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Three Essays in Experimental Economics: Market Performance, Voluntary Contributions to Public Goods, and Emissions Permit Trading

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THE PERFORMANCE OF DOUBLE-AUCTION AND POSTED-OFFER MARKETS WITH ADVANCE PRODUCTION

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Mestelman and Welland (1988) argue that laboratory environments which use double-auction and posted-offer trading institutions typically do not require producers to incur production costs prior to entering into contracts to deliver units of their product to consumers. They add to the available information about the performance of these institutions by introducing an advance production condition, under which producers must incur production costs before entering into contracts to deliver their product to consumers. The markets they examine are markets for perishable goods. Inventories of unsold goods may not be carried from period to period. The decisions made by producers and consumers in this environment are influenced by the inability of producers or consumers to carry goods from one period to another.

The sunk cost incurred in the advance production environment, coupled with the inability of sellers to lower prices within a trading period in the posted-offer institution leads to lower prices in markets with advance production than in posted-offer markets with production to demand. The added complexity of the advance production environment leads to a reduction in the share of the gains from trade realized by participants in these markets from that realized in the less complex, production-to-demand environments. The double-auction institution, however, continues to perform better than the posted-offer institution with respect to the gains from trade realized.

Mestelman and Welland (1991a) extend their earlier work to consider an environment in which producers must make production decisions in advance of sale, but in which they are able to carry inventories of their products costlessly from period to period. The ability to carry inventories should offset the uncertainty associated with advance production, and should aid producers in realizing the potential gains from trade.

Increased market efficiency is not generally realized with the introduction of inventory carryover. The performance of the double-auction institution does improve when inventories may be carried. Inventory carryover, however, introduces a level of complexity which does not permit efficiency gains to be realized by traders in the posted-offer institution.

The laboratory sessions run by Mestelman and Welland (1988, 1991a) use subjects who are inexperienced with the trading institutions within which they must make production and consumption decisions. This inexperience is a possible source of the inefficiencies realized by traders in the posted-offer environments. Another source of inefficiency in the posted-offer institution, relative to the double-auction institution, is provided by the small amount of price information available to producers and consumers in posted-offer environments. Mestelman and Welland (1994) present a new set of laboratory sessions which reproduce the results of the earlier work and extend it by adding experienced traders and by introducing a second price-posting in the posted-offer environment.

The introduction of experienced traders does not have a substantial affect on the performance of either market institution. This suggests that repeated trading, period after period, in double-auction and posted-offer environments provides sufficient experience to traders, that the participation in more than one session of trading may not be necessary for subjects to benefit from learning effects in laboratory environments. The second price-posting does, however, improve the performance of the posted-offer institution. This added price flexibility provides sufficient information to producers and consumers to permit producers to effectively manage any inventories which may accumulate. In addition, sufficient price information is revealed, and sufficient opportunity to vary prices exists with a second posting to permit the posted-offer institution to generate trade gains matching that in double-auction markets (which permit multiple, and nearly continuous, price postings).

Figure 1 shows time series of mean contract prices for traders in posted-offer and double-auction markets with two different parameter sets. In Design A, the surplus which would be realized by buyers if a competitive equilibrium is reached at a price of 35 cents is greater than that which would be realized by producers. In Design B, the surplus which would be realized by buyers and sellers at a competitive equilibrium price of 76 cents is equal. With each design the prices generated by the posted-offer institution are greater than those generated by the double-auction institution. This is a standard result, and provides a baseline for Design A (Mestelman and Welland 1988, 1991a) and for Design B (Mestelman and Welland 1994).

Figure 2 presents the time series of mean contract prices for Design A following the introduction of advance production. The key result is that the difference between the prices in double-auction and posted-offer institutions disappears with the introduction of advance production. The data in Figure 3, however, suggest that the differences between the gains from trade which are realized by traders under each institution (greater efficiency under the double-auction institution than under the posted offer institution) do not disappear. The change in efficiency from the production-to-demand environment to the advance production environment is not substantially different from zero after the first four or five periods for either institution.

When inventories may be carried from period to period, prices in both posted-offer and double-auction markets tend to fall (compare the time series in Figures 2 and 4), but the differences in price behaviour are negligible. Furthermore, inventory carryover does not lead to efficiency gains for either market institution. Figure 5 displays data on average market efficiency under advance production conditions for both posted-offer and double-auction institutions. The figure also shows the changes from these values, period by period, which result from the introduction of inventory carryover. Most notable is the marked reduction in the efficiency of the posted-offer institution.

Figure 6 provides a bridge between the sessions reported in Mestelman and Welland (1988, 1991a) and Mestelman and Welland (1994). The figure shows time series of mean contract prices for two sets of posted-offer and double-auction markets in which inventories may be carried and in which subjects are inexperienced. There is no substantal difference between market price performance across trading institutions and across sets of induced supply and demand schedules.

The use of subjects who have experienced the double-auction or posted-offer institutions results in a narrowing of the differences between the price performance of the two institutions (compare Figures 6 and 7). Furthermore, the time series tend to converge at the top of the competitive equilibrium band as prices rise with trader experience.

Experience does not lead to efficiency gains for traders in either of these institutions. Figure 8 displays time series data for market efficiency when traders are inexperienced and the differences between these efficiency measures and those realized by experienced traders.

The data in Figure 9 show the impact a second price posting has on experienced traders who may carry inventories in posted-offer environments. The time series of prices is slightly lower than that shown in Figure 7 for the posted-offer markets. The data for the double-auction and posted-offer markets are nearly indistinguishable.

In addition to the convergence of price behaviour between the double-auction and posted-offer institutions, the introduction of a second price posting has a significant impact on the gains-from-trade acheived by traders in the posted-offer environment. Figure 10 displays the average efficiency measures for thirty trading sessions (ten each of double-auction, posted-offer, and posted-offer with two price postings). Inventories may be carried in all of these sessions and all of the traders have participated in at least one similar trading institution prior to participating in these sessions. The posted-offer sessions with two price postings exhibit efficiencies which are significantly greater than those acheived by the posted-offer markets with a single price posting and which are no different than those acheived by traders in double-auction markets. Unlike the performances of posted-offer markets in other environments, which rarely exceed the efficiency levels acheived in double-auction markets after a dozen trading periods (see Figures 3, 5, and 8), the posted-offer markets with a second price posting ultimate rise above the efficiency levels reached by the double-auction markets with experienced traders who may carry inventories.

The success of the posted-offer markets with a second price posting is best understood by comparing the pattern of inventories carried in Figures 11 and 12. When traders are inexperienced, significantly more inventories are carried by sellers in posted-offer markets than by sellers in double-auction markets. In these environments, the perfect foresight competitive equilibrium production for the market is eleven units. Nothing should be carried as inventories from period to period. With inexperienced traders, inventories in posted-offer markets tends to be twice as large as in double-auction markets (roughly fifteen versus thirty percent of equilibrium output in Figure 11). The introduction of experienced traders and the second price posting in the posted-offer markets leads to reductions in inventories in both environments to less than ten percent of equilibrium output (see Figure 12). It is interesting to note that average inventory carryover did not fall when experienced traders were used in the posted-offer markets with a single price posting.

The series of laboratory sessions reported in these papers suggest that trader experience may not be an important factor in explaining differences between the performance of double-auction and posted-offer trading institutions. The additional characteristics of the environment into which these institutions are placed are substantially more important.

Advance production leads to an elimination of the advantage sellers enjoy in posted-offer markets relative to double-auction markets. This is reflected by the convergence of time series of prices (for addition analysis of rent asymmetries see Mestelman and Welland 1991b). The introduction of inventory carryover does not improve market efficiencies in double-auction markets, but substantially reduces the efficiency of posted-offer markets. Laboratory sessions suggest that the management of inventories is a particularly difficult task in the posted-offer environment. Experience does not improve the management of inventories, but the ability to post a second price during a production period does improve efficiency. The improvement is substantial. The second price posting is sufficient to lead to efficiency gains which rival those realized by experienced traders in double-auction markets who must make advance production decisions and who may carry inventories. In this environment, the double-auction trading institution no longer dominates the posted-offer institution.

