DEPARTMENT OF ECONOMICS

WORKING PAPER SERIES

1999-11

McMASTER UNIVERSITY

Department of Economics
1280 Main Street West
Hamilton, Ontario, Canada
L8S 4M4

http://socserv.socsci.mcmaster.ca/~econ/

Subsidizing Public Inputs

Neil Buckley, Stuart Mestelman and Mohamed Shehata*
McMaster University
Hamilton, Ontario, Canada

September 1999

Abstract

Investment in research and development may (with some probability) lead to reductions in a firm's production cost. If the production-cost savings associated with successful research and development is freely disseminated to other firms as soon as it is realized, too few resources may be allocated to this input. In such an environment, subsidies to the public input can lead to optimal input use. Four alternative subsidy instruments are considered in this paper. Two are *incremental* subsidies and the others are conventional *level* subsidies. One of the incremental subsidies and one of the level subsidies crudely capture characteristics of incentive mechanisms used in the United States and Canada. A laboratory implementation of these instruments generally confirms that incremental subsidies are inferior to level subsidies.

Send Correspondence to:

Stuart Mestelman
Department of Economics
McMaster University
Hamilton, Ontario L8S 4M4
Canada
e-mail: mestelman@mcmaster.ca

---

* The authors are pleased to acknowledge the financial support of the Management of Innovation and New Technologies Research Centre at McMaster University, programming support from Rob Moir, and administration assistance from James Chowhan. Versions of this paper were presented at the October 1996 and March 1999 meetings of the Economic Science Association in Tucson and New Orleans. We benefited from the comments of Ken Chan, Don McFetridge, Susan Laury, Rob Moir, Andy Muller, and Jan Potters.

Subsidizing Public Inputs

Neil Buckley, Stuart Mestelman and Mohamed Shehata

Introduction

In the 1970s and early 1980s considerable concern had been raised regarding sustained declines in industrial productivity and in the rate of industrial innovation by Canadian firms. It was feared that this would adversely affect the competitiveness of Canadian firms in global markets. Many researchers have attributed this decline in productivity and technological advancements to declines in industrial investment in research and development activities. As a consequence, questions were raised about the incentives to devote resources to research and development which were provided to Canadian businesses by federal and provincial governments. The governments of many countries provide subsidies to firms in their jurisdictions with whom Canadian firms compete in international markets. This helps them reduce the cost of research and development activities (an example of such a subsidy is the ability to charge current research and development expenses against current revenues when determining corporate income taxes, even if the research and development expenses are for capital goods), and may provide a competitive edge over other firms.

In an attempt to promote the innovative efforts of the private sector, the Canadian federal government amended the Canadian Tax Act in 1986 to provide firms several tax incentives to spend money on research and development. The most significant incentive was a tax credit equal to 35 percent of the value of qualified research and development expenditures each year (this is now 20 percent for large businesses and 35 percent for small businesses). In addition to the tax credit, firms were permitted to treat the research and development expenses incurred in any tax year as fully depreciable in the year of purchase. The change in the Tax Act with regard to expenditures on research and development inputs was meant to provide Canadian firms with tax incentives comparable to those enjoyed by their competitors.

The United States' Economic Recovery Tax Act (ERTA) of 1981 provided U.S. firms with similar tax incentives as those included in the Canada Tax Act in 1986. The tax credit offered to U.S. firms was different from the Canadian credit in several respects. First, the proportion of U.S. research and development expenditures which were eligible for tax credit was set at 25 percent (but reduced to 20 percent in 1986) and, second, the basis of the credit was the *increase* in research and development expenditures in any year above the average amount spent during the previous three years. A third difference is that the U.S. credit may only be applied against taxes due, while the Canadian credit may result in a net transfer from general tax revenues to the subsidized firm.

These differences between the U.S. and Canadian treatments of expenditures on research and development persisted into the 1990s. Warda (1994) describes the treatment of research and development expenditures by eleven industrial countries. Only Canada and Australia subsidize these expenditures based on the level of expenditures in a year rather than on the incremental expenditure.[1] The U.S., France, and Japan are among the countries which offer subsidies based on incremental expenditures.

Hughes and McFetridge (1985) investigate the impact of a subsidy based on the level of

---

[1] Four Canadian provinces provide incentives for expenditures on research and development which augment the federal government incentives. Only Ontario provides an incremental expenditure subsidy.

annual expenditure versus an alternative one based on incremental expenditure in a single-firm dynamic optimization context. They identify multiple theoretical equilibria including cyclical investment patterns when *increases* in investment are subsidized.

Attempts have been made to evaluate the effectiveness of the ERTA in stimulating research and development spending (see Baily *et al.* 1985, Barth *et al.* 1984, Berger 1993, Brown 1984 and 1985, Eisner *et al.* 1984, McCutchen 1993, Shehata and Ebrahim 1992). These report conflicting results but raise doubts about the effectiveness of the ERTA to stimulate increases in research and development spending. The evidence provided by these studies is limited by the methodologies employed (field or questionnaire data) and the collateral assumptions regarding the specific characteristics of firms and the extent to which innovations are appropriable across firms. Furthermore, tax policies are typically confounded in the field with a variety of shocks which are difficult for the analyst to control.

Researchers have attempted to control for many of the confounding factors present in field data by studying the incentives to invest in research and development activities in laboratory environments (see Davis, Quirmbach, and Swenson 1995, Isaac and Reynolds 1986). A common thread running through the research and development literature and reflected by these laboratory studies is that the producers competing in product markets will overinvest in research and development resources as they race to be the first to develop a new technology which can be excluded from competing producers and gain a cost advantage for themselves. Generally, the implications from this sort of environment is that research and development should somehow be regulated to avoid this supra-optimal allocation of research and development activities.

While tax incentives offered by national governments to producers in their jurisdictions generally are intended to aid national producers gain competitive advantages in international markets, there is always the sense that this is being done because it is good to develop new technologies and innovate *ceteris paribus*. As a starting point for the analysis of the effectiveness of alternative incentives to investment in research and development resources we are introducing a much simpler question, set in a much simpler environment. First, under what conditions would the subsidy of research and development activities clearly be an efficient policy? Second, what are alternative ways to implement subsidy schemes? Third, what are the theoretic predictions regarding the effectiveness of these alternative schemes? Finally, if implemented in a laboratory environment will the theoretic predictions be supported by the data? Our results suggest that an incentive scheme similar to that incorporated in the ERTA may not be as effective as the CTA scheme. The latter, however, may have much more dramatic redistribution effects.

Modelling the Environment

Introduction

The following model attempts to capture features of research and development expenditures which may be introduced into a controlled laboratory setting. In this setting the impact of alternative subsidy schemes can be evaluated. These subsidy schemes capture some aspects of tax-credit policies in use in the United States and in Canada. A perfectly competitive product market characterizes this environment. In addition, producers face fixed-production constraints. These production constraints may be used as treatment variables to study the impact of increasing production (or firm size) on the employment of research and development (R&D)

inputs. In this paper, however, the impact of firm size is not examined.

Throughout this study it is assumed that the gains from expenditures on R&D by any firm are easily appropriated by other firms in the industry. These gains are realized as reductions in production cost which depreciate fully within one decision period. R&D is characterized as a public input. As such, it is expected that self-interested profit-maximizing producers will consider the value of investing in the public input to their own cost reduction, but will have no incentive to consider the benefits other firms will realize from the investing producer's actions. This should lead to under-investing in R&D inputs, and provide a justification for intervention.

Clearly the case of fully appropriable R&D gains which have a one-period lifetime is an extreme case, but it focusses attention on a situation in which a subsidy is most likely to be a desirable policy intervention. A third abstraction introduced in this environment removes the uncertainty of R&D outcomes. It is assumed that there is a direct relationship between the level of R&D investment undertaken and cost reduction. This presumes that there is an expected success rate to investment in R&D inputs which is common to the industry and this expected success rate is realized. These abstractions permit us to focus on the reaction of decision-makers to the incentives induced by the alternative schemes which are expected to increase use of R&D resources.

The Baseline

R&D expenditures result in the reduction of production costs of the firm employing the R&D inputs as well as other firms in the industry (in this extreme case, diffusion of the new technology is immediate). R&D expenditures, however, are not costless. The typical firm's profit function is represented as

$$\Pi_i = P_i x_i - (x_i^2)/(A+R) - \alpha r_i \qquad \textbf{(1)}$$

where Π_i is the profit of firm i , P_i is product price, x_i is output, A is a positive constant, R is the industry's total investment in R&D, α is the price of a unit of R&D, r_i is the number of units of R&D purchased by the firm, N is the number of firms in the industry, and $R = \sum_{i=1}^{N} r_i$.

If output is treated parametrically, the firm's only decision is its investment in R&D inputs. Assuming this producer's profit maximizing decisions are characterized by zero conjectural variations (ZCV), the best response function for the typical producer in a competitive industry is

$$r_i = x_i/\alpha^{0.5} - A - \sum_{n \neq i}^{N} r_n \qquad \textbf{(2)}$$

If all of the firms in the industry are identical, there is a symmetric Nash equilibrium employment of R&D for each firm

$$r_i^o = x_i/(N\alpha^{0.5}) - A/N \qquad \textbf{(3)}$$

and a unique Nash equilibrium employment of R&D for the industry

$$R^o = x_i \alpha^{-0.5} - A \qquad \textbf{(4)}$$

for which any allocation of R&D among the firms in the industry which adds up to R^o is a Nash equilibrium. This is the Baseline environment.

If a planner maximized joint profits of the firms in this industry, the symmetric Pareto optimal employment of R&D for each firm in the industry will be

$$r_i^{*} \;=\; x_i/(N\alpha)^{0.5} \;-\; A/N \tag{5}$$

and $r_i^{*} > r_i^{o}$. This is not a Nash equilibrium.

<u>The C-Subsidies</u>

If the planner subsidizes the employment of R&D resources with the per unit subsidy

$$s^{*} \;=\; \alpha(N-1)/N \tag{6}$$

for either all R&D resources employed or for those employed beyond $\bar{r} < r^{*}$, profit maximizing ZCV producers will find r_i^{*} units of R&D inputs is a symmetric Nash equilibrium. The planner's choice for R&D investment

$$R^{*} \;=\; x_i(N/\alpha)^{0.5} \;-\; A \tag{7}$$

will be the unique Nash equilibrium investment for the industry under either subsidy, but any allocation of R&D investment among firms in the industry which adds up to R^{*} is a Nash equilibrium. These per unit subsidies, based on all R&D inputs or only those beyond the threshold $\bar{r}$, are called the C1- and C2-Subsidies, respectively (they reflect the Canadian environment which uses *level* rather than *incremental* subsidies).

If the firms in the industry can coordinate their R&D decisions, they could maximize the industry's profit (including the subsidy payment) by investing in

$$\hat{R} = x_i N/\alpha^{0.5} - A \tag{8}$$

where $\hat{R} > R^*$. This is neither a Nash equilibrium allocation nor a socially optimal allocation.[2] It can be maintained only through cooperation of the producers. Each, however, has an incentive to reduce his R&D expenditure from the joint profit maximizing expenditure.

The U-Subsidies

An alternative to the per unit level subsidy is a subsidy paid to producers for increases in R&D expenditures from decision period to decision period. This subsidy can take two different forms. The first is

$$S = s^*(r_{i,t} - r_{i,t-1}) \tag{9}$$

and is the U1-Subsidy. The second

$$\begin{aligned} S &= s^*(r_{i,t} - r_{i,t-1}) \quad \text{if} \quad (r_{i,t} - r_{i,t-1}) > 0 \\ S &= 0 \quad \text{otherwise} \end{aligned} \tag{10}$$

[2] The socially optimal allocation of resources to R&D inputs maximizes the firms' joint profits. If a subsidy is introduced, the resources transferred to firms must come from firms and individuals in the economy. In the formulation of this laboratory environment, the assumption is that the subsidized firms do not finance their own subsidizes. These come from others. If firms cooperatively act to maximize their joint profits (revenues from the sale of output less production costs less R&D input costs plus subsidies), their economic profits (revenues less production and R&D input costs) will be less than under optimal R&D input use. Because the subsidy is simply a transfer of resources among firms and individuals in the economy, it does not contribute to the social surplus.

is the U2-Subsidy. Investment changes in R&D inputs in period t by firm i is subsidized by s^* per unit change. In the case of the U1-Subsidy, increases in investment in R&D resources are rewarded, while reductions in investment in R&D resources are penalized. In the case of the U2-Subsidy, increases in R&D resources are rewarded, while decreases are not penalized (the U1- and U2-Subsidy schemes resemble the U.S. environment). Different solutions may emerge with these subsidy programs.

