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LABOR NEGOTIATIONS, MISPERCEPTIONS, AND REPEATED PRISONER'S DILEMMA: SOME EXTENSIONS AND AFTERTHOUGHTS

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ABSTRACT

Extending previous work of three of the authors [3], this study assumes that parties playing tit-for-tat in labor negotiations (modeled as Repeated Prisoner's Dilemma) may have different probabilities of misperceiving one another's moves. Also, the probability of misperceiving a friendly move may be greater than that of misperceiving an unfriendly move. Through simulation, greater perceptive ability by a player is shown to convey no competitive advantage although it may raise joint payoffs. Further, as the probability of misperceiving an unfriendly move as friendly converges to zero, average returns to the players become negligible. These results' behavioral implications are explored.

In labor negotiations, two parties (labor and management) face one another in repeated rounds of negotiations. Further, each round can be modeled as a game of Prisoner's Dilemma [1]. One commonly employed strategy for dealing with games of repeated Prisoner's Dilemma is called "tit-for-tat." The strategy requires that a party initially offer to cooperate with the other for mutual gain, but subsequently to replicate the opponent's move. For example, if management is cooperative in one round of negotiations, then labor would be cooperative in

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the next round. Conversely, if management is uncooperative, then labor would respond in kind in the next round.

Although "tit-for-tat" has many desirable properties as a strategy, Dixit and Nalebuff [2] demonstrate that when the parties misperceive their counterpart's moves, the results can be less than desirable for both parties. Essentially, a misperception may set off a period of alternating recriminations that are reminiscent of many "blood feuds" that have existed in history, some of which are still ongoing. An earlier work by three of the current authors [3] examines the effects that misperception has on the average joint payoff for the parties involved in negotiations, assuming that each party plays a "tit-for-tat" strategy. Through simulation, the study found that, while a lower probability of misperception by the parties extended the "honeymoon period" (the initial period of cooperation), once there is any misperception, the average joint payoffs are no better than if the parties pursued a completely random strategy. It should be noted, however, that a random strategy pursued by each party will give a better result than if each party is always aggressive (uncooperative).

The intent of this article is to include simulations that extend the results of the previous study to encompass circumstances it did not contemplate. There were two assumptions made in that article that this inquiry will relax. First, it was assumed that each party in the game has the same probability of misperceiving the moves of the other. If these probabilities are allowed to differ, will the average joint payoff be affected? In addition, will the relative payoffs of the players be affected? That is, does possessing an enhanced ability to perceive the moves of one's opponent grant a player any advantage if the players are pursuing a "tit-for-tat" strategy? Second, the earlier article assumed that the probability of perceiving a friendly move as unfriendly was the same as perceiving an unfriendly move as friendly. What if, as seems realistic to the authors of this article, the former is more often greater than the latter? How will the average payoffs of the players be affected? The answers to these questions and their implications for negotiations form the subject of this inquiry.

The assumption in Repeated Prisoner's Dilemma is that the game is repeated numerous times, sufficiently so that the game is perceived as unending by the players. Further, the payoff matrix to the players in each round of negotiations is assumed to be as indicated in Figure 1. Note that, in the game, management's strategy (to cooperate or not) determines the row of the final payoff while labor's strategy determines the column. The first entry in the ordered pair of any cell is management's payoff if that cell is reached, and the second entry is labor's payoff.

DIFFERENCES IN THE PERCEPTIVE ABILITIES OF THE PLAYERS

To test the effects on the outcomes where players have different abilities to perceive the moves of their opponents, the probabilities of misperception are set at

Labor → Management ↓	Don't Cooperate	Cooperate
Don't Cooperate	(0, 0)	(+20, –10)
Cooperate	(–10, +20)	(+10, +10)

Figure 1. Payoff matrix.

relatively low levels to see the effects over a large number of rounds. Here, management is assumed to be considerably less perceptive than labor (although this designation could easily be reversed). Initially, management's probability of misperceiving labor's move in a given round is set at one in a hundred ($p_M = 0.01$), while labor's probability of misperceiving management's move is only one in a thousand ($p_L = 0.001$). Labor's probability of misperception is then raised in increments of one-thousandths until it eventually equals that of management at one in a hundred. Thus, there are ten different sets of probabilities over which labor becomes increasingly less perceptive.

