Environmental Policy: Lessons from the Laboratory

Stuart Mestelman
McMaster University

January 2000

A version of this was presented as the John F. Graham Lecture at the 27th Annual Meeting of the Atlantic Canada Economic Association, 24 October 1998, University of New Brunswick at Saint John and appears in the Association proceedings. The paper has benefited from comments by Neil Buckley, David Feeny, and John Spraggon.

Environmental Policy: Lessons from the Laboratory

Stuart Mestelman
Department of Economics
McMaster University
Hamilton, Ontario, Canada L8S 4M4
mestelma@mcmaster.ca

January 2000

Abstract

The controlled laboratory experiment is spreading rapidly as a method for evaluating theories of economic behaviour and policy prescriptions. Environmental regulation is an area that is ripe for laboratory investigation. This paper presents insights drawn from the existing literature using laboratory methods in economics and related disciplines on the use of taxation and subsidy, standards and fines, transferable quota, and voluntary restraint as mechanisms for environmental regulation.

Environmental Policy: Lessons from the Laboratory

1. Introduction

The controlled laboratory experiment is spreading rapidly as a method for evaluating theories of economic behaviour and policy prescriptions. The applications to the evaluation of policy are frequently described as *testbedding*. In an early example of *testbedding*, Plott and Hong (1982) report an experiment they conducted in the mid-1970s whose results were instrumental in a U.S. Federal Trade Commission decision not to impose price posting on barges on the Mississippi River that were in competition with rail transport. This was probably the first time that laboratory methods were used to help evaluate policy issues. Shortly afterwards, in 1979 the U.S. Civil Aeronautics Board and Federal Aviation Administration commissioned a study to address the issue of allocating airport landing capacity following the Airline Deregulation Act of 1978. Alternative mechanisms were under consideration for the allocation of airport landing capacity and laboratory methods were introduced in an attempt to understand the incentive properties of these mechanisms (Grether, Isaac, and Plott 1989).

Environmental regulation is an area that is ripe for laboratory investigation. The recently negotiated treaty to limit the production of greenhouse gases (the Kyoto Protocol to the United Nations Framework Convention on Climate Change) provides an opportunity to consider a wide variety of mechanisms for meeting agreed upon targets for reducing greenhouse gas emissions worldwide. Among the mechanisms are the imposition of per unit taxes on emissions, offering subsidies to firms for generating emission reductions or offering subsidies to firms for the adoption of new, *clean*, technologies, the imposition of command-and-control quotas on emissions or transferable emission quotas, and the encouraging of voluntary environmental agreements. The last mechanism was Canada's official response to the commitment it made at the 1992 United Nations Conference on Environment and Development.

There has been laboratory work focussed directly on environmental regulation. Other work evaluates the potential of some of the mechanisms listed above even though it was not conducted with the problems of environmental regulation as the motivating factor. In the following sections, insights related to the use of taxation and subsidy, standards and fines, transferable emission quota, and finally voluntary restraint, are drawn from the existing literature which uses laboratory methods in economics and related disciplines.

2. The Nature of Laboratory Experiments[1]

2.1. Market Experiments

A laboratory market experiment in economics is conducted with human subjects, in practice usually university undergraduates. Typically about eight to twelve subjects are recruited for each market session. At the beginning of each session, participants are instructed about the rules of the experiment and assigned roles as buyers, sellers or traders. Usually they are told they will be participating in a market for an abstract product measured in units. Buyers are given a schedule indicating the redemption value to them of one, two, or more units in each period. For example the first unit may be redeemed for 100 lab dollars, the second for 50 lab dollars, the third for 45 lab dollars, and so on. The buyer's profit on each unit is the difference between its redemption value and the price actually paid to the seller. Sellers are given marginal cost schedules indicating what each unit they sell costs them. They compute their profit as the difference between the selling price and the marginal cost of the unit.

[1] Parts of this section are taken from Muller and Mestelman (1998).

Trading occurs for a number of market periods under rules specified by the experimenter. Trading may be done orally with manual record keeping or it may be mediated by computer programs of varying complexity and sophistication. At the end of the experiment, subjects' earnings are converted from lab dollars to local currencies at a previously announced exchange rate and the subjects are paid in cash. A typical undergraduate may earn about $30 for a two-hour session.

One cardinal principle in experimental economics is to pay subjects sufficiently well to ensure their decisions are motivated by market payoffs. This is one reason for using university students as subjects; the opportunity cost of employed adults, especially senior decision makers, would be much higher. A second cardinal principle is never to deceive the subjects. All the rules of the experiment are announced in advance and strictly followed. Our interpretation of the data, however, may be different from the subjects'. For example, in emission permit trading markets subjects are not told that the units they are trading represent permits to emit pollutants. In this way we hope to avoid biases induced by the nature of the commodity being traded.

2.2. Non-Market Decision-Making Experiments

Some economic decisions are made using mechanisms which are not market mechanisms. Voting schemes are frequently used to transfer resources from people to activities which yield benefits to the people who participate in the decision-making. The actions of the voting outcome are usually binding on all individuals in the group. In other situations, people are asked to make voluntary contributions to activities which will provide benefits to themselves and others. The laboratory can be used to evaluate the performance of alternative voting and voluntary contribution mechanisms for generating resources to produce goods which have public characteristics.

When considering voluntary contribution mechanisms for collecting resources to provide public goods, *value* for each subject is typically induced through a payoff table. Each participant is given a payoff table which shows how his payoff is related to his contribution and the contribution of the others who must also make voluntary contributions. After all participants make contributions (which are constrained by the subjects' endowments of resources), the members of the group are typically informed of the group contribution, from which they can determine their payoffs. Resources not contributed to the production of the public good are converted into private goods and generate a payoff to the subject. In this way making a voluntary contribution to a public good is not the only way in which a subject can earn a payoff.

3. A Case for Regulation and an Outcome of Command-and-Control Regulation

3.1. Market Failure in the Laboratory

The regulation of a market may be necessary if it can be demonstrated that the market has failed to generate an efficient allocation of resources. Within the context of environmental regulation, an example of a market failure is the presence of pollution emissions which are generated by the failure of market prices to reflect the costs these emissions impose on the consumers of the emissions. If laboratory methods are to be used to evaluate a control mechanism, it is important to demonstrate first that the market failure can be generated in the laboratory. Consider the following laboratory environment that has been adapted from Plott (1983).

A market environment is created in which there are twenty-five potential buyers of a product and twenty-five potential producers of the product. Each individual may sell or purchase only one unit of this product. Each buyer receives a sheet containing the private information that his *redemption value* for the unit he purchases is either $28, $26, $23, $21 or $17. There are five buyers with each redemption value. Each buyer knows *only* his own redemption value. No buyer has any information about the redemption values of any other buyer. Each seller receives a sheet containing the private information that her *cost of unit sold* is either $12, $14, $17, $18 or $22. There are five sellers with each cost of unit sold. Each seller knows *only* her own cost of unit sold. No seller has any information about the redemption values of any other seller.

The participants in this market are then told that by entering into contracts to sell a unit to a buyer (or buy a unit from a seller) they will be permitted to keep the difference between their redemption values (costs of units sold) and the contract price. Once a trading period has begun, participants enter into these contracts by wandering around the room and finding someone who is prepared to either buy from them or sell to them at an agreed upon price. Participants have a limited amount of time to form a contract. They are also told that what they reveal about their private information regarding redemption values or costs of units sold is their decision. They may share this information or keep it private. Once a pair of participants agree upon a contract price, they bring their contract forms to an invigilator who verifies that, in fact, this is a legitimate contract (traders may not enter into contracts which generate loses) and the formation of a contract is publicly announced. At the end of the trading period the average contract price and the volume of contracts is announced publicly. Then a new trading period begins.

There is an additional characteristic in this particular market environment. The participants are told that each time a contract is formed a cost of $0.25 is incurred by each market participant. If at the end of the trading period there have been fourteen contracts agreed upon, each of the fifty participants will incur a cost of $3.50. Therefore, trading profits will be reduced by damages associated with the production of this product. All members of the community suffer these damages. This is not unlike an environment in which production generates pollution which damages consumers and producers alike. Several questions remain. What is the optimal level of production and consumption? What might conventional economic theory predict will happen? What actually happens when this environment is made operational in a controlled setting?

On the left-hand side of each panel in Figure 1 there are three schedules which represent the redemption values, costs of units sold, and marginal externality costs described above. The redemption values, displayed in descending order, describe a conventional demand curve for this environment. The costs of units sold, displayed in ascending order, describe a conventional private marginal cost or supply schedule. By adding $12.50 to each step of the supply schedule, the private plus social marginal cost schedule is constructed. $12.50 is the marginal cost of the externality associated with each unit supplied. In the absence of the externality, this market would be expected to clear at a price between $21 and $18 with twenty units being sold. If the external costs were fully incorporated into the decision processes which lead to a competitive market equilibrium, we would expect only five units to be sold at a price between $26.5 and $26.

To the right of the schedules in the top panel are the contracts formed during the first three periods of trading. The pattern of contracts is comparable to that displayed in laboratory open-access free-form markets (Joyce 1983). There are 20, 18 and 18 contracts formed in periods 1, 2, and 3 respectively. The contracts are formed as if there was no externality present (efficiency, measured as the share of the potential surplus realized in the absence of the externality, rises from 91% of the attainable gains from trade to 96%). Once the external costs are considered, the efficiency measure falls dramatically. In the third period the participants realize, in total, loses equal to nearly three times the potential surplus. The lower panel in Figure 1 shows a replication of this result. This market environment unambiguously generates market failure.

3.2. Command-and-Control Regulation

Plott (1983) presents three different mechanisms which have at different times been either proposed or actually used to control pollution emissions. The underlying parameter set as reflected by the redemption values, private marginal costs and social marginal costs are presented on the left-hand side of the panels in Figure 2. These values are induced in a similar manner to that described in the previous section. There are twelve participants in Plott’s markets. Six are buyers and six are sellers. The trading institution is a double auction rather than an open-access free-form market. The optimal number of contracts is thirteen while the competitive equilibrium (in the absence of an externality) would be at twenty-four units and a price of $2.44. When an optimal number of contracts is formed, the marginal benefit of a unit is $2.69 and the marginal damage associated with its production is $0.36 (twelve subjects each incur a cost of $0.03). Panel A in Figure 2 shows that prices adjust rapidly towards the competitive equilibrium as in the markets shown in Figure 1. The externality is not internalized. Market failure characterizes this unregulated environment.

Suppose the regulator knows that thirteen units is the optimal output for this market. One command-and-control institution is to permit thirteen trades and then close the market. In this way the optimal level of damages are realized. This institution is similar to the institution used in many jurisdictions to regulate non-point-source pollution. When the air quality reaches a certain level, all producers must stop production until the air quality returns to an acceptable level. In this environment, Plott allows the double auction to proceed until thirteen units are sold. At that point the trading period ends. The results of the first three periods of a trading session are shown to the right of the redemption and cost schedules in Panel B of Figure 2. In each period the market efficiency under the command-and-control mechanism is greater than in the unregulated environment. The market price in the command-and-control environment is falling towards the marginal private cost of the thirteenth unit ($2.33), but the convergence is neither as rapid nor as complete as in the unregulated environment. This command-and-control environment fails to restrict buyers with redemption values less than $2.69 but greater than $2.33 from forming contracts. This reduces the efficiency of the mechanism. If the command-and-control mechanism was to limit each consumer and producer to buy and sell only two units in this market (or cut their consumption or sales by fifty percent from the unregulated environment), the symmetry of the underlying parameters would have generated a high surplus. But the symmetry of the underlying parameters make this a poor environment for evaluating command-and-control regulation based on a proportional reduction of consumption and production from the unregulated environment.

4. Two Cases of Taxation and Subsidy

4.1. An Output Tax

Plott (1983) also considers a tax on sales equal to the optimal marginal damage as a regulatory mechanism to correct for the market failure reflected by the trading in Panel A of Figure 2. The marginal damage at the optimal allocation is $0.36. When this tax is levied on producers for each contract into which they enter, the theoretical result is thirteen units of output at a price of $2.69 per unit. The contract prices in the first three periods of trading in one of the sessions reported by Plott are shown to the right of the demand and cost schedules in Figure 3. The efficiencies in these three periods exceeded those in the command-and-control environments and consistently exceeded 0.90 after the third trading period in both of the sessions reported by Plott. By the third period of the session shown in Figure 3 contract prices were nearly always at the predicted value of $2.69.

4.2. Taxes, Subsidies, Fines and Non-Point-Source Pollution

The environment presented by Plott (1983) is one in which a tax can be levied on each producer or consumer of the unit of output which contributes to the emissions. In some situations, however, it is not possible to associate the environmental damage with a specific producer or unit of output. As with the example presented above for command-and-control regulation, it may be possible to measure the ambient air or water quality but not identify how much of the offending emission comes from each of the firms emitting pollutants into the air or water. Holmstrom (1982) and Segerson (1988) suggest mechanisms which they argue should be useful for correcting the market failure which will result from situations comparable to the existence of externalities associated with non-point-source pollution.

Holmstrom describes a mechanism which, when translated from the context of moral hazard in labour contracts, imposes a fine on all members of the group of potential polluters if a critical level of environmental pollution is exceeded and Segerson suggests using taxes and subsidies set at marginal damages for pollution emissions above or below a regulated target. Spraggon (1999) evaluates these mechanisms in a laboratory setting.

