which the aggregate benefit to the individuals minus social damage is maximized:

$$(4) \qquad SP = \max_{(x_1,\dots,x_4)} \left[\sum_{n=1}^{4} B_n - 0.3 \sum_{n=1}^{4} x_n \right].$$

To be clear, under the tax/subsidy instrument the socially optimal outcome is a dominant strategy Nash equilibrium. But group payoff is maximized when all subjects choose zero. This, however, is not a Nash equilibrium. Under the tax instrument the socially optimal outcome is a Nash equilibrium but it is not dominant, in that if individuals believe that others will choose numbers that are below the Nash prediction it is in their best interest to choose higher numbers. As a result, we might expect to see subjects choosing numbers that are lower than the theoretical prediction under the tax/subsidy instrument if they are attracted to the group optimal outcome, and subjects choosing numbers that are higher than the theoretical prediction if they believe that others might choose lower numbers under the tax instrument. Notice that deviations of both kinds reduce the overall efficiency in the system, either because emissions are being reduced below the cost-effective level or because they are not being reduced enough.

The experiment was conducted over a computer network. Private payoffs were presented in a table with the instrument presented as a function [equation (2) or (3)]. Participants also had an on-screen profit calculator permitting them to calculate their payoff (private plus group component) from any feasible combination of their decision number and the aggregate decision number.

While experiments in similar environments suggest that subjects fail to choose the dominant strategy Nash equilibrium (e.g., Spraggon 2004b), Spraggon and Oxoby (2009) suggest that subjects who are familiar with the concepts of strategic decision making are more likely to make decisions consistent with the predictions of theory. Following along these lines, we are interested in identifying how providing participants with a more complete description of the environment (through recommended play and access to a payoff table) affects decision making. Our general hypothesis is that providing participants with better information about how an ambient pollution mechanism affects payoffs will effectively increase the decision making sophistication of participants with respect to that instrument, thereby resulting in greater Nash decision making and efficient implementation of the pollution target.

We conduct two treatments: a standard instruction treatment (which we refer to as standard) and a treatment with enhanced instructions complemented by a payoff table (which we refer to as enhanced). The difference between the instructions lies in the description of the private payoff function, which was an explanation of "marginal decision making." The following is the relevant part of the enhanced instructions:

> The purpose of the Group Payoff is to ensure that everyone chooses a certain Decision Number. Notice that by increasing your Decision Number by one you increase your Private Payoff by the number given in the third column of Table 1. However, by increasing your Decision Number by one you reduce the Group Payoff by 0.3. As a result you maximize your Total Payoff by increasing your decision number to the point where increasing your decision number by one more will increase your Private Payoff by less than 0.3.

Subjects were provided with hypothetical numerical examples and a question to test their understanding in both treatments.[1]

The payoff table (specific to each participant's capacity and instrument) indicated the total payoff (private plus group components) for feasible decision number choices and aggregate decision numbers. Given the size of the decision space, the payoff from each decision number was provided in intervals of five (e.g., the payoff from choosing 0, 5, 10, ..., 145, 150). Our goal here was to provide an alternate presentation of how payoffs are determined (cf. Charness, Frechette, and Kagel 2004).

Results

We find that when participants are provided with enhanced instructions and the payoff table, individual-level decisions are much closer to the theoretical predictions, which results in a significant increase in efficiency.

The data was collected from sessions conducted at the University of Calgary with 64 participants recruited from the undergraduate population. Each experiment consisted of 25 decision making periods and lasted approximately 90 minutes. Average earnings were between \$10 and \$25 (Canadian).

Primarily we are interested in whether or not the improved instructions result in individuals being more likely to choose their payoff-maximizing decision (which corresponds to the socially optimal decision). In addition, we also investigate whether the instruments are able to induce the group to choose the target level of emissions and the efficiencies obtained under each treatment. We measure efficiency as the difference between the optimal and actual value of the Social Planner's problem [equation (4)] as a percentage of the difference between the optimal and minimum possible value of the Social Planner's problem. This definition accounts not only for differences between the group total and the target, but for

[1] Instructions are available at http://www.umass.edu/resec/faculty/spraggon/.

reductions in payoff due to decision numbers that differ from individually optimal levels.[2]

We conduct our analysis in two stages. First we consider the differences across treatments for individual decisions. Here we have a total of 1,600 observations across both instruction and tax-tax/subsidy treatments. Although this data is not independent, the Nash equilibria are unique, and therefore identical decisions should be made in each period. We therefore employ standard techniques and evaluate the deviations from Nash behavior as summarized in the distributions of individual choices. Second, we consider decisions at the aggregate level. That is, at the group level (i.e., four participants facing the same mechanism, tax or tax/subsidy) does the introduction of enhanced instructions result in differences in aggregate decisions numbers or aggregate efficiency of the group? At this level, we have 16 independent group-level observations: 3 observations for each of the instruments with enhanced instructions and 5 observations for each of the instruments with the standard instructions. For this analysis, means were calculated for each four-subject group, and the mean of these means is calculated for each treatment cell.

