

**“The Effect of Incomplete Information in a  
Threshold Public Goods Experiment”**

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OF INCOMPLETE INFORMATION  
IN A THRESHOLD  
PUBLIC GOODS EXPERIMENT**

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# The Effect of Incomplete Information in a Threshold Public Goods Experiment

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## **Abstract:**

Fiscal stress and decreasing government budgets have led to renewed interest in voluntary contributions for the funding of public goods. This paper examines a voluntary contribution mechanism for the funding of lumpy public goods; the Provision Point Mechanism. Previous research has shown that this mechanism can be effective at providing public goods (Isaac, Schmitz and Walker, 1989; Bagnoli and McKee, 1991; Suleiman and Rapoport, 1992; Rapoport and Suleiman, 1993). However, these studies were all conducted in an environment of complete information about individual preferences, which fails to capture the uncertainties of the real world. This study tests the efficacy of the PPM in informationally limited settings and finds that incomplete information does not add to coordination problems as compared to complete information. In fact, the PPM appears to be more successful in environments where subjects have no information than in environments where information is present, but limited.

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## 1. Introduction

Fiscal stress experienced by state and local governments in the United States has resulted in budget cuts and a re-allocation of expenditures away from local services and the provision of public goods. Recent fiscal stress has also generated an increased interest among public officials in alternative institutional arrangements for the delivery of public services. Within the current political climate, options circumventing the "T-word," taxes, are particularly attractive. Voluntary contribution institutions of the type found in the nonprofit sector offer this feature, and thus represent a viable option to supplementing current mechanisms for determining public service levels. Perhaps fueled by the public policy interest in non-tax, decentralized methods of public finance, the economics literature has rekindled its theoretical interest in voluntary contribution models for providing public goods.

Since many public goods are lumpy (parks, roads, bridges, railway lines, community libraries, etc.),<sup>1</sup> an "all or nothing" contribution process, such as a Provision Point Mechanism (PPM) may be appropriate. In the typical PPM, the size of a proposed project and the associated total cost are predetermined. Members of the community impacted by the project submit bids stating their dollar commitment to covering the project costs. If the sum of contributions do not cover the cost of the project, it is not undertaken and all contributions are refunded.<sup>2</sup> If the sum

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<sup>1</sup>An important class of lumpy public goods are environmental ones. Taylor and Ward (1980) suggest that "Ecological systems such as lakes, rivers, the atmosphere, fisheries and so on can normally be exploited up to some critical level while largely maintaining their integrity and retaining much of their use value. If exploitation rates go beyond that critical level, use values falls catastrophically." (p. 353).

<sup>2</sup>The idea of refunds is tested in Isaac, Schmitz and Walker (1989). The PPM is more effective in providing public goods when subjects are offered a money-back guarantee upon a group's failure to meet a contribution threshold. However, the PPM does not have to include this feature; for example Asch, Gigliotti and Polito (1993) use a threshold game without any such guarantee.



of the contributions covers the cost of the project, then the project is provided. Additional institutional rules can be designed to handle the rebate of excess funds.<sup>3</sup>

Niagara Mohawk's Green Choice program is a good example of a PPM being used to fund a lumpy project, in this case, an environmentally friendly power station. Participants in the program commit to paying a fixed fee which is attached to their electric bill. If enough participants are solicited, the power station will be built.<sup>4</sup>

Four studies have tested the efficacy of the PPM and found it to be somewhat reliable. In Bagnoli and McKee (1991), groups funded the public good 85.7% of the time, while in the money-back-guarantee experiments of Issac, Schmitz, and Walker (1989), groups reach or exceed the threshold between 43% and 57% of the time. In less continuous settings, Suleiman and Rapoport (1992) and Rapoport and Suleiman (1993) find the public good being provided between 12% and 85% of the time, depending on the provision point level.

However, these studies were all performed under extremely rich informational environments. In these experiments, subjects were informed of the induced valuations for the public good of all other group members. In a real world environment, valuations (and distributions of those valuations) are generally private rather than public information. The question can be raised as to whether or not the success of the PPM, as illustrated in the existing studies, would hold up in a world of incomplete information.

Bagnoli and Lipman (1989), which provides the theoretical basis for the Bagnoli and McKee (1991) experiments, notes this concern.