Spraggon constructs an environment in which six individuals are each able to invest 100 tokens in an activity which provides a private gain to each of them. Unfortunately, in the process of generating their private gains, they impose costs on the other five people in the group and themselves. This environment is analogous to a group of polluting firms situated around a lake. Each of them has an incentive to invest the 100 input units into private production. Their own emissions associated with the use of the 100 input units are not sufficiently costly to provide an incentive to reduce their use of the input regardless of what the others around the lake choose as their input levels. Furthermore, it is impossible for a potential regulator to identify the quantity of input used by each firm. The regulator can, however, measure the total quantity of input used by the six firms.

The mechanism proposed by Holmstrom would have each firm pay a large fine if the total input use by the firms around the lake exceeded an announced target. The mechanism proposed by Segerson would have each firm pay a charge equal to the marginal damage associated with input use for each unit of input used beyond the target level by all firms around the lake. If input use fell below the target level, each firm would receive a subsidy equal to the optimal marginal damage for each unit that input use fell below the target level. Both mechanisms lead to a Nash equilibrium at the target level. However, the Holmstrom group-fine mechanism has a second Nash equilibrium at the *status quo* level of input use. Although both mechanisms will have a Nash equilibrium at the optimal allocation, it remains to be seen if this outcome will emerge behaviourally under these mechanisms from even as simple an environment as the one constructed by Spraggon.

Figure 4 presents two sets of time series data which aggregate results of two experiments (twelve sessions) conducted by Spraggon (1999). The first experiment uses subjects who each have the same payoff functions and endowments of inputs. The second experiment uses subjects who have the same payoff functions but different endowments of inputs. The parameters are constructed in such a way as to generate the same Nash equilibria in each experiment. The optimal outcome under both mechanisms is for 150 units of the input to be used in each production period. The sub-optimal Nash equilibrium under the fine is for 600 units to be used in each period.

In the case of the Segerson tax-and-subsidy mechanism, regardless of whether firms are homogeneous (three sessions) or heterogeneous (three sessions) the mean group outcomes (open circles) are very close to the Nash equilibrium for that environment. This result is comparable to the result obtained by Plott (1983) with the output tax when output imposes external costs on all traders. The Holmstrom group-fine mechanism does not work well at all. Figure 4 presents the mean levels of input use (solid circles) in each of twenty-five periods from six sessions (three with homogeneous agents and three with heterogeneous agents). Although when firms are homogeneous the group input levels tend to cycle around 350 units, they rise to more than 500 units for heterogeneous groups. While on average the input use under the group fine is reduced from the *status quo* input use of 600 units, it does not perform nearly as well as the tax-and-subsidy mechanism.

Regardless of whether a tax equal to marginal pollution damages can be levied on each polluting firm for each unit it produces or whether a comparable tax is levied on each firm in an airshed or watershed for the total emissions into the environment, the incentives are such that in laboratory environments optimal equilibria emerge. An alternative mechanism, the group fine (or *forcing contract*) does not perform nearly as well. The next step is to argue that if it does not work in the simple and controlled environment, it is unlikely to work in the much more complex field. Score one for the Pigouvian tax.

5. Transferable Quotas

5.1. The Prototype Permit Market Experiment

Crocker (1966) and Dales (1968) may have been the first economists to propose the use of emission permits for the regulation of pollution emissions. Montgomery (1972) provided the formal theoretical foundation. However, no matter how eloquent a written argument or elegant a theoretical proof, Plott (1983) provides a compelling demonstration of the power of markets to reallocate rights to pollute.

Plott (1983) completed his comparison of alternative mechanisms for internalizing the external costs associated with the production and consumption of a commodity by extending his environment to permit trading. Noting that the optimal level of production and consumption is thirteen units of output, he distributed thirteen permits-to-sell-a-unit among the twelve participants in his double auction markets. Using the same induced values as for the baseline, command-and-control standard, and tax environments, he instructed the sellers that they must acquire a permit-to-sell-a-unit before they may enter into a contract to sell a unit to a buyer. The predicted price of a permit-to-sell-a-unit is \$0.36, the marginal damage inflicted at the optimal level of sales. The predicted price of a unit of output is \$2.69. The contract prices for the first three periods of one of the two sessions reported by Plott are presented in Figure 5. The prices of the product converge to the predicted price much more rapidly than did the contract prices under the tax. Although the permit prices were below the predicted price in each of the periods (except for the third contract of the first period), they tend to converge at a price of $0.33 by the end of the third period and remain close to this price for the remaining seven trading periods (which are not reported here). This result provides very strong support for the use of transferable quotas as a mechanism for correcting market failure in the presence of pollution externalities.

5.2. The Environmental Protection Agency Auction

The 1990 Amendments to the Clean Air Act in the United States provided for the creation of markets for trading pollution emission permits (U.S. EPA 1991). The first market for permits to emit sulfur dioxide was conducted in the United States in 1993. The auction mechanism was created in a political environment and was not subjected to the scrutiny of economists with expertise in auction theory or with expertise in the evaluation of auction markets in the laboratory. The unique features of the EPA auction attracted attention once the legislation was passed establishing the auction. Cason (1993) noted that the EPA auction had incentives which might not be desirable. In particular, he believed that both buyers and sellers had incentives to under value the permits they wished to purchase or sell. His work suggested that the sellers' *asks* could collapse to values far below their actual values to the sellers while buyers' *bids* would be far below their true valuations.

The EPA SO_2 auction's particularly unique feature concerns the way in which bids and asks on units beyond the units mandated by the legislation are matched. The bids are arrayed in descending order (to form a demand schedule). The asks are arrayed in ascending order (to form a supply schedule). The intersection of the supply and demand schedules determine which units are sold and the purchasers of these units. The buyers and sellers of units are matched in a unique manner. The highest bidder pays his bid to the seller who asks the lowest price for his permit. Subsequent matches are made as the administrators of the auction move down the demand schedule and up the supply schedule. This process has poor incentive properties, in theory. Sellers have an incentive to ask less then their true valuation of the permit in order to get to the head of the supply queue and receive the bid of the highest bidder. On the other hand, bidders have the incentive to bid below their true valuations so that they will have a surplus after securing a permit.

Together, Cason and Plott (1993, 1996) evaluated the theoretical predictions of Cason (1993) and compared the performance of an auction with the unique features of the EPA SO_2 auction to the performance of a *uniform-price auction* with the same underlying supply and demand parameters. The successful buyers and sellers in the uniform-price auction are determined by the intersection of the demand and supply schedules formed in the same way as in the EPA auction. All successful buyers and sellers pay and receive a price midway between the higher of the highest successful ask and the highest unsuccessful bid and the lower of the lowest successful bid and the lowest unsuccessful ask. This auction has performed particularly well in laboratory settings (Davis and Williams 1997).

Figure 6 presents the bids, asks, contracts and induced values for periods 1, 2, 3, 9, 10, and 11 in a representative session conducted by Cason and Plott (1993). The circles identify bids and the boxes identify asks. The solid boxes and circles identify successful buyers and sellers. The dotted and dashed lines connect the induced values of the buyers and sellers (the underlying supply and demand schedules for permits). Notice how in the first three periods both bids and asks are below the induced values, and fall over time. By the ninth period successful sellers are setting their asks at zero and nearly all of the bidders submit bids below the competitive equilibrium price of 230 laboratory dollars. By the eleventh period the average contract price is below the competitive equilibrium price. The bids and asks provide no information about the underlying valuations of the successful participants in this market.

The comparison with the uniform-price auction is shown in Figure 7. Panel A in Figure 7 is identical to Panel B in Figure 6. Panel B in Figure 7 displays the bids, asks, and induced values for periods 9, 10, and 11 for one session of Cason's and Plott's uniform-price auctions. Notice how well the bids and asks track the induced values and how close the market clearing price is to the competitive prediction of 230 lab dollars.

The lesson that should be learned from Cason and Plott is that institutions matter. Introducing markets as regulating mechanisms will not necessarily lead to optimal or even near to optimal outcomes. Some market institutions perform better than others, and alternative institutions should be carefully evaluated before the allocation of valuable resources are trusted to them.

5.3. Banking Permits, Rights to Future Permits, and Uncertainty

A substantial program of laboratory research into tradable emission permits has been completed at the McMaster Experimental Economics Laboratory. Mestelman, Moir, and Muller (1999), Muller and Mestelman (1994), and Godby, Mestelman, Muller, and Welland (1997) report the outcomes of laboratory sessions which testbed proposals for nitrous oxide trading in southern Ontario (Nichols and Harrison 1990a, 1990b, Nichols 1992). The proposals differ from the U.S. EPA auction in a number of respects, notably the presence of two trading instruments, shares and permits, and the absence of a mandated auction with compulsory offers.[2]

Mestelman *et al.* (1999) and Muller and Mestelman (1994) implement trading for shares and permits in a multiple unit, open outcry, free-form market, similar to open-pit trading for commodities. This also provided traders with the opportunity to withdraw from the pit to negotiate private contracts. Traders were also allowed to carry unused permits from one period to another (to *bank* permits for future use) and after four trading periods the endowment of permits was reduced by fifty percent. Contract prices were not made public systematically, and so price and quantity information was incomplete at best. This experiment was clearly a testbed of the trading scheme described by Nichols and Harrison and demonstrated that the scheme could effectively reduce abatement costs for a given emission cap. The average abatement cost savings over five trading sessions was 74 percent of the potential savings.

Godby, Mestelman, Muller, and Welland (1997) report a large scale systematic test of the effects of bankable permits, tradable shares and uncertainty in a 2x2x2 factorial design. Trading was conducted in a computer-mediated double auction. This experiment confirmed the presence of price spikes in uncertain environments without banking and the ability of banking to eliminate the price instability. It also revealed a significant impact on market efficiency through the interaction of banking and trading shares. The double-auction institution yielded abatement cost savings which exceeded those realized in the less organized markets reported in the papers by Mestelman, Moir, and Muller

Figure 8 shows the effect of banking on contract prices in two sessions. Panel A contains

[2] A share is the right to a stream of permits in each future decision-period. The mandated contribution to the EPA auction was imposed on permit holders in an attempt to guarantee that some trades would take place.

the contract prices from a session in which there was no banking, no share trading, and no production uncertainty. The predicted equilibrium price in each of the first four periods is 14 laboratory dollars (L$). In the final eight trading periods, after the reduction in permissible emissions, the predicted price is in the range L$123 to L$136. The prices shown in Panel A converge over time towards L$14, and then rise into the upper band during the later periods. The introduction of banking allows traders to incur low abatement costs in the early periods and carry the permits saved into later periods when abatement costs will be greater. The predicted equilibrium permit price in a competitive environment with perfect foresight is between L$72 and L$78. The contract prices in Panel 2 of Figure 8 show remarkable stability near to the predicted contract price.

Permitting trades in the rights to a stream of future permits has the effect of reducing the number of transactions in these permit markets. Because traders can acquire the permits they need in future periods by purchasing shares early in the session, trading volumes fall. The convergence of prices to the predicted price range when traders may bank permits is unaffected, but tends to occur more rapidly than when shares are not traded. This result is shown in Panel B of Figure 9 which is contrasted in Panel A with the prices from a session in which shares may be traded but banking is not permitted. Of particular note is the reduced volume of trades in Figure 9 as compared with Figure 8.

When production is uncertain, and so the need for permits is uncertain, it is possible that producers may find themselves either in need of additional permits to meet their emission constraints or with a surplus of permits. In Godby *et al*. (1997) a reconciliation market was provided to the traders so that they could acquire needed permits to meet their legal emission constraints. Failure to acquire the appropriate permits would result in a substantial fine being levied on a producer in deficit.

Panel A in Figure 10 shows the contract prices during a reconciliation market in a session with no banking, but with share trading and production uncertainty. Although not many permits are traded in the twelve reconciliation periods, they are far from the equilibrium prices (L$14 in the first four periods and between L$123 and L$136 during the last eight periods). Panel B shows the prices of contracts formed during a session with share trading, production uncertainty *and banking*. The prices are quite stable and slightly below the predicted equilibrium band for a banking environment. Because large fluctuations in emission permit prices can create financial hardships for firms who produce in an environment in which there is uncertainty surrounding their need for permits, banking can play a valuable role in stabilizing a market. In addition, it can help achieve abatement cost savings for producers in short-run situations after which a major crank-down in allowable emissions will be imposed on producers.

Efficiency in these permit markets is measured as the percentage of potential abatement cost savings that are realized by the traders in these market sessions across the twelve periods of trading and production decisions. The traders in the double auctions in Godby *et al*. realized a greater share of potential savings than did the traders in the multiple-unit open-outcry markets of Mestelman, Moir, and Muller. Figure 11 displays the mean efficiencies in the eight different treatments studied by Godby *et al*. and the single treatment considered by Mestelman, Moir, and Muller. Although the parameterization of the double-auction sessions and the open-outcry sessions were different, these data suggest that the double-auction mechanism may be preferred the more loosely structured open-outcry environment (the comparable efficiencies are 90.5% and

74% respectively). Given the parameterizations of both environments, trading permits alone can implement the optimal allocation across the twelve trading periods. Shares are redundant instruments. Figure 11 shows, however, that when shares may be traded banking has a greater impact on efficiency than when shares may not be traded. This behavioural effect was not anticipated, and is certainly not a prediction from the equilibrium theory underlying these markets.