At each set of probabilities, a simulation was conducted in which Prisoner's Dilemma is repeated 10,000 times with each participant playing a "tit-for-tat" strategy. The simulation was repeated 100 times for each combination of probabilities. The average payoff for each player and the average joint payoff were then calculated over the repetitions. The results are presented in Figure 2, which shows the average payoff that management (the less perceptive party) receives against the average payoff that labor (the more perceptive party) receives.

As is readily apparent, the differences in the players' payoffs are scant. In a statistical test, those differences were found to be insignificant. Further, the mean absolute difference between the payoffs was well less than 0.01 (on a scale between zero and 20). Moreover, in the simulation, management had the higher average payoff in five of the cases and labor had the higher average payoff in the other five. The conclusion that one may draw from the lack of any significant difference in the payoffs is that if each of the parties is playing a "tit-for-tat" strategy, then the ability to better perceive an opponent's moves conveys no competitive advantage.

The reason that better perception does not lead to a higher payoff for an individual player is inherent in the "tit-for-tat" strategy. Because each party begins initially by cooperating with the other, the first repetitions of the game are characterized by maximum joint payoff (i.e., 20). This "honeymoon period" persists only so long as neither party misperceive the moves of its opponents. If either player (or both) mistakes the move of the other at any point, however, the "honeymoon period" ends, and the joint payoff will be less than 20. The

	Management's Payoff	Labor's Payoff	Deviation	Absolute Deviation
$p_M = .01, p_L = .001$	5.07358	5.07235	0.00123	0.00123
$p_M = .01, p_L = .002$	5.00692	5.00719	−0.00027	0.00027
$p_M = .01, p_L = .003$	5.06662	5.06503	0.00159	0.00159
$p_M = .01, p_L = .004$	4.99098	4.99224	−0.00126	0.00126
$p_M = .01, p_L = .005$	5.06499	5.06241	0.00258	0.00258
$p_M = .01, p_L = .006$	4.98014	4.98335	−0.00321	0.00321
$p_M = .01, p_L = .007$	5.02274	5.02505	−0.00231	0.00231
$p_M = .01, p_L = .008$	5.06732	5.06393	0.00339	0.00339
$p_M = .01, p_L = .009$	5.04907	5.05246	−0.00339	0.00339
$p_M = .01, p_L = .01$	5.12	5.11988	0.00012	0.00012

t-statistic	*p*-value	Mean Deviation	Mean Absolute Deviation
$t = -0.333$	$p = 0.7469$	−0.00015	0.001935

Figure 2. Average individual payoff.

hypothesis here (and in the earlier work by Haber, Malin-Adams, and Khamalah [3] was that once the "honeymoon" ends, the payoffs to the players will be no better than if each had pursued a random strategy. That is, over a large number of rounds, the average joint payoff should converge to 10, the only deviation accounted for by the higher payoff during the initial rounds of cooperation. The logic behind this conclusion is that, by assumption, once the initial period of cooperation is over, a player is equally likely to perceive a friendly move as unfriendly as they are to perceive an unfriendly move as friendly. Moreover, the convergence of the average joint payoff to 10 is independent of the probabilities of misperception by the players. The only effect that the probability of misperception has is to influence the length of the "honeymoon."

To test the hypothesis that, once the initial period of cooperation ends, average returns are not significantly better than random, one must first discount for the initial honeymoon. Because the assumption is that the misperceptions of the two parties are generated independently of one another, the probability that a misperception will occur in any given round is $p_M + p_L - p_M p_L$, where:

p_M = the probability that management will misperceive labor's move in a given round, and
p_L = the probability that labor will misperceive management's move in a given round.
(Note by assumption, $p_M > p_L$.)