Analysis at the Individual Level

Table 1 describes individual decisions by treatment and subject type. Recall that subjects were in groups of four, two large capacity and two medium capacity. Each chooses a decision number between 0 and 125 or 0 and 100 respectively over twenty-five consecutive decision periods. Information on payoff and aggregate group decision were reported after each period. As discussed earlier the theoretical prediction was 50 for the large capacity subjects and 25 for the medium capacity subjects.[3] The table shows that the enhanced instructions with table treatment led to decisions that were most consistent with the theoretical prediction. For both of the instruments and subject types, means are closest to the theoretical prediction, while medians and modes are identical with enhances instructions, which is not the case with standard instructions.

With the enhanced instructions, for the tax/subsidy instrument in periods 11–20, nearly 52 percent of decisions are either 50 or 51 for the large capacity subjects, and 55 percent of decisions are 25 for the medium capacity subjects. We do not observe any evidence for subjects attempting to implement the collusive outcome where everyone chooses zero. Less than 17 percent of decisions are below the Nash prediction (for both the large and medium capacity subjects). The results are not quite as strong for the tax instrument, with only 19 percent of decisions being 50 or 51 for large capacity subjects, and 28 percent of decisions being between 24 and 26 for the medium capacity subjects. For both subject types there are smaller peaks at slightly higher decision numbers. For the large capacity subjects, 28 percent of decisions are between 55 and 57, while for the medium capacity subjects 24 percent of decisions are between 35 and 40. These results are consistent with the Laury and Holt (2008) conclusion that decisions are less variable in dominant strategy environments.

With the standard instructions, the distributions of decisions are much flatter. For the tax/subsidy instrument in periods 11–20, 21 percent of decisions are zero and only 3 percent are between 50 and 52 (13 percent are between 44 and 46) for the large capacity subjects. For the medium capacity subjects, 28 percent of decisions are zero, 7 percent are 25. For the tax instrument, 27 percent of decisions are 50 for the large capacity subjects, while for the medium capacity subjects the largest peaks are at 40 with 15 percent of decisions, and 50 with 10 percent of decisions (only 1 percent of decisions are 25).

Figures 1 through 4 depict just how dramatic the differences between the standard and enhanced with table treatments are and show that the differences are consistent over time. Figures 1 and 2 compare the time-series of decisions for standard and enhanced instructions for the tax/subsidy. Notice that there is not much difference between the decisions of large and medium capacity subjects under the standard instructions. In contrast, decision making for the enhanced instructions is remarkably consistent with the prediction of theory for both subject types. This is also true for the tax instrument (Figures 3 and 4).

[2] For example, if two large capacity subjects chose 75 and two medium capacity subjects each chose 0, the group total would be 150, but the efficiency of this outcome would be only 89 percent due to the two choices which are not individually optimal.

[3] We are unconcerned with dynamic Nash equilibria as our interest is in whether or not these instruments induce compliance empirically.

Table 1. Mean Median and Modal Decision Numbers by Treatment

	Standard Instructions			Enhanced Instructions		
Treatment	Mean	Median	Mode	Mean	Median	Mode
TAX/SUBSIDY						
Large Capacity	35.03 (1.58)	37.5	0	49.03 (1.30)	50	50
N		250			150	
Medium Capacity	31.72 (1.51)	30	0	23.74 (1.00)	25	25
N		250			150	
TAX						
Large Capacity	59.12 (1.15)	60	50	49.27 (1.20)	50	50
N		250			150	
Medium Capacity	43.53 (1.29)	45	50	28.29 (1.19)	25	25
N		250			150	

Note: Standard errors are in parentheses.