5.4. Market Power and Emission Permit Trading

Godby (1997) undertook an investigation into the potential for market power in emissions trading markets. His first experiment, also presented in Brown-Kruse, Elliott and Godby (1995), consisted of twelve replications of a design originally proposed and piloted by Brown-Kruse and Elliott (1990). It involved groups of eleven subjects, one in the role of the dominant firm in an emission trading market and the others in the role of competitive fringe firms. Treatment variables were the initial allocation of permits (100% to the dominant firm or 100% to the fringe firms) and possibility to manipulate a downstream product market. This experiment displays striking results which suggest that market power can easily emerge in the presence of asymmetric information (when the dominant firm has information about the valuations of the competitive fringe). Godby (1997, 1999) extends the first experiment by aggregating the ten fringe firms into five firms and is able to generate similar market power results with larger fringe firms who are able to act as traders rather than either buyers or sellers of permits. This outcome is very different from the conjecture in Bohm (1998).

Bohm (1998, section 3.1, assumption 1) describes an environment in which there is a dominant purchaser of permits (the United States) and many relatively small sellers at the competitive equilibrium price (which is consistent with the Brown-Kruse, Elliott and Godby environment). He also assumes (section 3.1, assumption 2) that all traders have "roughly common knowledge of everybody's [marginal abatement cost functions]". He then describes a trading period that lasts for five calendar years across which countries may bank permits (section 3.1, assumptions 3 and 4). Finally, the permits will be traded in a double auction. Bohm (section 3.1, implication 1) conjectures that because trading will occur over a five year period, the trading partners will be likely "to know even better everybody's quota net supply functions, and hence will be able to estimate with good approximation the [marginal abatement cost] value at which all MACs are equalized." He then conjectures (section 3.1, implication 2) that as the dominant firm exercises market power, and acting as a monopsonist puts downward pressure on prices, other traders will enter into the market in competition, and that "this specific market does not allow a trader to remain in a dominant position when prices become increasingly favourable to him and unfavourable to others". Finally he argues (section 3.1, implication 3) that "market power in a double-auction market is unlikely to cause prices for all transactions, and the total volume of transactions, to deviate from their perfectly competitive levels".

Figure 12 summarizes the mean permit price data for ten trading periods across twelve sessions presented in Brown-Kruse, Elliott and Godby (1995) and Godby (1997). The open squares and circles identify mean prices for sessions in which the market power firm has the potential to exercise market power in both the permit market and the product market. The solid squares and circles identify mean prices for sessions in which the product market price is exogenously determined. When the market power firm is a buyer of permits (the situation described by Bohm as a likely scenario in which the United States will be the dominant buyer), permit prices are consistently kept *below* the predicted market power prices of 90 lab dollars (exogenous product price) and 75 lab dollars (endogenous product price). In the former case the mean market efficiency across the ten trading periods is 0.71 (71% of the potential gains from trade are realized), while in the latter case the mean market efficiency is -0.42 (gains are *reduced* from the no-trade environment by 42% of the potential gains from trade).

The major difference between the Brown-Kruse, Elliott and Godby (BEG) environment and Bohm's environment is the initial lack of common knowledge about marginal abatement costs. However, given Bohm's belief that within five trading periods sufficient information would be disseminated across traders that they would be able "to estimate with good approximation the [marginal abatement cost] value at which all MACs are equalized", it might be reasonable to consider only the final two or three trading periods in the BEG environment and argue that by then the traders have a pretty good idea of the marginal abatement cost functions of the participants in this environment. In these final trading periods, prices are nearly identical to the market power predictions.

Finally in regard to Godby's market sessions, when the dominant firm is a seller, it is able to exercise market power more effectively when there is a product market to manipulate than when the product market price is exogenously determined. However, even in the latter environment, there is a recurring tendency for the price to rise above the monopoly price.

Godby's work suggests that even the seemingly reliable double-auction institution may be subject to market power manipulation. This makes the use of economic (market) instruments for environmental regulation once again susceptible to market failure due to market imperfections. Not only is it necessary to overcome the existence of externalities, but policy analysts must be careful to craft trading institutions which will overcome structural features which can provide opportunities for traders to exercise market power.

6. Voluntary Restraints

6.1. Introduction

Voluntary restraint may be a vehicle to avoid the problems associated with market power. If firms voluntarily agree to internalize externalities, opportunities to exercise market power may not arise. Canada's official response to the commitment it made at the 1992 United Nations Conference on Environment and Development, the National Action Program on Climate Change, was based on voluntarism (see Macdonald, Palardy, and Smith 1997). Its major component, the Voluntary Challenge and Registry Program, is administered by Natural Resources Canada and provides a vehicle through which polluters are able to propose schemes by which they voluntarily pledge to reduce emissions, clearly describing the methods they will use and the time frame over which this will be accomplished. This is supposed to work because it will be reported publicly. Macdonald *et al*. (1997) note that the federal government has acknowledged that the program has been a failure.

Segerson and Miceli (1998) consider voluntary agreements to curb environmental pollution in a theoretical framework and conclude that the outcomes of these agreements are uncertain. Of particular importance in the success of voluntary agreements is the strength of the background threats which regulators can make if voluntary agreements are violated. A strong background threat means that failure to comply with a voluntary agreement will result in legislated enforcement of standards which will impose costs greater than those associated with voluntary agreement (e.g. if a voluntary cap-and-trade scheme is not supported by an industry within a prescribed period of time, the government will legislate pollution taxes with certainty).

There has not been any work in laboratory environments which directly addresses the issues surrounding voluntarism in environmental regulation. However, there are some laboratory environments which offer some insights into the problems associated with voluntary restraint programmes.

6.2. Voluntary Provision of Public Goods and Communication

There is a large and growing literature addressing the voluntary provision of public goods which uses laboratory environments (see Ledyard 1995 for a recent survey). A robust outcome from this literature is that when individuals must make decisions to allocate resources between activities which provide private returns and activities with returns based on group contributions, individuals generally *under contribute* to the group activity relative to the socially optimal contribution. However, they frequently *over contribute* relative to the individually rational prediction for the environment. The over-contribution tends to be much closer to the individually rational outcome than to the socially optimal outcome.

Figure 13 shows summary data from Chan, Mestelman, Moir, and Muller (1999) for contributions from twenty-four three-person voluntary contribution sessions across eight different treatments (three sessions for each treatment). The treatments accounted for two different information conditions and four different heterogeneity conditions. In addition, within each session, subjects first had to make decisions without being able to discuss them with the other members of the their group, but later they were permitted to meet to share information and discuss their decisions prior to four sets of four decision periods.

Heterogeneity is introduced in these sessions by providing subjects with different endowments of resources to allocate to private and public investments or by providing subjects with different returns to their public investments. The homogeneous treatment (Hom) has all subjects with the same endowment and the same payoff schedules. The moderately heterogeneous treatments (Het) have one subject in each group of three subjects with either a different endowment or different payoff schedule than the others. Finally, the most complex heterogeneity treatment (CHet) has one subject in each group with both a different payoff schedule and a different endowment than the other two members of the group. Subjects with complete information (CI) know the endowments and payoff schedules of the other two members of their groups. Under incomplete information (II), subjects only know the total endowment of their groups. Figure 13 reports the mean proportion of the gap between the Nash equilibrium contribution and the optimal contribution realized by participating groups in each period across the four periods preceding communication and across the four periods following each round of communication.

The first six decision-periods of each session are conducted without communication among the subjects. Generally, by the sixth period, mean voluntary contributions to the public good are close to the Nash equilibrium contribution of 21 resource units. Whether subjects have complete or incomplete information about the payoffs and endowments of others in their group, the level of voluntary contributions are relatively close to the Nash equilibrium (the mean for periods 3 - 6 account for 12 percent and 3 percent of the gap between the Nash equilibrium and optimal contributions respectively). Without communication, voluntary action does not lead to socially optimal outcomes.

After periods 6, 10, 14 and 18 subjects are permitted to meet with other members of their groups to discuss whatever they wish to discuss for four minutes. They may enter into non-binding agreements. Communication leads to increased cooperation and greater levels of group contributions after the first round of communication. Generally, complete information facilitates cooperation (in Figure 13 the open boxes are above the solid boxes for comparable treatments in 10 or 12 pairings). An interesting result of this experiment is the success of heterogeneous subjects relative to homogeneous subjects in maintaining relatively high levels of voluntary contributions.

With regard to communication, these public goods outcomes are not new to the economics literature (see Feeny 1992 for comparable references from the psychology literature). They suggest that permitting individuals the opportunity to communicate, when coordination of activities can lead to mutually beneficial outcomes, improves the ability of individuals to coordinate their actions. This type of result was also noted in the bargaining experiments of Hoffman and Spitzer (1982) and Harrison and McKee (1985) related to the Coase Theorem. These led to a series of sessions in which Harrison, Hoffman, Rutström, and Spitzer (1987) evaluated the introduction of bargaining among twelve individuals in a laboratory environment which replicated the Plott (1983) environment. They discovered that after several rounds of discussions, given the ability to form *binding* agreements, the twelve traders in the Plott environment were able to achieve very high levels of efficiency through agreements to set prices, limit production, and redistribute gains from trade. Figure 14 shows the effect of the Harrison *et al*. free-form bargaining, which was introduced after five trading periods during which prices and quantities were determined through trading in a double auction.

This does not, however, necessarily provide evidence that voluntary restraint programmes for environmental regulation will succeed if the firms in polluting industries may communicate among themselves. In the laboratory environments comparable to the ones described above, the polluters are the potential beneficiaries of efficient regulation. Coordination and increasing voluntary contributions benefits all members of the group.[3] Finally, all relevant agents communicate in these environments.

Schmitt, Swope and Walker (2000) consider the effect of communication in a common pool resource environment in which there are outsiders who may appropriate from the pool, but who do not participate in the coordinating communication. Figure 15 presents the average rents accrued by participants in the environment with outsiders (solid circles) compared with the results obtained by Ostrom, Gardner and Walker (1994) in an identical environment without outsiders (solid boxes). Communication is introduced after the tenth decision period, and precedes each subsequent decision period in the communication treatments. The Ostrom *et al*. sessions display the dramatic impact of communication on rents. The Schmitt *et al*. results suggest the equally dramatic effect of the existence of two outsiders in a group of eight appropriators.

These results suggest that communication is not sufficient to make voluntarism a successful device for environmental control. The participation of *all* relevant agents and the ability for them to enter into binding contracts is crucial.

---

[3] In addition, the Plott (1983) environment contains six sellers and six buyers, five of whom produce and consume two units in the optimal state. The remaining seller should sell three units and the remaining buyer should buy three units. In the pre-regulation state, all buyers buy four units and all sellers sell four units. An agreement for everyone to reduce sales and consumption by half attains an overall efficiency which is nearly the maximum possible. Therefore, the Harrison *et al*. bargaining solution may owe its success to the symmetry of the laboratory environment.

6.3. The Polluters' Environment

In the public good environment, all members of a group benefit when they all voluntarily contribute to the group activity. In the polluter-pollutee environment, the profit of the polluter falls as he incurs greater treatment costs to abatement emissions while the community surrounding the polluter benefits as less effluent is emitted into the environment. If this characterizes the environment into which regulators hope to introduce voluntary restraint programmes, it is unlikely that they will find polluters rushing to transfer benefits to other members of the society by participating in voluntary restraint programmes.

Social psychologists have developed a research tool which identifies the value orientation of subjects who will participate in their experiments. Subjects are identified as altruistic, cooperative, individualistic, competitive or aggressive based upon their responses to a series of choices between pairs of distributions of resources between themselves and anonymous peers. This tool has been introduced into the study of voluntary contributions made to public goods (see Offerman, Sonneman and Schram 1996). Figure 16 displays the distributions of the value orientation measures across three categories obtained from 209 undergraduate students at McMaster University in four different designs of the mechanism used to obtain value orientations (see Buckley, Chan, Chowhan, Mestelman and Shehata 1999).[4] The altruistic and cooperative

[4] The individualistic orientation identifies an individual who tends to select an allocation of resources between himself and an anonymous peer which maximizes his own gain. The cooperative orientation identifies an individual who attempts to maximize the sum of the gain to himself and his anonymous peer. A competitive orientation identifies an individual who attempts to maximize the amount by which his gain exceeds that of this anonymous peer's. Altruists and aggressors are at the extremes. The former will select the allocation of resources which most benefits his anonymous peer, while the aggressor selects that allocation which least benefits his anonymous peer. In these last two cases, the choices are independent of the decision-maker's gain. When the value orientation is at the maximum for an individualist in the environment used

individuals are included in the cooperative category while the competitive and aggressive individuals are included in the competitive category. Under no design does the altruistic or aggressive category contain more than three percent of the subjects. Slightly fewer than twenty-seven percent of outcomes were categorized as cooperative. Fewer than one percent were altruists. The proportion of cooperative outcomes is not significantly different across designs. This is consistent with others' results and suggests that we will be unlikely to find that agents we know to be profit maximizers will voluntarily transfer payoffs to others when in the more general population such voluntary transfers are infrequent.

6.4. The Role of Threats

If people will not normally transfer resources voluntarily to others, it may be necessary for there to be a threat of retaliatory action to the lack of voluntary restraint. These incentives must be carefully designed. Examples from laboratory environments suggest that endogenous sanctions may not fully correct market failures and threatened agents may not respond to threats in the way regulators may anticipate they will react (Ostrom, Gardner and Walker 1994).