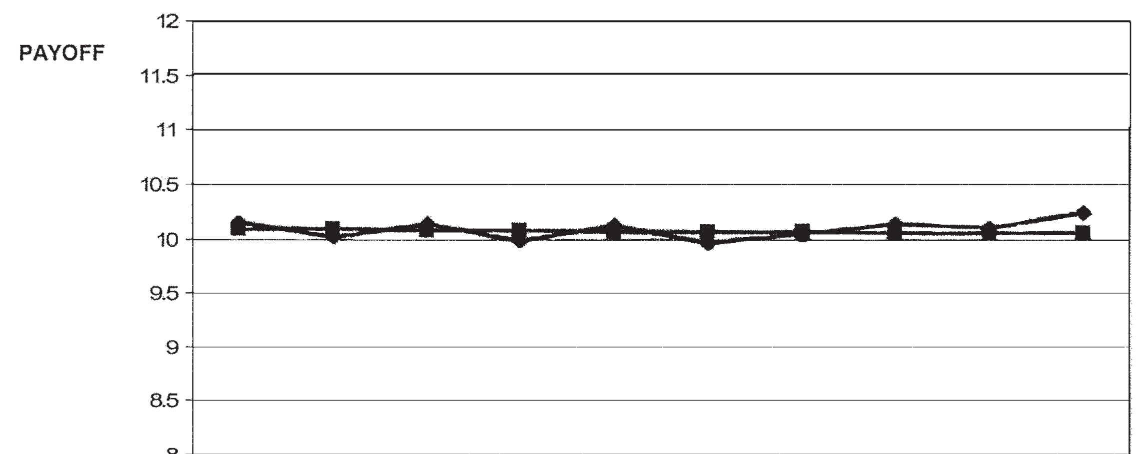
The expected length of the "honeymoon period" (H) is then $H = (p_M + p_L - p_M p_L)^{-1}$. Further, the expected average joint payoff where Prisoner's Dilemma is played repeatedly can be approximated as:

$$\pi = (H/N) * 20 + (1 - (H/N)) * 10$$

where: π = the expected average joint payoff
N = the number of rounds in the simulation.

Figure 3 plots the observed average joint payoff at each set of probabilities against the expected average joint payoff. The difference between the observed and the actual average joint payoffs was statistically insignificant with the mean absolute deviation of the difference being well less than 0.01. Thus, one can again conclude that, after the initial period of cooperation ends, a "tit-for-tat" strategy played by each party yields no better payoffs than if each had simply pursued an entirely random strategy.

One implication that emerges from the prior results is that, where both parties pursue a "tit-for-tat" strategy, the sole effect of increased perceptive ability (i.e., reduced probability of misperception) of the parties is to lengthen the period of initial cooperation. Accordingly, it is in the interest of both players to delay the first misperception by either for as long as possible. One should note, however, that the least perceptive player has the greatest probability of making the first



	a.01 b.001	a.01 b.002	a.01 b.003	a.01 b.004	a.01 b.005	a.01 b.006	a.01 b.007	a.01 b.008	a.01 b.009	a.01 b.01
Average Joint Payoff	10.14593	10.01411	10.13165	9.98322	10.1274	9.96349	10.04779	10.13125	10.10153	10.23988
Estimated Joint Payoff	10.090992	10.083472	10.077101	10.071633	10.06689	10.062735	10.059067	10.055804	10.052882	10.050251
Absolute Difference	0.0549382	0.0693625	0.0545490	0.0884132	0.0605104	0.0992453	0.0112767	0.0754464	0.0486479	0.1896287

t-statistic	*p*-value	Mean Deviation	Mean Absolute Deviation
$t = 0.7636$	$p = 0.4647$	0.021542	0.075202

Figure 3. Average joint payoff against expected average joint payoff.

mistake. If, as before, management (the less perceptive player) has a probability of misperception in any given round of the game of p_M, and labor (the more perceptive player) has a probability of misperception of p_L, then the probability that management will make the first mistake (M_M) is

$$M_M = p_M(1 - p_L)/[1 - (1 - p_M)(1 - p_L)];$$

the probability that labor will make the first mistake is

$$M_L = p_L(1 - p_M)/[1 - (1 - p_M)(1 - p_l)];$$

and the probability that they will simultaneously make the first mistake is

$$M_S = p_M p_L/[1 - (1 = p_M)(1 - p_L)].$$

The derivation of these probabilities is provided in the Appendix. Accordingly, the expected number of first mistakes (over 100 trials) for each player in each combination of probabilities of misperceptions in the current simulation would be as indicated in Figure 4. Note that, as labor becomes less perceptive relative to management, the expected number of times that labor misperceives first becomes greater and converges to that of management's.