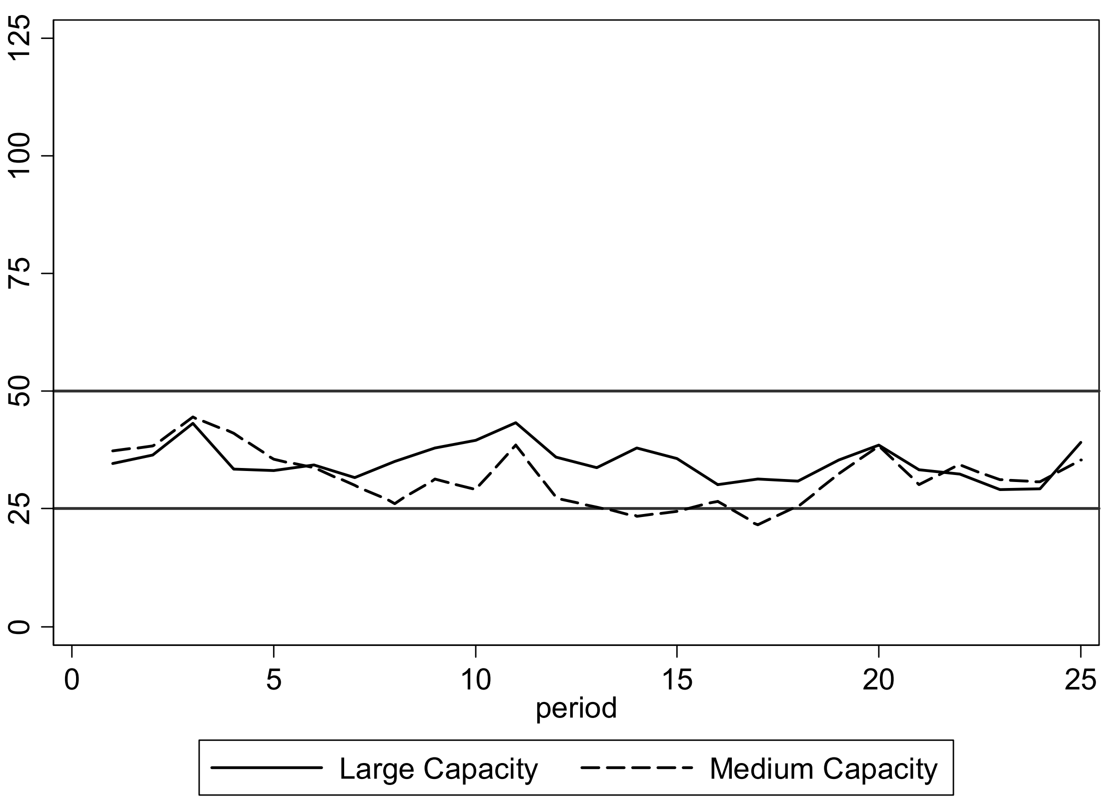

Figure 1. Mean Decision Number by Subject Capacity, for Tax/Subsidy, Standard Instructions

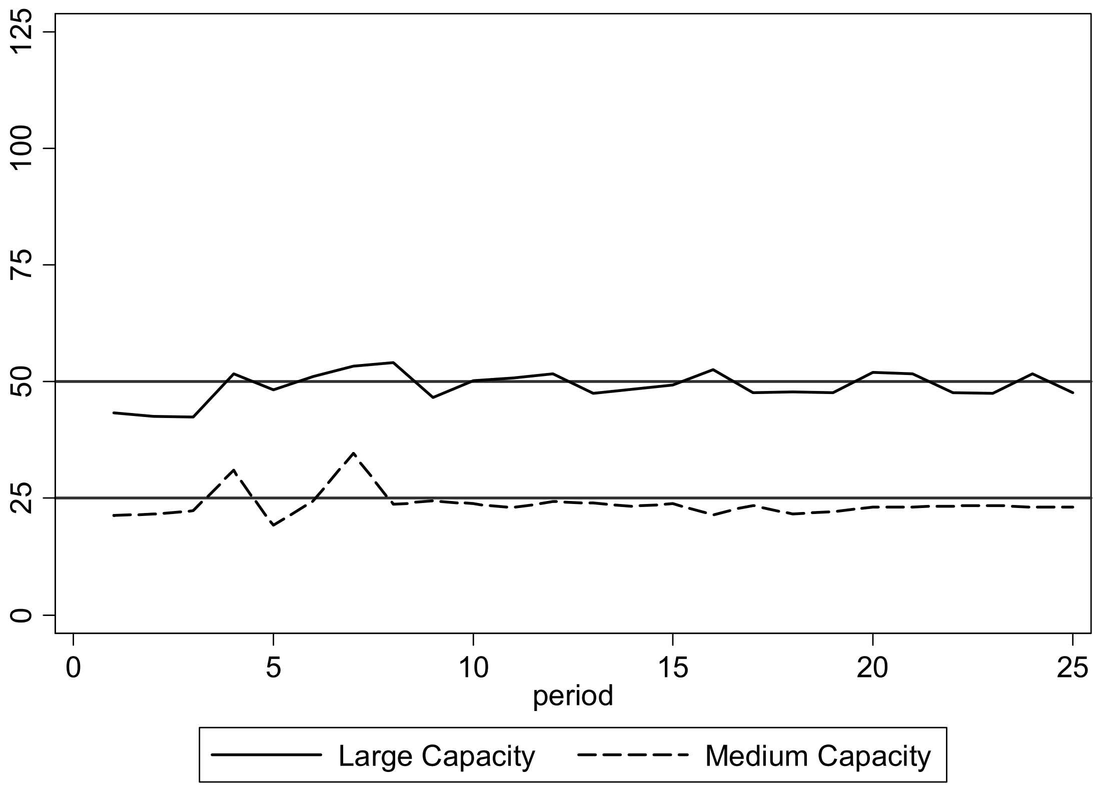

Figure 2. Mean Decision Number by Subject Capacity, for Tax/Subsidy, Enhanced Instructions