Moir (1999) studies an environment in which individuals appropriate resources from a common pool. Unregulated appropriation leads to over-appropriation of the resource. After several rounds of unregulated appropriation, Moir provides subjects with the opportunity to monitor, at a cost, the appropriations of the others extracting resources from the pool. At issue is the effect on the behaviour of subjects of knowing that others know you are drawing more than the *optimal* share from the pool. In a different treatment, Moir provides subjects with the

---

by Buckley *et al*. this person would be prepared to reduce his payoff by about ten percent if the anonymous peer could realize at least a ninety percent gain in his payoff. If the anonymous peer's payoff was less, the potential benefactor would prefer to maximize his private return.

opportunity to monitor, at a cost, and to sanction individuals who violate the *optimal* share standard. The sanctions are financial and are limited only by the amount the monitor is prepared to pay to sanction the violator. The greater the sanction, the greater the private cost to the monitor. Moir's results are summarized in Figure 17. After five periods of unregulated appropriation, the mean contributions of groups of appropriators are approaching the Nash equilibrium appropriation of 128 resource units. After the imposition of costly monitoring or costly monitoring and sanctioning the resulting appropriations diverge. With costly monitoring, appropriations are closer to the Nash equilibrium outcome than in the unregulated control groups. With costly monitoring and sanctioning, appropriations fall below the control groups' appropriations. However, even with sanctions, appropriations are well above the optimal value. Voluntarism on the side of regulation may help, but will not fully eliminate excessive appropriations from the common pool.

Falk, Lynn, Mestelman and Shehata (1999) also study the violation of standards. The data reported in Figure 18 were generated in a laboratory environment in which subjects' *moral development* was evaluated prior to their participating in a series of auditing decisions. Prior to participating in any treatments, all of the subjects were given information with which they had to make a determination of the *true state* of the environment in which they were participating. In each of three treatments, subjects had to chose to accept or qualify statements made by clients. If a client's statement is based on what the subject identifies as the *true state*, the subject should accept the statement. If the client's statement is based on something other than the *true state*, the statement should be qualified. In the first treatment, the subject incurred no cost from issuing a qualified statement. In the second treatment, the subject could lose the client in subsequent rounds (and hence the client's fee) if he issued a qualified report. In the third treatment, the subject could lose the client by issuing a qualified report, but if he did not issue a qualified report when he should, he might be discovered through an audit review. The subject knew the likelihood that an audit review would occur, that if reviewed his violation would be discovered with certainty and he would lose the client and pay a penalty. The introduction of the potential loss of a client should increase the frequency of violations. The subsequent introduction of the uncertain review should lead to a reduction in the frequency of violations.

Confronted with the first treatment in which issuing a qualified report is costless, subjects violate the standard (accept a statement when it should be qualified) in fewer than three percent of the possible cases. Regardless of the likelihood of losing a client, introducing the possibility of a loss by issuing a qualified report results in a substantial increase in the frequency with which the standard is violated. When the possible threat is introduced (the audit and its resulting penalties) violations of the standard are reduced when the chance of losing a client is 10 percent or 25 percent. Once the chance of losing a client rises to 40 percent, the audit does not have the desired effect. The introduction of the audit does not reduce the incidence of violations of the standard.

This result is consistent with laboratory work addressing risk attitudes and the purchase of insurance (see Elliott 1998). People frequently follow rules of thumb when making decisions to purchase insurance. They will often focus on the magnitude of the likelihood of specific events rather than actually compute the expected values of outcomes. In the Falk *et al*. environment, when the probability of the audit is greater than the probability of losing a client, there is a large reduction in the incidence of violations. When the probabilities are about the same, there is a smaller reduction in violations (in both magnitude and proportion). When the probability of losing the client exceeds the probability of the audit by a substantial amount, the audit does not lead to a reduction in violations.

These results suggest that Segerson's and Miceli's (1998) concern about the existence of a threat is important. Furthermore, the threat must be sufficiently large as to insure that even if people are not expected profit maximizers in the most formal sense, the threat will register as imposing a cost worth incorporating into any decision. Finally, volunteerism in the conduct of sanctions may not be an effective way to organize sanctions.

7. Conclusions

The laboratory results presented here are examples of ways in which laboratory methods can assist practical policy-makers in the design of institutions and mechanisms for environmental regulation. The work on emission trading by Cason (1993), Cason and Plott (1996), Godby (1997), Godby *et al*. (1997) and Mestelman *et al*. (1999) has identified unexpected flaws in the U.S. EPA trading institution, unexpected advantages to trading permit futures, and an unanticipated emergence of market power in double-auction markets.

Work by Plott (1983) and Spraggon (1999) has demonstrated the drawbacks to the use of industry quotas and forcing contracts to regulate non-point-source pollution and the effectiveness of the traditional, but rarely adopted, candidate for regulation, the Pigouvian emission tax.

Although there have been no laboratory environments created to directly evaluate the effectiveness of voluntary restraint as a method of environmental regulation, there are some hints as to the potential success of voluntary restraints which may be gleaned from the experimental economic literature. Although communication can lead subjects to effectively coordinate their contributions to public goods, the similarity between the public good environment and environmental pollution is questionable. The conventional public goods and common-pool resource laboratory environments tend to contain participants who will all gain from coordinated activities. It is not obvious in the field that polluters will benefit by increasing abatement activities or by retooling and replacing dirty technologies with clean technologies, even though it may be obvious that there will be a net increase in the social surplus. In these environments it is likely that the *public-good problem* will emerge and make it difficult for the many individuals who receive small benefits from emission control to share their aggregate gains with the producers who must incur increased cost through voluntary restraint. There is laboratory evidence which suggests that it is unlikely that individuals will voluntarily make sizable transfers to others (Buckley *et al*. 2000) and that they will be unable to effectively impose voluntary sanctions that can lead to optimal allocations (Moir 1999).

The implications regarding voluntary constraints when large numbers of people are involved suggests that direct regulation may be required to effectively limit environmental pollution. This comes full circle to emission trading policies. These combine the regulatory constraints necessary if voluntary restraint is unlikely to emerge, with the power of the market mechanism for distributing the limited acceptable emissions among the potential polluters. Pollutees benefit from the reductions in emissions while polluters realize part of the social surplus from emission reduction through the allocation of rights to pollute when the institution is established. Laboratory work related to emission trading environments suggests that trading institutions may be designed which can successfully reduce the cost of abating environmental pollution.

Laboratory economics is a tool which can be used to evaluate conjectures about economic behaviour of individuals or groups. There will always be new policy initiatives whose predicted outcomes will depend upon the behaviour of individuals in response to specific incentives. These are the sorts of policy initiatives that can best be evaluated using laboratory methods.

There is, however, a substantial difference between the laboratory and the naturally occurring environments. The laboratory environment may capture crucial aspects of the natural environment, but it cannot capture all aspects of the natural environment. Many contextual situations cannot be created in the laboratory and subjects cannot be invested with the context-specific human capital enjoyed by agents in the field.

An important aspect of interactions in the field is transaction cost (see Feeny 1998). Transaction costs are generally very low or nonexistent in laboratory environments. When they exist, they are well-defined and controlled. Typically, however, the objective of laboratory analysis of policy issues focusses, in well-defined contexts, on incentives which policy initiatives are expected to induce. If appropriately motivated subjects do not respond to these incentives in simple, controlled environments, it may be necessary to seriously question the likelihood that these incentives will be effective in the much more complex naturally occurring environment.

A final benefit of using laboratory environments to screen policy initiatives is that they are less costly to conduct than field studies with similar objectives. These costs are in terms of resources expended as well as time to complete and evaluate. It is less expensive to eliminate a poor policy initiative in the laboratory than to eliminate it after it has failed in the field, and if the laboratory evaluation is positive, the time by which field implementation is delayed is minimal.

References

Bohm, Peter. 1998. Benefits of international carbon emissions trading: theory and experimental evidence. Manuscript. Oslo: Stockholm University.

Brown-Kruse, Jamie and Steven R. Elliott. 1990. Strategic manipulation of pollution permit markets. Manuscript. Boulder: University of Colorado.

Brown-Kruse, Jamie, Steven R. Elliott and Rob Godby. 1995. Strategic manipulation of pollution permit markets. Department of Economics Working Paper 95-05. Hamilton, Canada: McMaster University.

Buckley, Neil, Kenneth S. Chan, James Chowhan, Stuart Mestelman, and Mohamed Shehata. 2000. Value orientation, income and displacement effects, and the voluntary provision of public goods. Department of Economics Working Paper. Hamilton, Canada: McMaster University.

Cason, Timothy. 1993. Seller incentive properties of EPA's emission trading auction. Journal of Environmental Economics and Management **25** (2), 177-195.

Cason, Timothy and Charles R. Plott. 1993. EPA's new emissions trading mechanism: a laboratory evaluation. Social Sciences Working Paper 863. Pasadena: California Institute of Technology.

Cason, Timothy and Charles R. Plott. 1996. EPA's new emissions trading mechanism: a laboratory evaluation. Journal of Environmental Economics and Management **30** (2), 133-160.

Chan, Kenneth S., Stuart Mestelman, Rob Moir, and R. Andrew Muller. 1999. Heterogeneity and the voluntary provision of public goods. Experimental Economics **2** (1), 5-30.

Crocker, Thomas. 1966. The structuring of atmospheric pollution control systems. In The Economics of Air Pollution. Harold Wolozin (editor). New York, NY: W. W. Norton and Company, 61-86.

Dales, John H. 1968. Pollution, Property and Prices. Toronto: University of Toronto Press.

Davis, Douglas D. and Arlington W. Williams. 1997. The effects of nonstationarities on performance in call markets. Journal of Economic Behavior and Organization **32** (1), 39-54.

Elliott, Steven R. 1998. Experiments in decision-making under risk and uncertainty: thinking outside the box. Managerial and Decision Economics **19** (4 and 5), 239-258.

Falk, Haim, Bernadette Lynn, Stuart Mestelman, and Mohamed Shehata. 1999. Self-interested behavior and ethics: the case of auditor independence. Journal of Accounting and Public Policy **18** (4-5), 395-428.

Feeny, David. 1992. Where do we go from here? Implications for the research agenda. In Making the Commons Work. David Bromley (general editor). San Francisco: ICS Press, 267-292.

Feeny, David. 1998. Suboptimality and transaction costs in the commons. In Designing Institutions for Environmental and Resource Management. Edna T. Loehman and D. Marc Kilgour (editors). Cheltenham, UK: Edward Elgar Publishing, 124-141.

Godby, Rob. 1997. The Effect of Market Power in Emissions Permit Markets. Ph.D. Thesis. Hamilton, Canada: McMaster University.

Godby, Rob. 1999. Market Power in Emission Permit Double Auctions. In Research in Experimental Economics **7** (Emissions Permit Experiments). R. Mark Isaac and Charles

Holt (editors). Greenwich, Connecticut: JAI Press, 121-162.

Godby, Rob, Stuart Mestelman, R. Andrew Muller, and Douglas Welland. 1995. Emission trading with shares and coupons when control over discharges is uncertain. Department of Economics Working Paper No. 95-09. Hamilton, Canada: McMaster University.

Godby, Rob, Stuart Mestelman, R. Andrew Muller, and Douglas Welland. 1997. Emission trading with shares and coupons when control over discharges is uncertain. Journal of Environmental Economics and Management **32** (3), 359-381.

Grether, David M., R. Mark Isaac, and Charles R. Plott. 1989. The Allocation of Scarce Resources. Boulder, Colorado: Westview Press.

Harrison, Glenn, Elizabeth Hoffman, E. E. Rutström, and Matthew Spitzer. 1987. Coasian solutions to the externality problem in experimental markets. Economic Journal **97** (2), 388-402.

Harrison, Glenn and Michael J. McKee. 1985. Experimental evidence of the Coase theorem. Journal of Law and Economics **28** (3), 653-670.

Holmstrom, Bengt. 1982. Moral hazard in teams. Bell Journal of Economics **13** (2), 324-340.

Hoffman, Elizabeth and Matthew L. Spitzer. 1982. The Coase theorem: some experimental tests. Journal of Law and Economics **25** (1), 73-98.

Hong, James T. and Charles R. Plott. 1982. Rate filing policies for inland water transportation: an experimental approach. The Bell Journal of Economics **13** (1), 1-19.

Joyce, Patrick. 1983. Information and behavior in experimental markets. Journal of Economic Behavior and Organization **4** (4), 411-424.

Ledyard, John O. 1995. Public goods: a survey of experimental research. In The Handbook of

Experimental Economics. John H. Kagel and Alvin E. Roth (editors). Princeton, NJ: Princeton University Press, 111-194.

Macdonald, Doug, Nancy Palardy, and Heather Smith. 1997. Firms, international regimes and instrument choice: lessons from Canadian implementation of the Rio Climate Change Convention. Manuscript. Toronto: Innis College, University of Toronto.

Mestelman, Stuart, Rob Moir, and R. Andrew Muller. 1999. A laboratory test of a Canadian proposal for an emissions trading program. In Research in Experimental Economics **7** (Emissions Permit Experiments) Charles A. Holt and R. Mark Isaac (editors). Greenwich, Connecticut: JAI Press, 45-91.