The U1-Subsidy

Consider the U1-Subsidy (reward for increasing investment and penalty for reducing investment) and the profit function

$$\Pi_i = \sum_{t=1}^{T} \Pi_{i,t} \tag{11}$$

where $\Pi_{i,t} = P_{i,t}x_{i,t} - x_{i,t}^2/(A+R_t) - \alpha r_{i,t} + s^*(r_{i,t} - r_{i,t-1})$. The R&D input $r_{i,t}$ appears in the profit expression for periods t and $t+1$. In the former period it appears twice, in the latter it appears once. The first-order conditions for the maximization of profit, Π_i, result in a set of best response functions identical to those in the Baseline environment in each decision period if there is not a final period. In this case, R^o is the industry Nash equilibrium investment in R&D. If there is a finite end period, T, the first-order conditions for each firm for period T will be identical to that for the C-Subsidies. If the market continues for a finite number of decision periods, T, in each period, up through $T-1$, the Nash equilibrium R&D investment is R^o, but in period T the Nash equilibrium R&D investment rises to R^*.[3]

---

[3] This formulation does not discount profits received in future periods. If future profits were discounted, the subsidy terms would not be eliminated from the first-order conditions in the first $T-1$ periods of the U1-Subsidy. The effect would be to reduce the price of the R&D input from α to $\alpha - d_i s^*$ in each period $t < T$, where d_i is the individual's discount rate (or perhaps

If the firms attempt to cooperate and maximize their joint profit, they will invest in R^* units of R&D during the first $T-1$ periods, and increase their investment to $\hat{R}$ units in the last period. In this case, optimal investment will only occur with cooperative behaviour in periods prior to the last market period.

<u>The U2-Subsidy</u>

Now consider the U2-Subsidy in which the subsidy is paid if investment in R&D resources are increased, but no penalty is imposed if investment falls from one period to the next. The producer who considered maximizing the intertemporal profit function **(11)** may consider investing in a low amount of R&D resources in one period and a high amount of resources in the next period in order to realize a subsidy in alternating periods. Rather than generating a symmetric Nash equilibrium in which r^o units of investment is undertaken in each period, the firm can increase profits by investing in r_L^o in one period and r_H^o in the next period. The former is a low level of investment, the latter is a higher level of investment. These values can be found by maximizing the two-period profit function

$$\begin{aligned}\Pi_{i,LH} = {} & P_{i,L}x_{i,L} - x_{i,L}^2/(A+R_L) - \alpha r_{i,L} \\ & + P_{i,H}x_{i,H} - x_{i,H}^2/(A+R_H) - \alpha r_{i,H} + s^*(r_{i,H} - r_{i,L})\end{aligned} \qquad \textbf{(12)}$$

---

the market interest rate). This reduction is much less than that realized with the C-Subsidies. The resulting R&D expenditure will be greater than the Baseline Nash equilibrium expenditure, but less than the Pareto optimal expenditure. The outcome will, however, be realized as a Nash equilibrium. In period T the Nash equilibrium investment will be the optimal investment R^*.

where the subscripts H and L identify the high and low investment periods. Given a finite number of periods, the symmetric Nash equilibrium first period investment will equal r^* and will be followed by the alternating investments of r_L^o and r_H^o in even- and odd-numbered periods respectively.[4] In the laboratory setting, if participants know when the session will end, the alternating low and high investments will continue until the last odd-numbered period. In the final period, the symmetric Nash equilibrium investment will be r^*.

Cooperative behaviour in this case leads to industry input use of $\hat{R}$ in the first period and will cycle between $\hat{R}_L$ and $\hat{R}$, where $Nr_L^o < \hat{R}_L < R^* < \hat{R}$. If period T is an even-numbered period, input use in that period also will be $\hat{R}$. Cooperative behaviour leads to cycling behaviour in which R&D input use is either sub- or supra-optimal.

<u>Predictions</u>

A prediction from this model for ZCV profit maximizing decision-makers is that the C-Subsidies of R&D activities can lead to increased employment of R&D resources, which are initially underprovided. The U1-Subsidy will not increase the employment of R&D resources until the final period in the planning horizon. The U2-Subsidy will lead to increased average employment of R&D resources over the course of the planning horizon. A Pareto optimal

---

[4] This is comparable to Hughes' and McFetridge's (1985) asymmetric subsidy case. However, this environment differs from theirs. They considered only a single profit-maximizing firm and there is no input externality. The environment introduced here has four firms whose input decisions affect the production costs of the other firms. The comparability which is of particular note is that when the incremental mechanism can only result in a subsidy, cycling appears as a profit-maximizing solution for the firm.

allocation will not be realized as a stable equilibrium, although Pareto optimal allocations will occur in some periods. Finally, the extent to which producers are able to cooperate in making input decisions can affect the ultimate outcome. In this environment, cooperation can lead to both more than and less than Pareto optimal allocations as investment in R&D resources cycles over time. These predictions of the effects of alternative subsidies to investment in R&D inputs can be tested in a laboratory setting.

Laboratory Environment

<u>Parameterization</u>

Select the parameters $\alpha = 1$, $A = 12$, $x_{i.t} = 24$, $N = 4$, $P_{i.t} = 2$ and obtain $r_i^o = 3$, $r_i^* = 9$, $r_L^o = 2$, $r_H^o = 9$, $\hat{r}_L = 6$, $\hat{r} = 15$ and $s^* = 0.75$. For the C2-Subsidy, $\bar{r}$ is selected to equal the baseline individual symmetric Nash equilibrium input use: $\bar{r} = 3$. R&D investment is bounded at $r_i^{\max} = 15$ to constrain the payoff table that is presented to participants in the laboratory sessions to a 16 by 46 matrix. The investment predictions described in the previous section are summarized in Table 1 for these parameter values. The predicted profits to each producer over ten periods ($T = 10$) under ten different scenarios derived from the discussion above are presented in Table 2 along with the subsidy paid to the producer under each scenario. For this analysis the assumption is made that the subsidy is financed from general revenues paid by others than the producers in the subsidized industry.

<u>Laboratory Implementation</u>

The experiment was administered using 72 student subjects from McMaster University.[5] Twelve subjects participated in each session. Each session lasted for thirty-six decision periods. There were six sessions. In periods 1, 2, 3, 13, 14, 15, 25, 26, and 27 of each session three groups of four individuals were formed. The composition of the groups did not change during periods 3 through 12, 15 through 24, and 27 through 36.[6] Periods 1, 2, 13, 14, 25, and 26 were practice periods. They were the first two periods of a new treatment (described as a new round to the subjects). The decisions that subjects made in these practice periods did not contribute to their earnings. Subjects did not know who was in their group at any time during the session. Each period the subjects were reminded that they, and each member of their group, could invest in up to fifteen units of a special input which could reduce their production costs. Each member of the group knew his profit function and that each other member of the group had the same profit function.

Subjects were given written instructions describing the decisions they had to make and the environment in which they were participating (see Appendix 1). The instructions were read aloud to the subjects and the subjects were given several questions to answer to test their understanding of the environment. After the invigilators were convinced that the subjects understood the environment, the session began.

Subjects were seated at computer terminals separated from each other by partitions. They

[5] The subject pool included men and women enrolled in the undergraduate programmes at McMaster University. All but four of the subjects had participated in a series of ring-tests to identify their value orientations. The four individuals were categorized as individualist (the category containing the majority of subjects).

[6] The groups were not constructed randomly. A conscious effort was made to guarantee that the no subject participated with the same three subjects in the three rounds of a session.

were given three minutes to choose their input use and to enter it on their computer terminal. This input had the characteristic of a public good in production. The subjects had a payoff table from which they could determine their payoff conditional on the amount of the input they used and the amount used by others in their group (see Appendix 2). After all twelve individuals entered their contributions, they were informed, via their computer monitors, of the total contribution made by the others in their group, their payoff for the period, and their accumulated payoff (exclusive of any subsidies) over all completed periods. Each individual knew this information was distributed to the others in the group. In all cases, the maximum input use by a group was sixty units per period. Finally, subjects knew how many periods would be in the round and the number of rounds in the session.

The subjects did not know how the treatments would change from round to round. In rounds which included subsidies for input use, the subsidies were introduced as additions to the profits realized through production and sale of their product.[7] Subjects received their accumulated lab dollar payoffs, converted into Canadian dollars, after the thirty-six decision periods were completed. The conversion rate was announced at the start of the session. The average compensation for participating was $7.59, $11.00, $9.96, $8.21 and $9.10 for the Baseline, C1-Subsidy, C2-Subsidy, U-1 Subsidy, and U2-Subsidy rounds respectively (standard deviations $0.76, $0.58, $0.73, $0.92, and $0.61 respectively). Each session lasted for less than ninety minutes and included a Baseline round, a C1-Subsidy round, and either a C2-Subsidy, U1-Subsidy or U2-Subsidy round. The Baseline round always was first. The experimental design is

[7] The details of the implementation of the subsidies are described in the Instructions included in Appendix 1.

presented in Table 3.

Results

Data

Tables 4, 5, 6, and 7 summarize mean group investment, efficiency, subsidy payments, and profit by treatment across the first nine periods of each round.[8] Table 8 reports regression coefficients using the nine-period mean group investment decisions by treatment which control for subject effects reflecting value orientations. Average period-by-period group investment is summarized in Figure 1.

Aggregate Input Use

Mean group input use over the first nine period of each treatment is summarized in Table 4. The period-by-period averages are shown on Figure 1. These data provide the bases for eight observations.

Observation 1: The quantity of input used by participants in the Baseline environment is greater than the Nash equilibrium quantity, but much less than the optimal quantity.

The average input use across all Baseline sessions was 17.01 units. The Nash equilibrium use is 12 units and the optimal use is 36 units. A ninety-five percent confidence band around the nine-period average input use runs from 15.35 units to 18.66 units. This does not include the Nash

[8] Nine-period averages are presented because the predicted behaviour in the tenth period for both the cooperative and non-cooperative scenarios for the U1-Subsidy is very different from behaviour in the preceding nine periods. To make average investment data comparable across treatments, only the first nine periods are pooled.

equilibrium use of 12 units.■

Observation 2: The quantity of input used by participants in the C1-Subsidy environment is consistent with optimal input use.

The average input use across all C1-Subsidy sessions is 34.70 units. The Nash equilibrium use is 36 units, which is the optimal use.[9] A ninety-five percent confidence band around the nine-period average input use runs from 31.34 units to 38.05 units. The null hypothesis that the average nine-period mean group input use is equal to 36 units cannot be rejected in favour of the alternative that it is less than 36 units (t-test, $p = 0.212$).■

Observation 3: The quantity of input used by participants in the C2-Subsidy environment falls short of optimal input use.

The average input use across all C2-Subsidy sessions is 29.41 units. The Nash equilibrium use is 36 units, which is the optimal use. A ninety-five percent confidence band around the nine-period average input use runs from 22.98 units to 35.83 units. The null hypothesis that the average nine-period mean group input use is equal to 36 units can be rejected in favour of the alternative that it is less than 36 units (t-test, $p = 0.023$).■

Observation 4: Neither the U1-Subsidy nor the U2-Subsidy lead to optimal input use.

The average input use across all U1-Subsidy and U2-Subsidy sessions was 19.80 and 22.11 units respectively. Ninety-five percent confidence bands around the nine-period averages are 13.76

[9] This is the socially optimal use. It is not the profit maximizing use which could emerge if the producers could cooperate. However, achieving the profit maximizing use would result in higher production plus R&D input costs than would be realized in the socially optimal state. Only producers would gain in this case because of a resource transfer through the subsidy.

units to 25.83 units and 18.40 units to 25.82 units for the U1-Subsidy and U2-Subsidy respectively. Neither of these bands contains 36 units.■

Observation 5: The C1-Subsidy successfully corrects the market failure attributed to the "public" nature of the input but the C2-Subsidy shows significant improvement over the baseline. The U2-Subsidy shows some improvement over the Baseline environment, but the U1-Subsidy shows no significant improvement.

The data in Table 4 suggest that the U-Subsidies provide a modest increase in input use while the C-Subsidies result in substantial increases in input use. Randomization tests (Moir 1998) indicate that the C1-Subsidy input use significantly exceeds that in the other environments ($p = 0.000$ with an approximate randomization test, $p = 0.052$, $p = 0.001$ and $p = 0.002$ with exact randomization tests on nine-period mean group input use comparisons with the Baseline, C2-Subsidy, U1-Subsidy, and U2-Subsidy respectively). The C2-Subsidy input use also significantly exceeds that of the Baseline, U1- and U2-Subsidies ($p = 0.000$, $p = 0.010$, and $p = 0.016$ respectively). The U2-Subsidy provides sufficient incentive to lead to input use which exceeds that in the Baseline environment ($p = 0.003$, exact randomization test), but the U1-Subsidy shows only marginal improvement ($p = 0.086$, exact randomization test). A comparison of the U1-Subsidy and the U2-Subsidy with each other suggests that the latter does not generate more input use on average than the former ($p = 0.203$, exact randomization test). The general observation is that the C-Subsidies outperform the U-Subsidies.■

Observation 6: An efficiency measure further supports the observations that the Nash equilibrium input use is consistently exceeded, that the C-Subsidies are successful in leading participants towards optimal input use, and that the U-

Subsidies only modestly increase production cost savings.