To determine whether or not average decisions are statistically significantly different from the theoretical prediction, we use regression analysis. Since decisions are constrained both from above and below, we use Tobit regression [see Greene (2000, chapter 20)]. Table 2 presents the results of four regressions conducted by subject capacity and instrument. We used a random effects Tobit regression to account for having repeated observations for individuals over time:

$$decision_{it} = \alpha + \beta_1 Enhanced_{it} + \nu_i + \varepsilon_{it},$$

where i indexes individual and t indexes period, *Enhanced* is a dummy variable to account for the enhanced instruction treatment, ν_i captures individual specific errors, and ε_{it} is a standard error term. The results are clear: in all cases except the medium capacity subject under the tax subsidy instrument, the enhanced instructions result in decisions closer to the theoretical prediction. That there is no significant effect of the enhanced instructions for the medium capacity subjects is not surprising as both Table 1 and Figure 1 suggest that decisions are reasonably close to the theoretical prediction for these subjects. Standard nonparametric tests (Kolmogorov-Smirnov and Mann-Whitney) also support this result. For each of the two instruments (tax/subsidy and tax) and two subject types (large and medium), these tests reject the null hypothesis that the distributions of individual decisions are the same across treatments in all cases. The largest p-value (0.0909) is for the tax instrument, with large capacity subjects comparing the standard and enhanced treatments.

Analysis at the Aggregate Level

Table 3 presents the aggregate outcomes for each of the treatments.[4] For both the tax/subsidy and tax instruments, aggregate decisions are more

[4] Each cell of Table 3 contains the mean and median of the aggregate group total for each of the observations in the session. As a result, the standard errors represent the variation between the number of sessions in each cell.

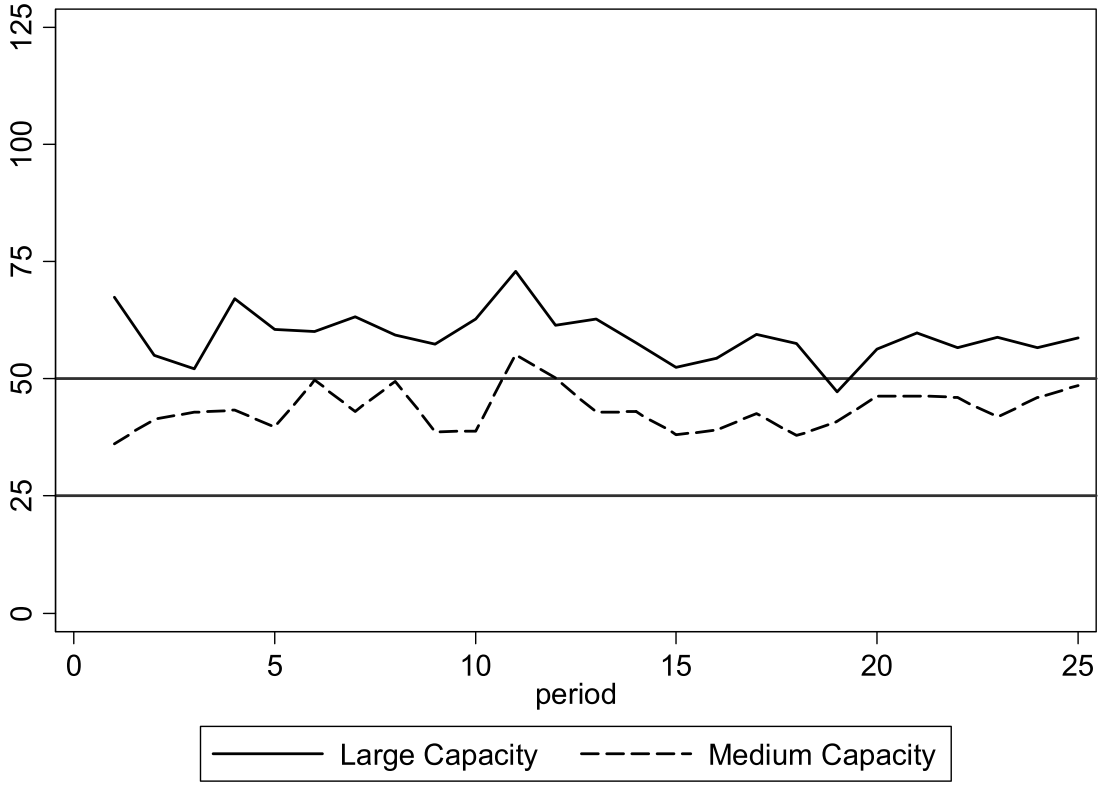

Figure 3. Mean Decision Number by Subject Capacity, for Tax, Standard Instructions