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<sup>3</sup>Provision point mechanisms have the potential to generate a surplus of funds. Marks and Croson (1996) investigate three alternative rebate rules for handling the disbursement of excess funds; no rebate, where excess funds are wasted, proportional rebate, where excess funds are allocated proportionally to individual contributions, and utilization rebate, where excess funds are used to increase the size of the public project.

<sup>4</sup>We thank William Schulze for bringing the Niagara Mohawk Green Choice Project to our attention. For more details on this program see Schulze (1995).

One caveat that must be mentioned is that we assume complete information throughout. This is, of course, a very strong assumption and may limit the applicability of our results. Intuitively, incomplete information may lead to underprovision as agents tradeoff their contribution against the probability that the public good is provided. (p. 585)

If their intuition proved to be correct, then prior results from PPM experiments would not illuminate the usefulness of this mechanism in a real-life implementation.

The study presented in this paper is designed to address this concern. A PPM is tested under three informational environments. Under *complete information*, subjects know the complete distribution of their group's valuations for the public good. This condition is similar to those used in previous studies. Under *incomplete information—known sum*, subjects know their own valuation for the public good and know the sum of their group's valuations. The distribution of the valuations, however, is not known. In this intermediate condition, subjects could get a feel for how their own valuation compared to the aggregate. With this information they could calculate their proportional share of the public good's value that they would receive, along with a proportionally fair contribution. In the third treatment, *incomplete information—unknown sum*, subjects know only their own valuation for the public good. No aggregate valuation or distribution information is provided.

While most experiments impose complete information, the third treatment best models a real-world environment. Community members who are asked to contribute toward a public good presumably know their own preferences, but neither the distribution nor the sum of the rest of the community's values. As Bagnoli and Lipman (1989) suggest, it is natural to conjecture that this severe lack of information would lower the frequency of successful provision.

However, results from this experiment suggest that incomplete information is not as problematic as intuition would lead us to believe. No significant differences in the frequency of provision, frequency of equilibrium play, or the absolute level of contributions was found between



any of the three treatments. If anything, the PPM worked even better when subjects had less information than when they had more. In the incomplete information--unknown sum treatment, contributions converged to the Nash equilibrium contribution level, while no convergence was observed in the incomplete information--known sum treatment.

These results are particularly heartening for economists and policymakers searching for voluntary contribution institutions which could partially substitute for taxation and other forms of public goods provision. They suggest that even with sparse information (like that in the real world) the PPM will provide a reliable voluntary mechanism for the funding of threshold public goods.

The paper is organized as follows. Section 2 describes the relevant literature in public goods research. Section 3 outlines the experimental design and procedures and section 4 presents the experimental results. Section 5 concludes.

## **2. Previous Literature**

This study uses a continuous contribution mechanism for a provision point game. Although previous studies have used this mechanism, almost all of them involved perfect information on the part of the players.<sup>5</sup>

Isaac, Schmitz and Walker (1989) use a provision point payoff function to examine the finitely repeated PPM with stable groups of four. Subjects are given complete information about their (homogenous) valuations for the public good. This study tests high, medium and low provision points with and without a money-back guarantee. Successful provisions of the public good range from 43% to 57%, depending on treatment.

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<sup>5</sup>For an excellent review of the experimental public goods literature see Ledyard (1995).

Bagnoli and McKee (1991) test the single streetlight model developed by Bagnoli and Lipman (1989) in an environment of complete information where groups play repeatedly together. A money-back guarantee is offered if the provision point is not met, but there is no rebate in the event of an excess. In the experiments of five-person groups the threshold was reached 85.7% of the time.

Suleiman and Rapoport (1992) use players with homogenous endowments and valuations for the public good and examine changes in the provision level. In this experiment subjects can contribute up to 5 tokens toward the public good. The public good is provided between 39% and 85% of the time, depending on the provision point level. Rapoport and Suleiman (1993) examine a similar environment where endowments (but not valuations) are heterogenous.<sup>6</sup> They find the public good being provided between 12% and 80% of the time, depending on the provision point level.<sup>7,8</sup>

These previous experimental studies of the PPM involved many successful provisions of the public good, particularly when the threshold was not "too high" relative to subjects' endowments. However, all utilized complete information designs in which subjects were informed of each other's value for the public good. This consideration is particularly pressing when we

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<sup>6</sup>Although endowments in this experiment were 3, 4, 5, 6 and 7 tokens, subjects could not contribute more than 5 of those tokens to the public good.

