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Worker Trust and System Vulnerability in the Transition from Socialism to Capitalism

by Andrew Schotter

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Comments Welcome

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Section 1: Introduction

It is an often heard statement, at least among economists, that Communism failed in Eastern Europe because it did not handle the incentive problem correctly. What this supposedly means is that a system that does not support and reward individual effort on the job is bound to create an atmosphere where free-riding and shirking abound. But exactly what was it that Communism got wrong and, by implication, what is it that we in the West get right about how to motivate work on the job? It is this question that we attempt to answer in this paper using the results of a set of experiments. It is our claim that economic systems like Communism or Capitalism are characterized by two properties which determine their success. One is a characteristic of the workers functioning in the system and the norms of work they have established among themselves. The other is a property of the incentive structure defined, either implicitly or explicitly, by the economic system itself. It is the match between theses norms and the characteristics of the incentive program imposed on the group that are the key ingredients in determining whether an incentive system works well and whether a group will make a smooth transition from one incentive system to another.

More precisely, most incentive systems define games for workers to play in which there is both strategic and stochastic uncertainty. For example, in Western style target based group incentive systems, like profit sharing, where the group's output must equal or exceed a target before the group is able to realize the full benefits of their work, workers face the prospect of working hard only to find out that, either because others have shirked or a negative stochastic shock to output has occurred, the target has not been met. Those who worked hard find themselves vulnerable to the laziness of others. This vulnerability, however, could be overcome by a group of workers if, depending on their history together and the work-norm they have developed, they trust each other and have some faith that each will try hard to achieve the target. Hence, trust and vulnerability must be matched with each other in order to have a group or economic system perform well. While a highly vulnerable Western style incentive system might fail miserably when imposed upon a group of Eastern European workers who have a history of shirking on the job under their old Communist style incentive system, one that is less vulnerable may do better.

It is this match between the trust that a group of workers have developed among themselves and the vulnerability of the economic system they are functioning under that we investigate in the experiments to be reported on here. What we find is that the match between vulnerability and trust is a key ingredient into what makes a group of workers work well together. Hence, if Eastern European countries can be characterized as low trust countries who are making the transition to highly vulnerable Western style incentive systems, then they must take care in choosing incentive schemes which properly match the degree of trust existing amongst the workers of their country. Choosing a Western style group incentive program with too high a level of risk (or vulnerability) may lead to disastrous results.

In this paper we will proceed as follows. In Section 2 we will present our definition of the "vulnerability" of an incentive system in terms of the vulnerability of the Nash equilibrium of the game it defines. In Section 3 we present our experimental design aimed at inducing different levels of trust and controlling for different levels of vulnerability amongst the subjects and games we have them play. In Section 4 we present the results of our experiment. This is first done descriptively and then more formally by presenting a set of formal hypotheses to be tested. Section 5 presents some conclusions.

Section 2: Vulnerability and Trust

2.1 Vulnerability

Vulnerability is a concept which attempts to capture what we consider to be the riskiness of a mechanism's equilibrium. It is our feeling that incentive mechanisms which hold out the prospect of workers being severely hurt financially when they put out high effort levels while others shirk, are unlikely to elicit such equilibrium effort levels from their workers. [1]

To more precisely define our concept of the vulnerability of an equilibrium consider two group incentive plans denoted plan A and plan B. It should be noted that each such plan defines a game for economic agents to play in which their strategies are their effort levels and their payoffs

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[1]There has been a great deal of experimental evidence presented recently by Van Huyck et. al (1991),(1990), and Cooper, DeJong, Forsythe, and Ross (1990) that the riskiness of an equilibrium and the out-of-equilibrium payoffs it determines when one's opponents tremble or make mistakes can have a dramatic effect on the likelihood that that equilibrium will be realized in any play of the game. Van Huyck et al. (1992) and Brandts and MacLeod (1991) even present evidence that an outside arbiter, with the power to suggest equilibria, may have a difficult time getting experimental subjects to coordinate on Pareto-dominant equilibria if those equilibria are too risky.

are defined by the group incentive formula, and depend on their own effort levels and the effort levels of their colleagues. (In the plan we investigate, the payoff to one agent depends on his effort level and the **sum** of the effort levels of his colleagues at work). For the sake of argument say that both group incentive schemes have two equilibria in the games they define, a unique and symmetric **low effort** equilibrium (which we will assume involves complete shirking and zero effort levels) and a unique and symmetric **high-effort** interior equilibrium. [By interior equilibrium we mean an equilibrium in which workers are choosing efforts in the interior of their feasible effort level sets and in which the probability of reaching the target is strictly less than 1. We will also define vulnerability for games where the equilibrium is asymmetric and dictates that targets are met with surety, but the intuition of our vulnerability concept is most easily described for the interior unique-symmetric equilibrium case and it is relatively easy to extend the intuition to the multiple equilibrium asymmetric case].

Since their payoffs are greatest at the high-effort equilibrium workers would like to see this equilibrium chosen. It is our contention, however, that the likelihood of such an equilibrium actually materializing depends on its vulnerability. To define vulnerability we ask the following question: If agent I, an individual agent in the organization, were to play according to the high effort equilibrium and put out a high level of effort (with an associated high level of disutility or cost) how fast would his payoff fall if others decreased their effort levels below that associated with the high effort equilibrium? If agent I's payoff would everywhere fall more steeply under plan A than under plan B, for identical reductions in others' efforts, we say that player I is more vulnerable at the equilibrium of plan A than plan B. More simply, people may be reluctant to choose the high effort equilibrium under plan A if they fear that even a small amount of shirking by their peers will have disastrous consequences for their payoff -- they are vulnerable at the equilibrium. The problems associated with such strategic vulnerability are generally compounded when there is a stochastic element affecting the group revenue function itself.

More formally, let us denote the payoff function to agent I in a group incentive program as $\pi_i(e_i, \Sigma e_{-i})$ where e_i is the effort level of agent i and Σe_{-i} is the sum of effort levels for all agents in the group other than i. Note that all group incentive plans discussed in this paper have symmetric and anonymous payoff functions of this type in the sense that a player's payoff is a function only of his effort level and **the sum** of the efforts of others in one's group. The identity of who puts out what effort is not important. Consider now incentive plans A and B and consider the payoffs $\pi_i^A(e^*_I, \Sigma e^*_{-I})$ and $\pi_i^B(e^*_I, \Sigma e^*_{-I})$ that each agent gets at the high-effort interior equilibrium of each plan, which we will assume exists, is unique, and symmetric across agents. Looking at $\pi_i^A(e^*_I, \Sigma e_{-I})$ and $\pi_i^B(e^*_I, \Sigma e_{-I})$ as a function of Σe_{-I} (holding e_i at its high-effort Nash equilibrium level e^*_I), we say that player I is more vulnerable at the high-effort Nash equilibrium of plan A than plan B if $\pi_i^A(e^*_I, \Sigma e_{-I})$ is everywhere below $\pi_i^B(e^*_I, \Sigma e_{-I})$ over the domain of the function from Σe^*_{-I} to 0.

The above definition of vulnerability is absolute in the sense that it does not judge the vulnerability of the equilibrium choice of a mechanism in comparison to other choices the agent could make. We might want to take these other choices into account, however since the decision to adhere to a high-effort equilibrium might depend on an agent's other options in the organization. For example, say that a mechanism has two equilibria, one being a "good" high-effort interior equilibrium and one being a "bad" shirking equilibrium or even, perhaps, a secure mini-max payoff (in the schemes we investigate here, secure payoffs are achieved by behavior consistent with the "bad" equilibrium -- by shirking completely). Let the low Nash or secure payoff be $\pi^i(\text{low})$ and the payoff at the good equilibrium be $\pi^i(\text{high})$. Returning to our functions $\pi_i^A(e^*_i, \Sigma e_{-i})$ and $\pi_i^B(e^*_I, \Sigma e_{-i})$ find, for each function, that Σe_{-i} which equates $\pi_i(e^*_{i,} \Sigma e_{-i})$ with $\pi_i(\text{low})$. $\Sigma e^*_{-i} - \Sigma e_{-i}$ would then measure the amount that others in a group could fall below their Pareto optimal equilibrium effort before player i would be better off at his or her secure or low-Nash payoff level. Defining D^{*A} and D^{*B} to be these deviations, we say that player I is more vulnerable at the high-effort Nash equilibrium of plan or mechanism A than mechanism B if $D^{*A} < D^{*B}$. In other words, under plan A player I is more vulnerable than under plan B if smaller deviations away from the Pareto optimal level by other agents would yield a payoff equal to the secure or low-Nash payoff of the mechanism. In short, we would expect that agents using plan B would be more likely to choose the good equilibrium since they are better off at it than they are at the low equilibrium for a larger set of deviations by their group members. Note, however, that this definition does not take the levels of these payoffs into account, so one might want to normalize these payoffs in some manner.

To illustrate these two vulnerability concepts, consider two hypothetical incentive schemes (A and B) which define two games each with a symmetric high-effort interior equilibrium each with identical payoffs. Such a situation might be depicted by Figure 2.1 which places, on the vertical axis the payoff to any agent I who adheres to the high-effort equilibrium (i.e., set his/her effort level at the effort level dictated by the symmetric high-effort equilibrium) and places the sum of the deviations of the other agents from the high effort equilibrium on the horizontal axis.

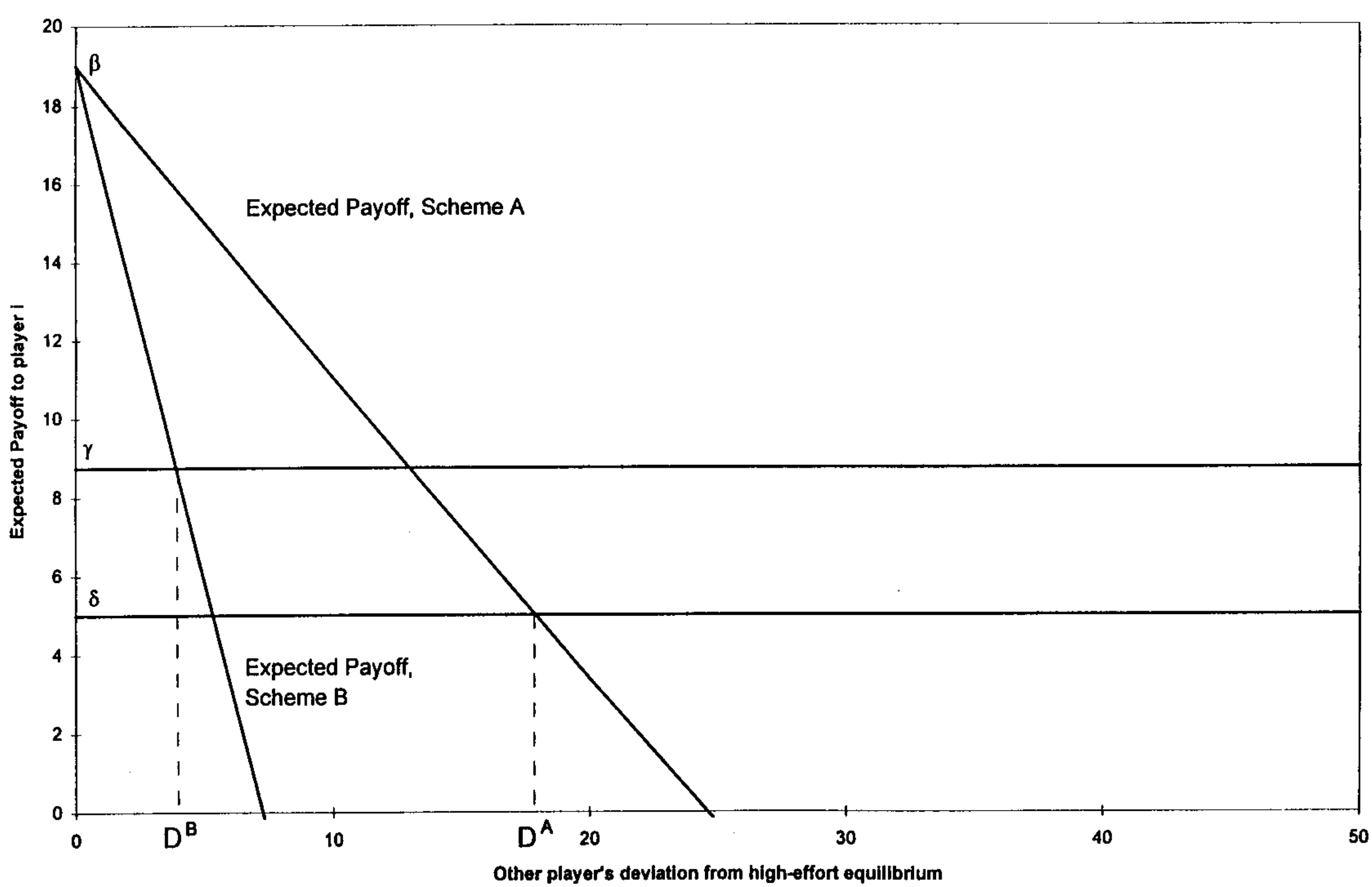
Figure 2.1 Here

Point β obviously represents the payoff to agent I at the high-effort Nash equilibrium of both schemes since at β all other agents are adhering to these equilibria as well (deviations are zero). The two straight lines emanating from β define the payoff to agent I under the two incentive schemes as the other agents deviate and choose effort levels below the equilibrium levels.