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VOLUNTARY PROVISION OF PUBLIC GOODS

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This research addresses the predictions of the model of voluntary public goods provision presented by Bergstrom, Blume, and Varian (1986) which extends the work of Warr (1983). It suggests that income redistribution from contributors to public goods to contributors to public goods will have no effect on the aggregate contributions to public goods, while redistribution from non-contributors to contributors will result in an increase in the provision of public goods.

Tests of the predictions of this voluntary contribution model are reported in Chan, Mestelman, Moir, and Muller (1996). Aggregate contribution data from three-person public goods environments support the neutrality theorem originally presented by Warr when income was redistributed among contributors. When income is redistributed from non-contributors to contributors, the predictions of Bergstrom et al. that public good provision would increase were observed. The individual contribution data, however, did not support the predictions of the conventional model. Individuals with relatively high incomes tended to undercontribute, relative to the conventional predictions, while individuals with relatively low incomes overcontributed.

Chan, Mestelman et al. suggest that participants in contribution games may bring notions of fairness into the laboratory which augment the induced payoffs provided by the experimenters. They propose that the average contribution by the group is the measure of the fair contribution. Deviations from this value will induce feelings of guilt or spite and will result in payoffs lower than the induced payoffs reflect. If the induced payoffs are augmented in this way, there is a unique individual Nash equilibrium in which individuals with lower incomes will overcontribute (relative to the predicted Nash equilibrium contribution when the payoff is not augmented) and individuals with higher incomes will undercontribute. Tests of these predictions are reported in Chan, Godby, Mestelman, and Muller (1996) and later integrated with the psychology literature on equity theory (see Walster, Walster, and Berscheid 1978) in Chan, Godby, Mestelman, and Muller (forthcoming). If the induced payoffs are augmented as suggested by equity theory, the neutrality theorem may not hold. Generally, the effect of redistribution on the aggregate level of voluntary contributions to public good provision is indeterminate.

The experimental design used by Chan, Mestelman et al. keeps subjects in the same three-person groups for fifteen decision periods. Chan, Godby et al. scramble the membership in the three-person groups after each decision period. The former treatment is called a *partners* treatment, while the latter is a *strangers* treatment. The strangers treatment is used to keep reputation effects and signalling from influencing the decisions of subjects. Furthermore, the Chan, Mestelman et al. design provides an across-subject effect of income redistribution, while the Chan, Godby et al. design provides a within-subject effect of income redistribution.

The payoffs induced in these environments result in an interior Nash equilibrium and an interior

Chan, Mestelman and Muller, “Voluntary Provision of Public Goods”, forthcoming in the *Handbook of Experimental Economics Results*, Charles R. Plott and Vernon L. Smith, editors, North Holland: Amsterdam.

Pareto Optimal allocation (if notions of fairness do not further augment the induced payoffs). There is no Nash equilibrium consistent with all participants contributing nothing to the public good. The payoffs are consistent with those in Bergstrom et al. and are represented as

$$U = (e - g) + G + (e - g)G$$

where U is the payoff to an individual, e is the individual's endowment of income, g is the contribution made to the group good and G is the sum of the contributions to the group good made by all individuals in the group. The income distributions and unaugmented Nash equilibria are presented in Table 1.

Table 1: Income Distributions and Nash Equilibrium Predictions

	Treatment				
Income (Nash Contributions)	A	B	C	D	E
Low Individual Income	20 (5)	18 (3)	15 (0)	12 (0)	9 (0)
High Individual Income	20 (5)	24 (9)	30 (15)	36 (18)	42 (21)
Total Income	60 (15)	60 (15)	60 (15)	60 (18)	60 (21)

Note: These predictions are for the case in which the induced payoffs are not augmented by notions of fairness. In all treatments the Pareto Optimal allocation of tokens to the public good is 31 tokens.

Figure 1 shows the mean aggregate contributions made in each of fifteen decision rounds when income is equally distributed across the three individuals in each group. Regardless of whether the treatment is a partners or a strangers treatment, the aggregate group contributions to public good provision is very close to fifteen tokens. This is consistent with both the conventional behavioural model and the model augmented by the attitudes of fairness which are reflected in equity theory.

The neutrality theorem (from the conventional model) implies that slightly asymmetric redistributions of income from {20, 20, 20} will have no affect on the aggregate voluntary contributions to public goods. Figures 2 and 3 show the mean aggregate contributions made by groups in which token income endowments are {18, 18, 24} and {15,15,30} respectively. In both cases the central tendency of aggregate contributions to public good provision is fifteen tokens, which is the Nash equilibrium prediction for the conventional behavioural model.

When the redistribution of income becomes sufficiently asymmetric, the best response function for a low income individual who is a self-interested payoff-maximizer will indicate that the individual would like to *remove* resources from the common pool (make a negative contribution to the public good). If individuals are constrained to make non-negative contributions to the public good, public good provision should increase as income redistribution becomes more asymmetric (as the rich get richer and the poor get poorer). Figures 4 and 5 show the mean aggregate contributions made by groups in which token income endowments are {12, 12, 36} and {9, 9, 42} respectively. These contributions are greater than fifteen tokens, and are very close to the predictions of 18 and 21 tokens of the conventional model.

These results are generally consistent with the predictions of the model described by Bergstrom et al. when tested against aggregated data. Tests with individual subject data do not conform with the predictions of the conventional model over the range of income distributions for which redistribution is predicted to be neutral.

Figure 1 reflects the individual contributions over the fifteen periods when each individual has an endowment of twenty tokens. Rescaling the vertical axis by dividing all of the numbers by three results in no change in the relative position of the contributions made in the partners and strangers treatments. The strong pattern of convergence to the Nash equilibrium contribution of five tokens is preserved. This is the predicted behaviour for both the conventional and augmented models.

Figures 6 and 7 show the average individual contributions over fifteen periods for subjects in strangers and partners sessions when low income individuals are endowed with 18 tokens and high income individuals are endowed with 24 tokens respectively. Figures 8 and 9 show comparable series of voluntary contributions when low income individuals are endowed with 15 tokens and high income individuals are endowed with 30 tokens respectively. The common pattern reflected by these data is that low income individuals tend to contribute more than the number of tokens predicted as the Nash equilibrium contribution by the conventional model and that high income individuals tend to contribute fewer tokens than predicted by the conventional model.

Once income distribution becomes so asymmetric that the non-negativity constraint on contributions should be a binding constraint, the predictions of the conventional model characterize the data better than the predictions of the augmented model. If the conventional model predicts a negative voluntary contribution, but subjects are not permitted to make such contributions, it is impossible to determine if these subjects are actually overcontributing in the laboratory environment. It is possible, however, to identify persistent undercontributions by high income subjects. Figures 10 and 11 show that high income individuals tend to undercontribute, relative to the conventional model's Nash equilibrium predictions, early in the session (when their endowments are 36 and 42 tokens respectively). But as these sessions progress, the average contributions of high income subjects tend to rise towards the Nash equilibrium prediction of the conventional model. This behaviour is different from that of high income individuals in environments in which the non-negativity constraint should not be binding.

Aggregate data from partners and strangers treatments of voluntary public goods environments suggest that the predictions of the conventional model of the voluntary contribution mechanism may be supported. Redistributing income among contributors leads to no change in the provision of the public good, but redistributing income from non-contributors to contributors leads to an increase in public good provision. Individual data from these laboratory environments, however, suggest that some notion of fairness may be brought into the laboratory by subjects. Equity theory provides a model of individual behaviour which incorporates attitudes of fairness and which leads to Nash equilibrium predictions which are supported by data from laboratory public goods experiments. This notion of fairness is bounded in its applicability. If the distribution of income across subjects in the laboratory is sufficiently large, the predictions of the conventional economic model (which does not incorporate fairness) are once more supported by individual subject data.