Moir, Rob. 1999. Spies and swords: costly monitoring and sanctioning in a common-pool resource environment. Manuscript. Saint John, Canada: University of New Brunswick.

Montgomery, David W. 1972. Markets in licenses and efficient pollution control programs. Journal of Economic Theory **5** (3), 395-418.

Muller, R. Andrew and Stuart Mestelman. 1994. Emission trading with shares and coupons: a laboratory experiment. The Energy Journal **15** (2), 185-211.

Muller, R. Andrew and Stuart Mestelman. 1998. What have we learned from emission trading experiments? Managerial and Decision Economics **19** (4 and 5), 225-238.

Nichols, Albert L. 1992. Emissions Trading Program for Stationary Sources of NOx in Ontario. Cambridge, MA: National Economic Research Associates, Inc.

Nichols, Albert L. and David Harrison. 1990. Using Emission Trading to Reduce Ground-Level Ozone in Canada: A Feasibility Analysis. Cambridge, MA: National Economic Research Associates, Inc.

Nichols, Albert L. and David Harrison. 1990. The Impact on Ontario Hydro of Emissions Trading for Nitrogen Oxides: A Preliminary Analysis. Cambridge, MA: National Economic Research Associates, Inc.

Offerman, Theo, J. Sonnemans and Arthur Schram. 1996. Value orientations, expectations and voluntary contributions to public goods. Economic Journal **106** (437), 817-845.

Ostrom, Elinor, Roy Gardner and James Walker. 1994. Rules, Games, and Common-Pool Resources. Ann Arbor, Michigan: University of Michigan Press.

Plott, Charles R. 1983. Externalities and corrective policies in experimental markets. Economic Journal **93** (1), 106-127.

Schmitt, Pamela, Kurtis Swope and James Walker. 2000. Collective action with incomplete commitment: experimental evidence. Southern Economic Journal, forthcoming.

Segerson, Kathleen. 1988. Uncertainty and incentives for nonpoint pollution control. Journal of Environmental Economics and Management **15** (1), 87-98.

Segerson, Kathleen and Thomas J. Miceli. 1998. Voluntary environmental agreements: good or band news for environmental protection? Journal of Environmental Economics and Management **36** (2), 109-130.

Spraggon, John. 1999. Exogenous Targeting Instruments for Eliciting Efficiency in Groups. Ph.D. Thesis. Hamilton, Canada: McMaster University.

United States Environmental Protection Agency (40 CFR) Part 73. 1991. Auctions, direct sales, and independent power producers written guarantee regulations and request for delegation of proposals to administer the auctions and direct sale; rule and notice. Federal Register (December 17), 65592-65609.

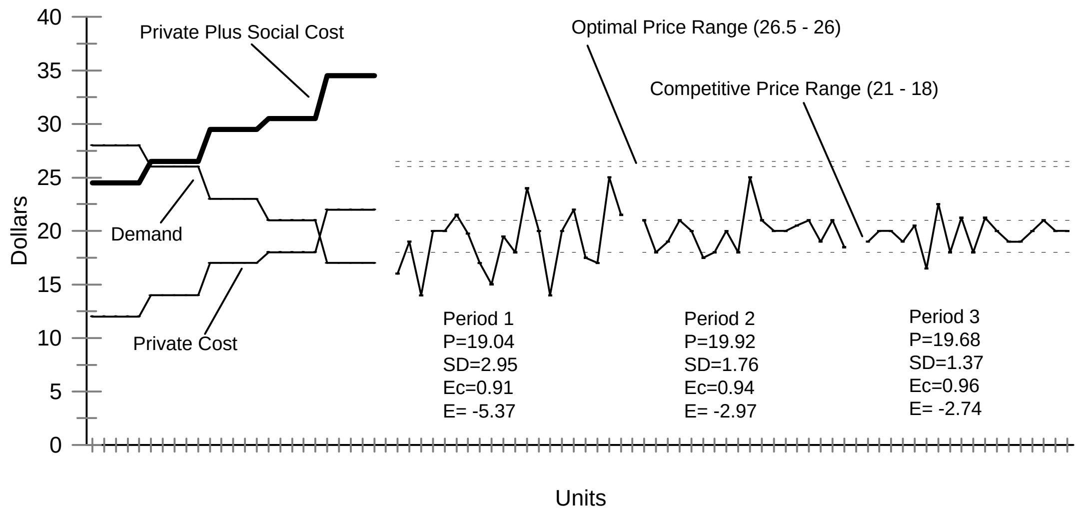


Figure 1 Panel A Open-Access Free-Form Market with Social Cost Session 1

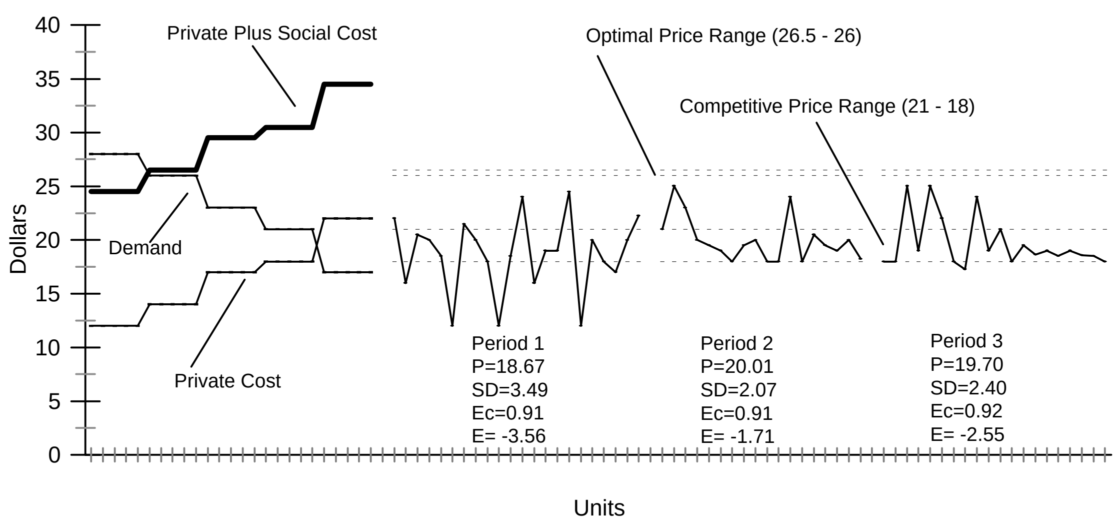


Figure 1 Panel B Open-Access Free-Form Market with Social Cost Session 2

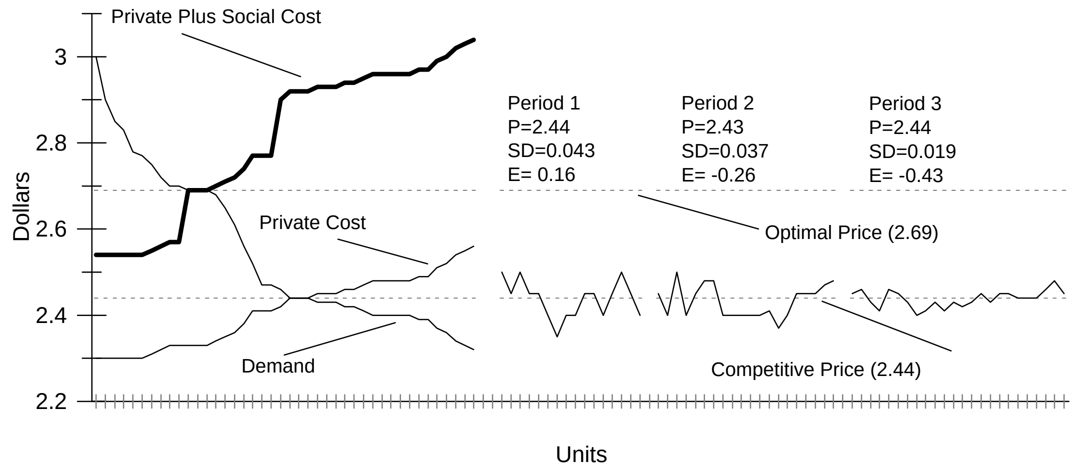


Figure 2 Panel A A Baseline Double Auction (Plott 1983)

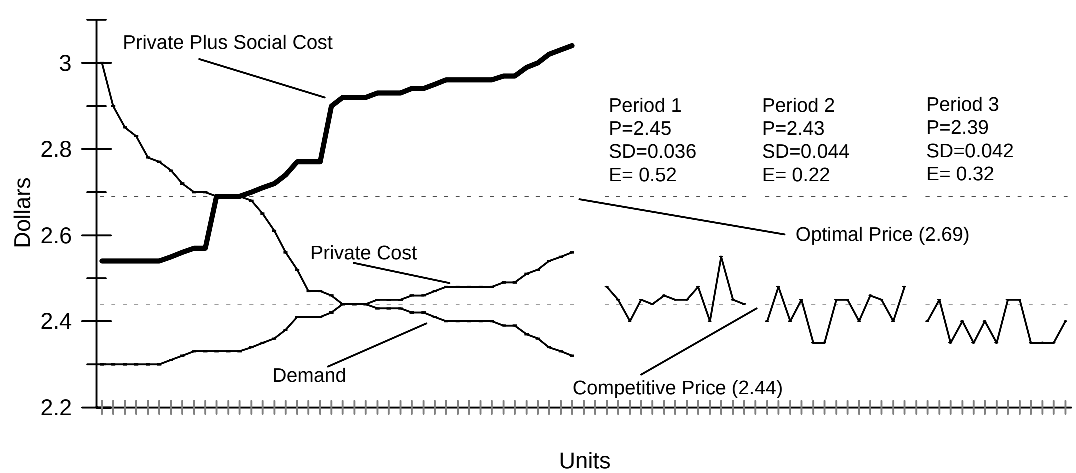


Figure 2 Panel B A Double Auction with Output Quota (Plott 1983)

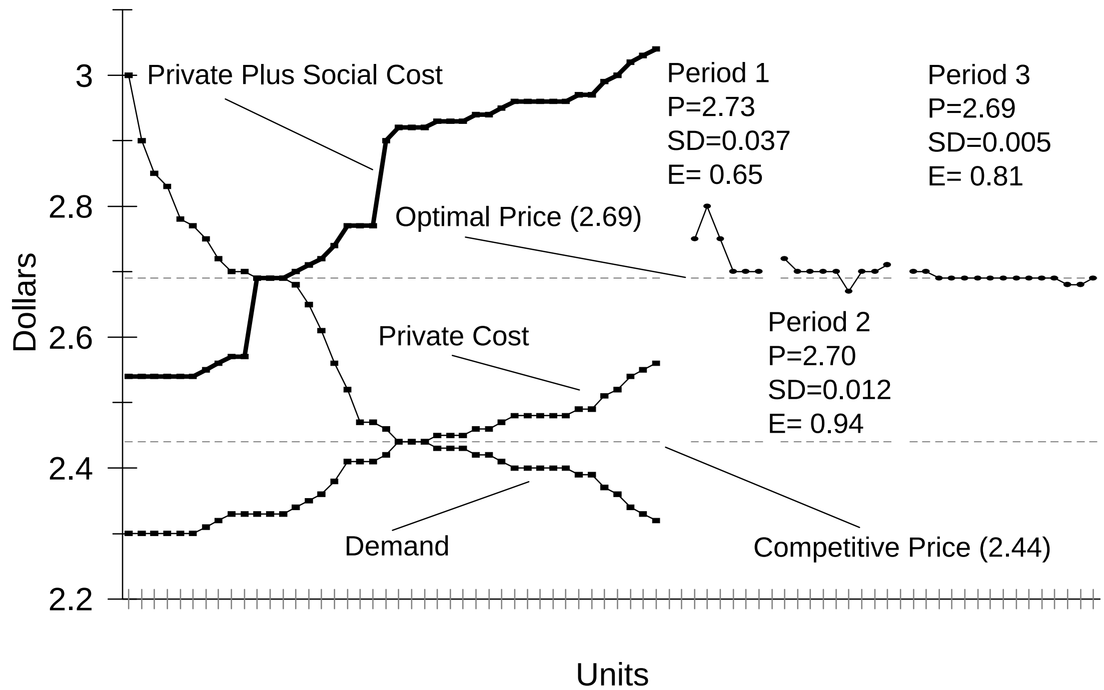


Figure 3 A Double Auction with Output Tax (Plott 1983)