As we can see, according to our first vulnerability definition, the high-effort equilibrium for schemes A is more vulnerable than that of scheme B since the expected payoff function for scheme A is everywhere below that of scheme B. If we let γ and μ be the secure payoffs that agents can guarantee themselves in schemes A and B respectively, then we see that again the high effort equilibrium of scheme A is more vulnerable than that of scheme B since $D^{*A} > D^{*B}$ meaning that it would take a larger deviation of effort away from the high-effort equilibrium for agents in scheme B than scheme A in order to make agents regret they had selected the high-effort equilibrium.

While for purposes of exposition these concepts have been defined for symmetric interior equilibria in our experiments we have employed incentive schemes where the equilibria are potentially asymmetric corner equilibria. After specifying the exact schemes used, we will re-define our vulnerability concepts appropriately .

Figure 2.1: Vulnerability



To make this discussion more concrete, consider the following Profit Sharing incentive scheme for a group with six workers which we used in our experiment. Under this scheme each worker chooses an effort level which we will represent as a choice of a number in the closed interval $e_i \in [0,100]$. The output of the group, Y, is the sum of the efforts chosen by the members of the group plus a random shock drawn from a uniform distribution with support [-a, +a]. When the group output is produced we can assume it is sold for a price of $1.5 so that Group Revenue is R = $1.5Y. Given this set up, a Profit Sharing group incentive scheme defines a target R* and a penalty wage for each worker, B, such that if the revenue of the group is greater than R* the workers divide all of this revenue among them equally while if it is less than R* each worker gets B.

More formally, the payoff to workers under this kind of forcing contract scheme is defined as follows:

$$\pi_i = \begin{cases} 1.5\left(\sum_{1}^{6} e_i + \epsilon\right)/6 - e_i^2/100 & \text{if } 1.5\left(\sum e_i + \epsilon\right) \geq R^* \\ B & \text{otherwise} . \end{cases}$$

Such forcing contracts have many Nash equilibria, each characterized by a different Y*- B pair. To find these Nash equilibria, let $P(e_i, \sum_{j \neq i} e_{-i})$ denote the probability that a group meets its target of Y* given an effort level of e_i by agent i and $\sum_{j \neq i} e_{-i}$ by the other agents excluding I. Note that for a fixed e_i and $\sum_{j \neq i} e_{-i}$, the expected value of the firm's output, conditional on meeting the target is

$$E(Y|Y > Y^*) = \frac{(e_i + \sum_{j \neq i} e_j + Y^* + a)}{2} ,$$

where the constant a represents half of the support of the random variable ϵ.[2]

Consequently each worker faces a payoff function of

$$\pi_i(e_i, \sum_{j \neq i} e_j) = B + P(e_i, \sum_{j \neq i} e_j) \left[\frac{\frac{1.5}{6}(e_i + \sum_{j \neq i} e_j + Y^* + a)}{2} - B \right] - \frac{e_i^2}{100} .$$

For a Nash equilibrium the following first order condition must hold for each i:

$$\frac{\partial \pi_i}{\partial e_i} = P'(\cdot)B + P'(\cdot) \left[\frac{1.5}{6} \; \frac{(e_i + \sum_{j \neq i} e_j + a + Y^*)}{2} \right] \; P(\cdot)(0.125) - \frac{2e_i}{100} = 0 , \qquad i \quad 1,2,....6$$

However, given our parameters no Nash equilibrium can entail effort levels such that $(\sum_i e_i - Y^* + a)/(2a) \geq 1$ since beyond this point the probability of reaching the target is 1 and any agent could increase his payoff by reducing his effort thereby saving on effort cost with no reduction in the probability of reaching the target. Hence we must supplement the first order condition with the above constraint.

In one of the experiments we ran we set a = ±40, B = 5 while in the other we set a = ±10 and B = 8.75. As Appendix B demonstrates these profit sharing schemes have multiple

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[2]This expression is derived as follows: Assume that the sum of the effort levels for the agents is $\sum_i e_i$. (Assume that $\sum_i e_i$ is large enough such that for some subset of positive random realizations of ϵ the target can be met or surpassed). The expression tells us what the expected output of the group will be conditional on meeting the target. Since $\sum_i e_i$ is the sum of the efforts of agents we know that the maximum effort possible is $\sum_i e_i + a$, where a is the largest positive random shock. The lowest possible output observable that meets the target is Y*. Since the shocks are uniformly distributed, asking what the expected output of the group will be conditional on the target being surpassed is equivalent to asking what is the expected value of a uniform random variable defined over [Y*, $\sum_i e_i$ + a] which is what the expression defines .

asymmetric equilibria all of which entail meeting the target with probability 1. In the first, ±40, any effort levels summing to 280 in which all agents select effort levels from the interval [45.625, 46.875] define a high-effort equilibrium (with a symmetric equilibrium of 46.66), while in the second scheme any set of effort levels adding up to 250 in which all agents choose in the interval [12.5, 73.314] is an equilibrium with a symmetric equilibrium of 41.66. In both experiments there exists a zero-effort equilibrium as well.

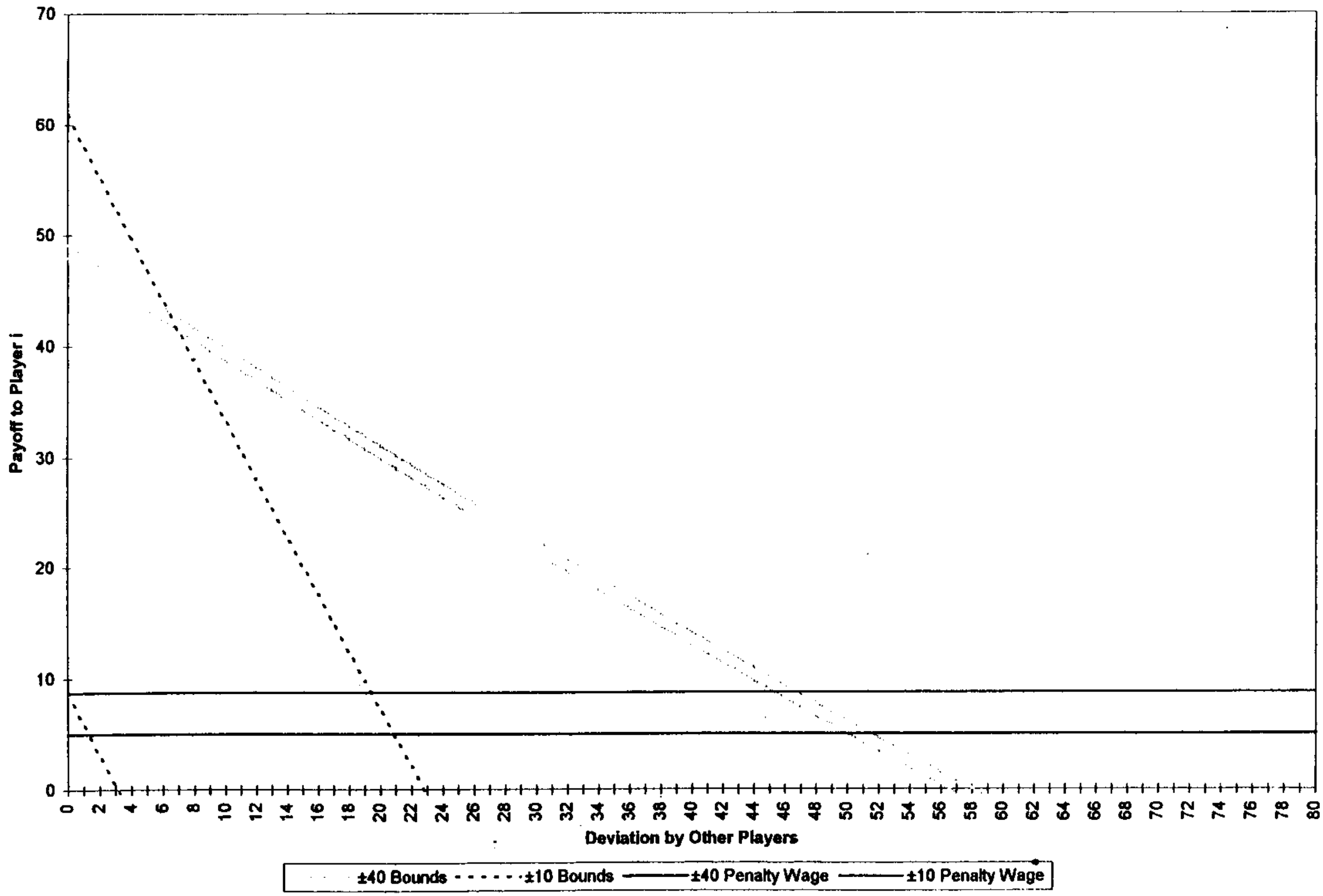
Note that these two schemes pose very different coordination problems for their agents to solve. In the ±10 high-vulnerability experiment there is a wide variety of behavior that is consistent with the high-effort equilibrium with effort levels varying from 12.5 to 73.314. The only problem remaining is one of coordinating who is going to choose a high and who a low effort level if the symmetric equilibrium is not selected. In the ±40 low vulnerability experiment the range of high-effort equilibrium behaviors is severely limited to [45.625, 46.875]. Such differences should make it easier to achieve a high-effort equilibrium in the ±40 case which is what we in fact see in our data.

To investigate the vulnerability of the equilibria of these Profit Sharing schemes consider Figure 2.2 which is the analogue of Figure 2.1 except for the fact that in these games we have multiple asymmetric equilibria.

Figure 2.2 Here

Figure 2.2 is the analogue of Figure 2.1 for the asymmetric multi-equilibrium case. For each specification of our profit sharing scheme we have two payoff functions depicting the payoff to a player in either scheme as the others in the group deviate from the high-effort

Figure 2.2: Asymmetric Equilibria Vulnerabilities



equilibrium. Since there are multiple equilibrium here involving asymmetric behavior on the part of agents, we no longer have a single function depicting the payoff for any agent given their choice of the high-effort equilibrium. Rather we have a continuum of such functions each conditional on a specific effort level chosen by the agent. For either scheme, the line furthest to the right is the payoff function for an agent in such a scheme when he/she is adhering to the equilibrium but at the lowest effort consistent with it (i.e. for an agent choosing $e_i = 12.5$ or 45.625 in the $a = \pm 10$ and $a = \pm 40$ cases respectively). The line closest to the origin for either scheme represents the same functions for an agent using the highest effort level consistent with that equilibrium (i.e. for an agent choosing $e_i = 73.314$ and 46.875 in the $a = \pm 10$ and $a = \pm 40$ cases respectively).