<sup>7</sup>In addition, Asch, Gigliotti and Polito (1993) run one treatment of a threshold public good with complete information, homogenous endowments and homogenous valuations. However, rates of successful provision are not reported.

<sup>8</sup>This literature is related to another which grew out of the (numerous) prisoner's dilemma experiments. Provision point public goods with binary contributions were first studied by Van de Kragt, Orbell and Dawes (1983). If at least some fraction of subjects in a group contributed their \$5 voucher to the public good, all members earned \$10. Follow-up studies involved the effects on this game of communication (Van de Kragt, Orbell and Dawes, 1983) and offering a money back guarantee or enforcing contributions (Dawes, Orbell, Simmons and Van de Kragt, 1986; Rapoport and Eshed-Levy, 1989). In addition, a number of theories were proposed to explain observed behavior, including both decision-theoretic models (Rapoport, 1985; Rapoport, 1987) and equilibrium models (Palfrey and Rosenthal, 1984; Palfrey and Rosenthal, 1988).



consider the equilibria of the PPM viewed as a game. These PPM have a continuum of efficient Nash equilibria in which the provision point is exactly met, as well as a continuum of inefficient Nash equilibria in which the provision point is not met (categorized below). These continua lead to a multi-person coordination problem, which information may be crucial to solving.<sup>9</sup>

The next section describes the experiment we designed to address this question.

### 3. The Experiment

#### *Procedures*

All sessions in this experiment involved inexperienced subjects recruited from undergraduate classes at Longwood College. The experiment was run by hand, although subjects were not permitted to communicate with each other in any way other than through their decisions in the experiment. At the end of the experiment subjects were paid their earnings from their decisions in private and in cash.

Subjects arrived at the experimental laboratory and were randomly assigned to groups of five. At the beginning of the experiment, subjects drew chips from a can to determine which valuation they would be assigned. This valuation was equivalent to the amount of cents they would receive if the public good was provided. The distribution of valuations used was the same in each treatment, (20, 30, 55, 65, 80), although the level of information individuals had about others' valuations varied. The groups and valuations remained constant for the entire 25 period experimental session.

In each period, subjects were endowed with 55 tokens. Subjects were publicly told that these endowments were homogenous. As in previous public goods experiments (Isaac, Walker

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<sup>9</sup>Other studies have examined heterogenous valuations and varying information about those valuations for *continuous* public goods. In these games, there is a unique or subgame perfect equilibrium for free riding, thus this problem of coordination is not as pressing. See Brookshire, Coursey and Redington (1990), Fisher, Isaac, Schatzberg and Walker (1995) and Palfrey and Prisbrey (forthcoming) for examples.

and Williams, 1989; Bagnoli and McKee, 1991) subjects were asked to allocate tokens between a Private Account and a Group Account, no mention was made in the experiment of "investments" or "contributions."

The Private Account is equivalent to private consumption and guarantees a value of 1¢ per token. The Group Account captures the threshold aspects of the public good. If the group allocated 125 tokens to the Group Account each member received their valuation. In all sessions of the experiment, a money-back guarantee was offered, thus if the provision point of 125 tokens was not met, contributions were returned to their contributors. Tokens allocated to the Group Account in excess of the threshold were not returned (this combination of refund and rebate rules is the same as those reported in Bagnoli and McKee, 1991).

### *Information*

The first treatment (*complete information*) involves heterogeneous agents operating in an environment of complete information. Subjects were told the entire distribution of valuations for the public good (20, 30, 55, 65, 80) as well as the sum of those valuations (\$2.50). This information was also placed on an overhead screen to create common information among subjects.

In the second treatment (*incomplete information—known sum*) subjects are told that valuations are heterogeneous, but that they will not be informed of the distribution. Subjects are, however, informed that the sum of the earnings from the group account is \$2.50. With this information, they can calculate their proportional fair share of the cost threshold. For example, the subject whose valuation is 30 cents receives  $30/250 = 12\%$  of the benefits from the public good, thus a proportionally fair contribution on his part would involve contributing 12% of the tokens necessary to provide the public good ( $.12 \times 125 = 15$  tokens).

In the final treatment (*incomplete information—unknown sum*) subjects are told that valuations are heterogeneous and that they will not be informed of the distribution of valuations.



Subjects were not, however, given any information about the sum of the valuations. Thus subjects are not able to use any relative measures of fairness to guide their decisions as they could in the second treatment. This treatment best captures the incomplete informational conditions of the real world.