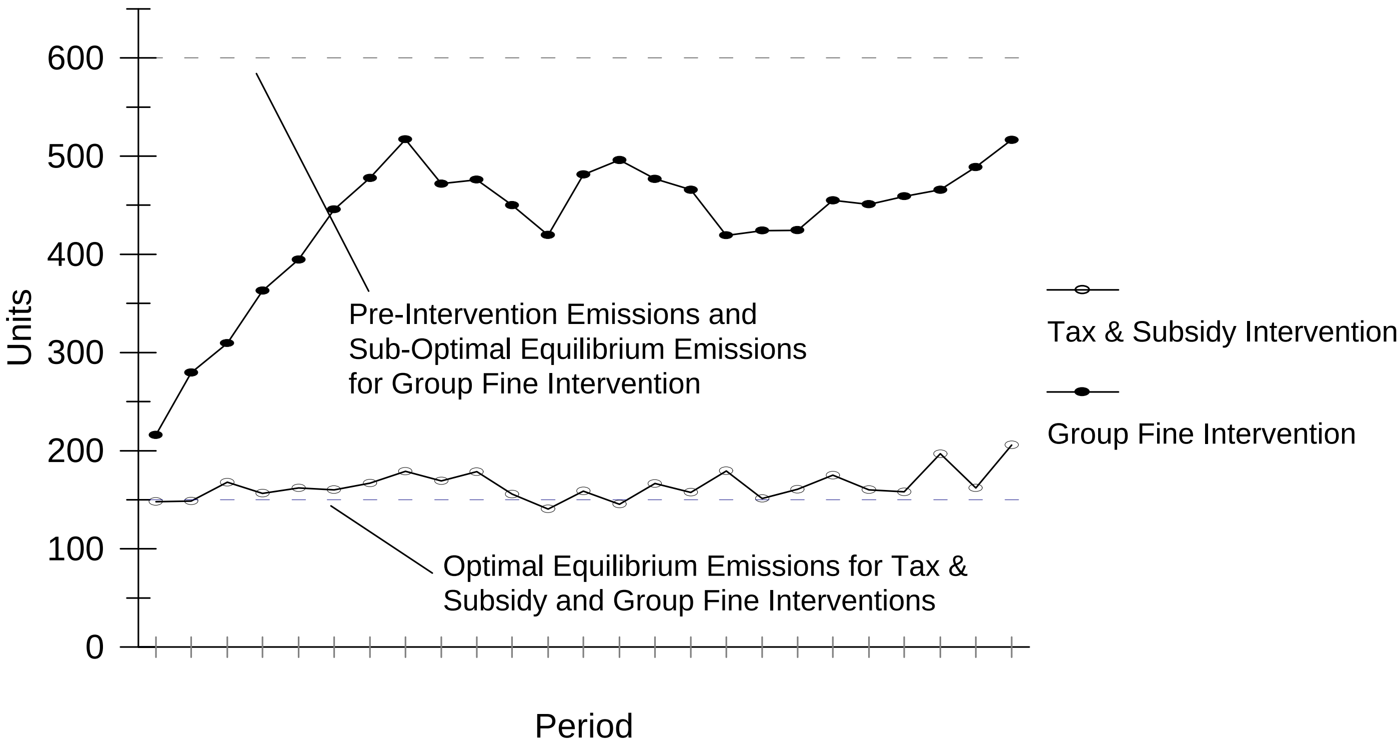


Figure 4 Non-Point Source Emissions with Alternative Interventions (Spraggon 1999)

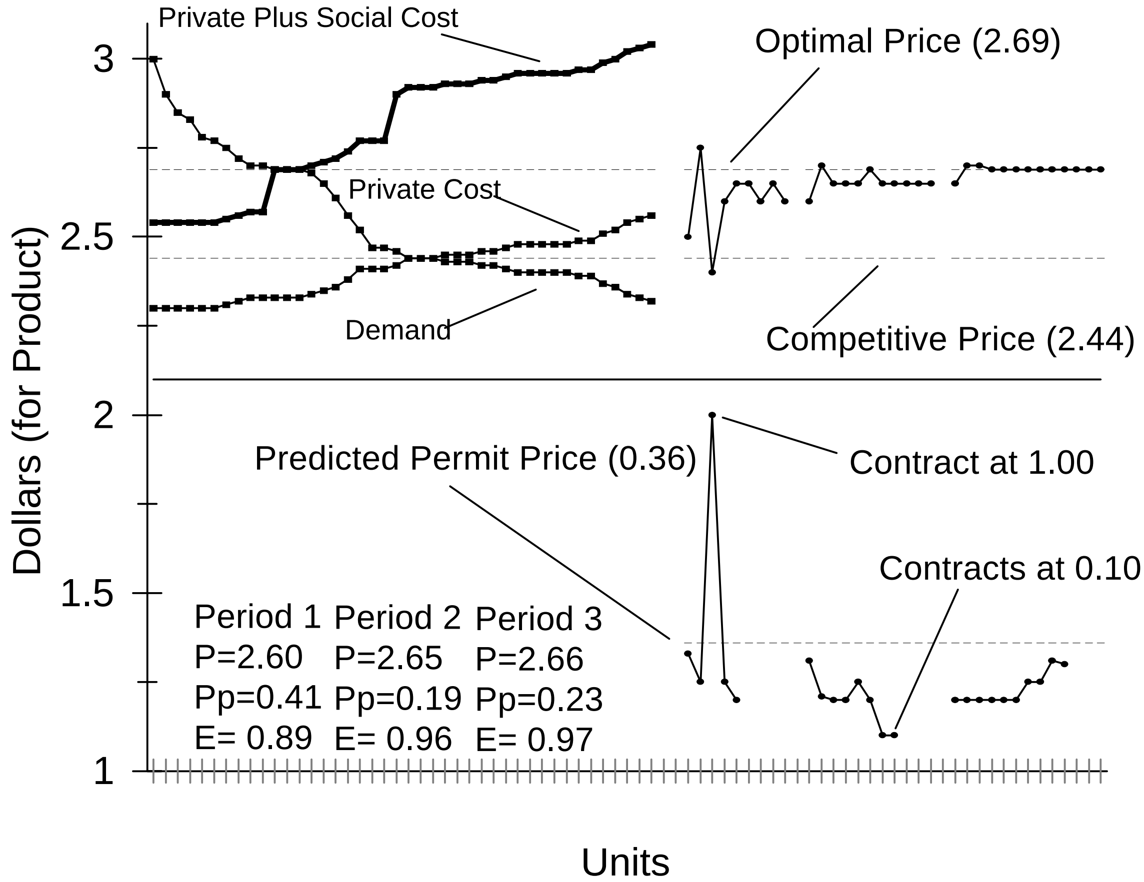
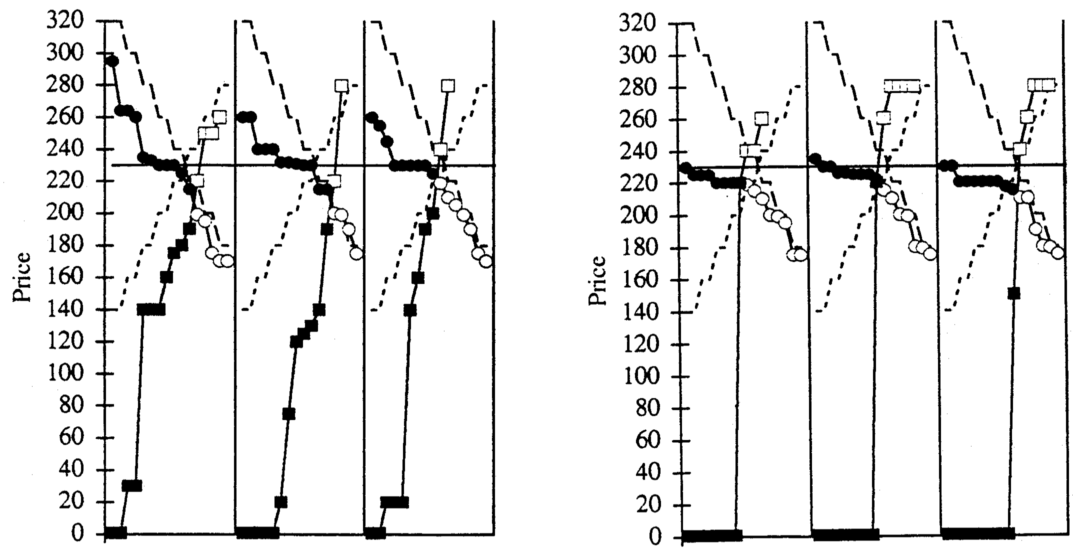


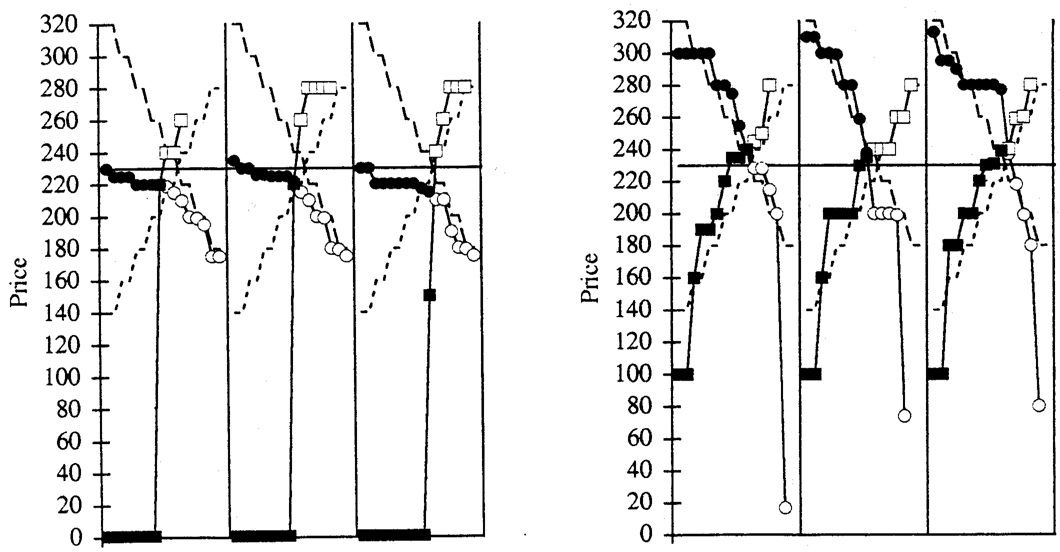
Figure 5 Simultaneous Double Auctions: One for Permits and One for Product (Plott 1983)



Panel A
Periods 1, 2, 3

Panel B
Periods 9, 10, 11

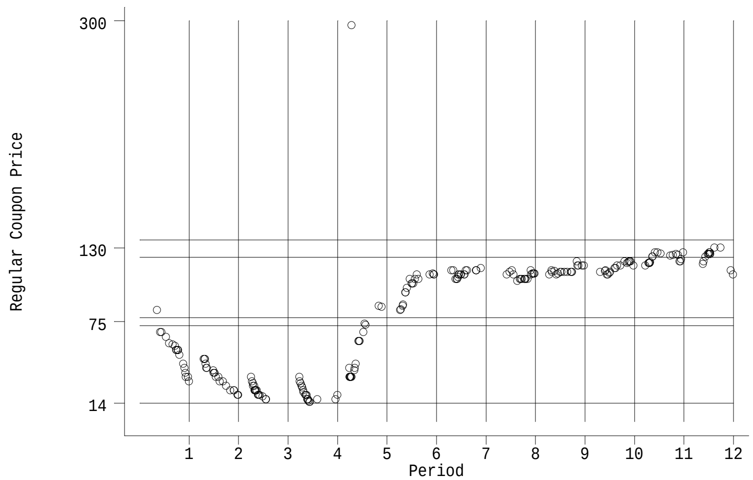
Figure 6 Bids and Asks in EPA Auction (Cason and Plott 1993)

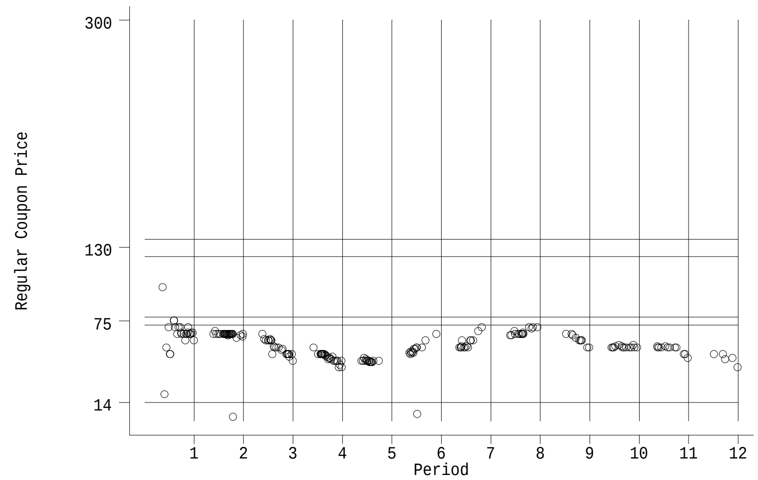


Panel A
EPA Auction
Periods 9, 10, 11

Panel B
Uniform Price Auction
Periods 9, 10, 11

Figure 7 Bids and Asks in EPA Auction and Uniform Price Auction (Cason and Plott 1993)