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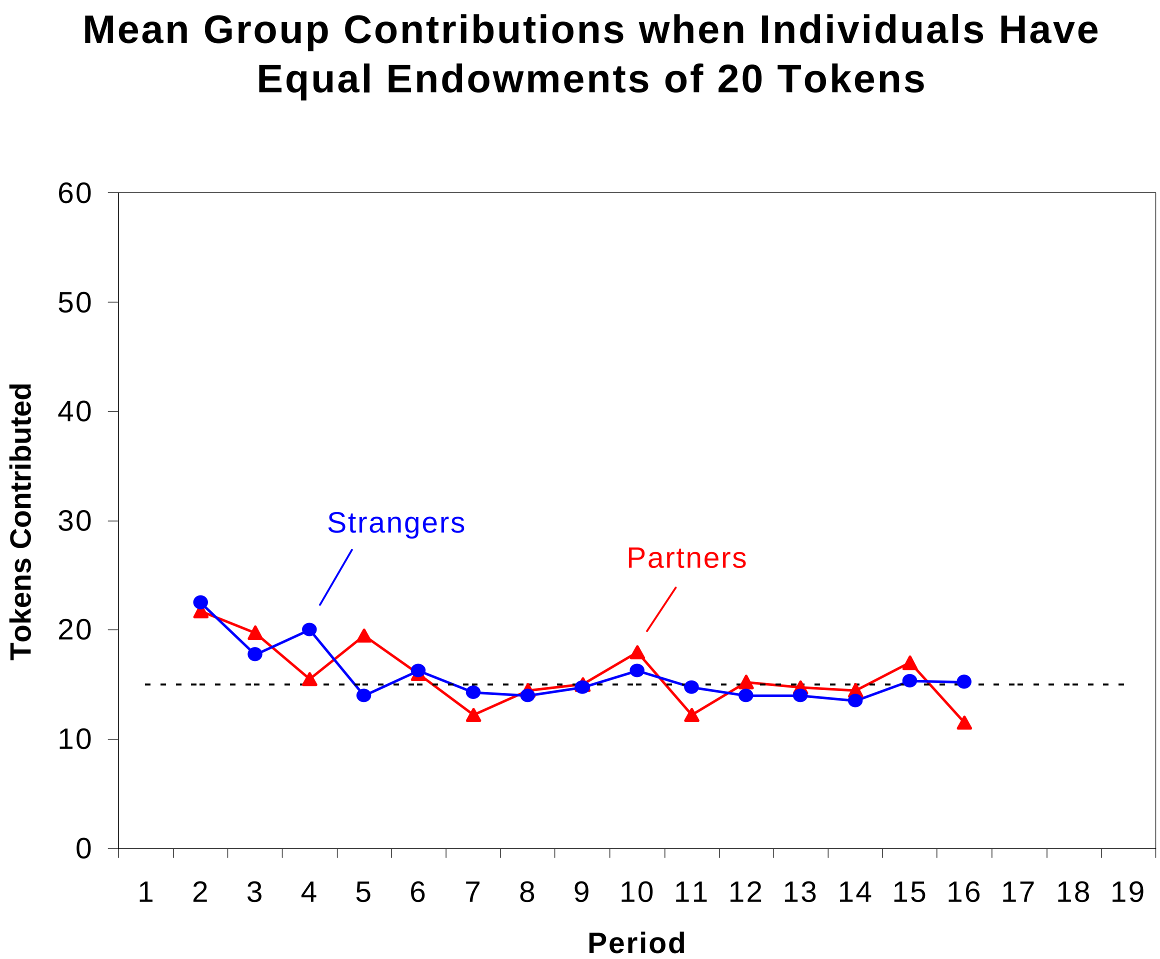

Figure 1. Mean group contributions converge to the Nash equilibrium contribution of 15 tokens under both the partners and strangers treatments.

Chan, Mestelman and Muller, "Voluntary Provision of Public Goods", forthcoming in the *Handbook of Experimental Economics Results*, Charles R. Plott and Vernon L. Smith, editors, North Holland: Amsterdam.

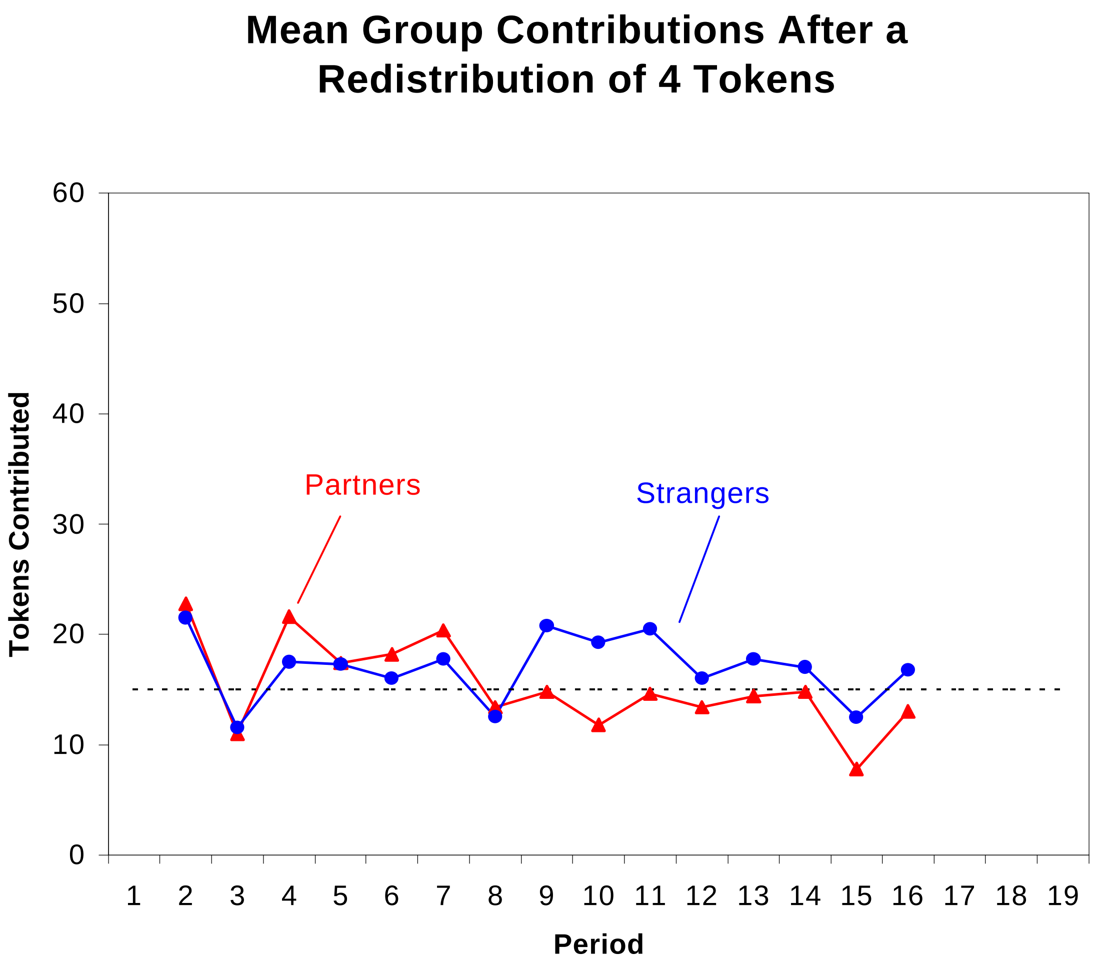

Figure 2. A small redistribution, from a baseline of equal endowments, of two tokens from each of two individuals to the third individual in a group increases the fluctuation of mean group contributions around the Nash equilibrium contribution of 15 tokens under both the partners and strangers treatments. There is no statistically significant difference between the behaviour of participants in these environments.