### *Equilibria*

All three treatments reported in this experiment have the same set of Nash equilibria. There is a continuum of efficient equilibria in which the provision point is exactly met as well as a continuum of inefficient equilibria in which the public good is not provided. The efficient equilibria consist of all the vectors in which (1) exactly 125 tokens are allocated to the group account and (2) no subject allocates more than his valuation to the group account. If these two conditions hold, no subject has any incentive to change his allocation. No such equilibrium can exist in which more than 125 tokens are allocated to the group account, each player would prefer to keep the extra tokens and invest them in his private account.

However, there are also a continuum of inefficient Nash equilibria in which somewhere between 0 and 92 tokens are allocated to the group account, but no player can or desires to unilaterally supplement the account to achieve the provision point.<sup>10</sup>

## **4. Experimental Results**

Two important results emerge from this experiment; first that the success of the PPM is not diminished when information becomes incomplete. Lack of information in the incomplete information conditions has no effect on the rate of successful provisions of the public good. The second result is that less information may even be a good thing. Contributions in the incomplete

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<sup>10</sup>An allocation vector like (0,23,23,23,23) yields 92 tokens in the group account and is a Nash equilibrium. Player 1 has the necessary 33 tokens to supplement the group account, but his bonus is only 20 tokens, thus he has no incentive to do so. No other player has the necessary 33 tokens, although they each would supplement if they could. No equilibrium of this sort exists in which 93 - 124 tokens are contributed



information--unknown sum condition converge toward the Nash equilibrium, while contributions in the incomplete information--unknown sum condition do not converge. Thus it appears that a little information (like the sum of the other players' valuations) may prevent convergence.

*The PPM under Incomplete Information*

The proportion of successful provisions of the public good and of Nash equilibria observed in each of the three informational conditions are shown in Table 1.

**Table 1**  
**Successful Provisions and Nash Equilibria**

	Successful Provisions	Proportion	Equilibria	Proportion
<i>Complete Information</i>				
Group 1	11	0.44	0	0.00
Group 2	13	0.52	1	0.04
Group 3	17	0.68	2	0.08
Group 4	9	0.36	1	0.04
Group 5	10	0.40	1	0.04
<b>Overall</b>	<b>60</b>	<b>0.48</b>	<b>5</b>	<b>0.04</b>
<i>Incomplete Information--Sum Known</i>				
Group 1	8	0.32	1	0.04
Group 2	19	0.76	0	0.00
Group 3	16	0.64	3	0.12
Group 4	11	0.44	1	0.04
Group 5	16	0.64	1	0.04
<b>Overall</b>	<b>70</b>	<b>0.56</b>	<b>6</b>	<b>0.05</b>
<i>Incomplete Information--Sum Unknown</i>				
Group 1	19	0.76	0	0.00
Group 2	13	0.52	1	0.04
Group 3	14	0.56	4	0.16
Group 4	11	0.44	2	0.08
Group 5	11	0.44	0	0.00
<b>Overall</b>	<b>68</b>	<b>0.54</b>	<b>7</b>	<b>0.06</b>

Using a t-test of proportions on independent data points (N=5 in each treatment) we cannot reject the null hypothesis that the proportions of successful provisions of the public good or of equilibria are the same between the three treatments. A similar Mann-Whitney U test on absolute numbers of successful provisions or equilibria is similarly insignificant.<sup>11</sup>

Thus the effectiveness of the PPM as a mechanism to provide threshold public goods appears unaffected by informational incompleteness. This result suggests that even with sparse information like that available in the real world, a voluntary mechanism will enable the public good to be provided slightly more than half the time.

In addition to not affecting the proportion of successful provisions or of Nash equilibria, incomplete information has no significant effect on the amount of contributions generated. Figure 1 shows average group contributions under each of the three informational conditions.

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Insert Figure 1 around here

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Figure 1 shows contributions averaged over five groups in each treatment. Figures 2, 3 and 4 below show group contributions over time, which are significantly noisier.

As can be intuited from this figure, no significant differences between contributions in the three treatments can be found. To see this, we ran a two-factor random effects GLS regression. The independent variable in the regression was the total group contribution. Independent variables were dummies for the two incomplete information treatments. The regression was stratified by groups, as well as by period. Table 2 describes the results of the regression.