Note that in this particular case our first vulnerability definition is not applicable since the payoff functions of the two schemes cross so that neither is everywhere below the other. However, our second definition is applicable because as we can see, given a secure payoff of 5 for the ±40 case and 8.75 for the ±10 case, we see that a much larger deviation is required by the ±40 case to make any agent adhering to the high-effort equilibrium regret his/her decision and wish she or he had shirked and set $e_i = 0$. In fact for the ±40 case if an agent was choosing the highest effort level (46.875) consistent with a high-level equilibrium he could tolerate a deviation away from that equilibrium by his cohorts of 50.08 before he had wished he had chosen differently while for the ±10 case a no deviation (i.e. the deviation is zero) would cause similar regret for such a high effort agent (i.e. one who at the high-effort equilibrium was choosing 73.314). For agents choosing the lowest possible efforts consistent with high-effort equilibria in these two schemes the comparable deviations are 51.56 and 19.39 in the ±40 and ±10 cases respectively.

2.2: Trust

While vulnerability can be defined deductively in terms of the properties of the payoff functions existing in a game, by trust we mean a belief derived inductively (empirically) that people have about each other's behavior.[3] In our Profit Sharing game high levels of trust correspond to placing significant amounts of probability mass on the event that your cohorts choose effort levels consistent with those dictated by the high-effort symmetric Nash equilibrium of the Profit Sharing game or more. So when workers "trust each other" they trust that if they play their part in the high-effort Nash equilibrium, others will as well. (Note that this obviously leaves a huge coordination problem for the agents since despite their desire to cooperate, especially in the high vulnerability case, there are a broad range of effort levels consistent with this goal depending on ones beliefs about one's cohorts.) Trust is a common shared belief. The experimental design described in the next section attempts to operationalize these two concepts and demonstrate their impact of the effort choices of subjects.

Section 3: The Experimental Design

In the experiments performed, undergraduate subjects were recruited from economics

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[3]The concept of trust has alternatively been called social capital by Coleman (1988) and more recently discussed by Putnam (1993, 1995) and Fukyama (1995). For all intents and purposes we can interchange these notions although it might make more sense to think of our experiments as inducing differential levels of social capital rather than trust since the idea of social capital is a more inclusive or broad term than trust and hence may capture feelings shared amongst people that are not strictly feelings of trust.

courses in groups of 12 and asked to report to a computer lab where the experiment was to take place. When they arrived, subjects were divided randomly into groups of six and these were the groups they were to remain with for the entire experiment. Each experiment performed had two parts. Part I was a trust-inducing experiment aimed solely at influencing the beliefs that subjects would have about each other as they entered Part II of the experiment. It presented the subjects with a coordination game, to be described below, which they played 10 times in succession.[4] After Part I was over, the instructions for Part II were handed out, read out loud, and questions about them answered. In Part II, subjects engaged in a profit sharing (forcing contracts) experiment of the type described above in which either the support of the random shock term was [-10, +10] or [-40,+40]. The final payoff of subjects was the sum of their payoffs in both Parts I and II of the experiment along with a $5.00 payment they received just for showing up. Average payoffs were $13.75 for about one hour and fifteen minutes and motivation was extremely high as measured by post-experiment interviews.

To give a better description of the decision tasks performed in Part I and Part II of our experiment, let us break up our discussion into two parts.

3.1: Part I -- The Minimum and Median Games

As stated before, Part I of our experiment was run simply to influence the experience of subjects upon their entrance into Part II. For that reason we chose to have them play either the Minimum Game (See VanHuyck et al. (1990)) or a particular version of the Median game (VanHuyck et al. (1991)) before engaging in Part II. We chose these games because they were

[4]The Instructions for the minimum game in Part I are attached as Appendix A.

coordination games with Pareto-Ranked equilibria which had proven to be reliable producers of Pareto-worst (in the case of the Minimum Game) and Pareto-best (in the case of our particular Median game) outcomes. Hence, we rely on experience in the Minimum Game to produce "low trust" norms in which people share a common history in which it is common knowledge that they all failed to cooperate with each other and provided themselves with the worst outcome available to themselves. The Median Game (at least the version we employed) was used in order to induce a "high trust" norm since it has proven to be a reliable producer of Pareto-best outcomes (see VanHuyck (1991)).

In the minimum game, six subjects are asked to choose an integer, c_i, between 1 and 7 and write this number on a piece of paper. The pieces of paper are then collected and the minimum of these numbers $\{c_1, c_2, c_3, c_4, c_5, c_6\}$ revealed. The payoff for any subject in this minimum game is $\pi_i = a \cdot \min\{c_1, c_2, c_3, c_4, c_5, c_6\} - be_i + c$. With a = .2, b = .10, and c = 60 our subjects in Part I faced the following game matrix:

Table 3.1: The Minimum Game

Your Choice				**Minimum Chosen**			
7	1.30	1.10	0.90	0.70	0.50	0.30	0.10
6		1.20	1.00	0.80	0.60	0.40	0.20
5			1.10	0.90	0.70	0.50	0.30
4				1.00	0.80	0.60	0.40
3					0.90	0.70	0.50
2						0.80	0.60

1							0.70

As can be seen here, any set of choices where subjects choose the same number is a Nash equilibrium yet the equilibria are Pareto ranked with the choice of all 7's being best and that with all 1's being worst. VanHuyck et al. found that when this game was played among a set of 14 to 16 subjects repeatedly for 10 rounds, the equilibrium consistently converged to the worst (all 1's) equilibrium. [5] Hence, it was our hope that with six subjects we could replicate this result and hence use this Part I experiment as a control for a low trust norm among our subjects. [6]

The Median Game has the exact same structure as the minimum game except for the payoff function which is:

$$\pi_i = a\cdot \text{(Median)} - be_i + c \qquad \text{if } e_i = \text{Median}$$

$$\pi_i = 0 \qquad \text{if } e_i \neq \text{Median.}$$

Here again any configuration of choices in which all subjects choose the same number is an equilibrium yet the Pareto-best equilibrium is the one where every subjects chooses 7. The payoff matrix facing subjects in this game is presented in Table 3.2.

Table 3.2: The Median Game
Median

[5]See Vince Crawford (1990) for an evolutionary explanation for why the worst equilibrium emerges. Basically, amongst the set of equilibria only the all-1's equilibrium is Evolutionarily Stable.

[6]It can be argued whether this was a treatment for trust or simply a treatment in which the subjects did badly and that their mutual trust was not affected at all.

Your Choice	7	6	5	4	3	2	1
7	1.30						
6		1.20					
5			1.10				
4				1.00			
3					0.90		
2						0.80	
1							0.70

Note that a compelling incentive exists to choose the all-seven equilibrium here since the out-of-equilibrium payoffs for all equilibria are zero so choosing the best equilibrium presents no additional risk yet provides the best payoff. Since this game had proven to be a reliable producer of Pareto-best outcomes (see VanHuyck, J., Battalio, R, and Beil, R. (1991)) we used it in Part I to provide what we felt would be a high trust control for Part II. Note also that the equilibrium payoffs for the Median Game are the same as those for the Minimum game although the out-of-equilibrium payoffs differ. This was done to insure that the act of coordinating choices on any number would be equally profitable across these two games.

Part I of the experiment was not done using a computer network and was done by hand. Subjects recorded their own choices on a worksheet and calculated their own payoffs which were checked by the experimental administrator after the experiment was over.

3.2: Part II – Profit Sharing

After Part I of the experiment was over, a new set of instructions was handed out and read to the same set of subjects. While subjects knew that there would be another part to the experiment they did not know what it would involve until these instructions were given to them. The experiments engaged in Part II were direct implementations of the Profit Sharing schemes (with random shocks [-10 +10] or [-40, +40]) described in Section 2.[7] Subjects were seated at computer terminals and when the experiment began they were asked to type a number between 0 and 100 into their computer terminals. Such a number can be interpreted as their unobservable effort levels, although in the instructions only neutral language was used. After these numbers were entered by each subject, the program guiding the experiment added up all of these numbers and drew a random number uniformly distributed between either ±10 or ±40 depending on the experiment. The random numbers for the group was added to the sum of their effort levels. In the instructions subjects were told that the higher the decision number they chose the higher their costs would be and they were given a cost table illustrating the cost of each integer between 0 and 100. (This table was an integer representation of the cost function $e_i^2/100$).

The payoffs for each experiment were then determined according to the rules of the Profit Sharing scheme which specified if the target was met the group revenue would be split among them and their cost of effort subtracted to determine their payoff. On the other hand, if the target was not met, each subject would receive their penalty wage of either 8.75 (in the [-10, +10] experiment) or 5 (in the [-40, +40] experiment). After each round subjects could see only their own effort levels and the output levels of their own group for the past 15 periods. No information about the individual effort levels of other subjects was ever revealed.

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[7]See Nalbantian and Schotter (1994) for testes of other group incentive mechanisms.

When round 1 of the experiment was over, round 2 started and was identical to round 1. Each experiment lasted for 25 rounds which we felt was a sufficient length of time to foster learning if any was to occur. The payoffs at the end of the experiment were simply the sum of the payoffs of the subjects over the two Parts plus a $5.00 show-up fee. Payoffs in each round were made in terms of points which were converted into dollars at a rate which was known in advance by all subjects.

A total of 24 groups of 6 subjects each were recruited to do this experiment under three different sets of parameters. The experimental design is spelled out in Table 3.3.

Table 3.3: Experimental Design

Experiment	Part I	Part II	Number of Groups of Six	Number of Subjects
1	Minimum Game: (Low Trust)	Profit Sharing: [-10,+10]- High Vulnerability	9	54

2	Median Game: (High Trust)	Profit Sharing: [-10, +10]	10	60
3	Minimum Game: (Low Trust)	Profit Sharing: [-40,+40]- Low Vulnerability	5	30
Total			**24**	**144**

As the experimental design indicates, we are looking at the interaction between trust and vulnerability. Subjects play a trust-inducing game in Part I followed up by group incentive games whose equilibria exhibit varying levels of vulnerability. While we have provided a definition of vulnerability for the game played in Part II we have not attempted a definition of trust for our Part I-game. However, if our a priori expectations are borne out about behavior in the Median and Minimum games we would expect that subjects in the Median game would converge on Medians in the range 5-7 while those in the Minimum game would converge on choices of 2 or below. Hence, we can expect that groups coming out of the Median and Minimum games will have very different experiences with each other. While one would have been successful in capturing practically all of the cooperative gains available to them, the other would have left quite a bit of money on the table, Our point is, that after this conditioning the level of group solidarity across these two groups would be very different. While it would be common knowledge in one group that they have successfully coordinated their choices, in the other it would be common knowledge that they failed to do so. Whether one calls the resulting state of mind "trust" will be left to interpretation. However, from extensive oral exit interviews we got a clear sense that these different experiences did have the impact on their expectations that we have predicted.

Section 4: Results

4.1: Descriptive Results

In this section we will proceed by first describing the results of the three experiments performed and then testing a set of six hypotheses which follow naturally from our experimental design.

4.1.1: Part-I Result

The results of the experiments are presented in Table 4.1 and Figures 4.1-4.4. We will first look at the results of the Part I Minimum and Median Games. As we can see from Table 4.1 and Figures 4.1a and 4.1b, subject behavior was dramatically different in the Median and Minimum games which preceded our high-vulnerability Part-II experiment. While in six of the 10 Minimum games performed the group converged to a minimum of 1 by the 10^{th} round, [8] in the remaining four games the last round minimum was 3, 3, 4, and 3. Since in these four games the Minimum Game failed to achieve their purpose of inducing a low-cooperation outcome, in the analysis of the data for Part II we will exclude these groups and analyze only those Part II experiments which followed Minimum-1 games.

In the 9 Median games the last round Median was 7 in two experiments, 6 in three experiments and 5 in four experiments. Despite its failure to reach 7 in all experiments, we will

[8] In three of the six games there was a unanimous choice. In the remaining three it was unanimous except for one choice in two of the games and two choices in one game.