similar to the target under the enhanced instructions rather than the standard instructions (Table 1). This difference is statistically significant for the tax instrument (p = 0.0253 for the Mann-Whitney test) but not the tax/subsidy instrument (p = 0.8815). Analysis of variance on the 16 session means using experience, treatment, and experience crossed with treatment as explanatory variables suggests that there are no significant differences between the treatments (all of the p-values are above 0.11). Indeed, simple t-tests based on the standard errors from the data suggest that only the group total for the tax instrument with standard instructions is significantly different from the target (p = 0.0030; p-values for the other treatments are all greater than 0.1458). That the aggregate decision numbers are very consistent with the target replicates the results of previous studies (Suter, Vossler, and Poe 2009, Vossler et al. 2006, Cochard, Willinger, and Xepapadeas 2005, Poe et al. 2004, and Spraggon 2002, 2004a). Figures 5 and 6, which depict the time-series of aggregate decision by treatment and instruction type, support the observations from Table 3. Figure 5 shows that there is very little difference in the aggregate decision for the tax/ subsidy instrument. Figure 6 suggests that aggre gate decisions are always higher with the standard instructions for the tax instruments.

There does seem to be an improvement in efficiency for the enhanced instructions over the standard instructions under both instruments (Table 3). The Mann-Whitney U test (p = 0.0253 tax/subsidy, p = 0.0526 tax) and analysis of variance p = 0.011 both suggest that this difference is statistically significant. Figures 7 and 8 show that these differences are broadly consistent over time.

The observations that aggregate decisions are quite similar and that there is a significant difference in efficiency is a direct result of decisions among the subjects who received the enhanced instructions being much closer to the theoretical predictions.

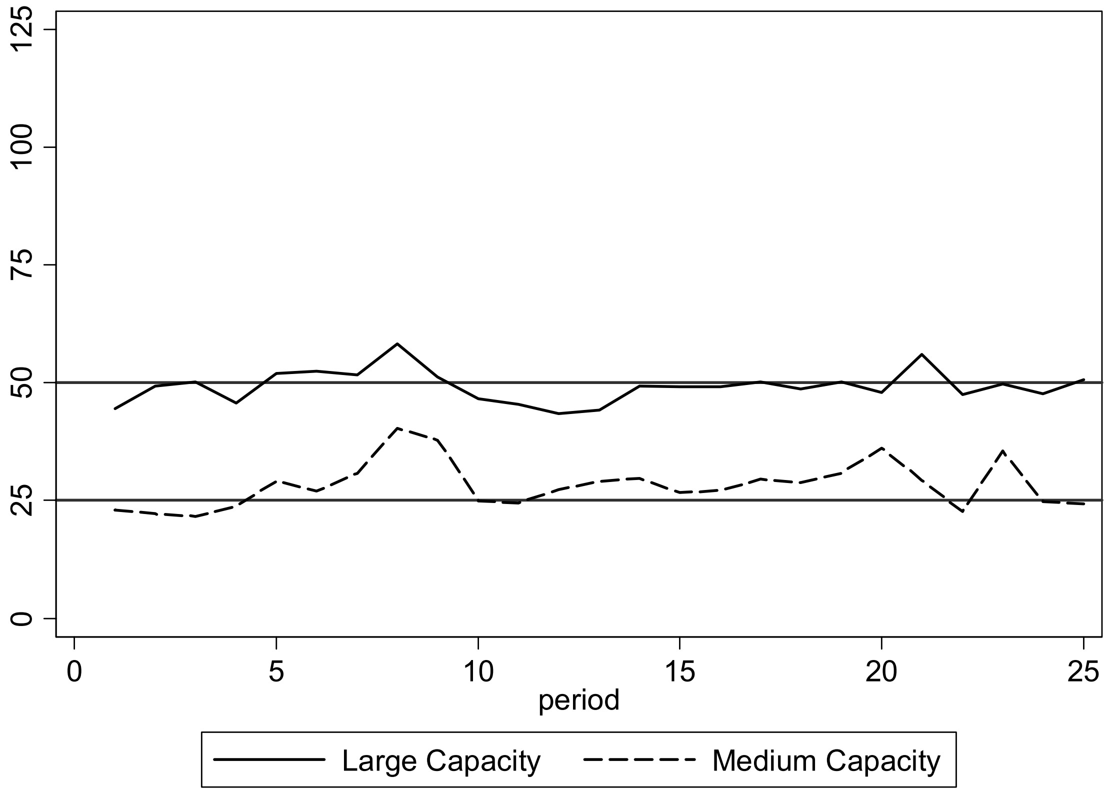

Figure 4. Mean Decision Number by Subject Capacity, for Tax, Enhanced Instructions

Table 2. Regression Results

	Large, Tax	Medium, Tax	Large Tax/Subsidy	Medium Tax/Subsidy
Enhanced	-9.565**	-16.052**	19.864***	-10.145
	(3.093)	(5.358)	(2.509)	(5.250)
Constant	59.108**	44.419***	40.027***	32.350***
	(1.866)	(2.898)	(1.665)	(4.520)
N	400	400	400	400

Note: Results from random effect tobit regression: $decision_{it} = \alpha + \beta Enhanced_{it} + v_i + \varepsilon_{it}$. * represents p < 0.05, ** represents p < 0.01, and *** represents p < 0.001. Standard errors are in parentheses.