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<sup>11</sup>For a comparison of successful provisions the t-statistic and associated two-tailed p-value for comparisons are: Complete information vs Incomplete information-known sum,  $t=.2540$ ,  $p=.8052$ ; Complete Information vs Incomplete information-unknown sum,  $t=.2029$ ,  $p=.8438$ ; Incomplete information-known sum vs Incomplete information-unknown sum,  $t=.0509$ ,  $p=.9605$ . A Mann-Whitney U test on the proportions of successful provisions yields similar results:  $U=9.5$ ,  $p>.548$ ;  $U=7.5$ ,  $p>.310$ ;  $U=11.5$ ,  $p>.842$  respectively. For the same t-test on proportion of equilibria:  $t=.0617$ ,  $p=.9522$ ;  $t=.1184$ ,  $p=.9083$ ;  $t=.0570$ ,  $p=.9558$ . A Mann-Whitney U test on the proportions of equilibria yields similar results,  $U=12$ ,  $p=1.0$ ;  $U=12$ ,  $p=1.0$ ;  $U=12.5$ ,  $p>1$ .

**Table 2****Two-Factor Random Effects GLS Regression (Contributions)**

Contributions	Coeff	SE	t-stat	p-value
Constant (Complete)	123.500	1.361	90.772	0.000
Incomplete--Known	1.160	1.889	0.614	0.539
Incomplete--Unknown	0.768	1.889	0.407	0.684

Average contributions in either of the incomplete information conditions were not distinguishable from those in the complete information condition. Thus the addition of incomplete information to the PPM has none of the negative effects hypothesized by Bagnoli and Lipman (1989). The proportion of successful provisions of the public good, the proportion of Nash equilibria and the contribution levels are not significantly different between the three treatments.

*Comparing Convergence*

However, there is a sense in which a little information turned out to be a dangerous thing in this experiment. In both the incomplete information--unknown sum and the complete information conditions, group contributions converged toward the equilibrium of 125 over time. Thus when subjects either knew everything or knew nothing they moved toward an equilibrium. However, in the incomplete information--known sum treatment no convergence was observed. Thus when subjects had a little knowledge (they knew the sum of the valuations of the other subjects but not their distribution) no convergence was observed. Figures 2, 3 and 4 show contributions in each of the three treatments broken out by group.

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Insert Figures 2, 3 and 4 about here

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These figures suggest that group contributions converge toward the equilibrium of 125 in some treatments and not in others.



To test convergence statistically we ran three separate one-way random effects GLS regressions, one for each treatment. In each, the dependent variable was the absolute distance of a group's contribution from the equilibrium contribution of 125 tokens, and the independent variables were the period number and the period number squared. The regressions were stratified by group but not by period number. Convergence over time toward the equilibrium will show up as a significantly negative coefficient on period, while nonlinear convergence will show up as a significant coefficient on period squared. The results of these regressions are shown in Table 3.

**Table 3**  
**One-Way Random Effects GLS Regressions (Diff125)**

<i>Complete Information</i>				
Diff125	Coeff	SE	t-stat	p-value
Constant	15.120	2.732	5.534	0.000
Period	-1.025	0.364	-2.816	0.005
Period Squared	0.029	0.014	2.116	0.034
<i>Incomplete Information—Sum Known</i>				
Diff125	Coeff	SE	t-stat	p-value
Constant	10.518	2.403	4.377	0.000
Period	-0.210	0.304	-0.690	0.490
Period Squared	0.002	0.011	0.140	0.889
<i>Incomplete Information—Sum Unknown</i>				
Diff125	Coeff	SE	t-stat	p-value
Constant	13.660	2.799	4.881	0.000
Period	-0.942	0.346	-2.719	0.007
Period Squared	0.023	0.013	1.747	0.081

Although the graph of contributions under complete information looks noisy (see Figure 2), statistical analysis suggests that groups actually converge toward the Nash equilibrium outcome of contributions equaling the provision point. In the middle information condition

(incomplete information--known sum), no convergence is observed, either in Figure 3 or statistically. However, under incomplete information--unknown sum, groups clearly converge toward the equilibrium contribution level of 125, both in Figure 4 and statistically.

The results of this experiment provide relatively good news for the voluntary provision of public goods. The unexpected success of the PPM under incomplete information suggests that it may be a viable option in real world public good provision. And the strong convergence toward the Nash equilibrium in that treatment suggests that such successful behavior is stable.