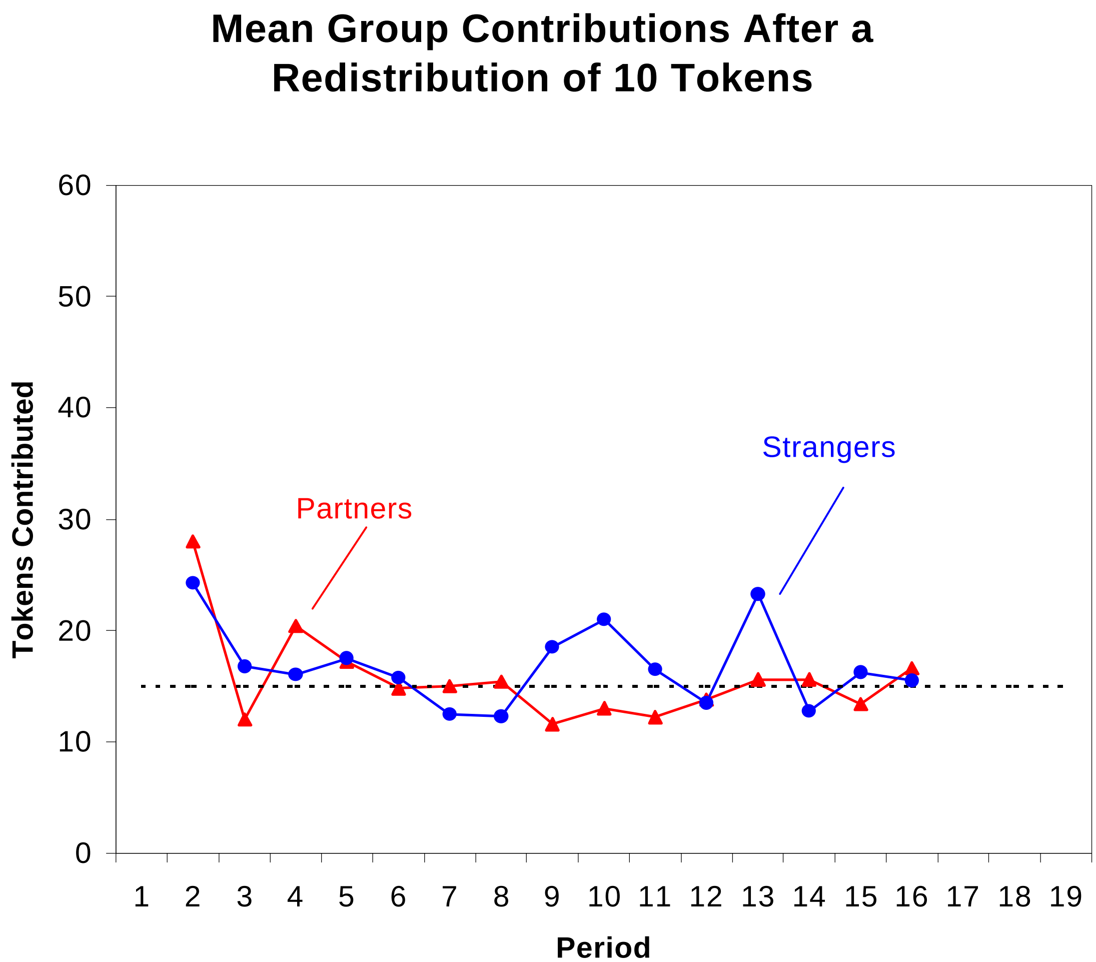

Figure 3. A redistribution, from a baseline of equal endowments, of five tokens from each of two individuals to the third individual in a group increases the fluctuation of mean group contributions around the Nash equilibrium contribution of 15 tokens under both the partners and strangers treatments. The pattern of group contributions is not substantially different from that following the smaller redistribution of income shown in Figure 2.

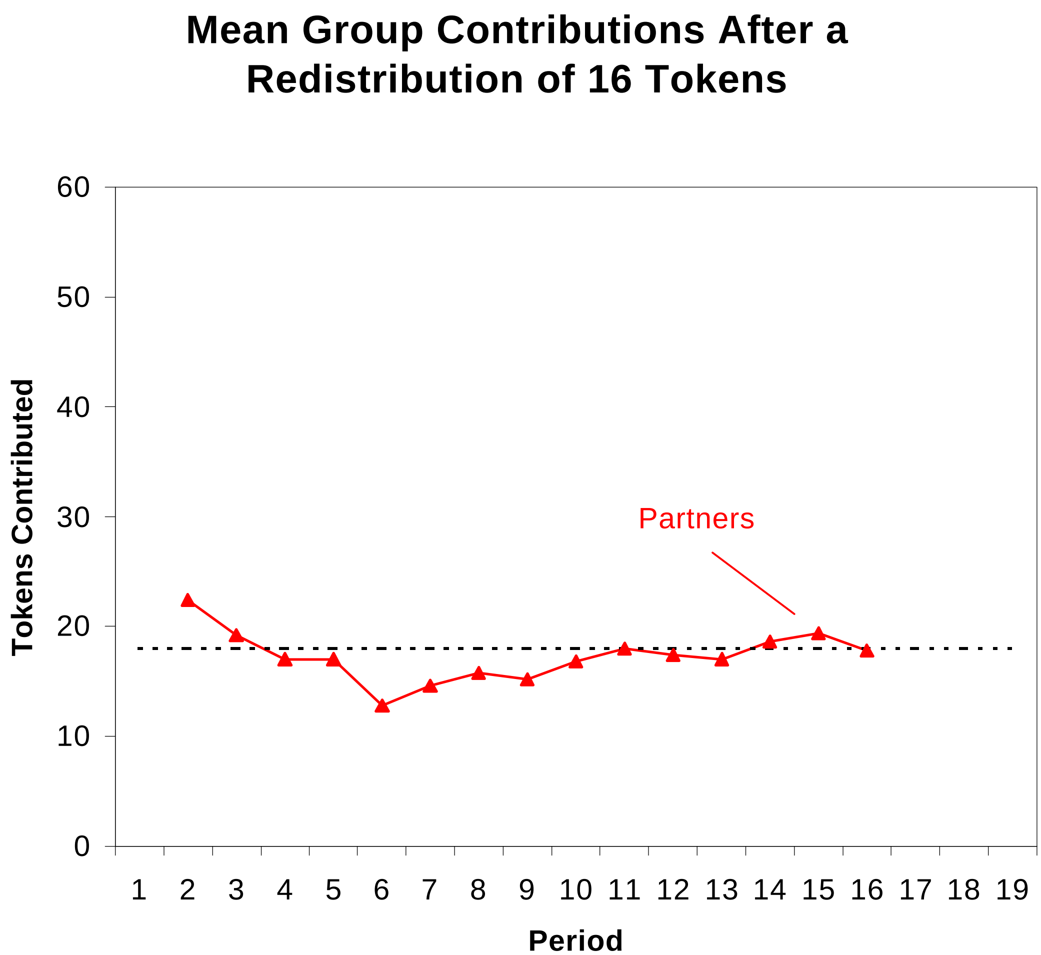

Figure 4. A redistribution, from a baseline of equal endowments, of 8 tokens from each of two individuals to the third member of a group leads to an increase in the Nash equilibrium contribution from 15 to 18 tokens. The mean group contributions following this redistribution converge to the Nash equilibrium contribution of 18 tokens.