Table 5 presents nine-period mean group efficiency by treatment. The efficiency measure is the share of the potential cost savings (when going from the Nash equilibrium to the optimal input use) which is actually realized under each treatment. The measure is a percentage of the optimal net gain that is achieved, because it is calculated using profit values that exclude any subsidy received. In the Baseline, the nine-period group average is 32.85 percent. This measure rises to 91.52 percent with the C1-Subsidy and 83.70 percent with the C2-Subsidy. It is 42.82 percent and 57.96 percent with the U1- and U2-Subsidies respectively. The average efficiency of the C1-, C2- and U2-Subsidy sessions are significantly different from that of the Baseline session (p = 0.000 with an approximate randomization test and p = 0.000 and p = 0.021 with exact randomization tests respectively). The average efficiency of the C2-Subsidy is significantly different from that of the U2-Subsidy, but the C1-Subsidy only shows marginal improvement over the C2 treatment in terms of average efficiency (p = 0.022 and p = 0.094 with exact randomization tests respectively). The U1-Subsidy and Baseline average efficiencies are not significantly different (p = 0.248, exact randomization test). These observations are consistent with the previous observations.■

Observation 7: The C-Subsidies and U2-Subsidy generate significant production cost savings from Baseline levels. Each lab dollar of production cost saved requires more than one lab dollar of subsidy.

Table 6 presents nine-period mean group subsidy payments by treatment and Table 7 presents profits (excluding subsidy payments) and cost savings by treatment. The difference between the profit earned in the Baseline rounds and the profit earned in the subsidy rounds is equal to the cost saving realized because of the use of investment in R&D inputs. The differences between the mean Baseline profit and the mean profit under the C1-, C2-, and U2-Subsidies are significant (p = 0.000 with an approximate randomization test, p = 0.000 and p = 0.021 with an exact randomization tests respectively). However, the difference between the mean Baseline profit and mean profit under the U1-Subsidy is not significant (p = 0.249 with an exact randomization test).

For the treatments which realized significant cost saving, the average per period cost of the C1-Subsidy was 26.0 lab dollars (L$), the C2-Subsidy, L$15.0, and of the U2-Subsidy, L$9.8. These are 1.84, 1.23, and 1.63 times the respective cost savings!■

Observation 8: The data support the conjecture that participants behave according to the non-cooperative equilibrium scenario.

Average group input use is displayed over time in Figure 1. The patterns of input use for the Baseline, U1-Subsidy, and U2-Subsidy over the first nine periods are comparable. The input use with the U2-Subsidy is consistently above that of the other two treatments. This is reflected in the statistical observations reported above. The levels of input use are not consistent with cooperative behaviour (see Table 1) during the first nine periods. The non-cooperative equilibrium solution predicts that in period 10 participants in the U1-Subsidy treatment will increase their input use from a low value (12) to the optimal value (36). The average pattern reflected in Figure 1 for the U1-Subsidy is consistent with this change in period 10. The period-to-period changes in average input use are not significantly different (p > 0.05, Wilcoxon Matched-Pairs Signed-Ranks Test) from period 1 through period 9. The change from period 9 to 10 is significant (p = 0.05, Wilcoxon Matched-Pairs Signed-Ranks Test). The non-cooperative equilibrium solutions predicts that in periods 9 and 10 the participants in the U2-Subsidy treatment will increase their input use to 36 units (after fluctuating between 36 and 8 units from periods 1 through 8). The fluctuations do not appear in the aggregate data (Figure 1), but in periods 9 and 10 input use rises above the levels used in previous periods and approaches 36 in the tenth period. The predictions for the Baseline and C-Subsidies are that in the former, input use will be stable and low (at 12) while in the latter it will be stable and high (at 36). The data more closely fit these predictions than those of the cooperative model of 36 and 60 respectively.■

A ninth observation is based on the data presented in Figures 2 through 6.

Observation 9: Cycling investment decisions characterize only the U2-Subsidy.

Figures 2, 3, 4, 5 and 6 include the per period input decisions of each subject by treatment. The non-cooperative equilibrium solution predicts cycles in individual input use for the U2-Subsidy in which input use rises one period and falls the next. The cycling should be contained within the range of 2 and 9 units of input. The cooperative solution predicts cycles within the range 6 and 15 units of input. If an individual is identified as adopting a cycling strategy when he generates at least one *M* or *W* pattern in his 10 data points, then cycling is the dominating characteristic of the U2-Subsidy. In the U2-Subsidy, this pattern appears in the data for half of the subjects (12 of 24) in the other four treatments it appears in no more than 12.5 percent of the subjects' data (3 of 24 for both the C2- and U1-Subsidies) and as infrequently as 5.5 percent of the subjects in the C1-Subsidy and 1.4 percent of the subjects in the Baseline treatment (4 of 72 and 1 of 72 respectively). Although subjects are not able to coordinate their decisions sufficiently in this environment to generate a cyclical pattern of investment, the many subjects do identify the incentive to alternative investment choices between high values in one period and low values in the next period.■

Regression Analysis

Basic regression analysis of the nine-period mean group input decisions by treatment further substantiate the observations above. Regression statistics based on the aggregate input data are summarized in Table 7. Before the basic regression of average group input use on the series of treatment dummies was computed (Regression 1 in Table 7), an equation detailing treatment order was estimated. Adding dummy variables to Regression 1 for each treatment that was faced in the last round of a session resulted in new coefficients which were not significantly different from zero, suggesting that there are no treatment order effects ($p = 0.672$ with an F-test on the significance of dummy variables detailing each treatment's order, and $p = 0.973$, $p = 0.515$, $p = 0.172$ and $p = 0.987$ using t-tests on the C1-, C2-, U1-, and U2-treatment order variables respectively).

Sixty-eight of the seventy-two subjects in this experiment participated in a series of laboratory sessions which elicited information about their value orientation. The results of these sessions were used to control for specific subject effects in the analysis of how the four treatments in this experiment affected the input decisions made by the subjects.

The subjects' value orientations were determined by their participation in a ring-test similar to that described by Offerman, Sonnemans, and Schram (1996). The variable used in the regression analysis reported in Table 7 is based on the angle of the vector which measures each subject's value orientation.[10] The subjects are categorized according to their scores. Individualists (subjects who tend to make decisions which maximize their well-being regardless of others) have value orientation scores between -22.5 degrees and 22.5 degrees (68 percent of the subjects). Cooperators (subjects who tend to make decisions which maximize the total payoff to themselves and an anonymous peer) have scores between 22.5 degrees and 67.5 degrees (30 percent of the subjects). One subject was a competitor (a subject who tends to maximize the difference between his payoff and the payoff of his anonymous peer). The variable added in Regression 2 counts the number of group members identified as being cooperators according to their individual value orientation. It was expected that the higher the number of cooperators, the greater will be the input use of the group.

The mean number of cooperators per group (1.111) is used to estimate the Baseline input use from the regression equation 2 in Table 7. This yields an estimate of 17.00 units of input for an average group of four subjects. The C1-Subsidy has a statistically significant effect on the group's contribution, increasing it by 17.69 units, to 34.69 units (p = 0.000, one-tailed t-test). The C2-Subsidy has a slightly lower effect on the group's contribution, increasing it by 12.31 units, to 29.32 units. While the C2-subsidy is significantly greater than the Baseline treatment (p = 0.000, one-tailed t-test), the C1- effect is significantly larger than that of the C2-Subsidy (p = 0.015, one-tailed t-test). The U1-Subsidy has a small positive contribution (3.24 units), but this is not statistically significant (p = 0.094, one-tailed t-test). Finally, the U2-Subsidy has a slightly larger and statistically significant contribution of 4.74 units (p = 0.028, one-tailed t-test). The

[10] This angle is with respect to the horizontal axis through the origin of a diagram representing the choices presented to subjects in the ring test.

regression results confirm the observations listed above after controlling for value-orientation characteristics of groups on input decisions. As expected, the number of cooperators in a group significantly increases the average group investment in the input by 1.63 units per Cooperator ($p = 0.022$, one-tailed t-test).

Discussion and Conclusions

The subsidy schemes included in the laboratory sessions described in this paper are extreme abstractions from subsidy schemes which have been used in Canada and the United States. The differences between the C1-Subsidy and the U2-Subsidy capture important differences between the schemes used in the two countries. In particular, the C1-Subsidy provides a subsidy to all investment in the public input undertaken in a given period, while the U2-Subsidy provides a subsidy equal to the difference between the investment in the public input undertaken in a given period and the average investment undertaken over a previous reference period. In the laboratory environment the reference period is the previous period and the baseline for the subsidy is the investment in that period. In the field, the reference period is the previous three years and the baseline for the subsidy is the three-period average investment in the input. The U1-Subsidy is an alternative version of the U2-Subsidy in which a penalty is paid if investment falls below a baseline level. The laboratory environment provides evidence on the extent to which the theoretic predictions are realized behaviourally.

The data from the laboratory sessions suggest that non-cooperative play dominates. Non-cooperative decision making is predicted to lead to optimal allocations with the C-Subsidies (with the C1-Subsidy being more costly to implement than the C2-Subsidy), no change from the

Baseline for the U1-Subsidy and cycling investment (with an average investment exceeding the Baseline investment) with the U2-Subsidy.

The data show near optimal group allocations to the investment input under the C1-Subsidy and significant improvement from the Baseline under the C2-Subsidy. There is no statistically significant improvement in input use from the Baseline under the U1-Subsidy, but the predicted average improvement in investment from the Baseline is realized under the U2-Subsidy. Individual and group behaviour under the U1-Subsidy displayed the large increase in final-period input use predicted by the theory, while cycling input use was the dominant characteristic of individual behaviour under the U2-Subsidy.

In spite of the success of the C-Subsidies at generating increased investment, and the more modest success of the U2-Subsidy, the cost of these schemes appears to be high. The gains realized through cost savings associated with the use of the special inputs are less than the money transferred to the subjects through the subsidy schemes. This suggests that from the perspective of distributional effects, if an input subsidy is going to be the policy instrument to induce the optimal allocation of a public input, it is important that it be integrated with a tax policy which would permit the subsidizing agency to recover some of the costs of the subsidy from those being subsidized. This is particularly important if the gains from the subsidy will immediately accrue to those being subsidized.

This laboratory environment does not help to evaluate the success or validity of the input subsidy programmes that have been implemented to encourage R&D investment unless there is a public input characteristic to this investment which would lead to too little investment in these inputs in the absence of intervention. Within this context, however, the incentives of the U-

Subsidies are clearly inferior to those of the C-Subsidies. This is a result that may be applicable to the subsidy of any activity with public good characteristics. Therefore, subsidizing *increases* in charitable contributions from one period to the next would not be as effective in increasing contributions to charitable organizations as would subsidizing the contributions themselves.

It is also interesting to note that Warda (1994) ranks Canada and Australia first and second respectively among eleven industrialized countries with regard to the attractiveness of their tax treatments for manufacturing companies to engage in R&D activities .[11] Of the eleven, only Canada and Australia offer level rather than incremental expenditure incentives.

What is unanswered by these laboratory sessions is why the C2-Subsidy failed to perform as well as the C1-Subsidy, even though the marginal incentives were identical. The twenty-four subjects in the Baseline and C1-Subsidy rounds who also participated in the C2-Subsidy rounds did not behave differently than the other forty-eight subjects who participated in Baseline and C1-Subsidy rounds ($p = 0.347$ and $p = 0.767$ respectively, exact randomization tests). Investigating the sensitivity of allocation decisions with respect to the choice of the level of input use beyond which a subsidy will be paid may shed some light on this result. Another useful extension of this work is to incorporate the financing of the subsidy as a constraint on the participants in the environment. This would permit an evaluation of the marginal incentive to increase input use while at the same time assuring that there is not a net transfer from non-subsidized members of an economy. This is particularly relevant if the gains from the subsidy are realized by the members of the subsidized community.

---

[11] The eleven countries are Australia, Canada, France, Germany, Italy, Japan, Korea, Mexico, Sweden, the United Kingdom, and the United States of America.