Figure 4.1b: Choices by Round, Minimum Game

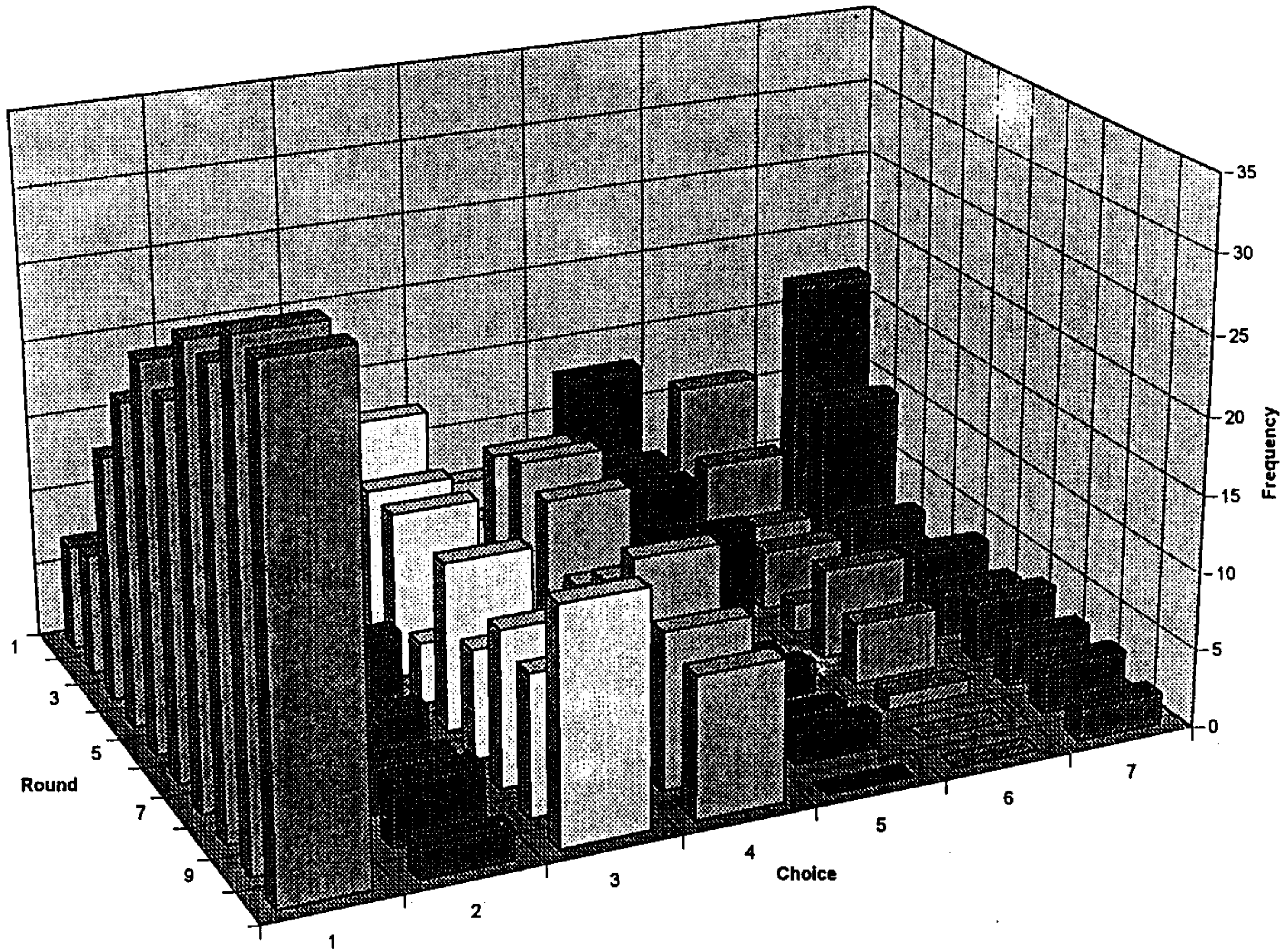
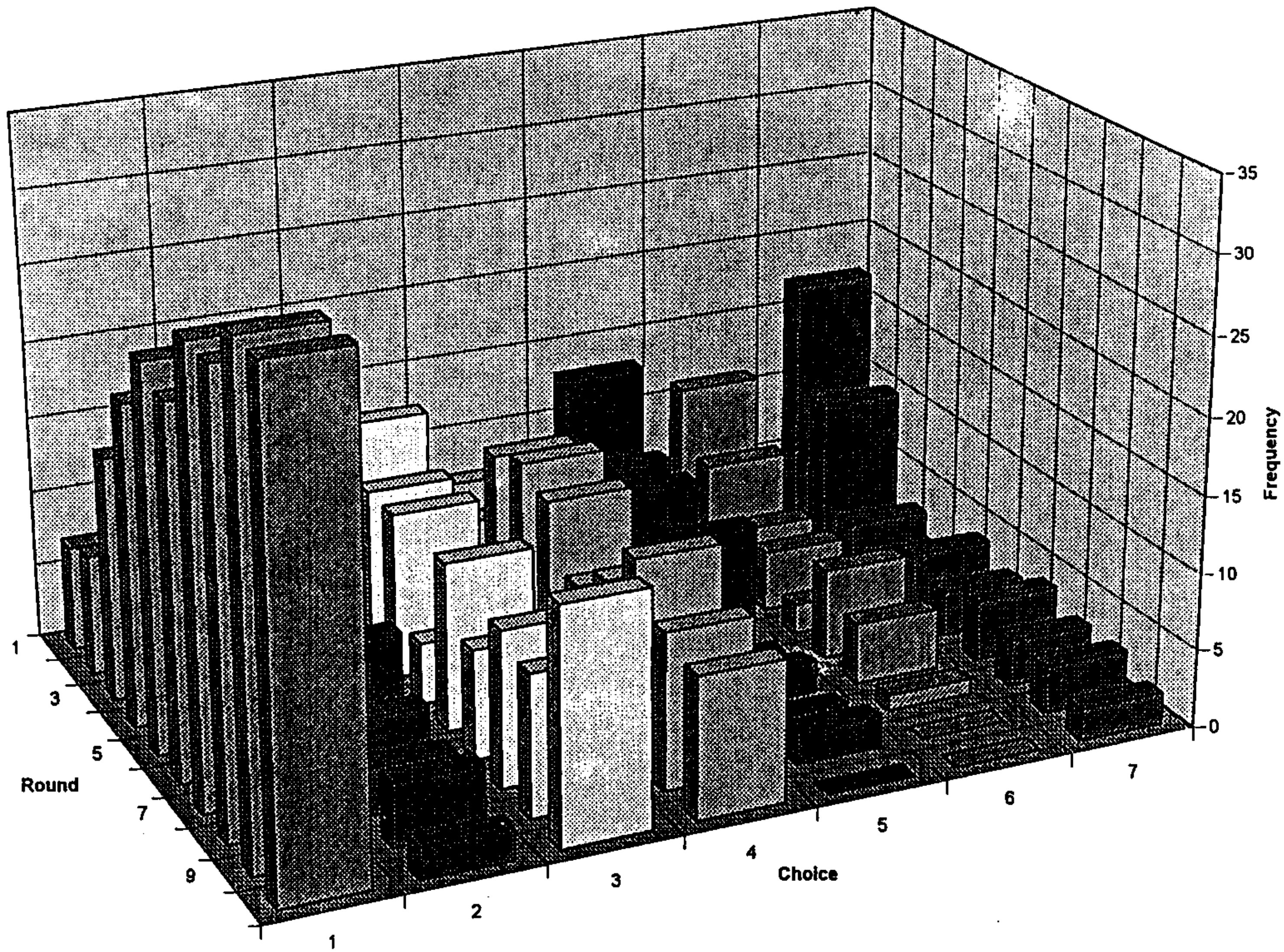


Figure 4.1b: Choices by Round, Minimum Game



use all of these observations in the Part II experiments which followed these games since Median choices of 5 or above are sufficiently far from the behavior of subjects in the Minimum game to offer a good comparison.

Figure 4.1a and 4.1b shows a three-dimensional picture of the choices of subjects over the nine Part-I Median and six Part-I Minimum games that proceeded the high-vulnerability Part-II experiments. As we can see there is quite a difference in the distribution of choices over time between these two experiments. While the majority of the mass of the frequency distribution is skewed above decision number 4 for the Median Game, at least from round 5 on, for the Minimum Game the mass is skewed below four over those same rounds. While this bifurcation in the results of these experiments is certainly as we predicted, the fact that subjects fail to unanimously coordinate their actions in a mutually best-response manner (even in round 10) indicates that we were not observing consistent Nash behavior.

To illustrate the difference between these games in a different manner, let us look at the fraction of the possible potentially available gains from trade that groups in these Part I games have captured. This is calculated by taking the maximum monetary payment available for the group $78.00 = (6 x $1.30) x 10 and dividing it into the actual amount of money the group has achieved for itself.

Hence define

Λ = (Actual Monetary Payment Received)/(Potentially Available Monetary Payment).

This is demonstrated in Figure 4.2 where the top line represents the mean fraction of the gains from cooperation attained by the group of subjects playing the Median Game over the 10 rounds of their experience while the bottom two lines represent the same statistic for the groups playing the Minimum game. As we can see, over the course of their interaction and especially in the last 10 rounds, a considerable difference exists between the payoff experiences of these two groups. For instance, in round 10 the fraction of the gains from cooperation captured in the Median Game was .77 while in the Minimum Game it was .508. This difference exists despite the fact that when a subject's decision number does not match the median in the Median Game his/her payoff is 0 while such out-of-equilibrium payoffs always provide positive payoffs for subjects in the Minimum Game. Hence, life outside of equilibrium is more profitable in the Minimum Game than in the Median Game and that fact allows subjects in that game to more easily capture some of the potentially available gains from cooperation.

Figure 4.2 Here

4.1.2: Part II Results[9]

The results of Part II are presented in Tables 4.1a- 4.1g and Figures 4.3 and 4.4.

Table 4.1a-4.1g Here

Figure 4.3 and 4.4 Here

In 4.3 we see the mean Revenue of groups participating in the Part II high vulnerability Profit Sharing game conditional on playing a previous Minimum or Median Game. These Figures

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[9]The results reported here are carried out mostly at the individual level. Perhaps a better analysis could be done at the group level since the variance across groups is significant. However, for proper statistical significance, since it takes six subjects to furnish one data point, an extremely large number of subjects would be needed to provide the proper power to statistical tests. While we have recruited 144 subjects and test pooled individual behavior across treatments, a number of our results could still be artifacts of a few groups within the data set. In the future we might try to extend this study by recruiting sufficiently large samples of subjects.