Conclusion

Our results demonstrate the value of the presentation of payoff information on the efficacy of ambient pollution instruments in economic experiments. In our treatment with standard instructions, we observed significant decision errors in the face of an exogenous targeting instrument. Relative to this treatment, recommended play (i.e., a description of the application of marginal decision making in the decision environment) and the presentation of payoff information in a table increased the efficiency of the instrument by increasing the consistency of decision making in line with the theoretical prediction.

It appears that recommended play and the presentation of a payoff table clearly demonstrate to

Table 3. Mean Aggregate Decision Numbers by Treatment, Tax/Subsidy

Treatment	Mean (Median) Group Total	Confidence Interval		Mean Group Efficiency
		Lower Bound	Upper Bound	
TAX/SUBSIDY				
Enhanced Instructions	145.55 (144) (15.44) [3]	79.10	212.00	96.40 (0.36) [3]
Standard Instructions	133.50 (141) (32.69) [5]	42.00	222.26	87.09 (3.56) [5]
TAX				
Enhanced Instructions	155.12 (155) (2.20) [3]	145.64	164.50	96.13 (1.82) [3]
Standard Instructions	205.30 (201) (8.59) [5]	181.45	229.15	89.59 (1.30) [5]

Note: Standard errors are provided in parentheses and number of observations are provided in square brackets.