## 5. Discussion and Conclusion

This study addresses a previously noted limitation to the literature on the Provision Point Mechanism; the assumption of complete information. The results indicate that, contrary to intuition, incomplete information of valuations for the public good does not add to coordination failure. The proportion of successful provisions of the public good, proportions of Nash equilibria reached and absolute level of contributions do not differ across the three informational treatments.

The most surprising result of the study is that in the context of a PPM a little knowledge can be a dangerous thing. When decision groups were only informed about their private valuations but could not compare this to an aggregate group valuation, contributions converged to the Nash equilibrium amount of 125. No similar convergence was found when groups were informed of their own valuations and had information about the aggregate group valuation.

The results of this study shed favorable light on the PPM. Agents in the nonprofit sector, politicians and firms involved in projects such as Niagara Mohawk should be encouraged by the conclusions. This research, combined with existing studies, offers evidence that in appropriate settings, the PPM is a reasonable mechanism to consider when trying to fund lumpy public goods. Further testing of the PPM under different environments will add to our body of knowledge and will aid policy makers in choosing the most appropriate implementation of the mechanism.



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Figure 1: Average Contributions

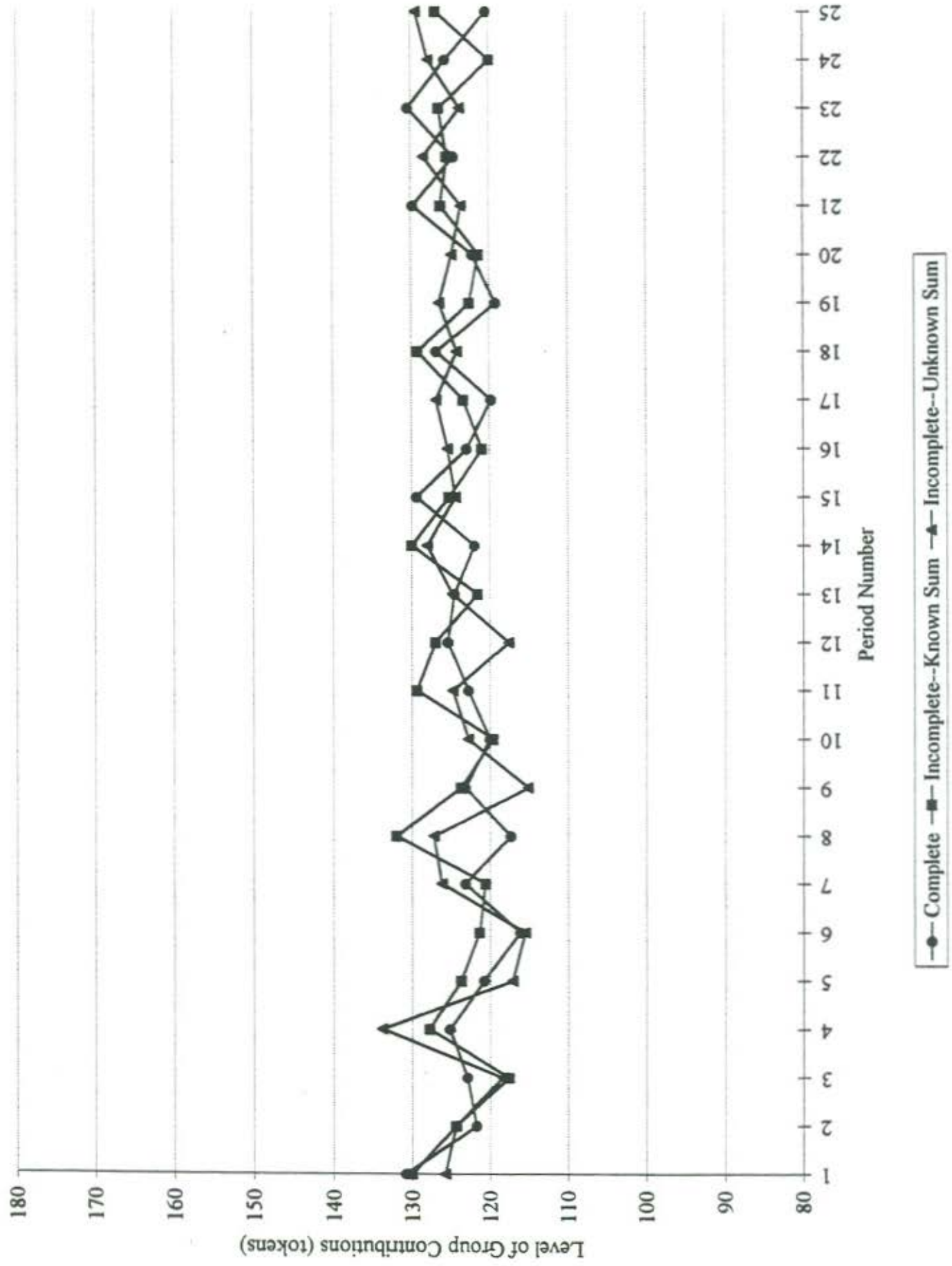


Figure 2: Group Contributions Complete Information

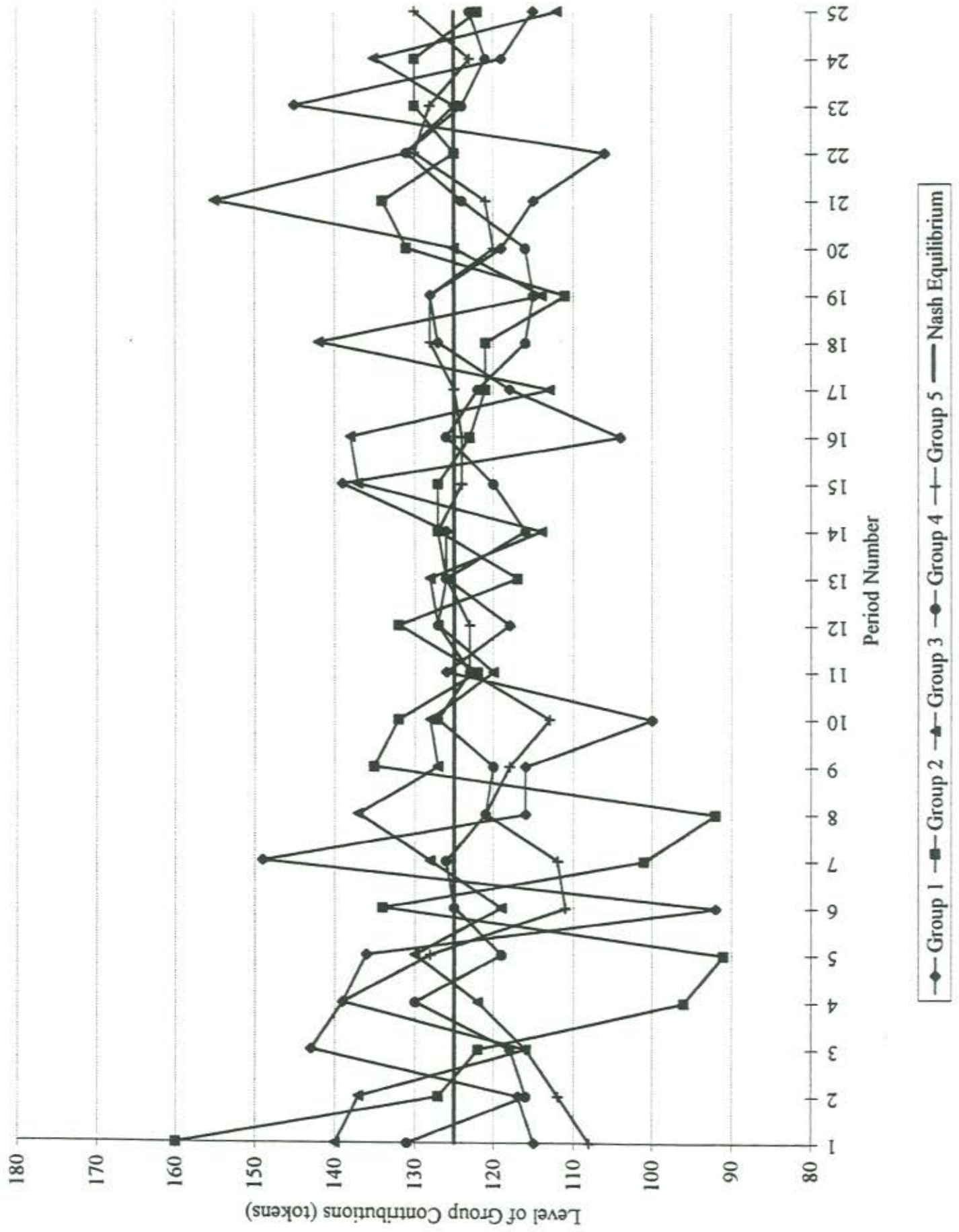




Figure 3: Group Contributions Incomplete Information--Known Sum

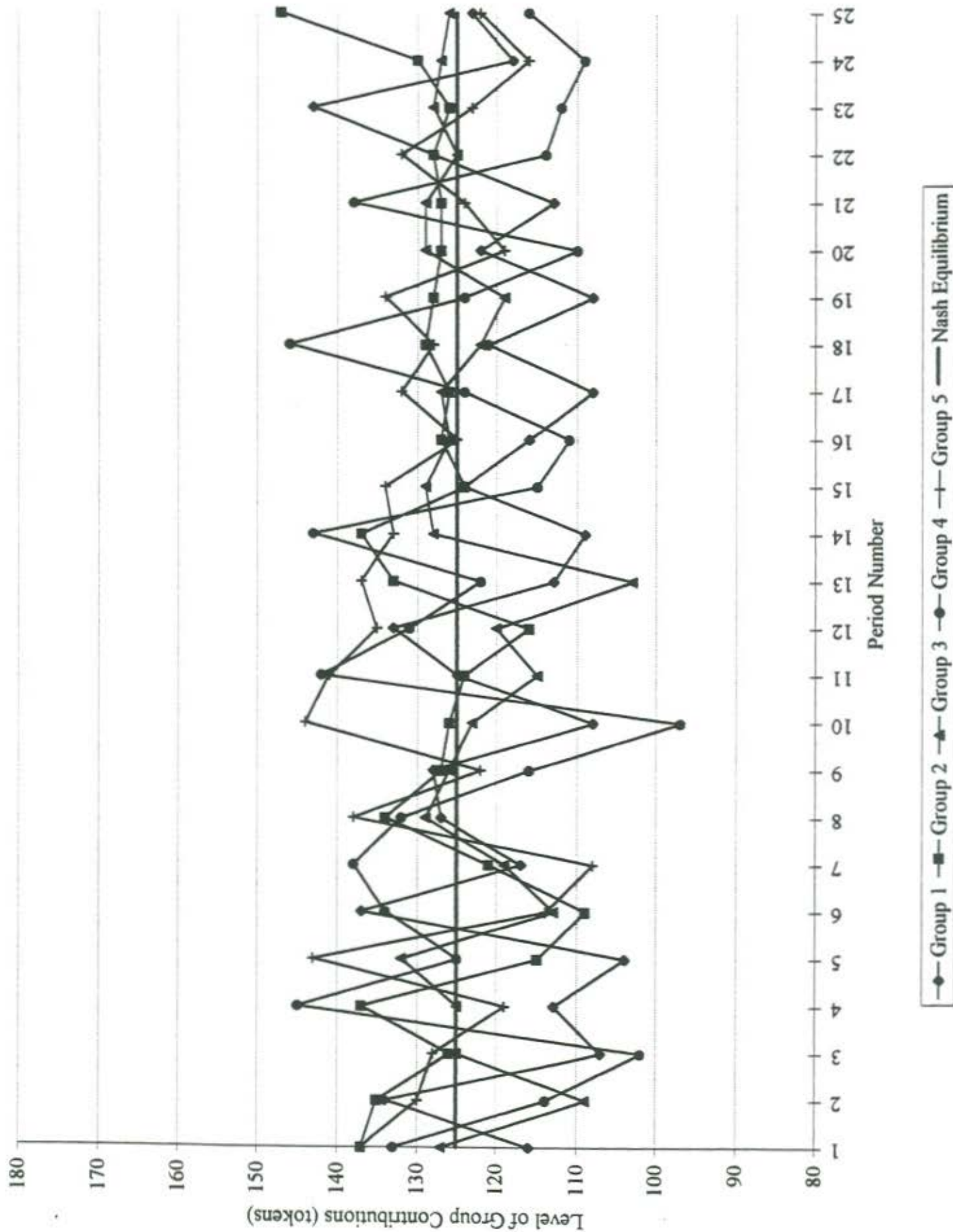


Figure 4: Group Contributions Incomplete Information--Unknown Sum