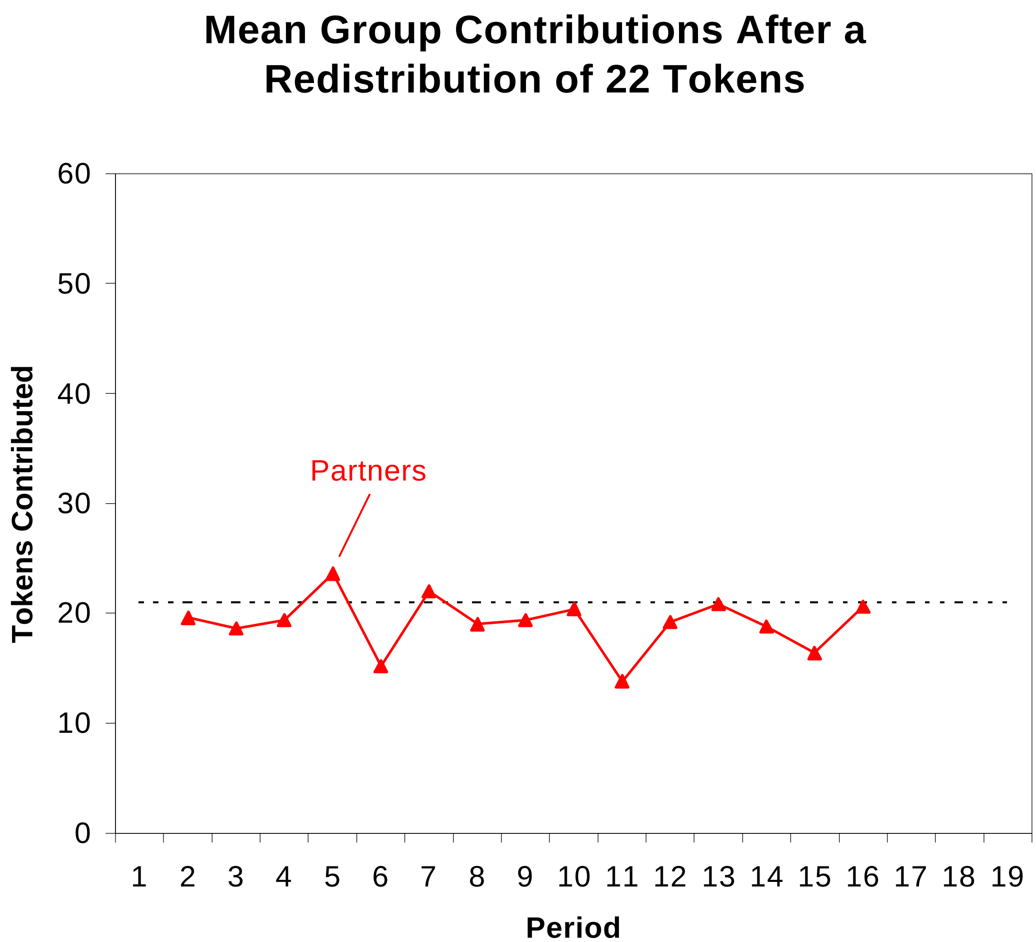

Figure 5. A redistribution, from a baseline of equal endowments, of 11 tokens from each of two individuals to the third member of a group leads to an increase in the Nash equilibrium contribution from 15 to 21 tokens. The mean group contributions following this redistribution tend towards the Nash equilibrium contribution of 21 tokens. Divergence is usually to a value below the Nash equilibrium contribution.

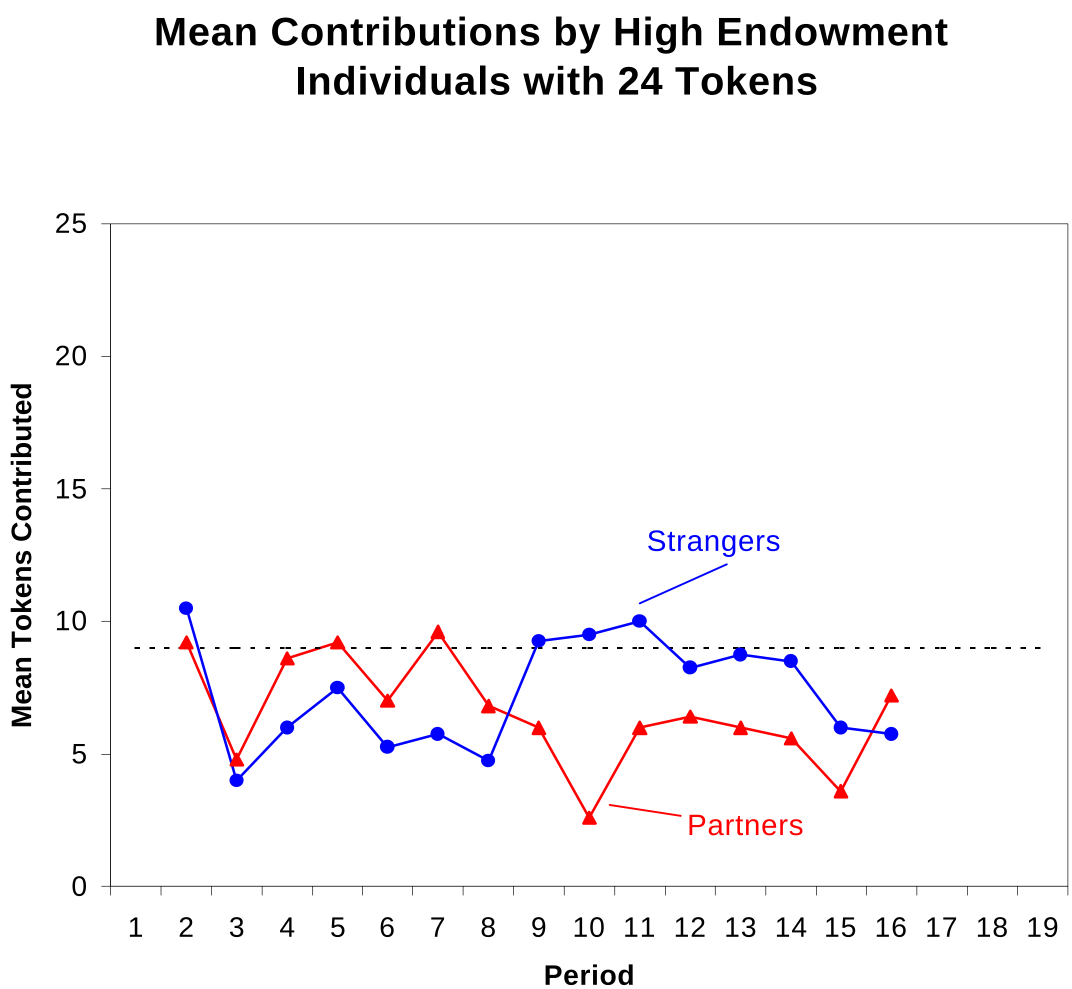

Figure 7. Individuals with endowments of 24 tokens are matched with two individuals who have 18 token endowments. Mean contributions for these high endowment individuals tend to be below the Nash equilibrium contribution of 9 tokens for both the partners and strangers treatments.