References

Baily, M., R. Lawrence, and Data Resources Incorporated (1985), "The need for a permanent tax credit for industrial research and development", commissioned by the Coalition for the Advancement of Industrial Technology, *Tax Reform Proposals - IX, Hearing Before the Committee on Finance*, 99th Congress, 1st Session (June 26), 75-167.

Barth, J., J. Cordes, and G. Tassey (1984), "The impact of recent changes in tax policy on innovation and R&D", in *Strategic Management of Industrial R&D*, B. Bozemen, M. Crow, and A. Link, Editors, Lexington Books: Lexington, MA, 23-84.

Berger, P. G. (1993), "Explicit and implicit tax effects of the R&D tax credit", *Journal of Accounting Research* 31 (2), 131-172.

Brown, K. M., Editor (1984), *The R&D Tax Credit: Issues in Tax Policy and Industrial Innovation*, American Enterprise Institute for Public Policy Research: Washington, DC.

Brown, K. M. (1985), *The R&D Tax Credit: An Evaluation of Evidence on its Effectiveness*, Joint Committee Print, S. Prt. 99-73, U.S. Congress, Joint Economic Committee, Government Printing Office: Washington, DC.

Davis, Jon S., Herman C. Quirmbach, and Charles W. Swenson (1995), "Income tax subsidies and research and development spending in a competitive economy: an experimental study", *The Journal of the American Taxation Association* 17 (Supplement), 1-26.

Eisner, R., S. H. Albert, and M. A. Sullivan (1984), "The new incremental tax credit for R&D: incentive or disincentive?", *National Tax Journal* 37 (2), 171-183.

Hughes, E. and D. G. McFetridge (1985), "A theoretical analysis of incremental investment incentives with an application to the case of industrial r&d", *Journal of Public Economics*

27 (3), 311-329.

Isaac, R. Mark and Stanley Reynolds (1986), “Innovation and property rights in information: an experimental approach to testing hypotheses about private R&D behavior”, in *Advances in the Study of Entrepreneurship, Innovation, and Economic Growth*, Volume 1, Greenwich, CN: JAI Press, 129-156.

Kachelmeier, S. J. And M. Shehata (1992), “Examining risk preferences under high monetary incentive: experimental evidence from the People’s Republic of China”, *American Economic Review* 82 (5), 1120-1141.

Kohlberg, L. (1969), “Stage and sequence : the cognitive-developmental approach to socialization”, in D. Goslin, Editor, *Handbook of Socialization Theory and Research*, Rand McNally: Chicago, 347-480.

McCutchen, W. W. Jr. (1993), “Strategy changes as a response to alterations in tax policy”, *Journal of Management* 19 (3), 575-593.

Moir, R. (1998), “A Monte Carlo analysis of the Fischer randomization technique: reviving randomization for experimental economists”, *Experimental Economics* 1 (1), 87-100.

Offerman, T., J. Sonnemans, and A. Schram (1996), “Value orientations, expectations and voluntary contributions in public goods”, *Economic Journal* 106 (437), 817-845.

Rest, J. R. (1979), *Development in Judging Moral Issues*, University of Minnesota Press: Minneapolis.

Shehata, M., and M. E. Ebrahim (1992), “The impact of tax policies on firms’ R&D spending behavior: the case of R&D tax credit”, Innovation Research Working Paper Number 12, Faculty of Business: McMaster University.

Warda, Jacek (1994), *Canadian R&D Tax Treatment: An International Comparison*, Report 125-94, The Conference Board of Canada: Ottawa.

Table 1

Predicted Symmetric Individual and Group Investment Decisions by Period and Treatment Under Alternative Scenarios

Treatment	Non-Cooperative Environment				Cooperative Environment			
	Periods 1-9		Period 10		Periods 1-9		Period 10	
	Ind'l	Group	Ind'l	Group	Ind'l	Group	Ind'l	Group
Baseline	3	12	3	12	9	36	9	36
C1-Subsidy	9	36	9	36	15	60	15	60
C2-Subsidy	9	36	9	36	15	60	15	60
U1-Subsidy	3	12	9	36	9	36	15	60
	Periods 2,4,6,8		Periods 1,3,5,7, 9.10		Periods 2,4,6,8		Periods 1,3,5,7, 9,10	
	Ind'l	Group	Ind'l	Group	Ind'l	Group	Ind'l	Group
U2-Subsidy	2	8	9	36	6	24	15	60

Note:

The planner's solution is given by the Baseline Cooperative Environment.

Table 2

Predicted Individual Profits (excluding subsidy payments) and Subsidy Payments Under Alternative Scenarios over Ten Periods in Lab Dollars

	Non-Cooperative Environment		Cooperative Environment	
	Profit	Subsidy	Profit	Subsidy
Baseline	210.00	0	270.00	0
C1-Subsidy	270.00	67.50	250.00	112.50
C2-Subsidy	270.00	45.00	250.00	90.00
U1-Subsidy	216.00	6.75	268.00	11.25
U2-Subsidy	230.80	27.75	254.00	38.25

Note:

The planner’s solution is given by the Baseline Cooperative Environment.

Table 3

Experimental Design: Number of Groups of Four Decision-Makers

	Treatments				
Round	B	C1	C2	U1	U2
1	18				
2		9	3	3	3
3		9	3	3	3

Note:

Six sessions were run. Each session consisted of three 12-period rounds with three groups of subjects. The allocation of treatments to rounds followed the pattern B-C1-X and B-X-C1, where X is either C2, U1, or U2. Each of the treatments, other than the baseline, was in rounds 2 and 3 an equal number of times.

Table 4

Mean Group Investment in Units of Input by Treatment: Periods 1 through 9

Group	Baseline	C1-Subsidy	C2-Subsidy	U1-Subsidy	U2-Subsidy
1	11.67	36.67	31.00	16.00	19.22
2	14.67	33.44	33.00	29.00	27.44
3	20.56	46.33	28.56	23.56	19.78
4	15.44	32.67	38.33	13.56	18.56
5	20.33	34.33	21.44	20.44	24.78
6	17.89	37.44	24.11	16.22	22.89
7	19.67	43.67			
8	13.56	22.33			
9	18.67	21.22			
10	16.33	37.78			
11	25.11	35.78			
12	16.67	30.33			
13	17.67	31.44			
14	16.33	38.00			
15	14.56	34.11			
16	18.89	45.89			
17	16.44	33.67			
18	11.67	29.44			
Average	17.01	34.70	29.41	19.80	22.11
Nash Equilibrium	12	36	36	12	23.6
Joint Profit Maximum	36	60	60	60	44
Pareto Optimal	36	36	36	36	36

Note:

Under the U2-Subsidy the Nash equilibrium group investment will be 8 in even-numbered periods and 36 in odd-numbered periods. If the four individuals maximized joint profits including the subsidy, investment will be 24 in even-numbered periods and 60 in odd-numbered periods. These result in average contributions over periods 1 through 9 of 23.6 and 44 respectively.

Table 5

Mean Group Efficiency by Treatment: Periods 1 through 9

Group	Baseline	C1-Subsidy	C2-Subsidy	U1-Subsidy	U2-Subsidy
1	-7.38	98.49	88.87	-10.74	38.27
2	17.84	92.12	90.29	90.60	72.79
3	63.67	91.93	84.85	78.20	44.40
4	12.00	92.68	97.72	6.53	42.93
5	61.18	96.23	60.01	57.24	76.36
6	29.39	96.73	80.47	35.09	73.01
7	57.12	94.97			
8	-3.79	68.29			
9	48.12	59.07			
10	36.30	99.18			
11	85.17	97.52			
12	32.53	95.89			
13	36.75	94.84			
14	26.79	95.43			
15	22.75	93.72			
16	57.03	90.85			
17	37.44	98.75			
18	-21.69	90.60			
Average	32.85	91.52	83.70	42.82	57.96

Note:

Efficiency in each period is equal to $100(\Delta\Pi / \Delta\Pi^{*})$, where $\Delta\Pi$ is the difference between actual group profit (less subsidies) and the predicted Nash equilibrium baseline group profit (L$84) and $\Delta\Pi^{*}$ is the difference between the Pareto optimal group profit (L$108) and the predicted Nash equilibrium baseline group profit.

Table 6

Mean Group Subsidy Payment by Treatment in Lab Dollars: Periods 1 through 9

Group	Baseline	C1-Subsidy	C2-Subsidy	U1-Subsidy	U2-Subsidy
1	0	27.5	15.6	1.3	9.7
2	0	25.1	17.5	3.1	14.7
3	0	34.8	13.8	1.6	7.7
4	0	24.5	21.3	0.8	10.7
5	0	25.8	9.4	2.4	7.8
6	0	28.1	12.7	1.0	8.4
7	0	32.8			
8	0	16.8			
9	0	15.9			
10	0	28.3			
11	0	26.8			
12	0	22.8			
13	0	23.6			
14	0	28.5			
15	0	25.6			
16	0	34.4			
17	0	25.3			
18	0	22.1			
Average	0	26.0	15.0	1.7	9.8

Table 7

Mean Group Profit (excluding subsidy) by Treatment in Lab Dollars: Periods 1 through 9

Group	Baseline	C1-Subsidy	C2-Subsidy	U1-Subsidy	U2-Subsidy
1	82.2	107.6	105.3	81.4	93.2
2	88.3	106.1	105.7	105.7	101.5
3	99.3	106.1	104.4	102.8	94.7
4	86.9	106.2	107.5	85.6	94.3
5	98.7	107.1	98.4	97.7	102.3
6	91.1	107.2	103.3	92.4	101.5
7	97.7	106.8			
8	83.1	100.4			
9	95.5	98.2			
10	92.7	107.8			
11	104.4	107.4			
12	91.8	107.0			
13	92.8	106.8			
14	90.4	106.9			
15	89.5	106.5			
16	97.7	105.8			
17	93.0	107.7			
18	78.8	105.7			
Average Profit	91.9	106.0	104.1	94.3	97.9
Average Cost Saving		14.1	12.2	2.4	6.0

Note:

Average cost saving under a subsidy treatment is the difference between average profits (excluding the subsidy payment) under a subsidy treatment and the average profit in the Baseline treatment. The difference in profit is attributable to the increase in the use of the R&D input.

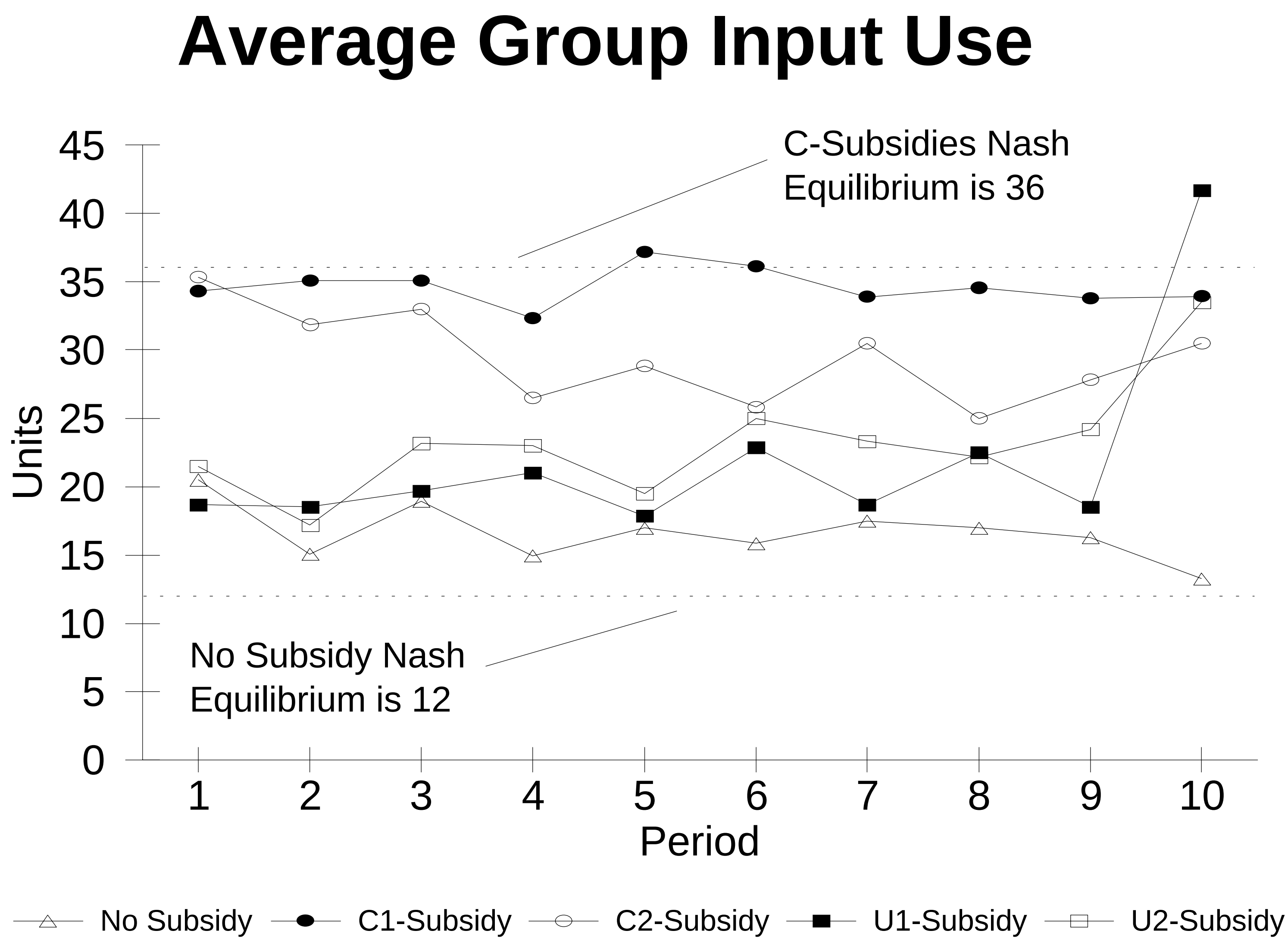
Table 8

Regression Coefficients Using Nine-Period Mean Group Investment in Input by Treatment