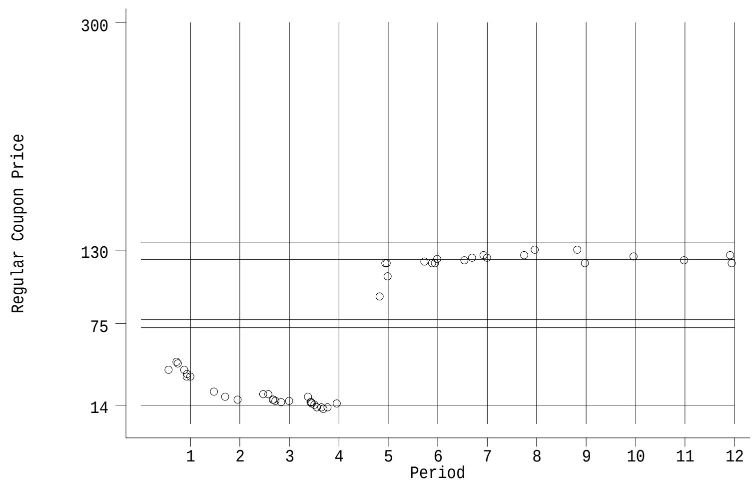




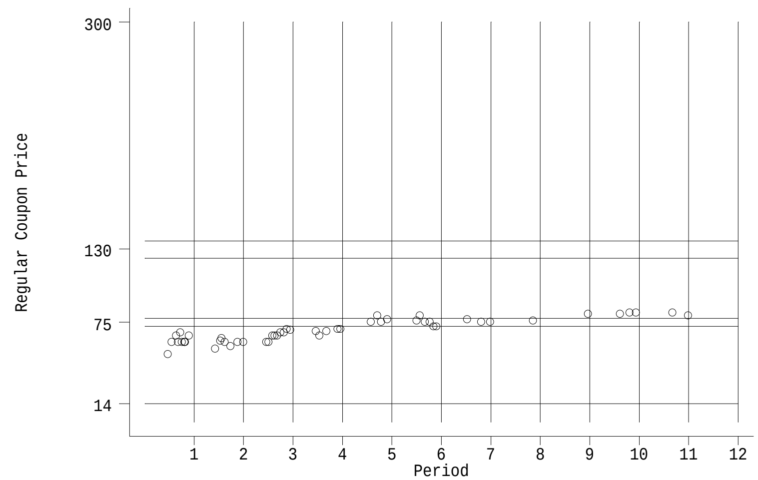
Panel A
No Banking, No Share Trading
No Uncertainty

Panel B
Banking, No Share Trading,
No Uncertainty

Figure 8 Permit Contract Prices (Godby *et al*. 1995)

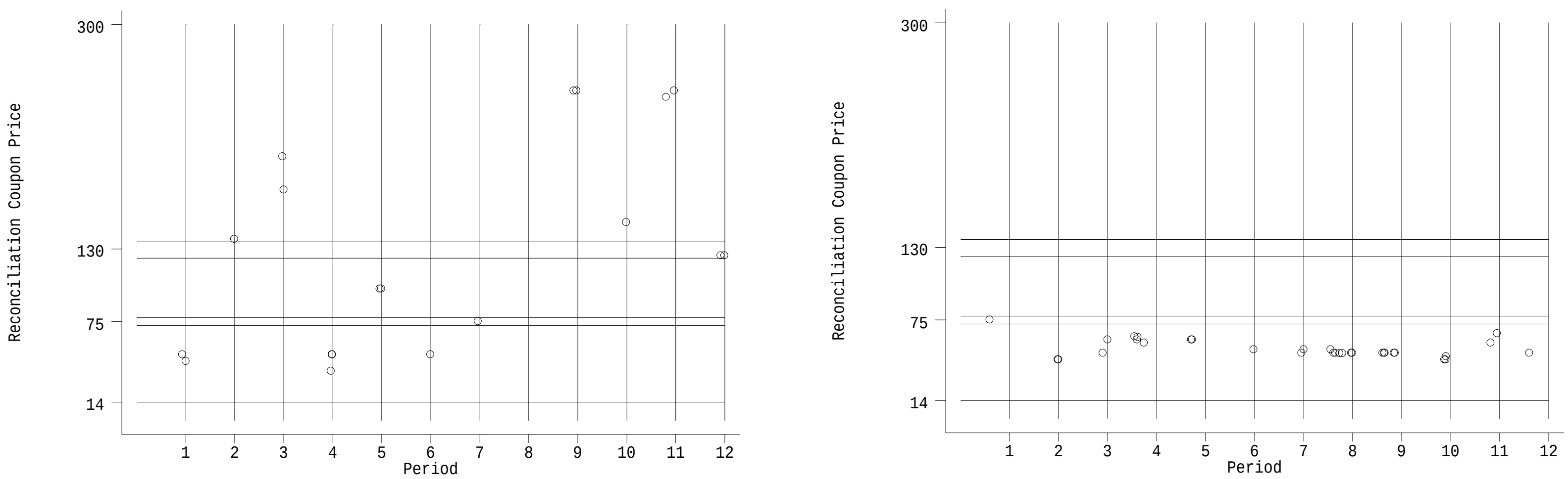


Panel A
No Banking, Share Trading
No Uncertainty



Panel B
Banking, Share Trading,
No Uncertainty

Figure 9 Permit Contract Prices (Godby *et al*. 1995)



Panel A
No Banking, Share Trading,
Uncertainty

Panel B
Banking, Share Trading,
Uncertainty

Figure 10 Reconciliation Permit Contract Prices (Godby *et al*. 1995)

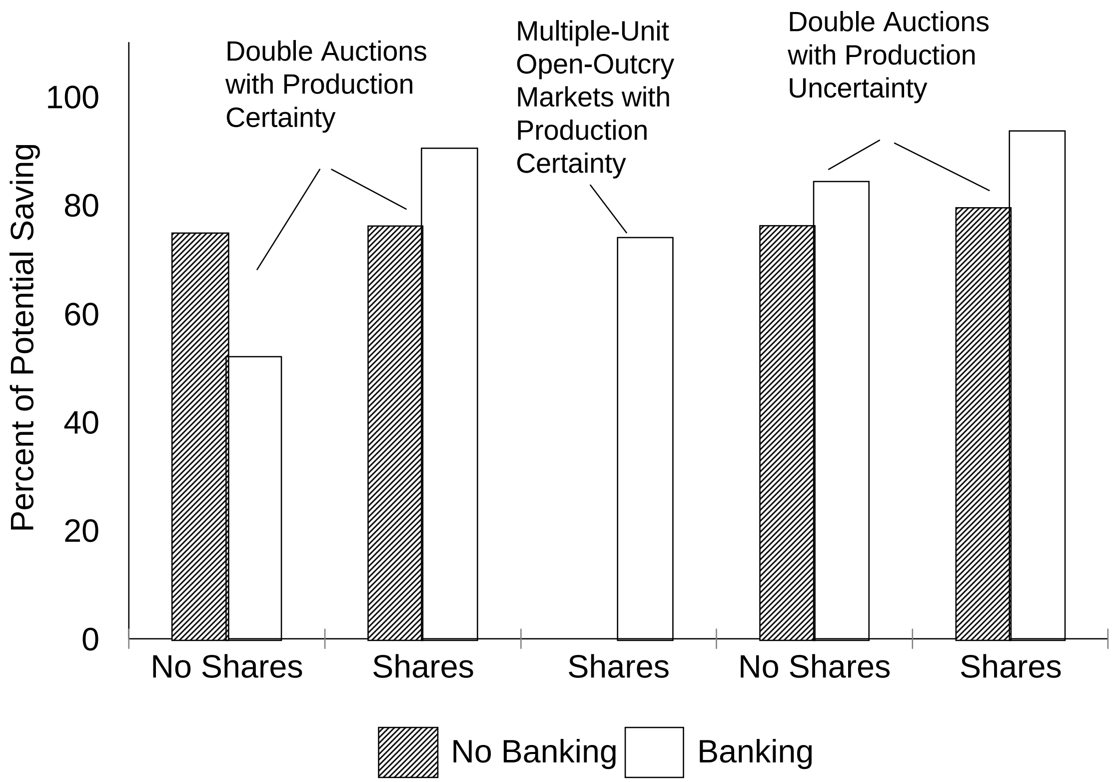


Figure 11 Efficiencies of Emission Trading Institutions
(Godby *et al*. 1997, Mestelman *et al*. 1999)

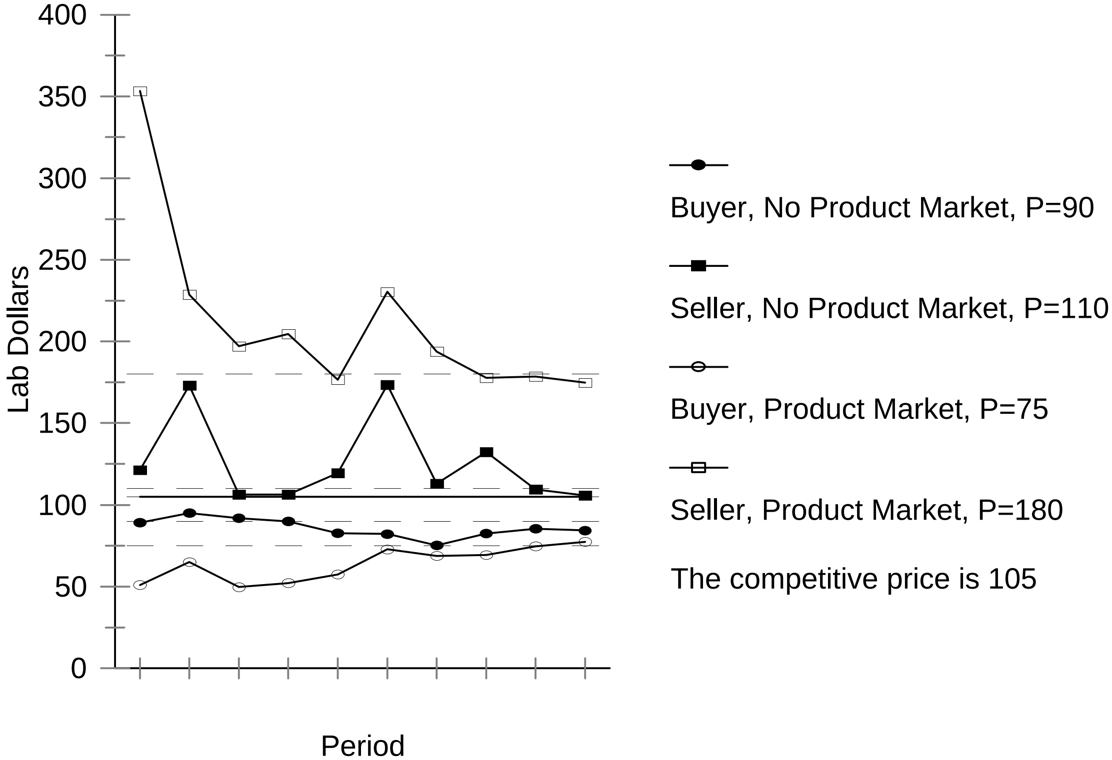


Figure 12 Mean Permit Prices with Market Power (Godby 1997)

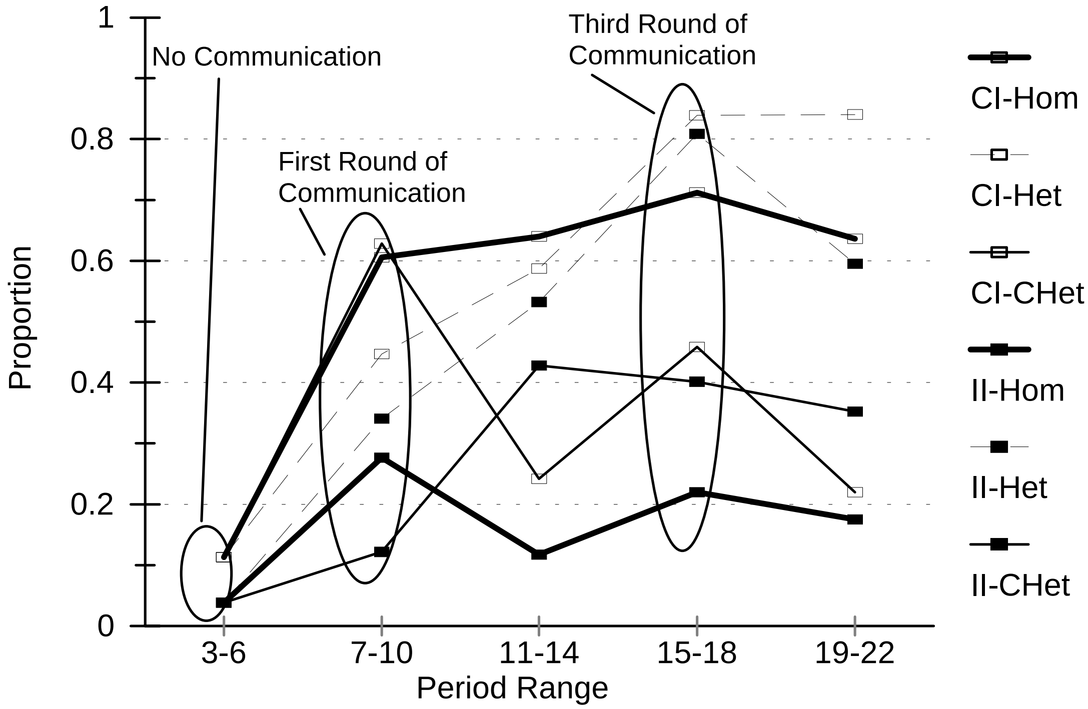


Figure 13 Mean Proportion of the Gap between the Nash Equilibrium Group Contribution and the Optimal Group Contribution Realized Over Five Four-Period Sequences (Chan *et al*. 1999)