Figure 4.2: Fraction of Potential Gains Captured

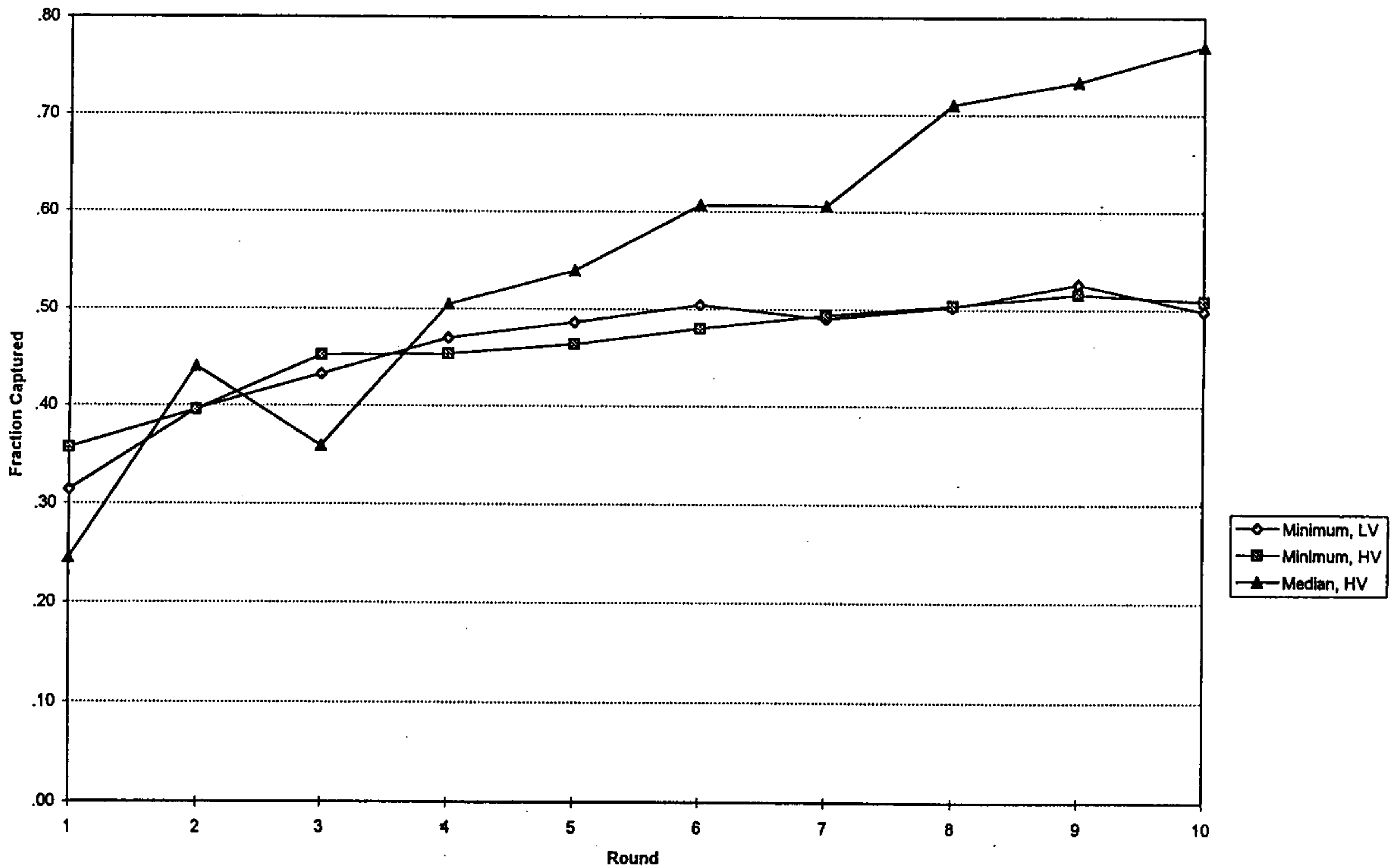


Figure 4.3: Mean Group Revenue

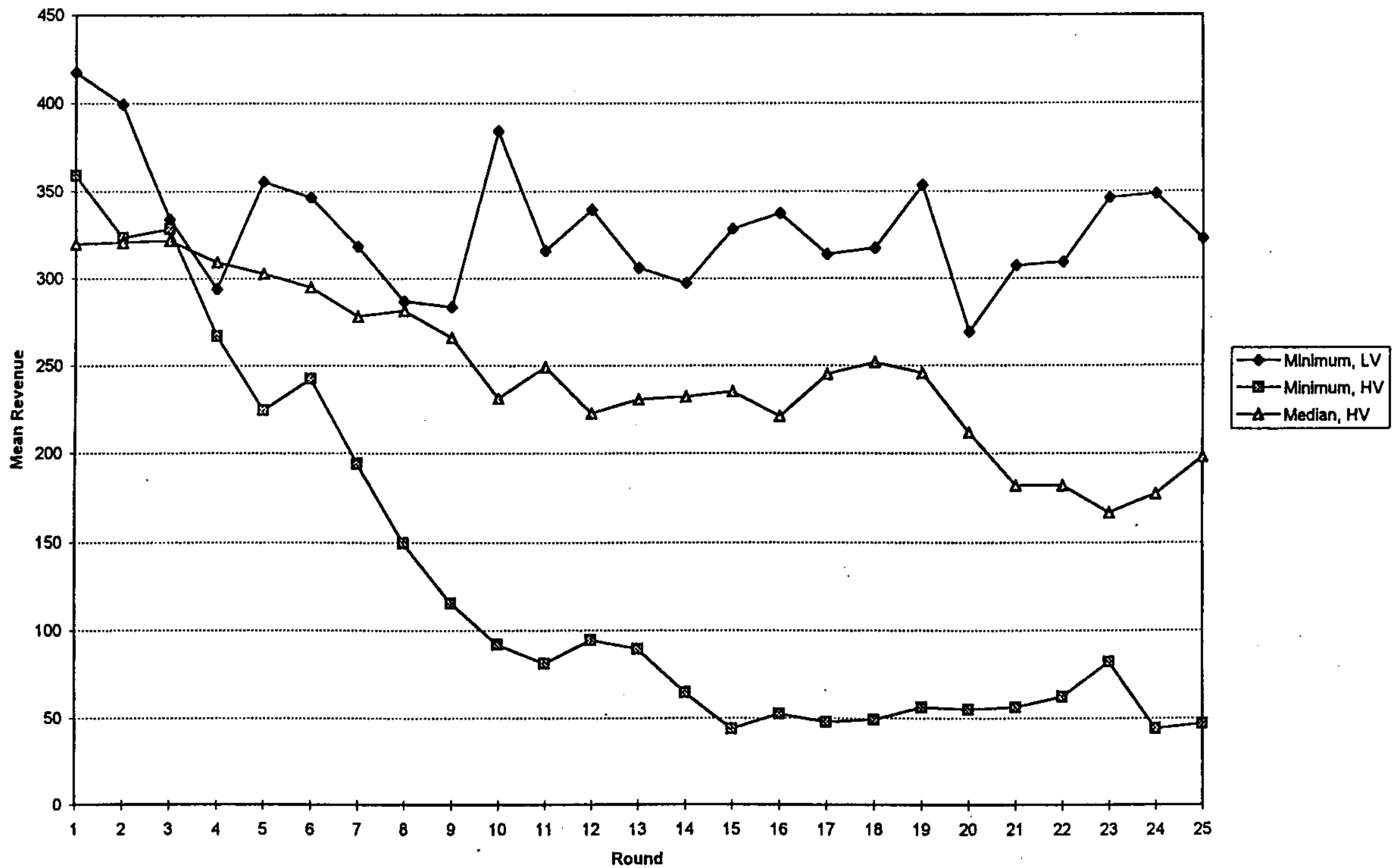
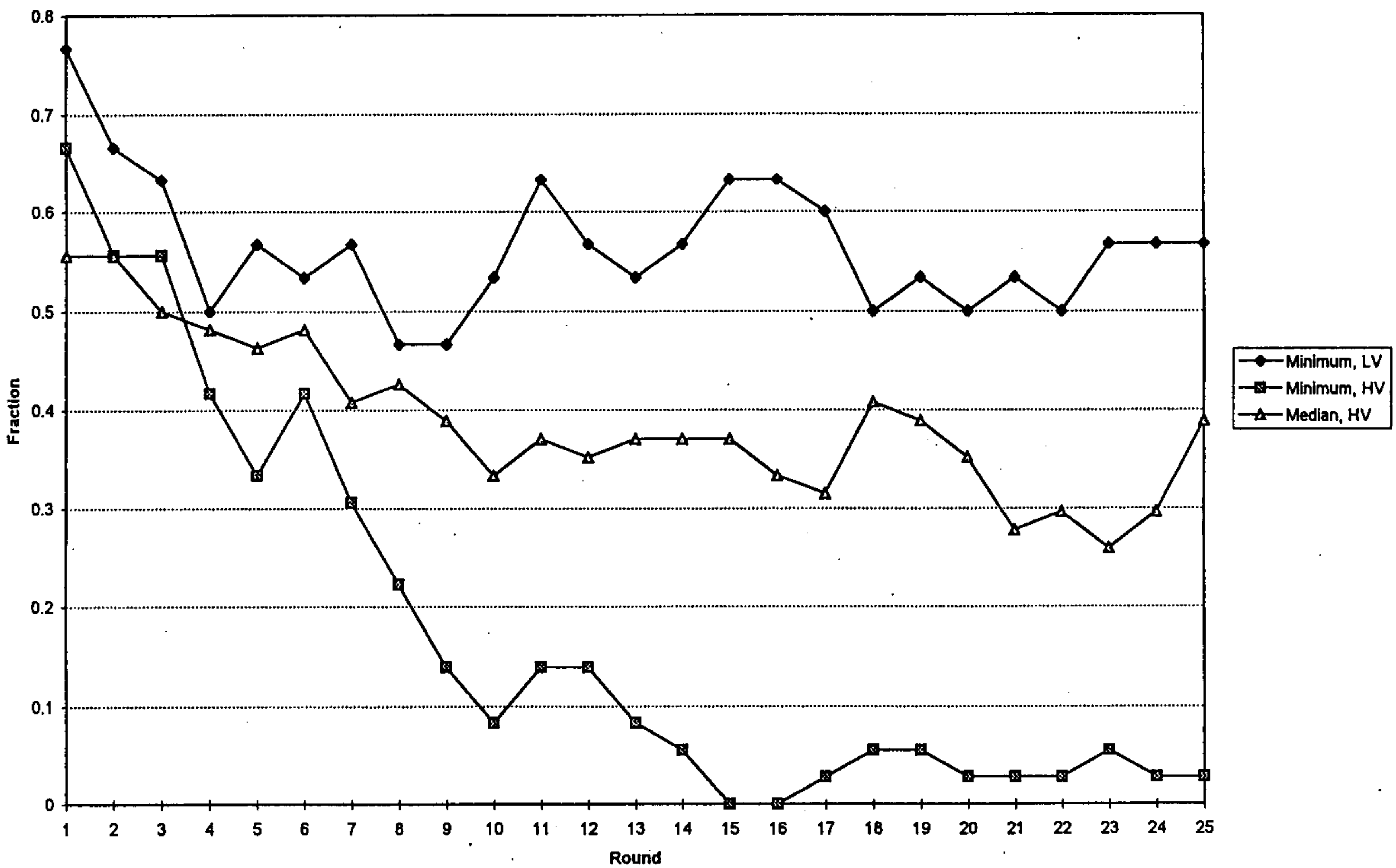


Figure 4.4: Fraction Choosing 40 or Above



graph the round-by-round mean revenue data pooled over all 9 Median group experiments and those 6 Part I Minimum experiments whose last period minimum had converged to 1 as well as those groups who played the Minimum Game in Part I and then the Low Vulnerability Profit Sharing game in Part II. Figure 4.4 presents the fraction of subjects choosing 40 or more in any round of these low and high vulnerability experiments. Figure 4.4 is offered to demonstrate how the Phase I game affects the attempt of subjects in the Phase II high-vulnerability experiment to coordinate on a high-vulnerability equilibrium.

The impact of trust on this attempted coordination is unclear. Subjects who trust others but are still self-regarding may expect others to choose high effort levels in the equilibrium range [12.5, 73.314] and hence best-respond by choosing low (yet still equilibrium) effort levels. However, trust may be regarded not only as a probability belief about the actions of others but actually part of an other-regarding norm[10]. In this case, such an other-regarding norm could carry over to behavior in the Phase-II experiments. In this case we might expect high effort levels from everyone. Hence, we split the equilibrium effort level range in this experiment into high-effort choices, $e_i \geq 40$ and low-effort choices $e_i \leq 40$ (roughly the mid-point of the range) and checked to see if our highly-trust treatment led to relatively high choices in the high-vulnerability experiments.

Comparing the behavior of subjects in the high-vulnerability game there seems to be little difference in their behavior in the first round of the Profit Sharing experiments conditional on

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[10]For an elaboration of this point see the thoughful comments of Jonathan Baron in this volume.

their experience in Part I. In fact, the number of subjects choosing 40 or more in round 1 was greater among the subjects who played the Minimum game than it was among those who played the Median game. More precisely, as we see in Table 4.1, 67% of the subjects who played the Minimum game and then the high-vulnerability Profit Sharing game chose 40 or more in the first round of the Sharing Profits game, while only 56% of those who previously played the Median game did. Hence, it does not appear that the Part I game had any effect on the exhibited trust existing among the subjects at least in the first round of their Part II experiment. However, by round 8 a dramatic difference appears with 43% of the Median game subjects choosing 40 or more but only 22% of the Minimum Game subjects doing so. From round 8 on the difference increases until in round 25 only 2.8% of the subjects in the Part-I Minimum-Game experiment attempted to choose 40 or more while 39% of the Median Game subjects were still attempting to do so. The same stylistic facts appear for mean revenue where mean revenue for the Minimum Game groups in period 1 was 359 while for the Median groups it was 320. By round 25 these revenues had decreased to 47 and 198 for the Minimum and Median groups respectively.