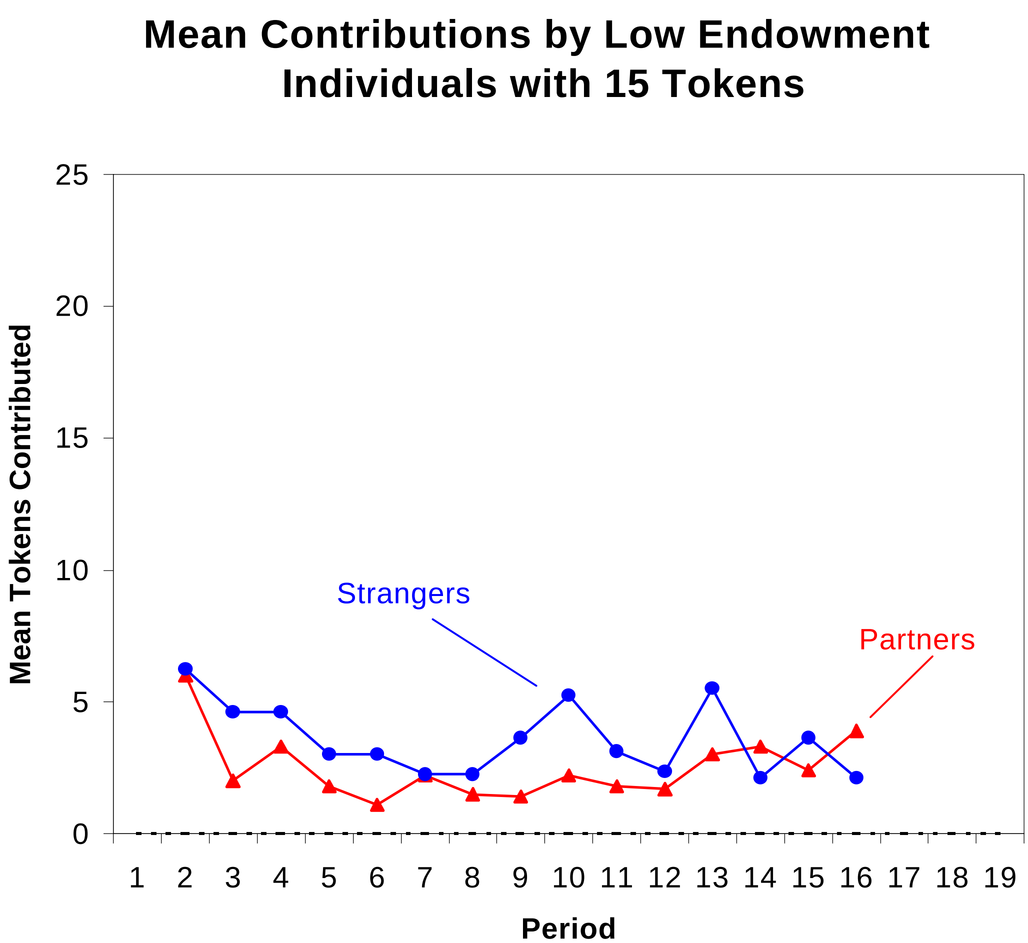

Figure 8. Individuals with endowments of 15 tokens are matched with an individual who has a 15 token endowment and an individual who has a 30 token endowment. Mean contributions for these low endowment individuals do not converge to the Nash equilibrium contribution of 0 tokens, but are consistently greater than zero under both the partners and strangers treatments.

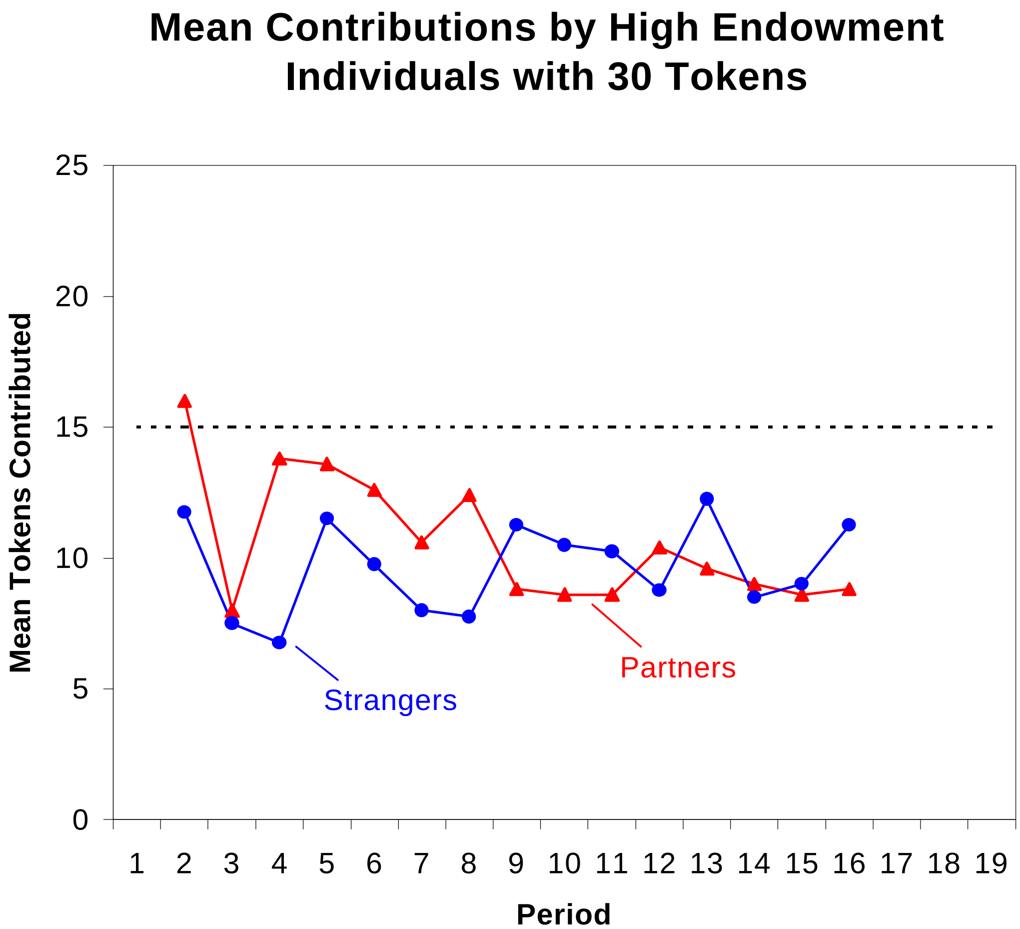

Figure 9. Individuals with endowments of 30 tokens are matched with individuals who have 15 token endowments. Mean contributions of these high endowment individuals do not converge to the Nash equilibrium contribution of 15 tokens, but are consistently below the Nash equilibrium contribution under both the partners and strangers treatments.

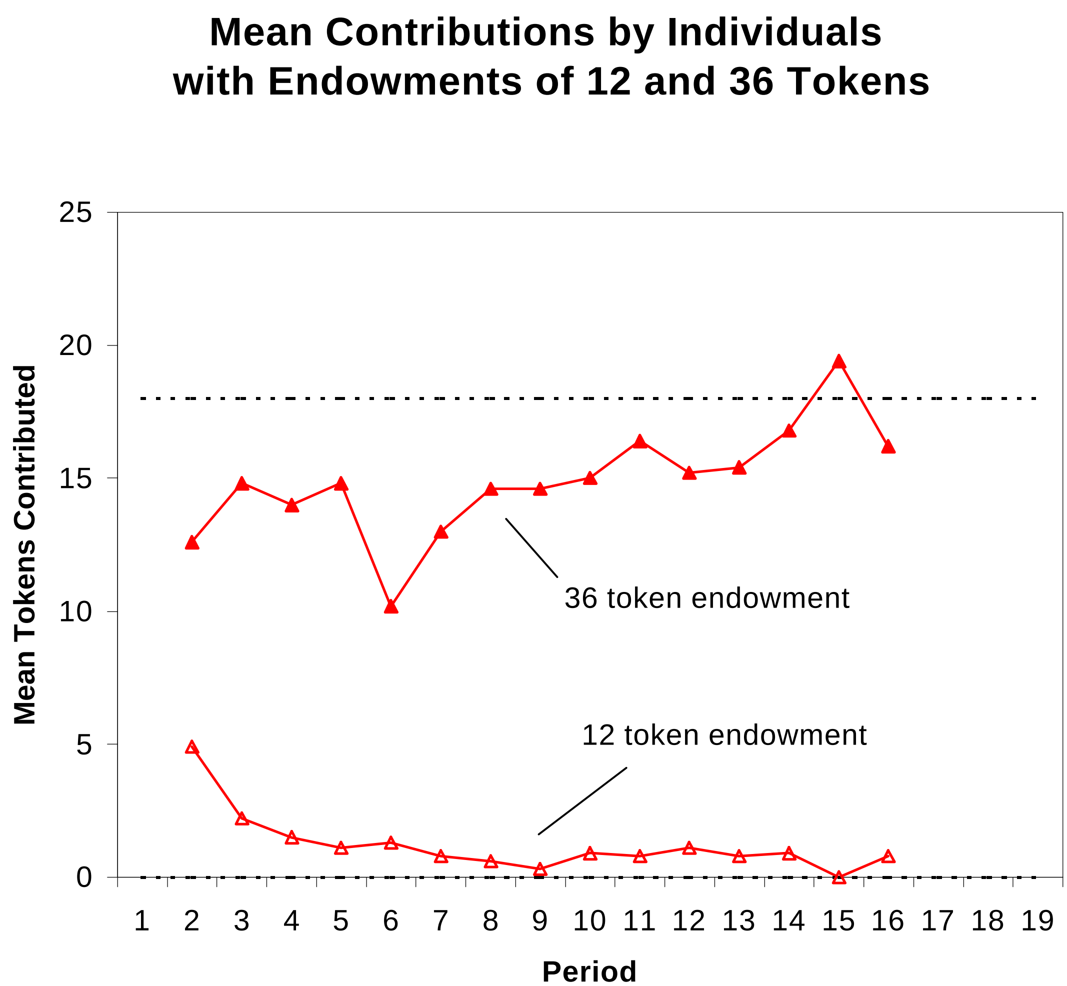

Figure 10. When groups consist of two individuals who are each endowed with 12 tokens and one endowed with 36 tokens, mean contributions by individuals endowed with 12 tokens converge towards the Nash equilibrium of 0 tokens, while mean contributions by individuals endowed with 36 tokens tend to rise towards the Nash equilibrium contribution of 18 tokens.