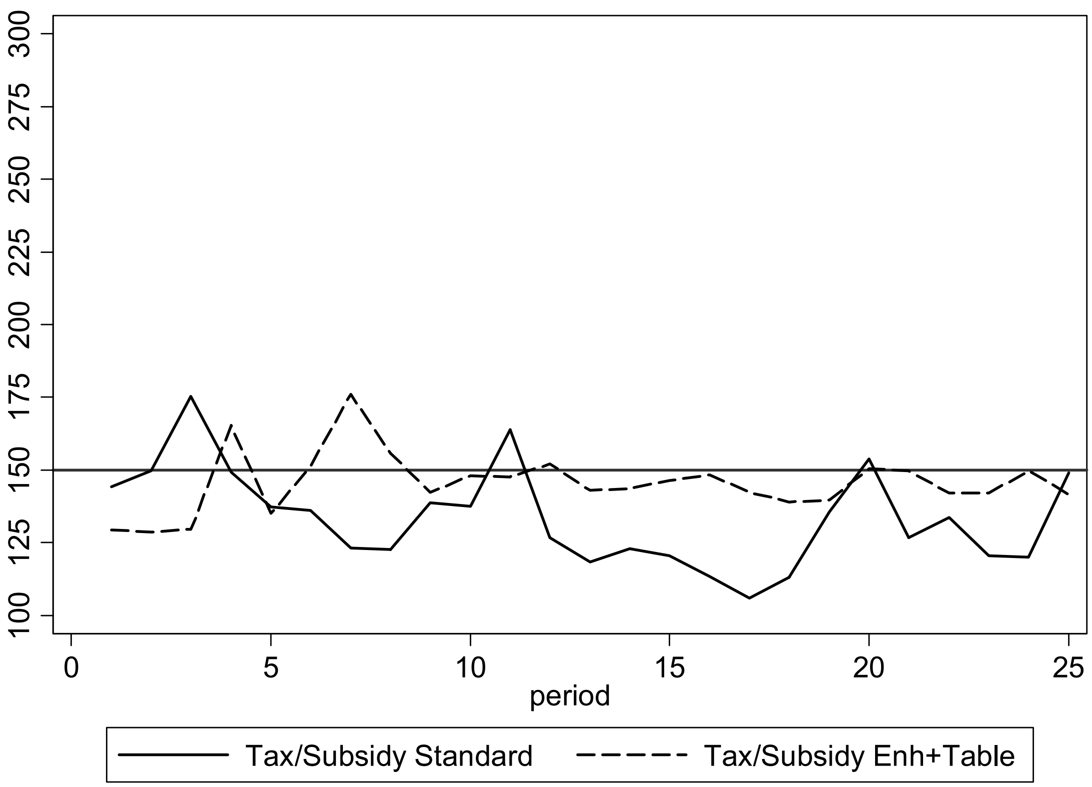

Figure 5. Mean Group Totals by Treatment and Period, Tax/Subsidy Instrument

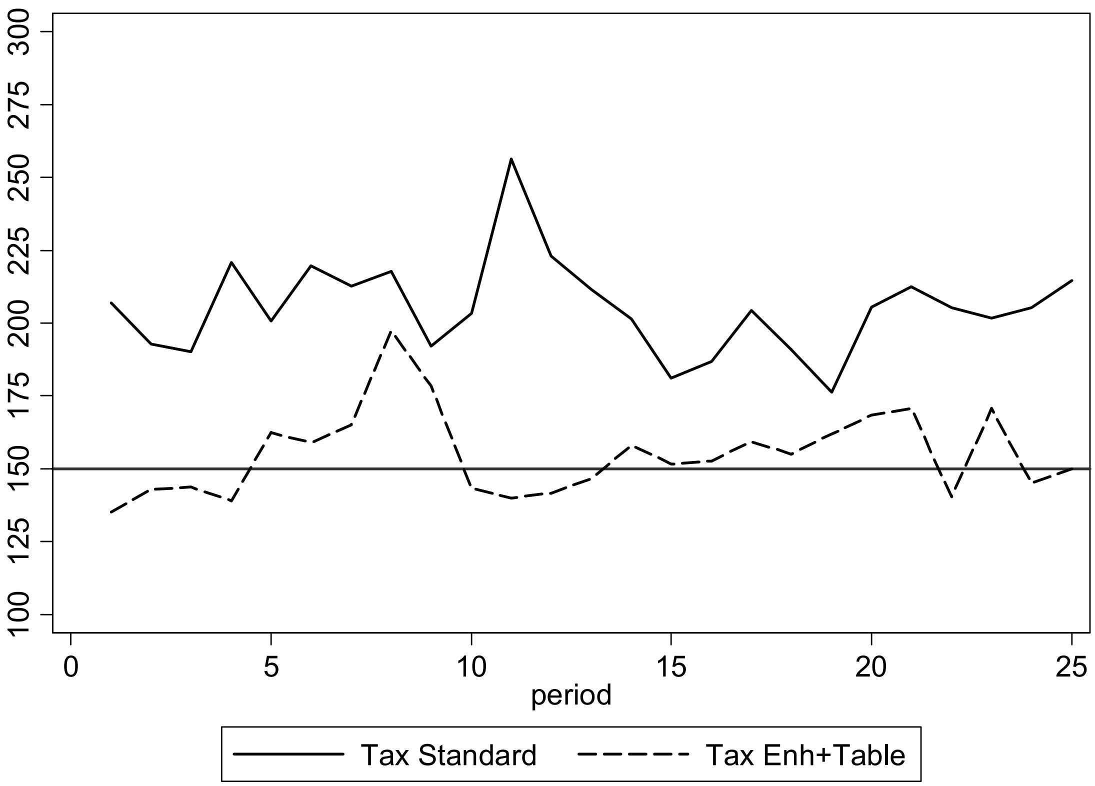

Figure 6. Mean Group Totals by Treatment and Period, Tax Instrument

participants how to make profit-maximizing decisions in a (relatively) complex environment. While the flavor of recommended play utilized here emphasizes the tools individuals should use in making their decisions (i.e., marginal analysis), the payoff table clearly demonstrates to participants that they have a dominant strategy. The coupling of recommended play with the payoff table results in a clear increase in Nash decision making on the part of participants. These results are in line with the work of authors such as Chou et al. (2009) and Charness, Frechette, and Kagel (2004), who provide support for the predictions of game theory when subjects understand the form of the game.

Our result should be considered promising with regard to the use of ambient pollution mechanisms in the field. Shortle and Horan (2001) point out many of the problems that plague non-point source pollution mechanisms and their applicability in the field. Our experiments demonstrate that, as Cabe and Herriges (1992) suggest, when coupled with effective information on the use and consequences of these instruments, tax and tax/subsidy mechanisms can efficiently implement pollution targets. These results suggest that policymakers can effectively use these instruments in the field where decision makers (i.e., firms) are experienced in making profit-maximizing decisions. By educating polluters in terms of how these instruments affect the profits of firms, policymakers should be able to implement targets for non-point source polluters efficiently through the use of ambient pollution mechanisms.