Counter to our expectations, the impact of the Part I experience was not detectable in the round-1 play of the Profit Sharing game but rather in the robustness of cooperative play after the first round. This a very significant finding since trust can mean a willingness to absorb disappointment in the group's failure to reach a goal and keep on playing cooperatively. While the Minimum Game subjects exhibited high levels of trust in their round 1 (and first-five round) behavior, this trust was superficial and quickly evaporated once the target was not met. Subjects in the Median game attempted high-effort Nash play for far longer durations than did their

Figure 4.5: High Effort Equilibria Plays in High Vulnerability Treatments

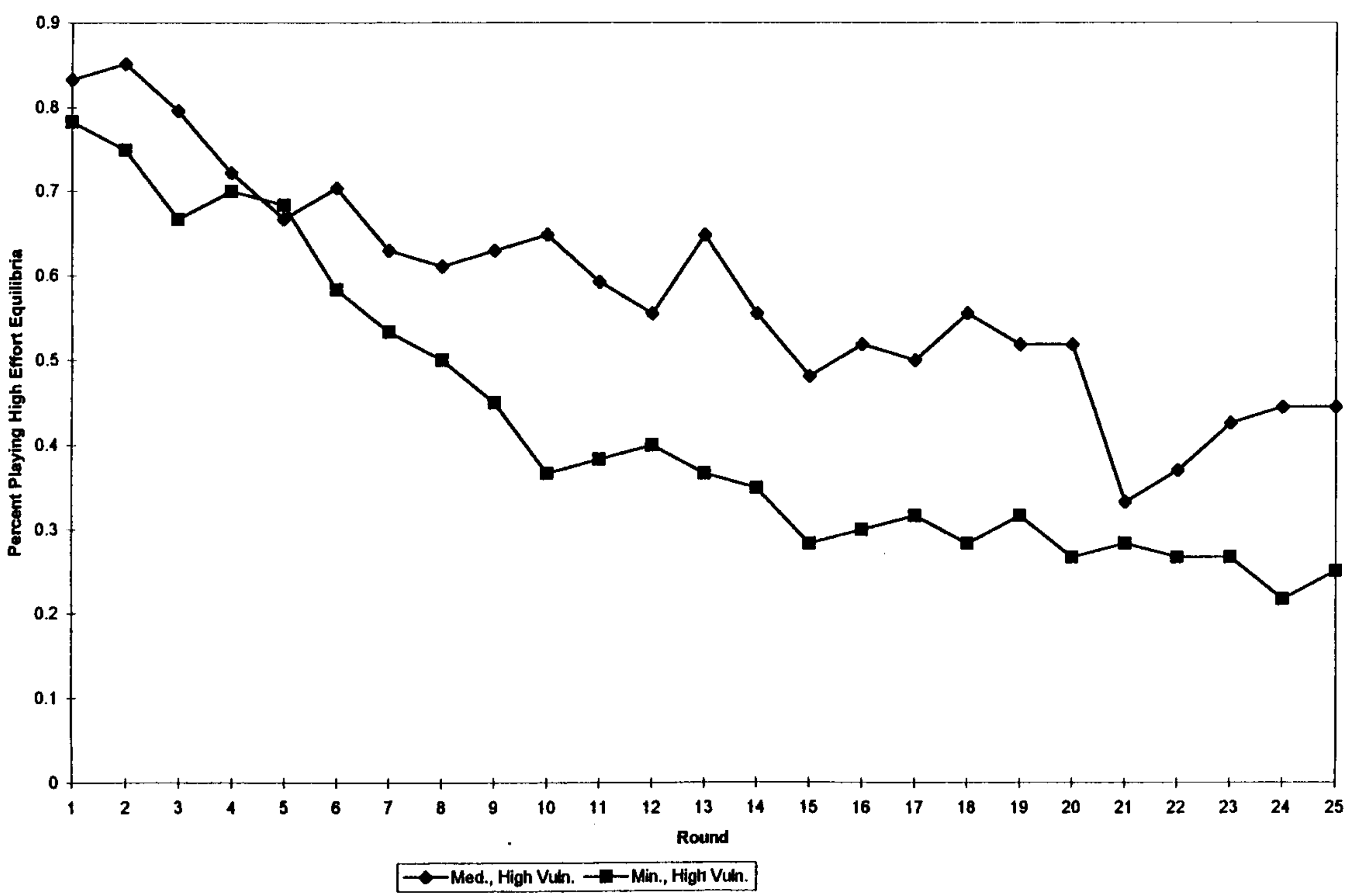
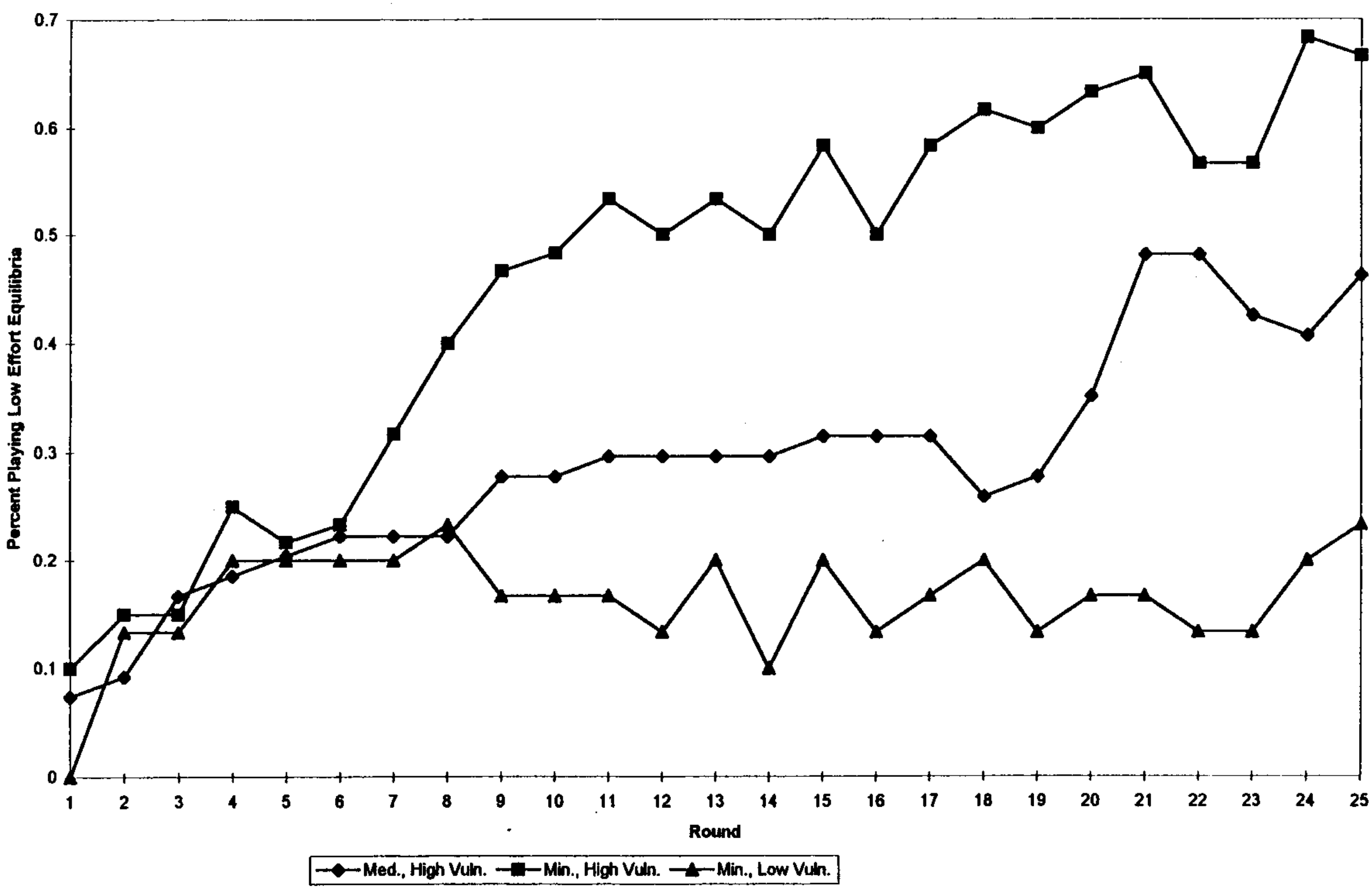


Figure 4.6: Low Effort Equilibria Plays



cohorts in the Minimum Game experiment.

The the results of the low-vulnerability experiment were confounded by the type of coordination problem this scheme implied for the high-effort equilibrium. Remember that this experiment was run on subjects completing the Minimum game but then playing the Profit Sharing game with a random term of ±40. Hence, while the Phase I treatment could be expected to lead to a lack of trust and therefore low efforts, in the Phase II game, the fact that it is relatively easy to coordinate actions at the high-effort equilibrium might counter-act this lack of trust and lead them to attempt to achieve a high effort equilibrium. The second factor seemed to have dominated the first. For example, not only did first round group revenue of subjects in this experiment exceed that of any high-vulnerability experiment (the mean revenue for the Minimum Game and Median Game groups were 359 and 320 respectively while for the Low Vulnerability group it was 418), but it remained higher throughout the 25 rounds ending at an average rate of 323 as opposed to 47 for the Minimum-Game High-Vulnerability subjects and 198 for the Median-Game High-Vulnerability experiments. Furthermore, four of the five low-vulnerability groups made the target of 360 on an average of 17.5 of the 25 rounds (the remaining group never surpassed the target at all).

To get a different view of how the Phase I Minimum and Median Games affected choice in the Phase II high-vulnerability experiment consider Figures 4.5 and 4.6. In Figure 4.5 we present the fraction of subjects who in any round of the high vulnerability experiment chose an effort level consistent with the high-effort equilibrium conditional on the game they played in Phase I. Figure 4.6 presents the fraction of subjects choosing the low effort equilibrium (i.e.

choosing 1 or 0). As we can see, at the pooled individual level after round 5 it is clear that subjects who participated in the Median Game in Phase I chose effort levels consistent with the high-effort equilibrium with far greater frequency than did those subjects who had previously played the Minimum Game. Likewise, looking at Figure 4.6 it is evident that subjects who played the Minimum Game in Phase I and then the high-vulnerability experiment in Phase II were much more likely to shirk and play the low effort equilibrium in Phase II as time progressed. Subjects playing the low-vulnerability experiment in Phase II were the least likely to choose 0 or 1 in the Phase II game doing so less than 20% of the time at the end of the experiment while practically 70% of the high-vulnerability Minimum-Game subjects chose to do so.

The results of this experiment actually introduce a new variable into the picture since now it appears that even in a low trust environment, if the high-effort equilibrium provides clear guidance as to how to coordinate equilibrum behavior (as in the ±40 experiment), such equilibria may still be achievable. Hence, coordination difficulties must be added to vulnerability and trust as a determining characteristic of when cooperation will be observed.

4.2: Formal Hypothesis Tests

In this section of the paper we will formally test some implications derived from the descriptive statistics presented above. These hypotheses, can be considered as substantiation of the more impressionistic evidence presented above.

4.2.1: Part I Hypotheses

Since Part I of the experiment was run only to induce a sense of trust among the subjects, in our hypothesis testing we will only concern ourselves with whether subjects in the Median and Minimum games experienced differential histories by asking whether they converged to different choices in their last rounds. In addition, we will ask whether we can characterize these different Part-I games as being more or less cooperative by comparing the fraction of the gains from cooperation they capture. These concerns are summarized by the following two null hypotheses.

Hypothesis 1: The distribution of last round choices in the Part-I Minimum game is identical to the distribution of last round choices in the Part-I Median Game.

To investigate Hypothesis 1 we use a Kolmogorov-Smirnov test to compare the distribution of last round choices of subjects in their respective games (see Figures 4.1a and 4.1b). Comparing the last-round sample of nine Median game and six Minimum game experiments (samples of 54 and 36 respectively) we see that there is a significant difference between the last round choices of the Minimum and Median game subjects ($p \leq 0.0001$).