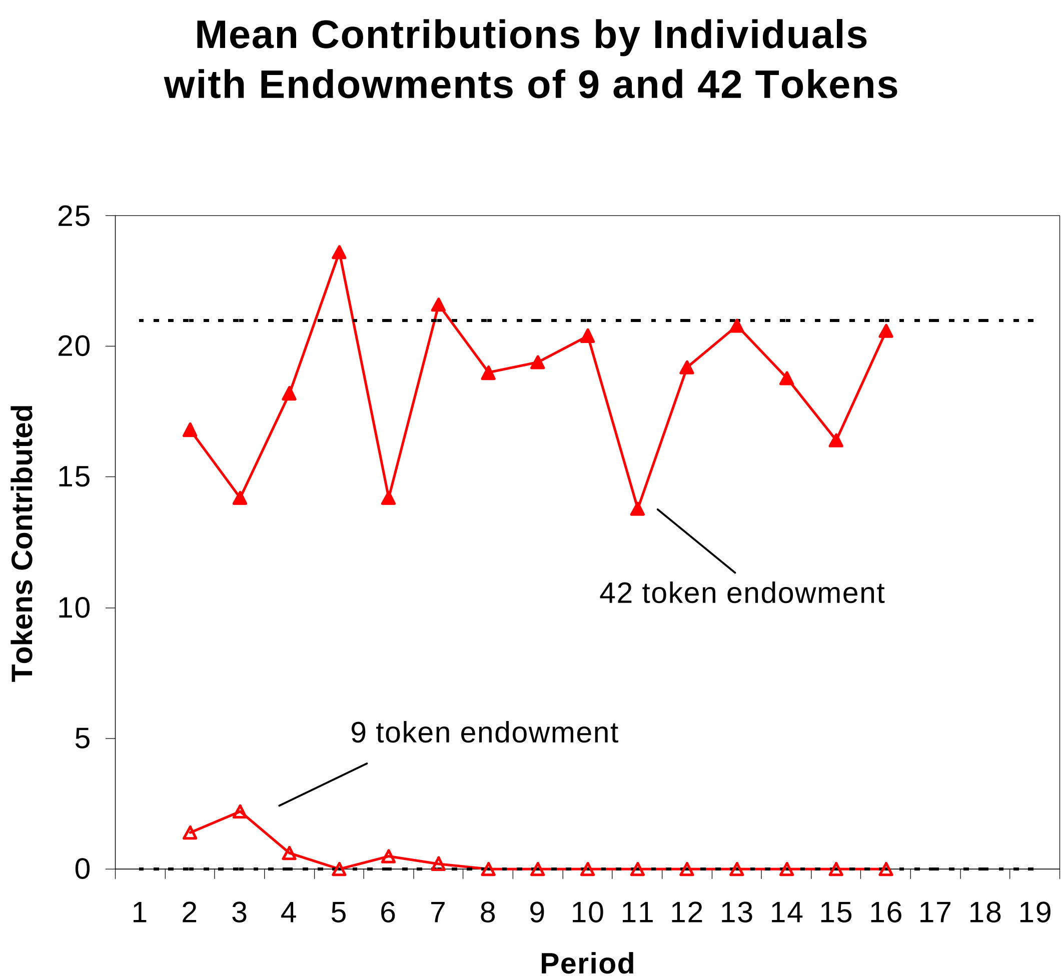

Figure 11. When groups consist of two individuals who are each endowed with 9 tokens and one endowed with 42 tokens, mean contributions by individuals endowed with 9 tokens rapidly converge to the Nash equilibrium of 0 tokens. Mean individual contributions by individuals endowed with 42 tokens tend to be attracted towards the Nash equilibrium contribution of 21 tokens, but frequently fall below this value.

SHARE TRADING AND COUPON BANKING INTERACT TO IMPROVE PERFORMANCE IN EMISSION TRADING MARKETS

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Emissions trading refers to the exchange of permits conveying the legal right to discharge specified quantities of waste. Unlike naturally occurring markets for many commodities and services, emissions trading markets are the product of deliberate choices by regulatory authorities. Frequently these choices must be made without practical experience or clear guidance from theory. Laboratory experiments are well-suited to investigating such choices without the high economic and political cost of field trials.

Under a typical emissions trading plan the regulatory authority sets a quota on the total allowable discharge of a specified waste during each control period. This quota is distributed among eligible firms in the form of permits which we shall call coupons. Some rule is required to determine the allocation of coupons among firms. Normally firms' initial shares of coupons will be proportional to their shares of pre-regulatory emissions, perhaps adjusted to reflect some standard of best practice. Firms are then free to trade coupons among themselves.

The demand for coupons is derived from firms' discharge of wastes, which is determined in turn by their technological choices and volume of production. Firms may or may not be able to control their production processes and volumes precisely. If not, at the beginning of the control period they will be uncertain about the exact quantity of coupons they will require by the end. This uncertainty may lead to unstable coupon prices, since firms may arrive at the end of a control period having discharged more or less waste than expected. They must attempt to clear their surplus or deficit of coupons in what may be termed a 'reconciliation' market. Both the supply of, and demand for, coupons will be highly price inelastic and small variations in excess demand for reconciliation coupons may cause great variation in coupon prices. This may be avoided if firms are permitted to carry forward ("bank") unused permits from one period to the next because firms can then meet unexpected demand from their coupon inventories.

Two important design decisions are whether to allow banking of unused coupons and whether to allow explicit trading in shares of future coupons. This paper reports evidence on the effect of these design choices on laboratory markets. It turns out that uncertainty in the control of discharges demonstrably promotes instability in permit prices. Banking greatly reduces price instability and allows private gains from reallocating discharges over time at the cost of degrading market signals and reducing market efficiency. Share trading enhances the precision of market signals and largely offsets the loss in market efficiency caused by banking.

These results are due to Godby, Mestelman, Muller and Welland (1997). They created a laboratory environment in which coupons were distributed to subjects through shares bearing two coupons in each of the first four periods and one coupon in each of the remaining eight periods. Trade was conducted through a computer-mediated double-auction.

In the most complex treatment (with banking, share trading and uncertainty in the control of discharges) subjects first traded shares, then received coupon dividends. Next, they traded coupons and then chose how much waste they planned to discharge in the current period and the corresponding use of coupons. Actual discharges were then computed by adding a random element which was previously determined but unknown to the participants. Finally, subjects were informed of their actual coupon requirements and allowed to participate in a reconciliation market. Subjects were provided with computerized assistance in valuing coupons and shares: a planner allowed experimentation with the probable consequences of holding varying numbers of coupons and shares and a wizard advised on the increment or decrement in expected profit which would be caused by a unit change in holdings of coupons or shares, assuming these were efficiently allocated. The individual effects of coupon banking, share trading and uncertain control of discharges were investigated through a complete 2x2x2 factorial design replicated three times.

Figure 1 illustrates a baseline session in which there is neither banking of coupons nor trading of shares and in which control of discharges is accurate. Prices generally follow the competitive market prediction, being low in periods 1 to 4 when the coupon dividend is high and high in periods 5 to 12 when the coupon dividend is low. Most of the adjustment to the lower coupon dividend occurs within two periods.

Figure 2 confirms that introducing uncertainty creates price instability when banking is not permitted. Regular coupon prices continue to be low in periods 1 to 4 and high subsequently, but they adjust relatively slowly to the predicted equilibrium bands. Reconciliation trades are highly variable and lie distinctly off the path of regular coupon prices.