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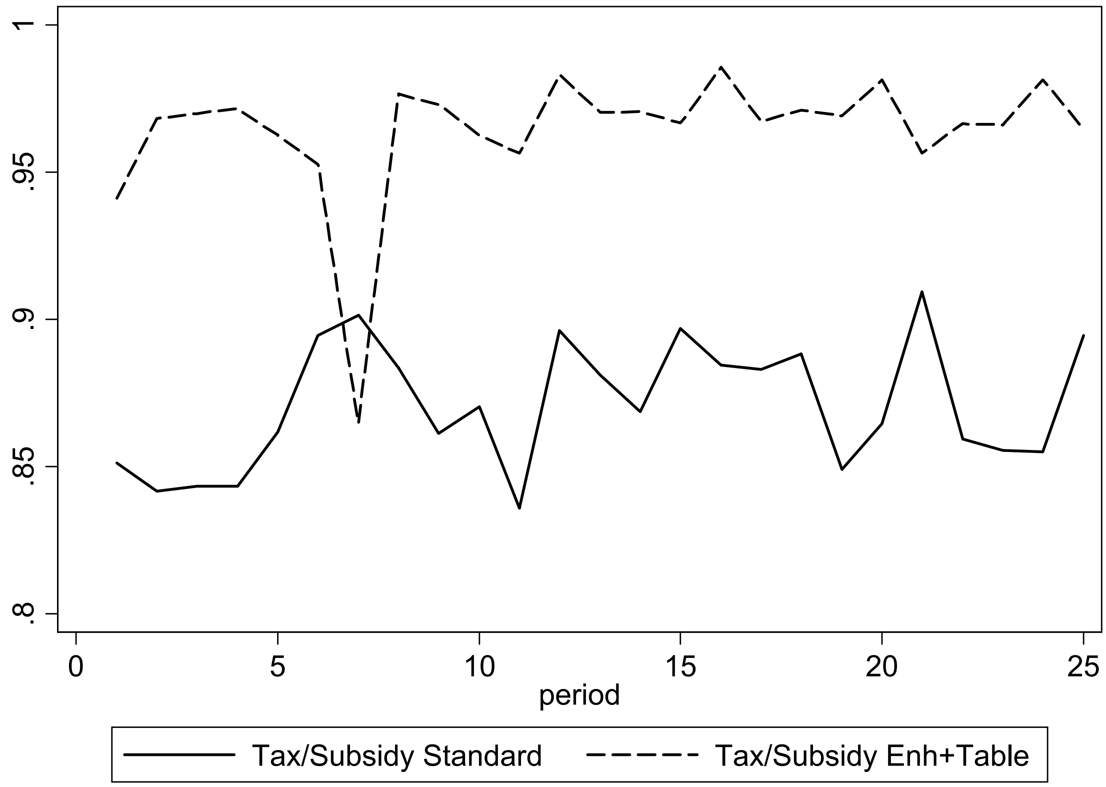

Figure 7. Mean Efficiency by Treatment and Period, Tax/Subsidy Instrument

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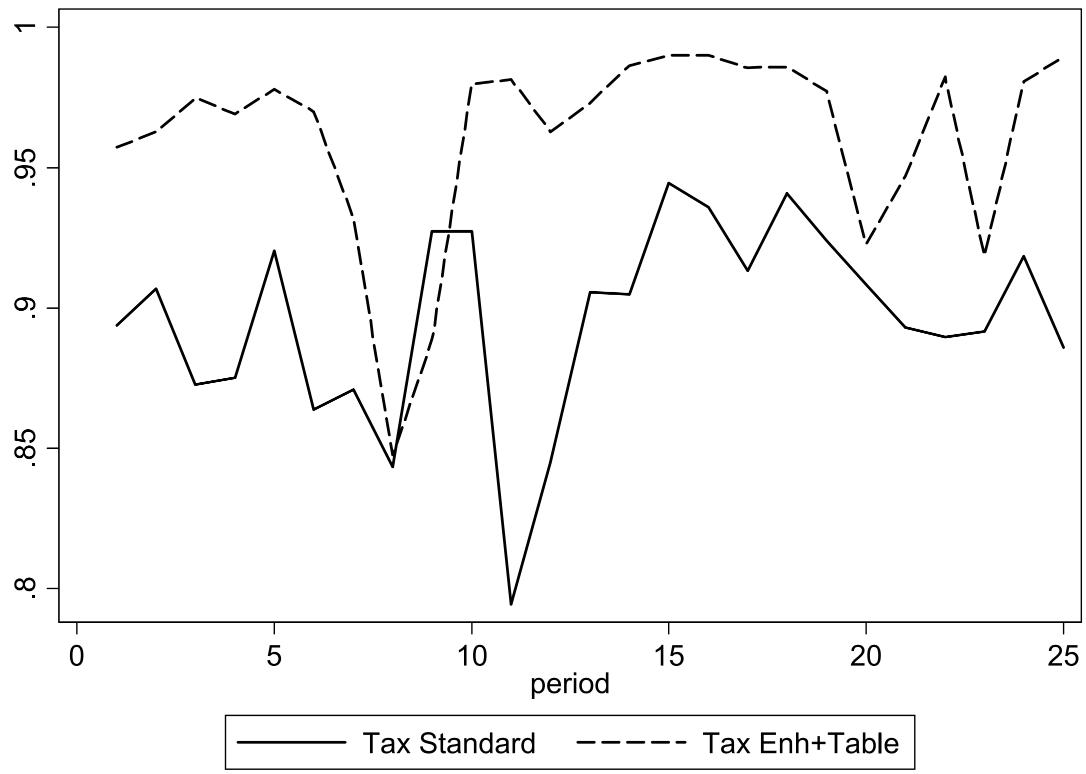

Figure 8. Mean Efficiency by Treatment and Period, Tax Instrument

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