Variable	Regression 1			Regression 2		
	Coefficient	Standard Error	p-Value	Coefficient	Standard Error	p-Value
Constant (Baseline)	17.006	1.249	0.000	15.193	1.492	0.000
C1-Subsidy	17.691	1.767	0.000	17.691	1.701	0.000
C2-Subsidy	12.401	2.498	0.000	12.311	2.419	0.000
U1-Subsidy	2.790	2.498	0.270	3.243	2.428	0.188
U2-Subsidy	5.105	2.498	0.046	4.742	2.425	0.056
# of Cooperators				1.631	0.786	0.043
Adjusted R Square		0.673			0.693	
Observations		54			54	

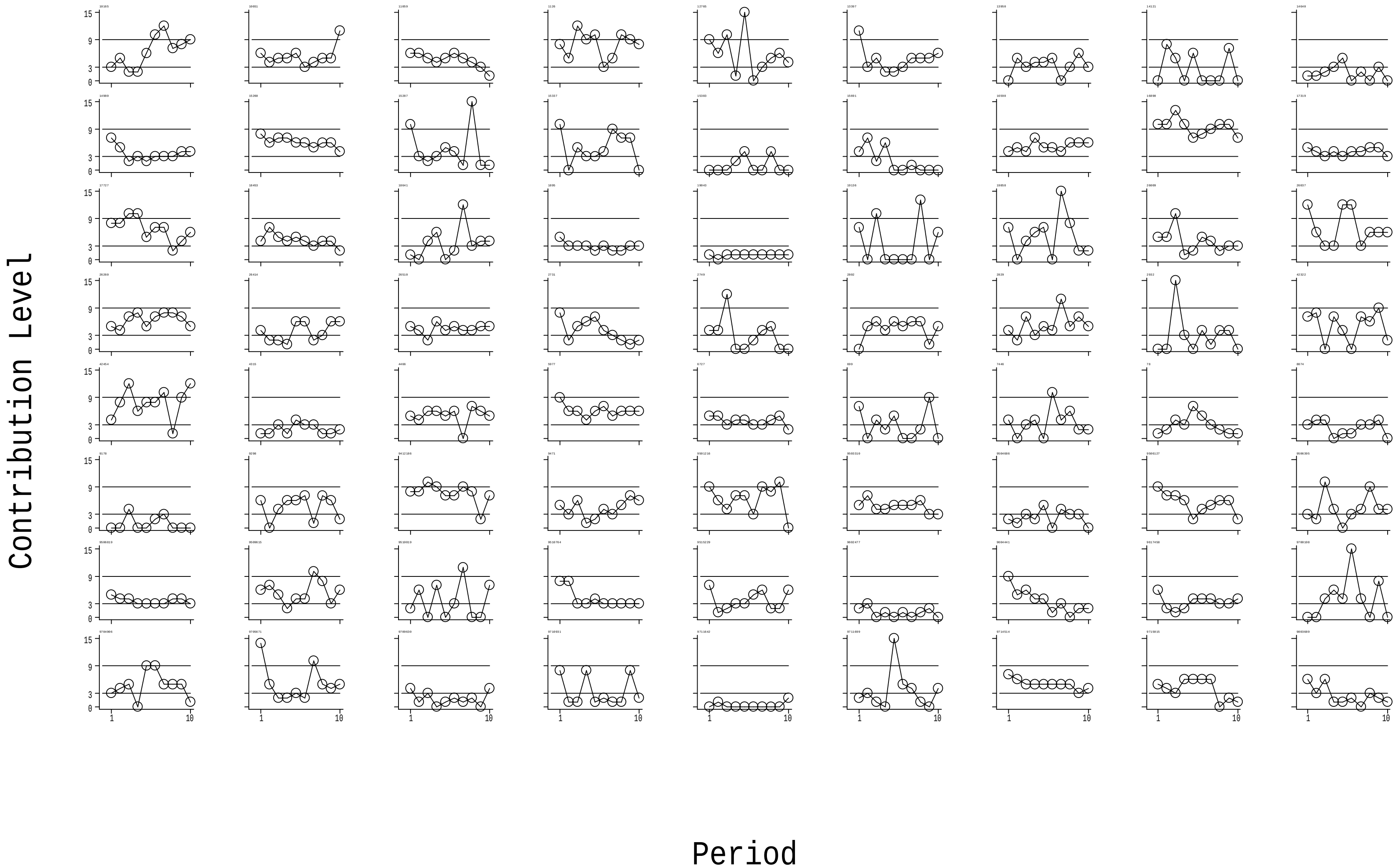
Note:

The common elements in both regressions are treatment dummy variables. The variable added into Regression 2 is the number of cooperators in the group (mean = 1.111, standard deviation = 0.904), an integer value which can range from 0 to 4 based on each group member’s value orientation measure.



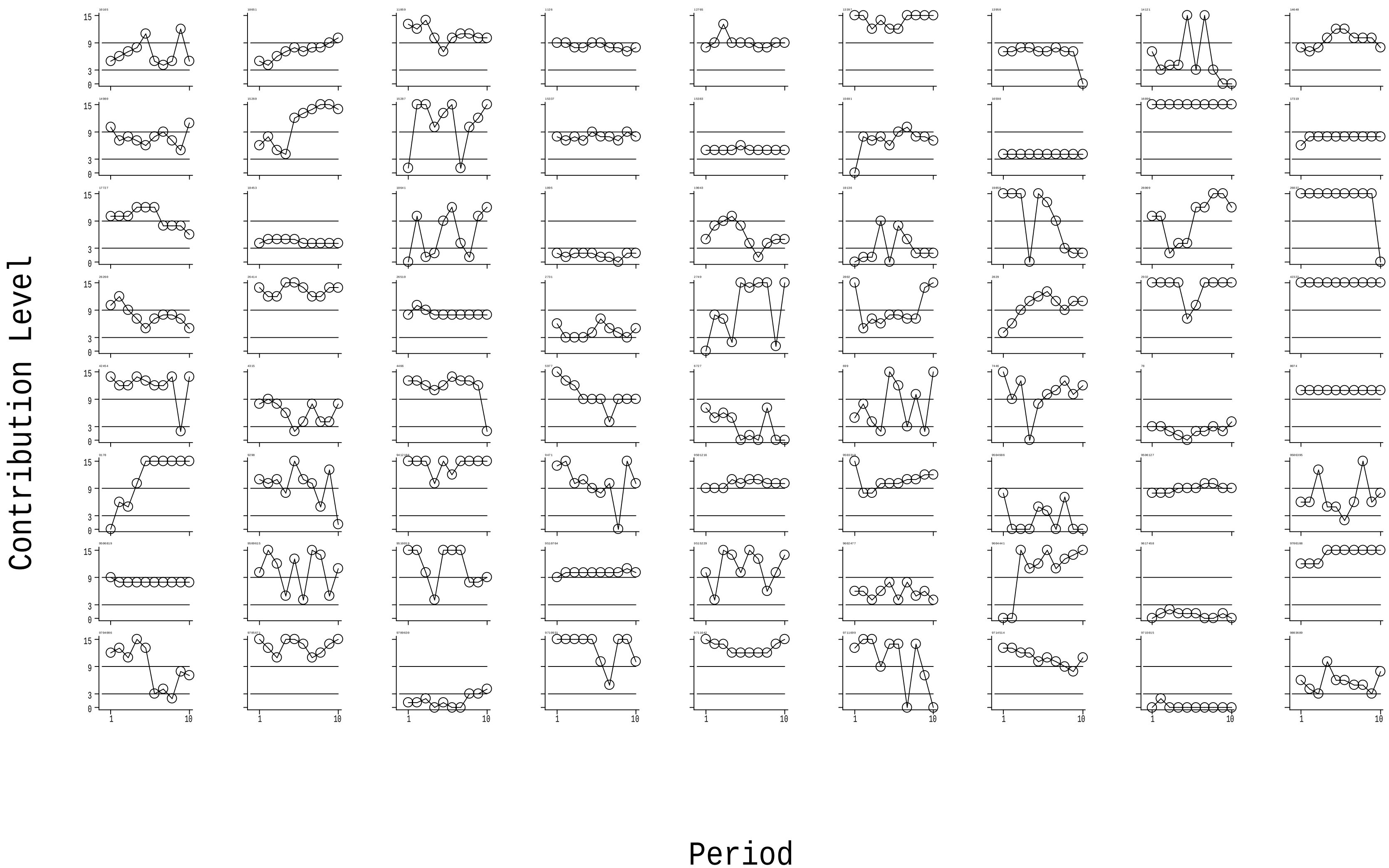
Average Group Input Use
C-Subsidies Nash
Equilibrium is 36
No Subsidy Nash
Equilibrium is 12
Units
45
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
Period
No Subsidy
C1-Subsidy
C2-Subsidy
U1-Subsidy
U2-Subsidy

Figure 1



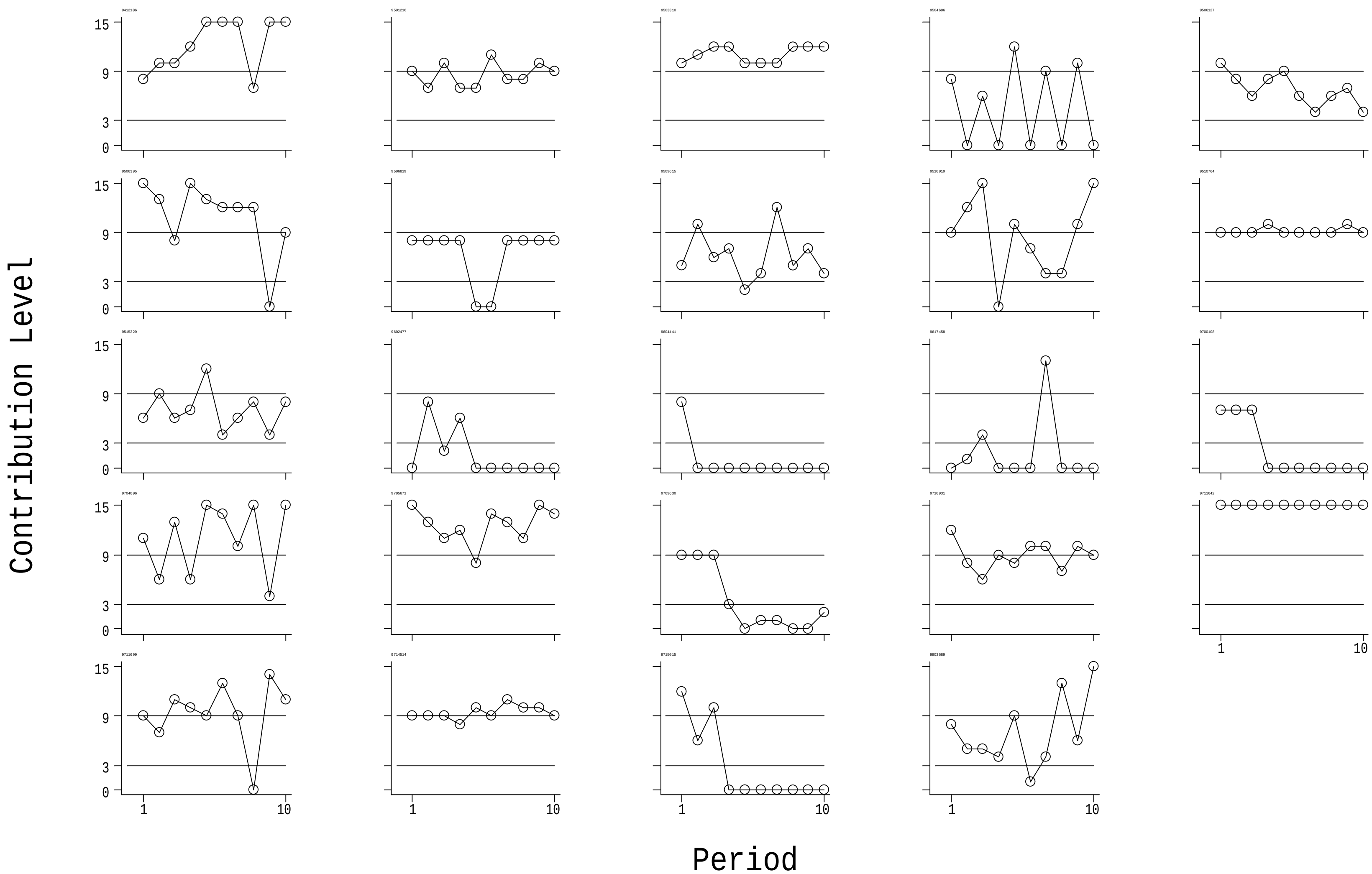
Individual Subject Contributions for Baseline Treatment