Figure 3 confirms that introducing banking into an uncertain environment reduces price instability. Some trading persists in reconciliation markets, but prices are generally much closer to the regular coupon prices. Figure 3 also illustrates some general characteristics of banking with or without uncertainty. Banking tends to smooth out coupon prices over time; indeed the competitive equilibrium price band is constant, despite the reduction of coupon dividend from two to one per share in period five. The observed prices in periods 1 to 4 lie distinctly above the no banking competitive equilibrium and closing prices approach the banking equilibrium band. However, regular coupon prices tend to drift away from the equilibrium in later periods, indicating overbanking of coupons in the middle periods of the session and consequent oversupply at the end.

Figure 4 shows that introducing share trading has a remarkable effect on market outcomes. The volume of coupon trading is much reduced. Coupon prices adjust more rapidly and completely to the reduction in coupon dividends in period 5. Share prices conform roughly to expectations. In equilibrium, the prices of a share should equal the value of the coupons to which it entitles the bearer. Share prices are most easily illustrated by plotting the coupon equivalent price, that is the actual price divided by the coupons borne by the share. Assuming the midpoints of equilibrium price bands, equilibrium coupon equivalent share prices are 72, 80, 91, and 107 in the first four periods and 130 thereafter. Figure 4 shows that the coupon-equivalent price of shares conforms roughly to this path.

Figure 5 shows that adding share trading to the banking environment under uncertainty markedly improves the price performance of the market. Share prices, regular coupon prices and reconciliation prices all tend to lie in the competitive equilibrium band. The figure also illustrates the consistent reduction in total coupon volumes found in all share-trading sessions.

Institutional factors affect the efficiency as well as the price behaviour of emissions markets. Efficiency can be measured by the percentage of available reduction in system abatement cost, i.e., gains from trade, that are realized under a trading institution. Godby, Mestelman, Muller and Welland considered a wide variety of efficiency measures differentiated chiefly by the definition of potential gain from trade.

Figure 6 plots adjusted net efficiency by treatment. In this measure, the potential gains from trade are defined to take into account both the slight reduction in aggregate coupon availability caused by the realization of the random error term uncertainty treatments and the impossibility of reallocating coupons over time under the no banking treatments. Figure 6 reveals three remarkable results. First, on average banking reduces adjusted net efficiency. This requires careful interpretation. Banking increases the total gains from trading because firms are able to allocate their own coupon use optimally over time.[1] However, the potential gains in efficiency from trade rise more than the observed gains, resulting in a decline of measured efficiency. Second, share trading always increases adjusted net efficiency in each of the four combinations of Banking/No Banking and Certainty/Uncertainty. Third, there is a strong interaction between coupon banking and share trading. Share trading provides very little additional efficiency when there is no banking, but when banking is present the addition of share trading restores almost all of the lost efficiency. Put another way, the negative effect of banking is much larger in the absence of share trading.

The results are significant for both environmental policy and the study of markets. Proposals for explicit trading in shares, prominent in Canadian policy discussions five years ago, are now less frequently heard. The laboratory results suggest this is unfortunate. At a broader level, the results raise two questions about auction markets generally.

First, what explanation is to be offered for the apparent reduction in market efficiency induced by banking? One conjecture is that banking provides agents a degree of flexibility in production planning without a corresponding market to guide it. If so, a complete series of future markets might provide the market signals required for improved intertemporal efficiency.

Second, what explanation is to be offered for the role of shares in improving price performance and reducing the efficiency losses due to banking? On the one hand, shares seem to be a substitute for organized trading in future coupons. If this is the case, performance should be enhanced even more by instituting such futures markets. On the other hand, trading in shares may represent a way of reducing the complexity of futures markets, in which case a market restricted to trading current coupons and shares might actually outperform a more complete set of futures markets.

Reference

Godby, R.W., S. Mestelman, R.A. Muller, and D. Welland (1997) Emissions Trading with Shares and Coupons when Control over Discharges is Uncertain. Journal of Environmental Economics and Management 32(3), 359-381.

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[1]Note that these private gains can correspond to social gains only if the original time allocation of coupons was sub-optimal.

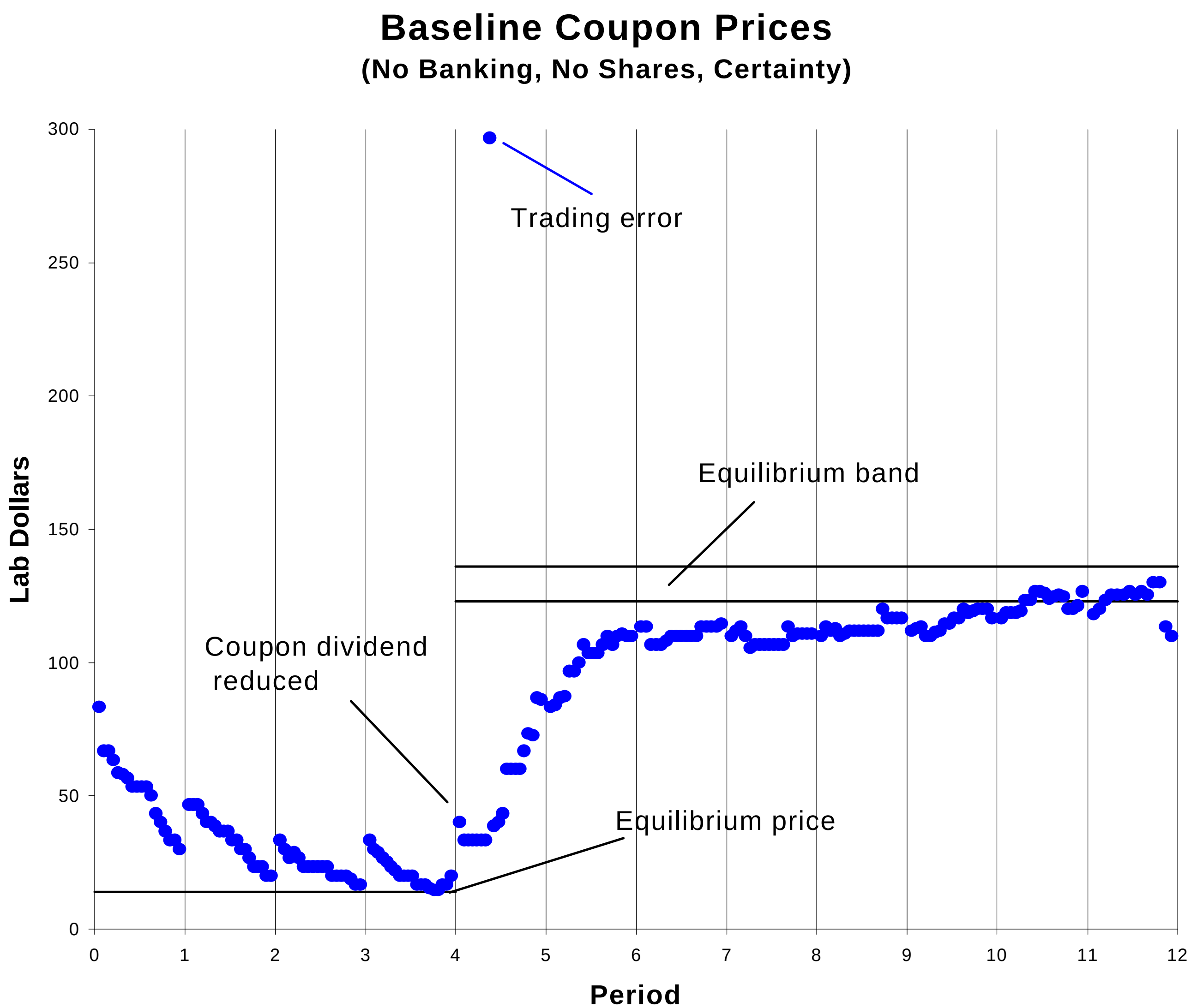

Figure 1. Baseline coupon prices conform to competitive benchmark predictions. In periods one to four, prices approach the competitive equilibrium price of 14 from above. In period 5, coupon dividends are cut in half. Prices rise rapidly towards the competitive equilibrium band of 123 to 136. Note the high volume of coupon trades.