	Expected First Mistakes by Management	Expected First Mistakes by Labor	Expected Simultaneous First Mistakes
$p_M = .01, p_L = .001$	90.90082	9.008189	0.090992
$p_M = .01, p_L = .002$	83.30551	16.52755	0.166945
$p_M = .01, p_L = .003$	76.8697	22.899	0.231303
$p_M = .01, p_L = .004$	71.3467	28.36676	0.286533
$p_M = .01, p_L = .005$	66.55518	33.11037	0.334448
$p_M = .01, p_L = .006$	62.35885	37.26474	0.376412
$p_M = .01, p_L = .007$	58.65328	40.93325	0.413467
$p_M = .01, p_L = .008$	55.3571	44.19643	0.446429
$p_M = .01, p_L = .009$	52.40613	47.11793	0.475939
$p_M = .01, p_L = .01$	49.74874	49.74874	0.502513

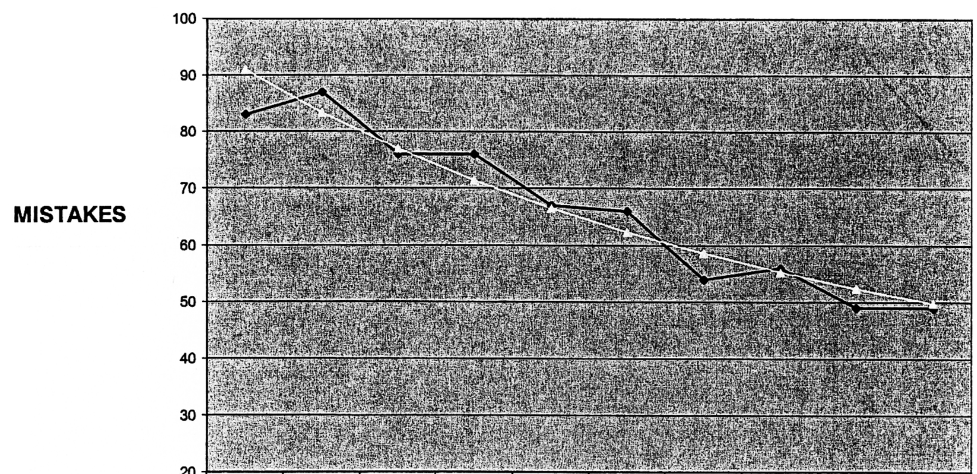
Figure 4. Expected first mistakes.

Figure 5 plots the actual number of times in the simulation that management made the first mistake against the expected number of times given the relative probabilities. Although the distribution of management's actual first mistakes varies around the expected distribution to some degree (as indicated by an average absolute difference of slightly greater than three mistakes), the expected distribution still seems to be a reasonably good predictor of the actual distribution. The relatively small average deviation of the actual number of mistakes from the expected number indicates that the expected number is close to an unbiased estimator of the actual number. Further, a paired *t*-test does not allow one to conclude that a statistically significant difference between the two distributions exists.

The consequence for the course of negotiations between two parties is that, where a large degree of difference in perceptive ability exists between the two, it is the less perceptive player that is more likely to set off the period of alternating recriminations. Once the non-cooperative behavior begins, better perceptive ability simply assures that the lack of cooperation persists for a longer period and, therefore, conveys no advantage.

Assuming that increasing one's perceptive abilities requires resources of at least time, if not money, one might assume that the party that is already more perceptive will have little incentive to invest more resources because they will be less and less likely to be the party that initiates alternating recriminations. This may not be the case, however. Recall that the length of the "honeymoon period," after which returns are no better than random, is determined by the inverse of the sum of the probabilities of misperception of the players less their product. It may matter little, then, which player increases its perceptive ability. That is, a given increment (decrement) to the perceptiveness of one player may have about the same effect on the sum of probabilities as an equal increment (decrement) to the perceptiveness of the other player. Consequently, despite the fact that the less perceptive player is more likely to initiate the alternating rounds of recrimination, the effect on the length of the "honeymoon" and, consequently, on the average payoffs is similar regardless of whether it is labor or management that increases its perception.

To demonstrate the conditions under which increases in perception by each party have similar effects, define H_L and H_M to be the partial derivatives of the expected length of the "honeymoon" period (H) with respect to p_L and p_M respectively. It can be shown directly that: $H_L/H_M = (1 - p_M)/(1 - p_L)$. The ratio of these derivatives indicates the degree to which an increase in labor's perceptiveness will increase the length of the honeymoon relative to that of management. If the ratio is greater than one (e.g., if management is substantially more perceptive than labor so that $p_L > p_M$), then an increase in labor's perceptiveness (a decrease in p_L) will have a greater impact on extending the "honeymoon period" than would an increase in management's perceptiveness. Conversely, if the ratio of the derivatives is less than one, then increases in management's



	a.01 b.001	a.01 b.002	a.01 b.003	a.01 b.004	a.01 b.005	a.01 b.006	a.01 b.007	a.01 b.008	a.01 b.009	a.01 b.01
Actual Player A	83	87	76	76	67	66	54	56	49	49
Estimated Player A	90.900819	83.305509	76.869699	71.346705	66.555184	62.358846	58.653278	55.357143	52.406134	49.748744
Absloute Difference	7.9008189	3.6944908	0.8696993	4.6532951	0.4448161	3.6411543	4.6532782	0.6428571	3.4061343	0.7487437