Figure 2



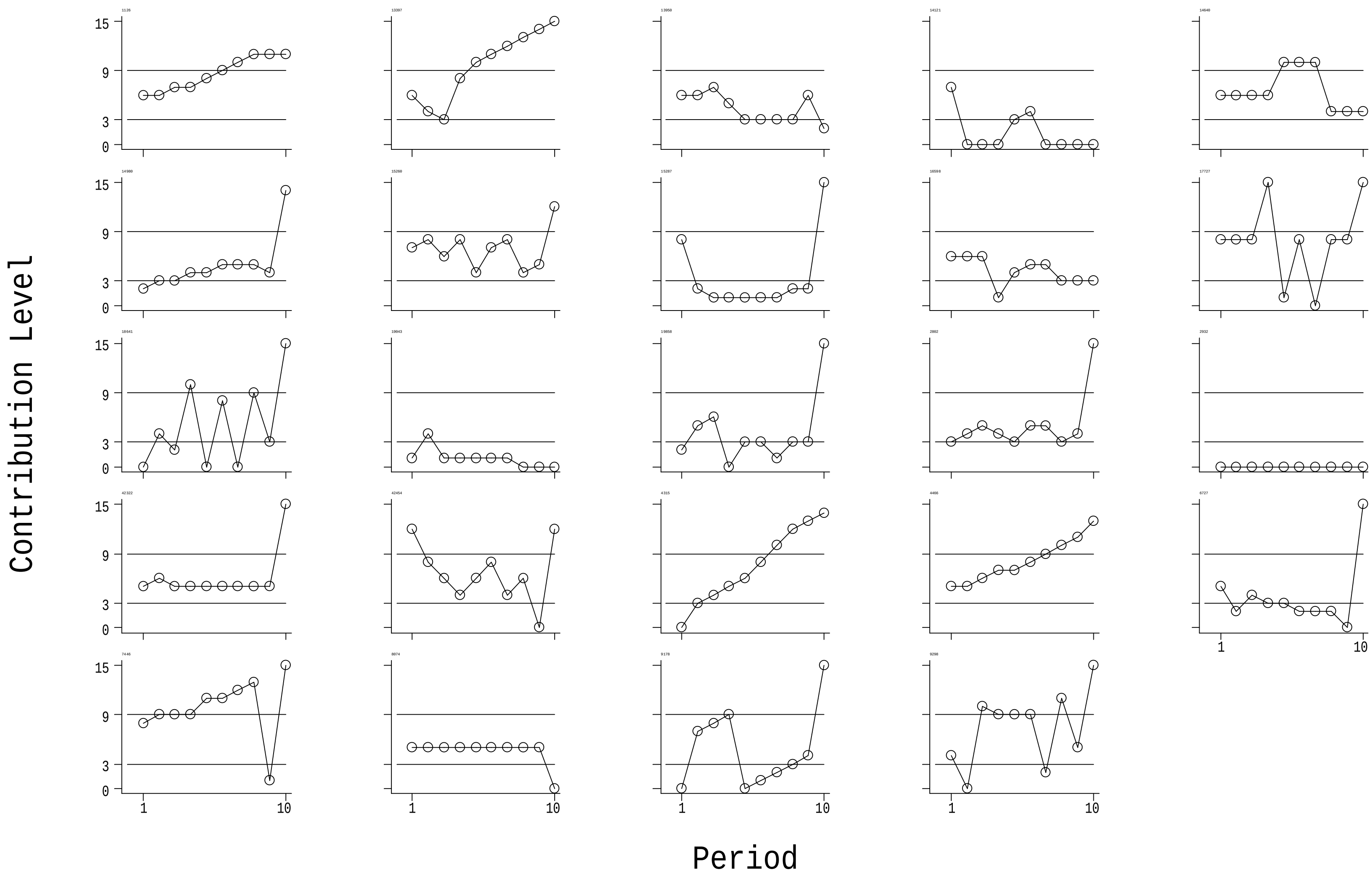
Subject Contributions for C1-Subsidy Treatment

Figure 3



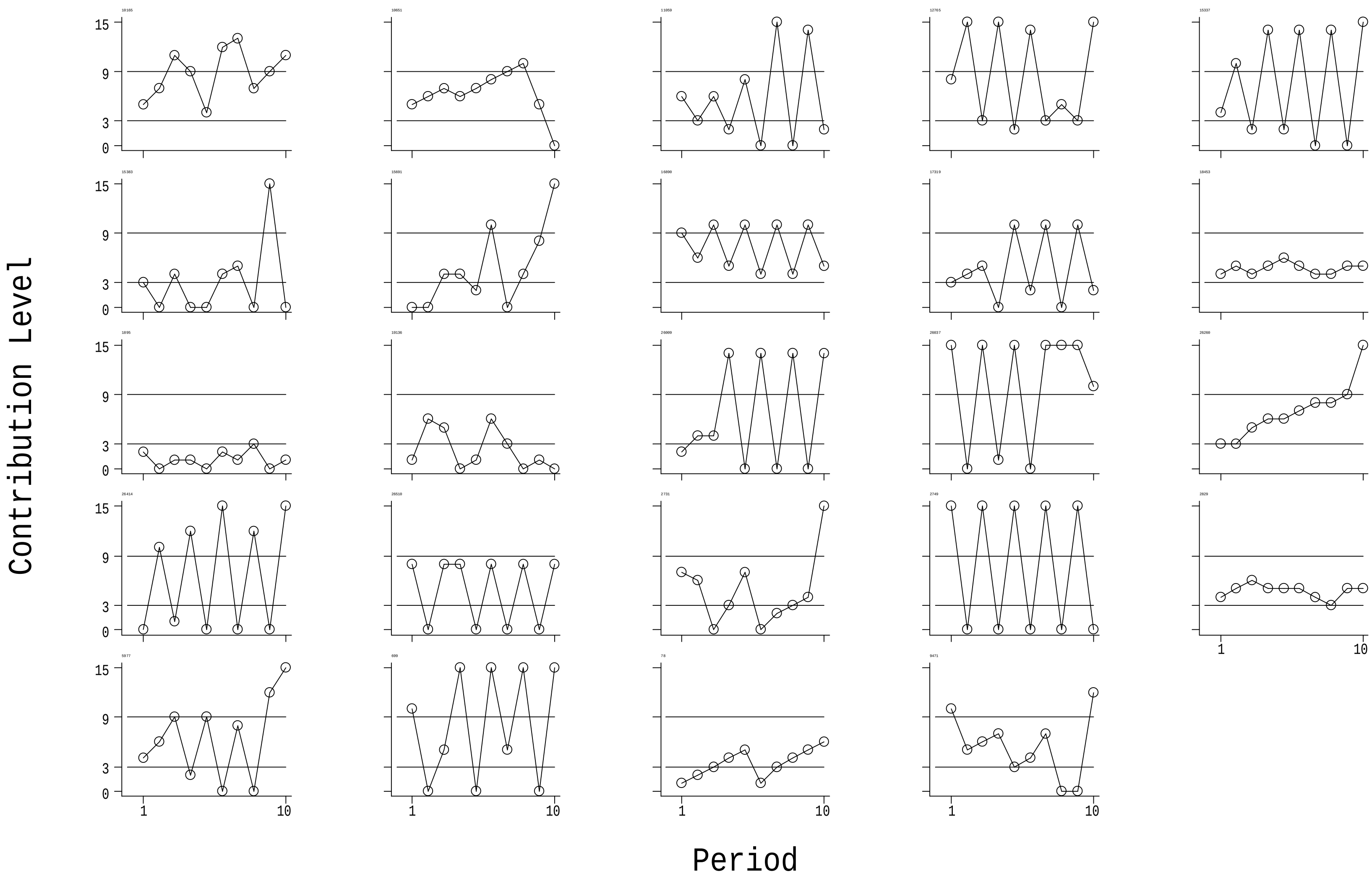
Subject Contributions for C2-Subsidy Treatment

Figure 4



Subject Contributions for U1-Subsidy Treatment

Figure 5



Subject Contributions for U2-Subsidy Treatment

Figure 6

Appendix 1. Instructions 5and Record Sheets

1. Instructions for Baseline Treatment
2. Sample Payoff and Practice Questions
3. Baseline Record Sheet
4. Instructions for C1 Treatment in Round 2
5. C1 Treatment Record Sheet for Round 2
6. Instructions for C2 Treatment in Round 3
7. C2 Treatment Record Sheet for Round 3
8. Instructions for U1 Treatment in Round 3
9. U1 Treatment Record Sheet for Round 3
10. Instructions for U2 Treatment in Round 3
11. U2 Treatment Record Sheet for Round 3
12. Cumulative Payoff Sheet

INSTRUCTIONS

General

This is an experiment in economic decision-making. Various research foundations have provided funds for this research. The instructions are simple, and if you follow them carefully, you may earn a considerable amount of money, which will be paid to you in cash. As researchers, we will learn from your decisions. This is not an examination. There are no correct or incorrect decisions.

The Introduction

Each of you is a member of a 4-person group. The other members of your group are in the room, but you will not know who they are. You produce a product which is sold in a market at a predetermined price. You can affect your profit from the sale of this product by the input decision you make. At the start of each decision period you and each of the other members of your group receive an endowment of 15 tokens. You will have to decide how many tokens you will invest in an input used to reduce the cost of the product you produce. Your profit from production will depend upon the number of tokens **you and others in your group** invest in this special input. As the investment you and others make in the special input increases, your production costs fall. As your investment increases, however, your total cost of acquiring this special input increases.

To assist you in making decisions, you have been provided with a payoff table which shows how your payoff will be affected by what you invest in the special input and by what the other members of your group invest in this input.

The Example

Included in your folder is a sample payoff table. The numbers on the table are illustrative only. They do not provide any information about the actual decisions you will have to make after we complete reviewing the instructions. Please look at the sample payoff table.

Across the top of the sample table are the numbers 0 through 3. These represent the different number of tokens which you may invest in the special input. In this example, your maximum investment is 3 tokens. The numbers 0 through 9 running down the left side of the table are the different number of tokens which the other three participants together may invest in this input. Read question 1 on the sheet containing the sample payoff table. In these examples, you are player 4.

To find your earnings, you must find your investment on the table and the investment made by player's 1, 2 and 3, together. You invested 2 tokens. Players 1, 2, and 3 together invested 5 tokens. You can find your payoff by reading across the row associated with an **Investment in the Input by Others** of 5 (the sixth row from the top) to the column associated with **Your Investment in the Input** of 2 (the third column from the left). The intersection of the sixth row and the third column shows a payoff of 60 lab dollars.

To test your understanding of how payoffs are determined, please answer questions 2 and 3 on the sheet with the sample table. Write the answers in the places indicated on the sheet. If you have any questions, please raise your hand and we will help you.

The Investment Problem

Included with these instructions, along with the sample payoff table, is the payoff table which will be used during this session. The payoff table shows the payoff that you will receive from your investment and the investment of others in the input. You may also use the payoff table to determine the payoff of any member of the group conditional on the contribution that person makes and the contributions made by the others.

You are participating in a decision-making session with three other people. Each member of each group will have an endowment of 15 tokens. You will participate in two practice periods, after each period the members of the groups will be scrambled. After the two practice periods, you will participate in ten periods with the same group members and your decisions will contribute to your earnings in the session. After ten periods, the members of your group will be changed, and you will receive a new set of instructions and you will participate in another round (two practice periods and ten periods which will contribute to your earnings in the session). You will not know the identity of the members of your group in any period.