Hypothesis 2: The fraction of the potentially available gains from cooperation captured by subjects in the Median Game experiment are equal to those captured in the Minimum Game experiment.

To test this hypothesis we employ a Wilcoxon test using the pooled data generated by all six Minimum-Game experiments and all nine Median-Game experiments over the 10 rounds of their existence. Based on this test we can reject the null hypothesis that the fractions of gains achieved in these two experiments were identical in favor of the alternative hypothesis that the gains captured were greater in the Median experiment at the 5% level of significance (z statistic 1.94, p= 0 0529).

Part-II Hypotheses

In Part-II of Experiments 1 and 2 we investigate whether the experience subjects had in Part I of the experiment created differential degrees of trust among the subjects to the point that it affected their behavior in Part II. Our first hypothesis investigates probably the purest trust effect induced by our Part I games by looking at the round-one choices of subjects in the Part II Profit Sharing game. We expect this first round (first five round) behavior to be insightful since it should reflect only the expectations of subjects about the choices of their cohort since at least in this Part II game, they have no history together. We are interested in two things. Are the choices in Part II higher for subjects with experience in the Median game and how many subjects in the first rounds of these experiments attempted to choose an effort level greater than or equal to 40 (i.e. that effort level dictated by the Nash equilibrium).

Hypothesis 3: The sample of first round choices in the Part-II ±10 Profit-Sharing Experiment is not affected by which Part I experiment subjects took part in.

Here again we use a χ^2 test to test for differences between the samples of first round choices in the Part-II ±10 Forcing Contract experiment. What we find is that no significant differences (at the 5% level of significance) exist (p = .087) in the way in which subjects make their choices in the first round of the Part-II high vulnerability games. Hence, if differential levels of trust existed, it did not manifest itself in the first-round behavior of subjects in their Part-II experiment. Looking at the first five rounds and all subsequent five round periods, however, we do see a significant difference between the choices of subjects who had previously played the Median and Minimum games with the Median Game subjects choosing significantly higher in all five round periods. Hence, trust seems to manifest itself more dramatically in the ability of Part I Median groups to choose higher effort levels later into the experiment than did those subjects who played the Minimum game in Part I.

The fact that we could not detect any difference in the way our subjects started off their play in the Part II ±10 Profit Sharing game between the Minimum and Median Game treatments is not surprising since such a broad range of behavior is consistent with high-effort equilibrium behavior. As we said, even if a subjects chooses an effort level as low as 12.5 such behavior would be consistent with a high-effort equilibrium if the subject thought that others would exert sufficiently high efforts. In fact, with such a big coordination problem it is not even clear what the impact of trust is on behavior. For example, as we said before, high trust levels combined with self-regarding behavior might lead to low effort levels since high trust indicates a high probability that others will exert high effort levels and exerting a low effort level could be rationalized given those beliefs. On the other hand, low trust might lead a subject to think that if the target is going to be reached he or she will have to contribute relatively more since others can not be relied on. This would predict higher effort levels in low trust groups. To help sort this out we divided the range of equilibrium effort levels in the high-vulnerability experiments [12.5, 73.314] into a high effort subset $e_i \geq 40$ and a low effort subset $e_i \leq 40$. The impact of trust on behavior could possibly be seen in the willingness of subjects to offer "high" effort levels above 40 in the first of first five rounds.

But, first round (or first five-round) behavior is not the entire story. From previous experiments using the Profit Sharing scheme[11] we know that this scheme is particularly sensitive to the failure of the group to make the target early on in their experience with each other. When the group falls short of the target, effort levels tend to tumble and group output many time quickly approaches the bad 0-effort equilibrium. However, if subjects trust each other they should be willing to persist in their high-effort choices for a longer time and their cooperativeness should be more robust to failures on the part of the group to reach the target and we should observe higher output persisting longer in the groups. These considerations lead to Hypothesis 4.

Hypothesis 4: The fraction of subjects who choose an effort level of 40 or more in the first round or in each of the five five-round periods of the Part-II ±10 high-vulnerability experiment should be independent of the Part-I game these subjects played.

This hypothesis presents a rather static test of the idea that even if there is no observable differences between the behavior of subjects in the first or perhaps the first five rounds of the Part II experiment conditional on which game they played in Part I, differences may be detectable later on in the Part II game and therefore the trust built up in Part I may manifest itself in better staying power or persistence for the Part I Median game subjects in Part II. Using a χ^2 test once again we see that the fraction of subjects choosing 40 or more in the first five rounds of the Part-II experiment is independent of which game was played in Part I ($p = 0.936$). However, for the first round there was a significant difference with Part-I Minimum subjects attempting

[11]See Nalbantian and Schotter (1995).

choices of 40 or more with greater frequency ($p = 0.027$). Starting with the third five round period we do detect significant differences between the behavior of subjects depending on their Part I experience. For example, a χ^2 test indicates that significant difference do exist between the two groups of subjects in each of the five round periods starting in period 10 ($p \leq 0.001$ in all three remaining five-round periods). What this indicates, perhaps, is that given the coordination problem presented to subjects by the high-vulnerability experiment, subjects in the high trust Median game condition were more willing to attempt coordination later into the experiment while low trust subjects gave up earlier on.

As stated before, Hypothesis 4 presents a static view of the persistence phenomenon by looking at five-round snapshots of behavior on a group level. In Hypothesis 5 we present a more dynamic examination of the persistence question by estimating discrete-time hazard functions on individual pooled data. These discrete-time hazard functions are in essence conditional probability functions indicating the probability of cooperating in period t (choosing 40 or more) conditional on the fact that you had been cooperating in period t-1. This hazard function was estimated as a probit regression using the pooled set of individual observations of subjects in each of our two Part-II experiments. What we are looking for is a difference in the time variable coefficient across these two regressions since that would indicated whether the probability of persisting in cooperation in period t, conditional on cooperation in period t-1, was different for these two groups as time progressed.

Hypothesis 5: Equilibrium Effort Persistence (Hazard Functions).

The probability that an individual persists in choosing an effort level of 40 or

greater (i.e. an effort level consistent with the symmetric high-effort equilibrium) conditional on his or her previous round high-equilibrium effort choice will be independent of the Part-I game he engaged in when playing the Part-II high-vulnerability Profit Sharing game.

The regression results used to test Hypothesis 5 are presented in Table 4.2.

Table 4.2a
Hazard Function Estimates: Part-II High Vulnerability Following Minimum Game

Probit Estimates

y	Coefficient	Std. Error	t	P >|t|	95% Confidence Interval	
time	-.04083	.0196	-2.081	0.039	-.0795	-0.0208
constant	.6419	.1746	3.675	0.000	.2969	.9870

Log Likelihood = -100.683
Pseudo R^2 = 0.0212
Number of Observation = 157

Table 4.2b
Hazard Function Estimates: Part-II High Vulnerability Following Median Game

Probit Estimates

y	Coefficient	Std. Error	t	P >|t|	95% Confidence Interval	
time	-.00809	.0103	0.784	0.433	-.0121	.0283
constant	1.0363	.1418	7.305	0.000	.7576	1.315

Log Likelihood = -193.714
Pseudo R^2 = 0.0016
Number of Observation = 506

As we see, while the time coefficient is significant and negative in the regression run on the Part-I Minimum Game subjects, it is not significant for subjects who played the Median Game in Part-I. This is not surprising since cooperative persistence did not seem to diminish at all for subjects who first experienced the Median game while it dropped dramatically for those whose first interaction was with the Minimum Game. Such a finding is consistent with our a priori expectations since the lack of trust among Minimum-Game subjects could be expected to yield a decay of cooperative persistence over time while such a decay may not be observed if our subjects actually built up significant levels of trust in their Part-I experience together.[12]

4.3: The Effect of Vulnerability

As you recall, one of the motivations for this paper is the fact that we expect the match between the level of trust existing between workers and the vulnerability of the incentive plan they are placed in to be an important predictor of the performance of that group incentive plan. Hence, we expect that low trust groups would perform better when placed in low vulnerability incentive plans than in high ones since such low vulnerability plans rely less on trust for proper performance. This proposition can be tested by a comparison of the results in Experiments 1 and 3 since in each of these experiments subjects play the identical Minimum game in Part I of the experiment but then face Forcing Contract schemes with differing levels of vulnerability. These

[12]It should be noted that persistence is not the same thing as cooperation. For example, we ran an unconditional probit regression on the probability of cooperating in any given round unconditional on cooperation in the previous period and found that in both of those regressions the time variable was significant and negative in both the Minimum and Median-Game group subjects. Hence, time does lead to a decay of cooperativeness. It only affects the persistence of such cooperation in the Minimum-Game subject group.

considerations yield a set of hypotheses which make comparisons between the results of Experiments 1 and 3 as opposed to Experiments 1 and 2.

While Hypotheses 3-5 test the impact of trust on the performance of subjects in High-vulnerability games, Hypothesis 6 investigates the impact of vulnerability on the behavior of subjects conditioned with the same low-trust Minimum game in Part I. Hence in the hypotheses that follow we are comparing the behavior of subjects in two different Part-II experiments (one with low and one with high vulnerability) who participated in identical Part-I Minimum games. For these games we ask the same questions as we asked in Hypotheses 3 and 4 as summarized in Hypothesis 6.

Hypothesis 6: The sample of effort choices in either the first round, the first five rounds, or each of the five five-round periods in the low vulnerability game is not significantly different from the sample of choices in the high vulnerability game. In addition, the fraction of subjects who choose an effort level of 40 or more in the first round or in each of the five five-round periods does not differ according to the vulnerability of the Part-II experiment.

As we saw in the descriptive statistics offered earlier, there were dramatic differences in the behavior of subjects performing the low and high vulnerability experiments after experiencing the Minimum game in Part I. For example, using a $\chi 2$ test we can reject the hypothesis that the distribution of choices in the first round, or first, second, third, fourth or fifth five-round periods of the Part-II Profit Sharing game was identical whether or not the game played was a high or low vulnerability game ($p = 0.001$, $p = 0.012$, $p \leq 0.001$, $p \leq 0.001$, ,

$p \le 0.001$, $p \le 0.001$, respectively). We can also reject the hypothesis that the fraction of subjects attempting cooperation (effort choices above 40) was the same for these two groups over the same time periods (($p = 0.033$, $p = 0.021$, $p \le 0.001$, $p \le 0.001$, $p \le 0.001$, $p \le 0.001$, respectively).

As was mentioned above, we expect that these results differ so dramatically from those of the high-vulnerability experiments since the low-vulnerability experiment presented subjects with a very different coordination task in adhering to a high-effort equilibrium. In this experiment the range of equilibrium behavior was severely restricted when compared to the high-vulnerability experiment. With subjects making choices over a smaller set of equilibrium effort levels we might expect that the probability of reaching the target would be significantly increased while the temptation to free ride on the high-effort equilibrium effort levels of others would significantly decreased.

Section 5: Conclusions:

This paper has investigated the complementary nature of worker trust and system . vulnerability on the behavior of laboratory subjects. As was indicated in the introduction, the performance of workers on the job is influenced not only by the incentive properties of the incentive mechanism they are functioning under, but also by the norms of trust they have developed with their fellow workers. Worker groups with low levels of trust or with common histories of shirking on the job, should be matched with incentive systems which do not make the workers excessively vulnerable to the free-riding of their colleagues.

In additon, when multiple high-effort equilibria exist, the task of coordinating on one equilibrium confounds the effects of trust and vulnerability. A fuller analuysis of the relationships between these three influences has yet to be carried out but should provide an interesting research agenda.

If there is a lesson to be learned from these experiments for Eastern Europe it is probably that we can not expect Western style incentive systems imposed on Eastern European workers with their histories of low productivity and shirking to work as well as those same systems do in the West. The archetypical Socialist worker has neither the experience with risky variable-pay schemes where large amounts of pay are at risk nor the established work ethic to be willing to exert high levels of effort without some assurance that his or her fellow workers will also. While this ethic might be built by first educating workers as to the existence of both the high and low effort equilibrium and some moral suasion as to which to choose, unless some prior preparation is offered, (some social capital built up) it is likely that the straight forward institution of such incentive schemes is likely to fail.