PROBABILITY

t-statistic	p-value	Mean Deviation	Mean Absolute Deviation
$t = -0.356$	$p = 0.730$	–0.45021	3.0655

Figure 5. Actual number of mistakes per 100 games against expected number of mistakes.

perceptiveness will have greater impact on the length of the "honeymoon" than would increases in that of labor's perceptiveness. In the simulation conducted here, because the probabilities of misperception are very low, the ratio of the derivatives is close to one. Accordingly in this case, increases in perceptiveness by one party can be expected to have virtually the same impact on the expected length of the "honeymoon" and the expected average payoffs as similar increases by the other.

In any event, one implication that emerges from the analysis is that, in general, an increased investment in its own perceptiveness by one player will have the effect of extending the "honeymoon period," and, therefore, increasing not only its average payoff, but also that of the other player as well. Thus, such investment by a player generates an externality (i.e., benefits for their opponent that the investing player does not fully capture). Given that each player will invest in its own perception only so long as the incremental benefits it receives exceed the incremental costs, each player will tend to invest less than would be jointly optimal. Put another way, both parties would be better off (due to an extended "honeymoon period") over and above their costs, if each invested more.

In this light, the role of the procedure of fact-finding (and to some extent mediation) becomes apparent. The fact-finder will make his/her conclusions available to each party of a labor negotiation. The effect then is to raise the perceptive ability of both parties to a dispute. Moreover, as the costs of fact-finding are jointly borne, the costs to each party will be lower than if that party had to acquire equal perceptiveness individually. A competent fact-finder will have the effect of, not only facilitating the settlement of the current dispute, but of improving the bargaining relations of the parties by extending the "honeymoon period."

Considering that the individual payoffs for the players are inherently linked by the "tit-for-tat" design, another common negotiating practice can be explored. It is usually the case that, during labor negotiations, management is reluctant to open its books to inspection. It is often claimed that the risk that its competitors will somehow obtain a copy is too great. While this can be a legitimate concern, another important factor is often overlooked in the decision to keep the books closed. When it refuses to open its books to inspection during a labor negotiations, management is, in effect, reducing the perceptive ability of labor, thereby reducing both labor and management's average payoff. The only time this strategy could be optimal is if the risk of having the records leaked is sufficiently great to warrant a significant loss of perception.

Furthermore, the risk that labor will believe that management is being uncooperative is compounded by the knowledge that management is willing to reduce the possible payoff just to minimize a risk that labor will naturally find to be minimal. Labor might conclude, therefore, that management was trying to disguise the true nature of its position. In response, labor might be far less forgiving of any management move that labor perceives as uncooperative. Because of this danger, a management decision not to open the books during negotiations may well poison a bargaining relationship for some time, to the detriment of both parties.

ASYMMETRIC PERCEPTION OF FRIENDLY AND UNFRIENDLY MOVES

Where cooperative moves are more likely to be perceived as non-cooperative than non-cooperative moves being perceived as cooperative, the outcomes for both players will be reduced if they are pursuing "tit-for-tat." In the limit, if there is no possibility of an unfriendly move being perceived as friendly, then eventually both players will cease cooperating with one another, reaching the worst possible joint outcome (the "grim solution").

To demonstrate the reduced payoffs if misperception of friendly moves is more likely than misperception of unfriendly moves, a simulation was conducted in which both management and labor each had a payoff of misperceiving a friendly move as unfriendly of one in one hundred ($p = 0.010$). The probability of both perceiving an unfriendly move as friendly was then allowed to vary from zero to one in one hundred in increments of one in one thousandths ($p = 0.000$ to $p = 0.010$ with $\Delta p = 0.001$). Again the simulation had runs of 10,000 rounds repeated 100 times for each combination of probabilities.