Each period you will have no more than 3 minutes to decide how many tokens you will invest in the input. You may not invest more than your endowment of tokens. You are not required to invest anything in this input. The **MESSAGE** line of the computer screen in front of you will display the message **You must invest between 0 and 15 tokens in the input**. It will also be presented in the **INSTRUCTIONS** line on the screen with the message **Please enter period i investment between [0 - 15]**, where 15 is your endowment of tokens and i is the current period.

The computer will display up to eight periods of information on your investments, the investments of the other members of your group, and your payoffs based on the values on your payoff table. After the eighth period, the first period will be replaced by the ninth period's investments and payoffs. You must keep your own records of investments and payoffs for the entire session on the record sheet which is included in your folder. Your cumulative lab dollar payoff based on the payoffs on the payoff table must be maintained on your record sheet.

Your cumulative lab dollar payoff on your record sheet will be converted into dollars at the rate reported at the top of the record sheet. At the end of the session (three rounds) this will be paid to you in cash.

You should not communicate to anyone other than the researchers during the session. If you have any questions, please raise your hand and one of us will help you.

Practice Periods

To begin the first practice period of this round, enter two (2) tokens as your investment in the special input in the first practice period. When the computer indicates the investments of others and the payoff you receive, record these numbers on your record sheet.

When the second practice period begins, select whatever investment you wish to make for this period. Record your investment, the investment of others, and your payoff on your record sheet. If this was not a practice period, you would also record your total profits over all periods in the right-most column.

Again, you should not communicate to anyone other than the researchers during the session. If you have any questions, please raise your hand and one of us will help you.

Technical Note

Formally, the payoff reported by the computer monitor, and on the payoff matrix, is calculated using the equation

$$\text{Lab Dollar Payoff} = 48 - [576/(12 + x + Y)] - x \qquad (1)$$

where x indicates the number of tokens you invest in the input and Y indicates the number of tokens <u>the others in your group</u> invest in the input. If there are four players in your group and you are player 4,

$$Y = a + b + c \qquad (2)$$

where a, b, and c are the investments in the input made by player 1, player 2, and player 3, respectively. Each player has the same lab dollar payoff function. Each payoff table is constructed from the payoff function in (1) above. Because each player has the same endowment of tokens, each player's payoff table is the same as each other player's payoff table.

SAMPLE PAYOFF TABLE AND PRACTICE QUESTIONS

		Your Investment in the Input			
		0	1	2	3
Investment in the Input by the Others	0	20	25	30	35
	1	25	30	40	40
	2	30	45	50	45
	3	35	40	60	50
	4	40	45	70	55
	5	35	50	60	60
	6	30	45	50	55
	7	25	30	35	40
	8	20	25	30	35
	9	15	20	25	30

<u>Questions</u>

1. If player 1 invests **1** token, player 2 invests **1** token, and player 3 invests **3** tokens, what will be your payoff if you invest **2** tokens?

Your earnings ______

2. If player 1 invests **2** tokens, 3 invests **1**, and you invest **3** tokens, what will be player 2's payoff if she invests nothing (**0** tokens) and if she has the same endowment and payoff table as you have?

Player 2's earnings ______

3. If player 1 invests **2** tokens, player 2 invests nothing (**0** tokens), amd player 3 invests **1**, what will be your payoff if you invest **3** tokens?

Your earnings ______

Subject I.D. ___________ Conversion Rate: 30 Laboratory Dollars = 1 Canadian Dollar

Record Sheet				
A	B	C	D	G
Period	Number of Input Units You Used	Number of Input Units Used by Others	Period Profit = Profit from Screen	Total Profit Over All Periods From Period 3 Onward
P1				
P2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

ROUND TWO INSTRUCTIONS

In addition to the payoff identified on the payoff table, your record sheet contains a Payoff Adjustment (column E) which increases your profit by 0.75 lab dollars for each unit of input in which you invest. When you complete your record sheet, be certain to fill in this column. Your total profit, if correctly recorded on your record sheet, may be different from the value shown on the computer screen by the value in column E.

Practice Periods

To begin the first practice period of this round, enter two (2) tokens as your investment in the special input in the first practice period. When the computer indicates the investments of others and the payoff you receive, record these numbers on your record sheet. Now complete the box in column E for this practice period. Your entry should be 0.75 times two (your investment in the special input this period) or 1.50. Write 1.50 in column E and enter the sum of columns D and E in column F.

When the second practice period begins, select whatever investment you wish to make for this period. Record your investment, the investment of others, and your payoff from the monitor on your record sheet. Then multiply your investment in the special input by 0.75 and enter this in column E. Finally enter the sum of column D and E in column F. If this was not a practice period, you would also record your total profits over all periods in the right-most column.

Again, you should not communicate to anyone other than the researchers during the session. If you have any questions, please raise your hand and one of us will help you.

Technical Note

Formally, the payoff reported by the computer monitor, and on the payoff matrix, is calculated using the equation

$$\text{Lab Dollar Payoff} = 48 - [576/(12 + x + Y)] - x \qquad (1)$$

where x indicates the number of tokens you invest in the input and Y indicates the number of tokens the others in your group invest in the input. If there are four players in your group and you are player 4,

$$Y = a + b + c \tag{2}$$

where a, b, and c are the investments in the input made by player 1, player 2, and player 3, respectively. Each player has the same lab dollar payoff function. Each payoff table is constructed from the payoff function in (1) above. Because each player has the same endowment of tokens, each player's payoff table is the same as each other player's payoff table. **This payoff table does not include any Column E Payoff Adjustments.**

Subject I.D. ___________ Conversion Rate: 30 Laboratory Dollars = 1 Canadian Dollar

Record Sheet						
A	B	C	D	E	F	G
Period	Number of Input Units You Used	Number of Input Units Used by Others	Profit from Screen	Profit Adjustment = 0.75 Times the Number of Input Units You Used	Period Profit = Columns D + E	Total Profit Over All Periods From Period 15 Onward
P13						
P14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						

0.75 Times the Number of Input Units Used = Column E Value																
Number of Input Units Used	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
E Value	0	0.75	1.5	2.25	3.0	3.75	4.5	5.25	6.0	6.75	7.5	8.25	9.0	9.75	10.5	11.25

ROUND THREE INSTRUCTIONS

In addition to the payoff identified on the payoff table, your record sheet contains a Payoff Adjustment (columns E) which increases your profit by 0.75 lab dollars for each unit of input in which you invest beyond the third unit. If the numbers in columns E1 and E2 are negative, your Payoff Adjustment is set equal to zero (0). When you complete your record sheet, be certain to fill in these columns. Your total profit each period, if correctly recorded on your record sheet, will be different from the value shown on the computer screen by the value in column E3.

Your cumulative lab dollar payoff on your record sheet will be converted into dollars at the rate reported at the top of the record sheet. At the end of the session (three rounds) this will be paid to you in cash.

You should not communicate to anyone other than the researchers during the session. If you have any questions, please raise your hand and one of us will help you.

Practice Periods

To begin the first practice period of this round, enter two (2) tokens as your investment in the special input in the first practice period. When the computer indicates the investments of others and the payoff you receive, record these numbers on your record sheet. Now complete the box in column E1 for this practice period. Your entry should be 2 (your investment in the special input this period) minus 3, or -1. Write -1 in column E1. The entry in column E2 is - 0.75. In column E3 you enter zero (0) because your entry in column E2 is negative. Now enter the sum of columns D and E3 in column F.

When the second practice period begins, select whatever investment you wish to make for this period. Record your investment, the investment of others, and your payoff from the monitor on your record sheet. Then enter the difference between your investment in the special and 3 in column E1. Your entry in column E2 is 0.75 times the number in column E1. If this number (in column E2) is negative, your entry in column E3 will be zero (0). If the number in column E2 is positive, you enter this number in column E3. Finally enter the sum of the numbers in column D and column E3 in column F. If this was not a practice period, you would also record your total profits over all periods in the right-most column.

Again, you should not communicate to anyone other than the researchers during the session. If you have any questions, please raise your hand and one of us will help you.

Technical Note

Formally, the payoff reported by the computer monitor, and on the payoff matrix, is calculated using the equation

$$\text{Lab Dollar Payoff} = 48 - [576/(12 + x + Y)] - x \qquad (1)$$

where x indicates the number of tokens you invest in the input and Y indicates the number of tokens the others in your group invest in the input. If there are four players in your group and you are player 4,

$$Y = a + b + c \qquad (2)$$

where a, b, and c are the investments in the input made by player 1, player 2, and player 3, respectively. Each player has the same lab dollar payoff function. Each payoff table is constructed from the payoff function in (1) above. Because each player has the same endowment of tokens, each player's payoff table is the same as each other player's payoff table. **This payoff table does not include any Column E3 Payoff Adjustments.**

Subject I.D. __________ Conversion Rate: 30 Laboratory Dollars = 1 Canadian Dollar

Record Sheet								
A	B	C	D	E			F	G
Period	Number of Input Units You Used	Number of Input Units Used by Others	Profit from Screen	Profit Adjustment			Period Profit = Columns D + E3	Total Profit Over All Periods From Period 27 Onward
				E1 Number of Input Units You Used This Period (from Column B) Minus 3	E2 0.75 Times the Number in Column E1	E3 E2 if E2 is greater than 0; otherwise enter zero (0)		
P13								
P14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								

0.75 Times the Number in Column E1													
Number In Column E1	0	1	2	3	4	5	6	7	8	9	10	11	12
E2 Value	0	0.75	1.5	2.25	3.0	3.75	4.5	5.25	6.0	6.75	7.5	8.25	9.0

ROUND THREE INSTRUCTIONS

In addition to the payoff identified on the payoff table, your record sheet contains a Payoff Adjustment (columns E) which increases your profit by 0.75 lab dollars for each unit of input in which you invest (column E1) but which reduces your profit by 0.75 lab dollars for each unit in which you invested in the previous period (column E2). When you complete your record sheet, be certain to fill in these columns. Your total profit, if correctly recorded on your record sheet, may be different from the value shown on the computer screen by the sum of the values in columns E1 and E2.

Practice Periods

To begin the first practice period of this round, enter two (2) tokens as your investment in the special input in the first practice period. When the computer indicates the investments of others and the payoff you receive, record these numbers on your record sheet. Now complete the box in column E1 for this practice period. Your entry should be 0.75 times two (your investment in the special input this period) or 1.50. Write 1.50 in column E1. Because this is your first period, your investment in the previous period is zero. Therefore, your entry in column E2 is zero (0). Now enter the sum of columns D, E1, and E2 in column F.

When the second practice period begins, select whatever investment you wish to make for this period. Record your investment, the investment of others, and your payoff from the monitor on your record sheet. Then multiply your investment in the special input by 0.75 and enter this in column E1. Your entry in column E2 will be 0.75 times two (your investment in the special input in the previous period). Finally enter the sum of column D and E1 minus the number in column E2 in column F. If this was not a practice period, you would also record your total profits over all periods in the right-most column.

Again, you should not communicate to anyone other than the researchers during the session. If you have any questions, please raise your hand and one of us will help you.

Technical Note

Formally, the payoff reported by the computer monitor, and on the payoff matrix, is calculated using the equation

$$\text{Lab Dollar Payoff} = 48 - 576/(12 + x + Y) - x \qquad (1)$$

where x indicates the number of tokens you invest in the input and Y indicates the number of tokens the others in your group invest in the input. If there are four players in your group and you are player 4,

$$Y = a + b + c \qquad (2)$$

where a, b, and c are the investments in the input made by player 1, player 2, and player 3, respectively. Each player has the same lab dollar payoff function. Each payoff table is constructed from the payoff function in (1) above. Because each player has the same endowment of tokens, each player's payoff table is the same as each other player's payoff table. **This payoff table does not include any Column E1 and E2 Payoff Adjustments.**

Subject I.D. __________ Conversion Rate: 30 Laboratory Dollars = 1 Canadian Dollar

Record Sheet

A	B	C	D	E		F	G
Period	Number of Input Units You Used	Number of Input Units Used by Others	Profit from Screen	Profit Adjustment		Period Profit = Columns D + E1 - E2	Total Profit Over All Periods From Period 27 Onward
				E1 Plus: 0.75 Times the Number of Input Units You Used This Period	E2 Minus: 0.75 Times the Number of Input Units You Used Last Period		
P25					0		
P26							
27					0		
28							
29							
30							
31							
32							
33							
34							
35							
36							

0.75 Times the Number of Input Units Used in Periods t or t-1 = Column E1 or E2 Values																
Number of Input Units Used	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
E Value	0	0.75	1.5	2.25	3.0	3.75	4.5	5.25	6.0	6.75	7.5	8.25	9.0	9.75	10.5	11.25

ROUND THREE INSTRUCTIONS

In addition to the payoff identified on the payoff table, your record sheet contains a Payoff Adjustment (columns E) which increases your profit by 0.75 lab dollars for each unit of input in which you invest (column E1) but which reduces your profit by 0.75 lab dollars for each unit in which you invested in the previous period (column E2). If the difference between the two numbers is negative (if the number in column E1 minus the number in column E2 is negative), your Payoff Adjustment is set equal to zero (0). When you complete your record sheet, be certain to fill in these columns. Your total profit each period, if correctly recorded on your record sheet, will be different from the value shown on the computer screen by the value in column E3.