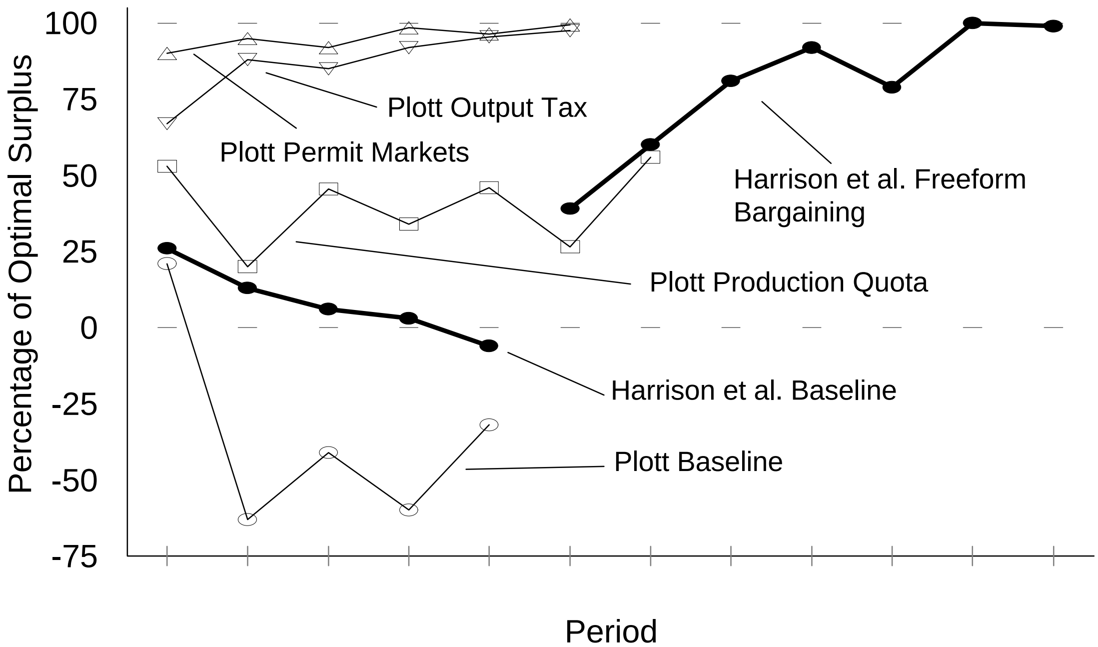


Figure 14 Efficiencies with Market Interventions and Free-Form Bargaining (Plott 1983, Harrison *et al*. 1987)

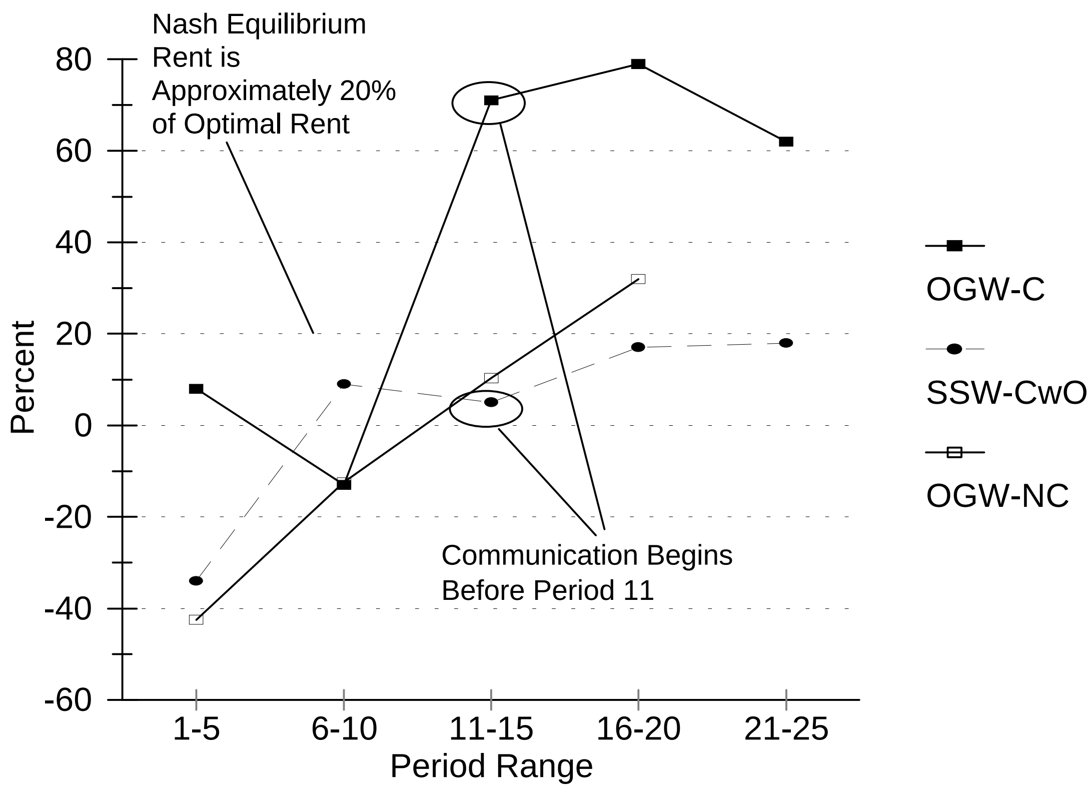


Figure 15 Average Per Period Rent, with and without Communication, with and without Outsiders (Ostrom *et al*. 1994 and Schmitt *et al*. 2000)

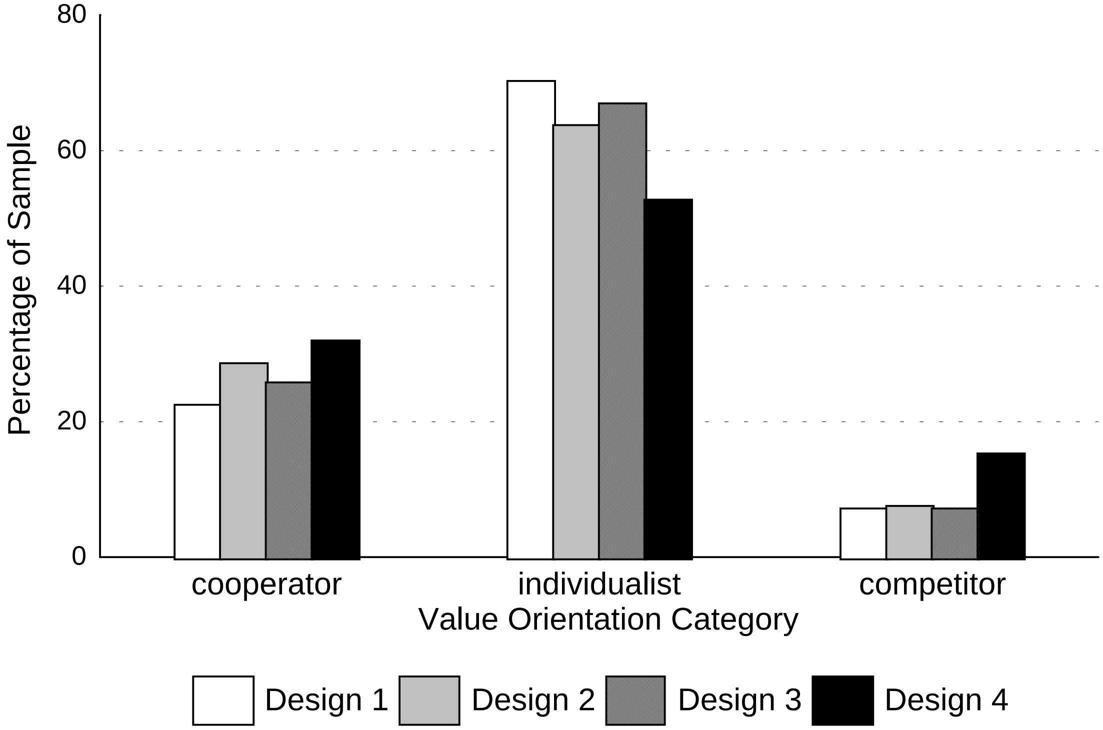


Figure 16 Distributions of Value Orientation Measures by Category (Buckley *et al*. 1999)

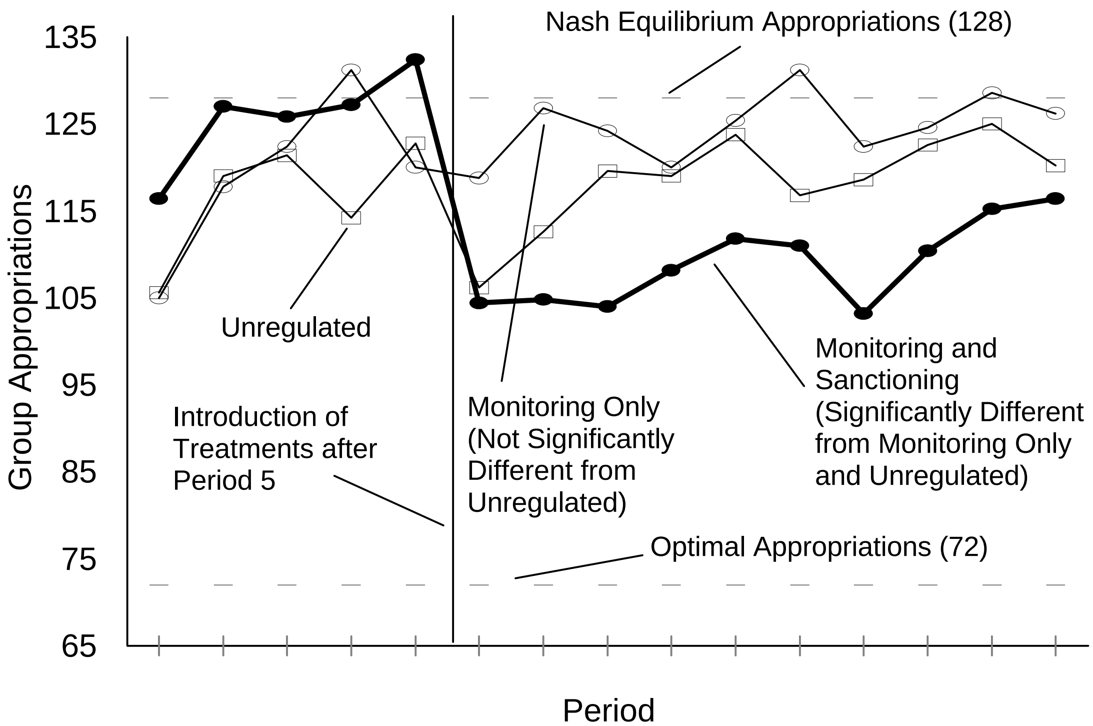


Figure 17 Mean Group Appropriations and Costly Monitoring and Sanctioning (Moir 1999)

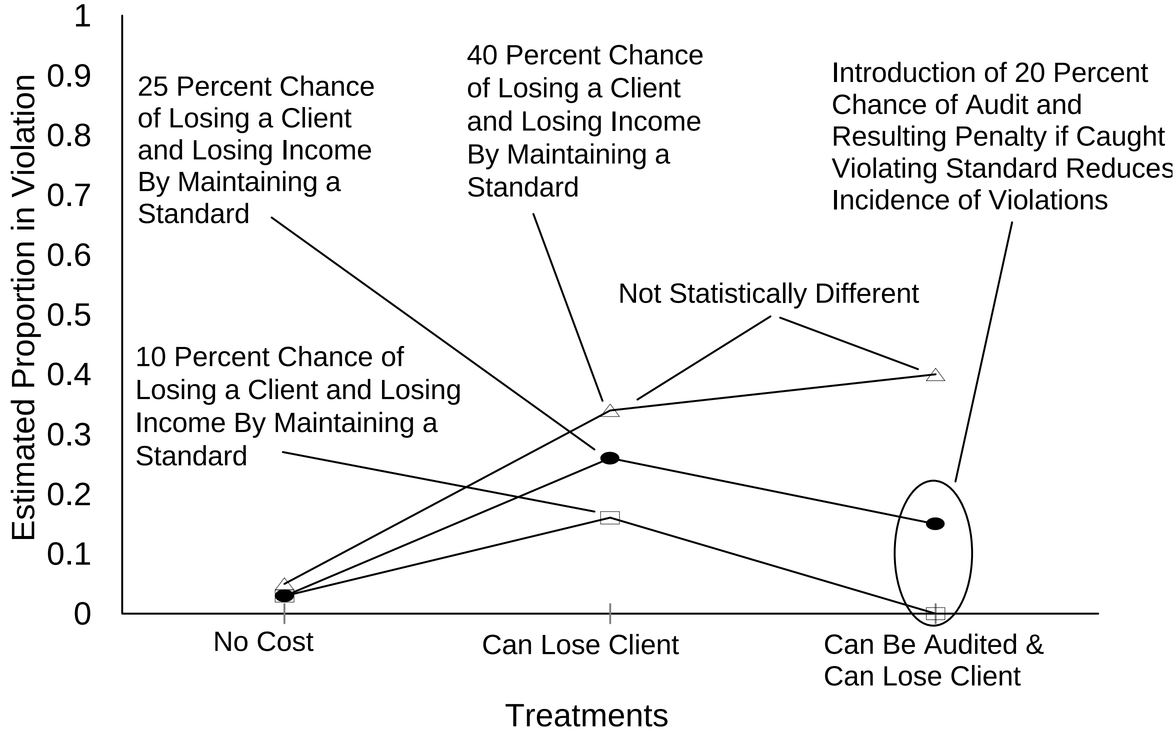


Figure 18 Estimated Violations of a Standard (Falk *et al*. 1999)