Figure 6 illustrates the path of the average joint payoffs as the probability of misperceiving an unfriendly move as friendly is decreased from $p = 0.010$ to $p = 0.000$. As expected, the average joint payoff decreased as the probability of misperceiving an unfriendly move was decreased. The form of the relationship between the average payoff and the probability of misperceiving an unfriendly move as friendly appears non-linear. A statistical test rejected the hypothesis of a simple linear relation. When that probability became zero, the average joint payoff was very close to zero. The slight positive average payoff can be attributed to the initial rounds of the simulation in which there is a "honeymoon" (average joint payoff of 20) followed by a period of alternating recriminations (average joint payoff of 10). After these rounds, however, the "grim solution" will prevail *ad infinitum*.

To this point, the assumption has been that the players in the game each pursue "tit-for-tat" as their operating strategy. In light of the possibility of misperception, however, Dixit and Nalebuff [2, pp. 113-115] suggest that a more patient strategy is more appropriate. That is, they argue that one should not immediately respond in kind to a perceived uncooperative move by one's counterpart. Rather, one should take a longer view of the bargaining history of one's opponent, responding only if the opponent's past moves appear to be uncooperative with sufficient frequency.

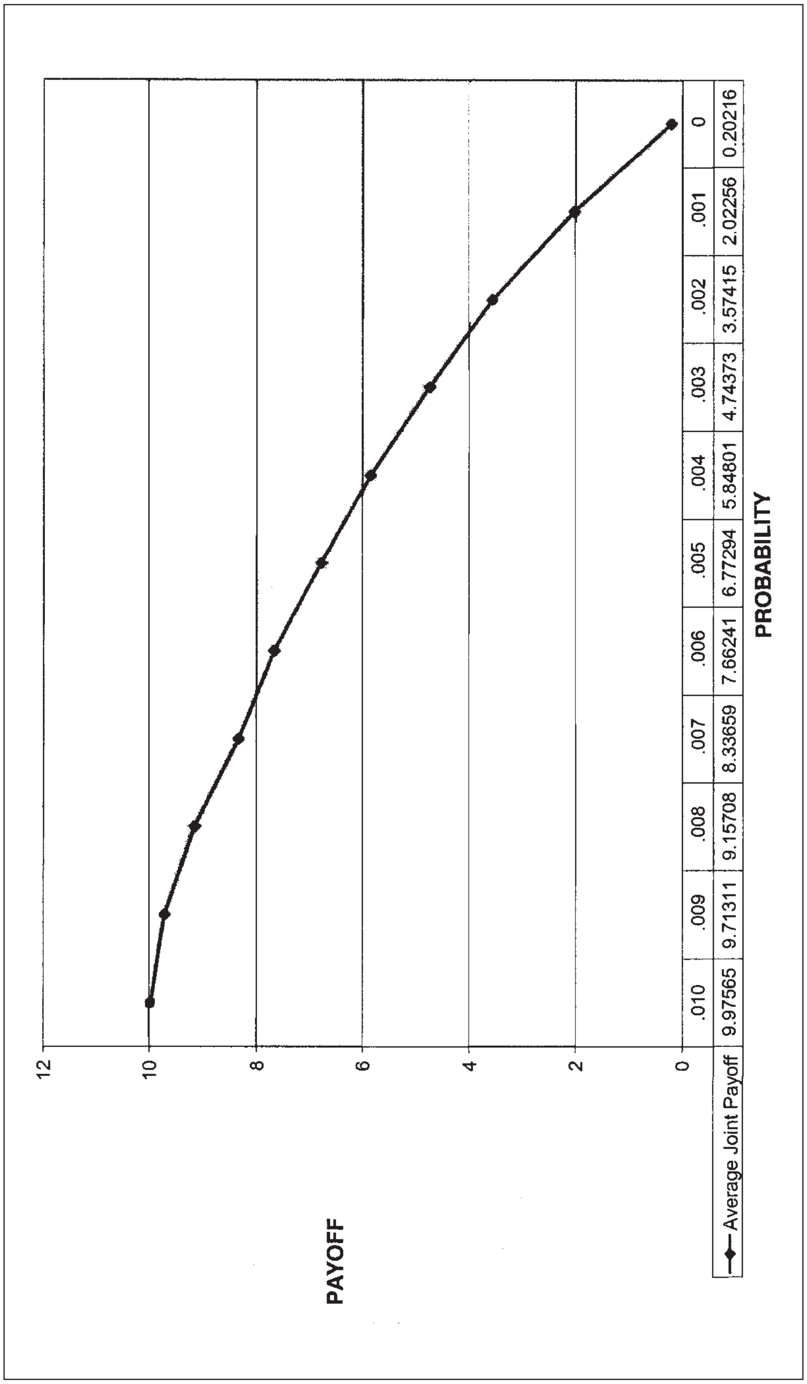


Figure 6. Average joint payoff.