This paper has investigated the complementary nature of worker trust and system vulnerability on the behavior of laboratory subjects. As was indicated in the introduction, the performance of workers on the job is influenced not only by the incentive properties of the incentive mechanism they are functioning under, but also by the norms of trust they have developed with their fellow workers. Worker groups with low levels of trust or with common histories of shirking on the job, should be matched with incentive systems which do not make the workers excessively vulnerable to the free-riding of their colleagues.

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1. Appendix: Derivation For Range of Asymmetric Equilibria

The problem facing each individual is to choose e_i to Maximize

$$\left(\frac{Y^* - \sum_{j\neq i} e_j - e_i + a}{2a}\right) B + \left(\frac{\sum_{j\neq i} e_j + e_i - Y^* + a}{2a}\right)\left(\frac{\sum_{j\neq i} e_j + e_i + Y^* + a}{8}\right) - \frac{e_i^2}{100}$$

s.t.

$$\frac{\sum_{j\neq i} e_j + e_i - Y^* + a}{2a} \leq 1$$
$$e_i, \lambda \geq 0$$

Let the Lagrangian be denoted as Z with shadow value λ

First Order Conditions give

$$\begin{aligned}
\frac{\partial Z}{\partial e_i} &= \frac{-B}{2a} + \frac{1}{8}\left(\frac{\sum_{j\neq i} e_j + e_i - Y^* + a}{2a}\right) + \frac{1}{2a}\left(\frac{\sum_{j\neq i} e_j + e_i + Y^* + a}{8}\right) - \frac{e_i}{50} - \lambda \geq 0 \\
\frac{\partial Z}{\partial \lambda} &= \sum_{j\neq i} e_j + e_i - Y^* - a \leq 0
\end{aligned}$$

We know that all equilibria that are corner solutions will have the feature that $\sum e_i = Y^* + a$ (surity payoff) or $\sum e_i = 0$. We are looking at situations involving the former.

Consider the case when we have $a = 40$, $B = 5$, $Y^* = 240$. First order conditions become

$$\begin{aligned}
\frac{\partial Z}{\partial e_i} &= \frac{-1}{16} + \frac{1}{8}\left(\frac{\sum_{j\neq i} e_j + e_i - 200}{80}\right) + \frac{1}{80}\left(\frac{\sum_{j\neq i} e_j + e_i + 280}{8}\right) - \frac{e_i}{50} - \lambda \geq 0 \\
\frac{\partial Z}{\partial \lambda} &= \sum_{j\neq i} e_j + e_i - 280 \leq 0
\end{aligned}$$

We can see that the only consistant case here is $e_i > 0$, $\lambda > 0$, which is a corner solution. The maximum value e_i can take on then is (in the limit) that in which we set λ equal to 0 in the first FOC with the condition that the second is met with equality

$$\begin{aligned}
\frac{-1}{16} + \frac{1}{8}\left(\frac{\sum_{j\neq i} e_j + e_i - 200}{80}\right) + \frac{1}{80}\left(\frac{\sum_{j\neq i} e_j + e_i + 280}{8}\right) - \frac{e_i}{50} &= 0 \\
\frac{-1}{16} + \frac{1}{8} + \frac{7}{8} - \frac{e_i}{50} &= 0
\end{aligned}$$

which gives the solution $e_i = 46.875$ as the maximum possible value. If this is then the maximum value possible, we can calculate the minimum by showing that if five players chose this maximum value, then the sixth would chose the minimum and that this vector of choices is a Nash equilibrium. Since we know from the second FOC that the sum of efforts is 280, the minimum possible value must be $e_i = 45.625$. Therefore the range of possible asymmetric equilibrium choices for these parameters fall in the interval $[45.625, 46.875]$ with the symmetric equilibria being $e_i = 46\frac{2}{3}, \forall i$.

Now consider the case when $a = 10$, $B = 8.75$, $Y^* = 240$. This gives first order conditions

$$\begin{aligned}
\frac{\partial Z}{\partial e_i} &= \frac{-7}{16} + \frac{1}{8}\left(\frac{\sum_{j\neq i} e_j + e_i - 230}{20}\right) + \frac{1}{20}\left(\frac{\sum_{j\neq i} e_j + e_i + 250}{8}\right) - \frac{e_i}{50} - \lambda \geq 0 \\
\frac{\partial Z}{\partial \lambda} &= \sum_{j\neq i} e_j + e_i - 250 \leq 0
\end{aligned}$$

again $e_i > 0$, $\lambda > 0$, will be the only consistant case. With these parameters the same technique used above will not give desirable results

$$\begin{aligned}
\frac{-7}{16} + \frac{1}{8}\left(\frac{\sum_{j\neq i} e_j + e_i - 230}{20}\right) + \frac{1}{20}\left(\frac{\sum_{j\neq i} e_j + e_i + 250}{8}\right) - \frac{e_i}{50} &= 0 \\
\frac{-7}{16} + \frac{1}{8} + \frac{25}{8} - \frac{e_i}{50} &= 0
\end{aligned}$$

which would give a solution of $e_i = 140.63$. This is clearly inconsistant with incentive compatibility. Such an answer does make sense however as we know with $a = 10$ there won't be interior solutions. Thus we need to look to incentive compatibility constraints to find the maximum and the minimum anyone is willing to exert.

Again we need to use the second FOC being equal to 0 (ie $\lambda > 0$) to establish that in any equilibrium it must be that the sum of the efforts is equal to 250. This then being the case, we can find the maximum effort level by setting the expected wage equal to the penalty wage and solving for e_i.

$$\begin{aligned}
\left(\frac{250 - \sum_{j\neq i} e_j - e_i}{20}\right) 8.75 + \left(\frac{\sum_{j\neq i} e_j + e_i - 230}{20}\right)\left(\frac{\sum_{j\neq i} e_j + e_i + 250}{8}\right) - \frac{e_i^2}{100} &= 8 \\
\frac{500}{8} - \frac{e_i^2}{100} &= 8
\end{aligned}$$

Solving for e_i we get $e_i = 73.314$. Now clearly we again cannot find the minimum by assuming that five players exert the maximum and taking the difference from the equilibrium total as we did above as this would result in a negative effort level. What we need to do in this case is to again remember the fact that the efforts must sum to 250, which gives the high payoff with surity and find the level of effort that sets the maginal revenue from the surity payoff equal to the marginal cost of the individual. The payoff of individuals, *given that the high payoff is reached with surity,* is

$$\left(\frac{1.5\left(\sum_{j\neq i} e_j + e_i + \varepsilon\right)}{6}\right) - \frac{e_i^2}{100}$$

taking first order conditions wrt e_i we get

$$\frac{1}{4} - \frac{e_i}{50} = 0$$

Solving, we get $e_i = 12.5$ as the minimum any worker is willing to exert. Thus in this case the asymmetric equilibria can fall in the range $[12.5, 73.314]$ with the symmetric equilibrium being $e_i = 41\frac{2}{3}, \forall i$.

To establish vulnerabilities simply use these values of e_i in the payoff function and vary the contributions of others away from equilibrium.

APPENDIX A:
INSTRUCTIONS

1) Minimum Game Instructions
2) High-Vulnerability (±10) Instructions

PAYOFF TABLE

SMALLEST VALUE OF X CHOSEN

YOUR CHOICE OF X	7	6	5	4	3	2	1
7	1.30	1.10	.90	.70	.50	.30	.10
6	---	1.20	1.00	.80	.60	.40	.20
5	---	---	1.10	.90	.70	.50	.30
4	---	---	---	1.00	.80	.60	.40
3	---	---	---	---	.90	.70	.50
2	---	---	---	---	---	.80	.60
1	---	---	---	---	---	---	.70

WORKSHEET

Round	Your Decision Number (1,2,3,4,5,6,7)	Minimum of Group	Payoff
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
		Total Payoff	

DO NOT TOUCH any computer key until we instruct you to.

In round 1 of the experiment, you and the other five subjects in your group will be asked to type in a number between 0 and 100. The computer will prompt you to do so by stating:

"Please enter a number between 0 and 100"

We call the number you enter your decision number. You enter your decision number by typing it on the number keys and hitting the return key when you are finished. The computer will then confirm your choice by stating:

"You have chosen ___. Is that what you wanted?

If this is, in fact, the decision number you want to enter, push the Y (Yes) key. Your participation in this round of the experiment will then be over. If you wish to change your mind, or you made a mistake in your typing, type N (No), and you will be prompted to choose another number. When you have successfully decided upon a decision number and entered it, your participation in this round of the experiment will be over.

Round-By-Round Payoffs

In each round of the experiment you will receive a payment in a fictitious currency called "francs." (The francs you earn will be converted into dollars at the end of the experiment at a rate to be described shortly). The payment you receive will depend on your decision number and those of the other members of your group as well as the realization of a random number. Precisely how the random number influences your payment is described in the next section. Your actual payoff (or earnings) in any round is the difference between the payment you receive and the direct cost to you of the decision number you selected as given by the cost schedule of Table 1. In other words:

Earnings = Payment - Decision Cost.

Let us see specifically how both these components determine your earnings.

Clearly, 360 francs is a "**group target;**" so long as that target is satisified, the group will split equally all revenues they create so that the payment each member receives rises as Group revenue rises. Below that group target, however, your payment is a fixed amount (8.75francs) completely independent of Group Revenue.

The **group target** of 360 francs is indicated in column 4 on your screen. Your payment for each round of the experiment will be calculated by the computer and appear in Column 5 on your screen.

How Your Earnings are Determined

Your payoff or earnings in any round will equal the payment you receive, as described above, **minus** the cost of your decision number. Decision costs are presented in Table 1. You will note that for each decision number you might choose over the range 0 to 100, there is an associated cost to be incurred. You can read your cost table by looking down the first column and finding the decision number you are contemplating. The second column will then inform you what it will cost you to choose that decision number. For example, a decision number of 25 has an associated cost of 6.25 francs, while the decision number 50 has a cost of 25 francs. Several important features of this cost schedule are evident in this example and are especially noteworthy. First, the larger the decision number, the higher the cost you must incur. Second, the cost of decision numbers increases at an increasing rate. Hence, the cost of choosing decision number 50 is more than twice the cost of choosing 25; The cost of choosing 100 is more than twice the cost of choosing 50. You can verify this characteristic of costs of decision numbers by considering other examples from the cost schedule.

The cost of the decision number you choose will be deducted from the payment you are due in that round to determine your actual earnings for the round. Again,

Earnings = Payment - Decision Cost.

The cost of your decision number for each round will appear in column 6 on your screen.

Decision number	Cost	Decision number	Cost
1	0.01	51	26.01
2	0.04	52	27.04
3	0.09	53	28.09
4	0.16	54	29.16
5	0.25	55	30.25
6	0.36	56	31.36
7	0.49	57	32.49
8	0.64	58	33.64
9	0.81	59	34.81
10	1	60	36
11	1.21	61	37.21
12	1.44	62	38.44
13	1.69	63	39.69
14	1.96	64	40.96
15	2.25	65	42.25
16	2.56	66	43.56
17	2.89	67	44.89
18	3.24	68	46.24
19	3.61	69	47.61
20	4	70	49
21	4.41	71	50.41
22	4.84	72	51.84
23	5.29	73	53.29
24	5.76	74	54.76
25	6.25	75	56.25
26	6.76	76	57.76
27	7.29	77	59.29
28	7.84	78	60.84
29	8.41	79	62.41
30	9	80	64
31	9.61	81	65.61
32	10.24	82	67.24
33	10.89	83	68.89
34	11.56	84	70.56
35	12.25	85	72.25
36	12.96	86	73.96
37	13.69	87	75.69
38	14.44	88	77.44
39	15.21	89	79.21
40	16	90	81
41	16.81	91	82.81
42	17.64	92	84.64
43	18.49	93	86.49
44	19.36	94	88.36
45	20.25	95	90.25
46	21.16	96	92.16
47	22.09	97	94.09
48	23.04	98	96.04
49	24.01	99	98.01
50	25	100	100