Your cumulative lab dollar payoff on your record sheet will be converted into dollars at the rate reported at the top of the record sheet. At the end of the session (three rounds) this will be paid to you in cash.

You should not communicate to anyone other than the researchers during the session. If you have any questions, please raise your hand and one of us will help you.

Practice Periods

To begin the first practice period of this round, enter two (2) tokens as your investment in the special input in the first practice period. When the computer indicates the investments of others and the payoff you receive, record these numbers on your record sheet. Now complete the box in column E1 for this practice period. Your entry should be 0.75 times two (your investment in the special input this period) or 1.50. Write 1.50 in column E1. Because this is your first period, your investment in the previous period is zero. Therefore, your entry in column E2 is zero (0). In column E3 you enter the difference between the values in columns E1 and E2. Now enter the sum of columns D and E3 in column F.

When the second practice period begins, select whatever investment you wish to make for this period. Record your investment, the investment of others, and your payoff from the monitor on your record sheet. Then multiply your investment in the special input by 0.75 and enter this in column E1. Your entry in column E2 will be 0.75 times two (your investment in the special input in the previous period). Your entry in column E3 will be the difference between the numbers in E1 and E2. Finally enter the sum of the numbers in column D and column E3 in column F. If this was not a practice period, you would also record your total profits over all periods in the right-most column.

Again, you should not communicate to anyone other than the researchers during the session. If you have any questions, please raise your hand and one of us will help you.

Technical Note

Formally, the payoff reported by the computer monitor, and on the payoff matrix, is calculated using the equation

$$\text{Lab Dollar Payoff} = 48 - 576/(12 + x + Y) - x \qquad (1)$$

where x indicates the number of tokens you invest in the input and Y indicates the number of tokens the others in your group invest in the input. If there are four players in your group and you are player 4,

$$Y = a + b + c \qquad (2)$$

where a, b, and c are the investments in the input made by player 1, player 2, and player 3, respectively. Each player has the same lab dollar payoff function. Each payoff table is constructed from the payoff function in (1) above. Because each player has the same endowment of tokens, each player's payoff table is the same as each other player's payoff table. **This payoff table does not include any Column E3 Payoff Adjustments.**

Subject I.D. __________ Conversion Rate: 30 Laboratory Dollars = 1 Canadian Dollar

Record Sheet								
A	B	C	D	E			F	G
Period	Number of Input Units You Used	Number of Input Units Used by Others	Profit from Screen	Profit Adjustment			Period Profit = Columns D + E3	Total Profit Over All Periods From Period 27 Onward
				E1 0.75 Times the Number of Input Units You Used This Period	E2 0.75 Times the Number of Input Units You Used Last Period	E3 E1 - E2 if E1 - E2 is greater than 0; otherwise enter zero (0)		
P25					0			
P26								
27					0			
28								
29								
30								
31								
32								
33								
34								
35								
36								

0.75 Times the Number of Input Units Used in Periods t or t-1 = Column E1 or E2 Values																
Number of Input Units Used	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
E Value	0	0.75	1.5	2.25	3.0	3.75	4.5	5.25	6.0	6.75	7.5	8.25	9.0	9.75	10.5	11.25

Subject I.D. _________

Cumulative Payoff Sheet

(1) Total Payoff from Period 12 Column G ___________

(2) Total Payoff from Period 24 Column G ___________

(3) Total Payoff from Period 36 Column G ___________

(4) Grand Total ___________

(5) Grand Total Divided by 30 ___________

(6) Line (5) Value Rounded to Highest Dollar ___________

____ ___________________________

Name (Printed) Student Number

Appendix 2. Payoff Table

Your Investment in the Input

Investment in the Input by Others

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	0.00	2.69	4.86	6.60	8.00	9.12	10.00	10.68	11.20	11.57	11.82	11.96	12.00	11.96	11.85	11.67
1	3.69	5.86	7.60	9.00	10.12	11.00	11.68	12.20	12.57	12.82	12.96	13.00	12.96	12.85	12.67	12.43
2	6.86	8.60	10.00	11.12	12.00	12.68	13.20	13.57	13.82	13.96	14.00	13.96	13.85	13.67	13.43	13.14
3	9.60	11.00	12.12	13.00	13.68	14.20	14.57	14.82	14.96	15.00	14.96	14.85	14.67	14.43	14.14	13.80
4	12.00	13.12	14.00	14.68	15.20	15.57	15.82	15.96	16.00	15.96	15.85	15.67	15.43	15.14	14.80	14.42
5	14.12	15.00	15.68	16.20	16.57	16.82	16.96	17.00	16.96	16.85	16.67	16.43	16.14	15.80	15.42	15.00
6	16.00	16.68	17.20	17.57	17.82	17.96	18.00	17.96	17.85	17.67	17.43	17.14	16.80	16.42	16.00	15.55
7	17.68	18.20	18.57	18.82	18.96	19.00	18.96	18.85	18.67	18.43	18.14	17.80	17.42	17.00	16.55	16.06
8	19.20	19.57	19.82	19.96	20.00	19.96	19.85	19.67	19.43	19.14	18.80	18.42	18.00	17.55	17.06	16.54
9	20.57	20.82	20.96	21.00	20.96	20.85	20.67	20.43	20.14	19.80	19.42	19.00	18.55	18.06	17.54	17.00
10	21.82	21.96	22.00	21.96	21.85	21.67	21.43	21.14	20.80	20.42	20.00	19.55	19.06	18.54	18.00	17.43
11	22.96	23.00	22.96	22.85	22.67	22.43	22.14	21.80	21.42	21.00	20.55	20.06	19.54	19.00	18.43	17.84
12	24.00	23.96	23.85	23.67	23.43	23.14	22.80	22.42	22.00	21.55	21.06	20.54	20.00	19.43	18.84	18.23
13	24.96	24.85	24.67	24.43	24.14	23.80	23.42	23.00	22.55	22.06	21.54	21.00	20.43	19.84	19.23	18.60
14	25.85	25.67	25.43	25.14	24.80	24.42	24.00	23.55	23.06	22.54	22.00	21.43	20.84	20.23	19.60	18.95
15	26.67	26.43	26.14	25.80	25.42	25.00	24.55	24.06	23.54	23.00	22.43	21.84	21.23	20.60	19.95	19.29
16	27.43	27.14	26.80	26.42	26.00	25.55	25.06	24.54	24.00	23.43	22.84	22.23	21.60	20.95	20.29	19.60
17	28.14	27.80	27.42	27.00	26.55	26.06	25.54	25.00	24.43	23.84	23.23	22.60	21.95	21.29	20.60	19.91
18	28.80	28.42	28.00	27.55	27.06	26.54	26.00	25.43	24.84	24.23	23.60	22.95	22.29	21.60	20.91	20.20
19	29.42	29.00	28.55	28.06	27.54	27.00	26.43	25.84	25.23	24.60	23.95	23.29	22.60	21.91	21.20	20.48
20	30.00	29.55	29.06	28.54	28.00	27.43	26.84	26.23	25.60	24.95	24.29	23.60	22.91	22.20	21.48	20.74
21	30.55	30.06	29.54	29.00	28.43	27.84	27.23	26.60	25.95	25.29	24.60	23.91	23.20	22.48	21.74	21.00
22	31.06	30.54	30.00	29.43	28.84	28.23	27.60	26.95	26.29	25.60	24.91	24.20	23.48	22.74	22.00	21.24
23	31.54	31.00	30.43	29.84	29.23	28.60	27.95	27.29	26.60	25.91	25.20	24.48	23.74	23.00	22.24	21.48
24	32.00	31.43	30.84	30.23	29.60	28.95	28.29	27.60	26.91	26.20	25.48	24.74	24.00	23.24	22.48	21.71
25	32.43	31.84	31.23	30.60	29.95	29.29	28.60	27.91	27.20	26.48	25.74	25.00	24.24	23.48	22.71	21.92
26	32.84	32.23	31.60	30.95	30.29	29.60	28.91	28.20	27.48	26.74	26.00	25.24	24.48	23.71	22.92	22.13
27	33.23	32.60	31.95	31.29	30.60	29.91	29.20	28.48	27.74	27.00	26.24	25.48	24.71	23.92	23.13	22.33
28	33.60	32.95	32.29	31.60	30.91	30.20	29.48	28.74	28.00	27.24	26.48	25.71	24.92	24.13	23.33	22.53
29	33.95	33.29	32.60	31.91	31.20	30.48	29.74	29.00	28.24	27.48	26.71	25.92	25.13	24.33	23.53	22.71
30	34.29	33.60	32.91	32.20	31.48	30.74	30.00	29.24	28.48	27.71	26.92	26.13	25.33	24.53	23.71	22.89
31	34.60	33.91	33.20	32.48	31.74	31.00	30.24	29.48	28.71	27.92	27.13	26.33	25.53	24.71	23.89	23.07
32	34.91	34.20	33.48	32.74	32.00	31.24	30.48	29.71	28.92	28.13	27.33	26.53	25.71	24.89	24.07	23.24
33	35.20	34.48	33.74	33.00	32.24	31.48	30.71	29.92	29.13	28.33	27.53	26.71	25.89	25.07	24.24	23.40
34	35.48	34.74	34.00	33.24	32.48	31.71	30.92	30.13	29.33	28.53	27.71	26.89	26.07	25.24	24.40	23.56
35	35.74	35.00	34.24	33.48	32.71	31.92	31.13	30.33	29.53	28.71	27.89	27.07	26.24	25.40	24.56	23.71
36	36.00	35.24	34.48	33.71	32.92	32.13	31.33	30.53	29.71	28.89	28.07	27.24	26.40	25.56	24.71	23.86
37	36.24	35.48	34.71	33.92	33.13	32.33	31.53	30.71	29.89	29.07	28.24	27.40	26.56	25.71	24.86	24.00
38	36.48	35.71	34.92	34.13	33.33	32.53	31.71	30.89	30.07	29.24	28.40	27.56	26.71	25.86	25.00	24.14
39	36.71	35.92	35.13	34.33	33.53	32.71	31.89	31.07	30.24	29.40	28.56	27.71	26.86	26.00	25.14	24.27
40	36.92	36.13	35.33	34.53	33.71	32.89	32.07	31.24	30.40	29.56	28.71	27.86	27.00	26.14	25.27	24.40
41	37.13	36.33	35.53	34.71	33.89	33.07	32.24	31.40	30.56	29.71	28.86	28.00	27.14	26.27	25.40	24.53
42	37.33	36.53	35.71	34.89	34.07	33.24	32.40	31.56	30.71	29.86	29.00	28.14	27.27	26.40	25.53	24.65
43	37.53	36.71	35.89	35.07	34.24	33.40	32.56	31.71	30.86	30.00	29.14	28.27	27.40	26.53	25.65	24.77
44	37.71	36.89	36.07	35.24	34.40	33.56	32.71	31.86	31.00	30.14	29.27	28.40	27.53	26.65	25.77	24.89
45	37.89	37.07	36.24	35.40	34.56	33.71	32.86	32.00	31.14	30.27	29.40	28.53	27.65	26.77	25.89	25.00

Recent working papers

2001-01	John B Burbidge	'Awkward Moments in Teaching Public Finance' John F Graham Lecture at the Atlantic Canada Economics Association Annual Meetings
2000-06	Alok Johri Lohn Leach	Middlemen and the Allocation of Heterogeneous Goods
2000-05	John B Burbidge Gordon M Myers	Tariff Wars and Trade Deals with Costly Government
2000-04	Donald Dawson Lonnie Magee	The National Hockey League Entry Draft, 1969-1995: An Application of a Weighted Pool-Adjacent-Violators Algorithm
2000-03	Neil Buckley Kenneth S. Chan James Chowhan Stuart Mestelman Mohamed Shehata	Value Orientations, Income and Displacement Effects, and Voluntary Contributions
2000-02	R Cooper Alok Johri	Learning by Doing and Aggregate Fluctuations
2000-01	Yorgos Y. Papageorgiou David Pines	Externalities, Indivisibility, Nonreplicability and Agglomeration