The risk of not responding immediately to a perceived uncooperative move is that a player runs the risk of being victimized over any grace period that it might extend to its opponent. Note that the resulting payoff to the victim in the grace period would then be below that which it could obtain even in the "grim solution." Conversely, if a player does respond when it mistakenly detects a seemingly uncooperative move, that player runs the risk of unnecessarily initiating a period of alternating and/or mutual recrimination. If the probability of perceiving a friendly move as unfriendly is the same as the probability of perceiving an unfriendly move as friendly, then the parties playing "tit-for-tat" will obtain payoffs approximately equal to that which they could have obtained had they both played a random strategy (here, an average payoff of 5 for each).

If the probability of misperceiving an unfriendly move is less than that of misperceiving a friendly move, however, then a "tit-for-tat" strategy will yield average payoffs that are less than random. In the limit, as the probability of misperceiving an unfriendly move approaches zero, the average payoff will approach zero for each player (i.e., the "grim solution"). Faced with a move that appears to be uncooperative, a player must weigh the risk of being victimized against the risk of mistakenly setting off a period of mutual warfare. The choice of strategy is not clear-cut and should depend critically on the player's assessment of each risk.

CONCLUSION

The current inquiry examined the consequences of players pursuing a "tit-for-tat strategy" under a broader set of circumstances than was contemplated in earlier work by three of this article's authors.

First, where the abilities of players to perceive their opponent's move differed, increased perceptive ability conveyed no significant competitive advantage to an individual player. The only effect that increased perceptive ability of the players has is to increase the length of the initial period of cooperation. Moreover, the length of the "honeymoon period" is more dependent upon the perceptive ability of the less perceptive player rather than upon its more perceptive counterpart.

Second, where the probability of misperceiving a friendly move is greater than the probability of misperceiving an unfriendly move, the average joint payoff will be reduced below that which would be obtained if the probabilities were equal (i.e., that which would be obtained if both players pursued an entirely random strategy). In the limit where the probability of misperceiving an unfriendly move goes to zero, the players will receive only those payoffs that are associated with the "grim solution" of the game. Here, each player will receive a payoff of approximately zero. The reduced payoff caused by lowering the probability of misperceiving an unfriendly move adds to the downside risk of the period of alternating and/or mutual recriminations that would occur after a mistake is made during the "honeymoon period." In responding to a perceived uncooperative move then, a player must carefully consider the risk to its payoff inherent in this period of recriminations against the risk of being victimized by the other player.

APPENDIX

As before, let p_M be the probability that management misperceives labor's move in a given period and p_L be the probability that labor misperceives management's move in a given period. Then the probability that management will misperceive labor's move in period 1, but labor correctly perceives management's move in that period is $p_M(1 - p_L)$. Both parties will correctly perceive the other's move in any given period with probability $(1 - p_M)(1 - p_L)$. Then, the probability that management will misperceive labor's move before labor misperceives management's and that management's misperception first occurs in nth period is $p_M(1 - p_L)(1 - p_M)^{n-1}(1 - p_L)^{n-1} = p_M(1 - p_M)^{n-1} (1 - p_L)^n$. Consequently, the probability that management will misperceive labor's move before labor misperceives management's is the infinite sum of the probabilities that it will occur in any given period. That sum can be represented as:

$$M_M = p_M(1 - p_L) + p_M (1 - p_M) (1 - p_L)^2 + p_M(1 - p_M)^2(1 - p_L)^3 + ... = p_M(1 - p_L)/[1 - (1 - p_M) (1 - p_L)]$$

By symmetry, the probability that labor will misperceive management's move before management misperceives labor's is:

$$M_L = p_L(1 - p_M)/[1 - (1 - p_M) [1 - p_M) (1 - p_L)]$$

Because there are only three possibilities, the probability that management and labor will misperceive each other at the same time will be:

$$M_S = 1 - M_M - M_L = 1 - \{p_M(1 - p_L)/[1 - (1 - p_M)(1 - p_L)]\} - \{p_L(1 - p_M)/[1 - (1 - p_M)(1 - p_L)]\} = p_M p_L/[1 - (1 - p_M)(1 - p_L)]$$

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