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Due to a mix-up, entirely the fault of this editor, this article by authors Lawrence J. Haber, Nicholas Malin-Adams, and Joseph N. Khamalah entitled "Labor Negotiations, Misperceptions, and Repeated Prisoner's Dilemma: A Simulation" should have appeared in Vol. 32, No. 3 as it was the original piece on this subject. The article that appeared in Vol. 32, No. 3, "Labor Negotiations, Misconceptions, and Repeated Prisoner's Dilemma: Some Extensions and Afterthoughts," was prepared as an extension of the original article. I apologize to the authors for my error and hope this was not an inconvenience to our loyal readership.

LABOR NEGOTIATIONS, MISPERCEPTIONS, AND REPEATED PRISONER'S DILEMMA: A SIMULATION

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ABSTRACT

Parties to most labor negotiations generally have dual incentives. Each party has, on the one hand, the incentive to cooperate with the other for mutual benefit (similar to gains from trade), and, on the other, the incentive to compete with the other party for as large a portion of the gains as possible. These dual incentives can be represented in the form of a game of "Prisoner's Dilemma." In this game, however, each party would have the rational incentive to pursue a non-cooperative strategy rather than to cooperate for mutual gain. Consequently, the game would predict that there would be frequent work stoppages to the detriment of both parties. This article reports on the results of a simulation of the strategy commonly called "Tit-for-Tat" when applied to a situation where "Prisoner's Dilemma" is played repeatedly without a determinant end. Preliminary results show that if the game is

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played a large number of times, the effect of any misperception (even at very low probabilities) on the average payoffs of each party is drastic. In fact, the parties would do almost as well by simply randomly choosing whether or not to cooperate.

INTRODUCTION

In the course of most labor negotiations, the participants generally have dual incentives. Each party has the incentive to cooperate with the other for mutual benefit. That is, if an agreement can be concluded, both parties will benefit (similar to gains from trade). Each party also has the incentive to compete with the other side for as large a portion of the gains as possible. The dual incentives faced by each party to the negotiation can be represented in the form of a game of "Prisoner's Dilemma." The difficulty that ensues in this game is that each party in the game would have the rational incentive to pursue a non-cooperative (i.e., competitive) strategy rather than to cooperate for mutual gain. As a result, the game would predict that there would be frequent work stoppages to the detriment of both parties. See Haber and Wellington [1] for a more detailed treatment of the game of "Prisoner's Dilemma" in the context of labor negotiations.

While "Prisoner's Dilemma" is useful in representing the circumstances that would exist in an individual negotiation, it oversimplifies labor-management relations in that those relations develop dynamically over time. It is most often the case that labor and management frequently must negotiate with one another, not just over the terms of new contracts, but over a myriad of contract-related issues. From these repeated negotiations a bargaining history emerges. In essence, then, the parties are confronted with a situation in which the "Prisoner's Dilemma" game repeats with no determinant endpoint.

While there is no obvious best strategy to deal with seemingly unending games of "Prisoner's Dilemma," one strategy has emerged with many desirable properties. The strategy is commonly called "Tit-for-Tat." "Tit-for-Tat" requires that a player be cooperative in an initial negotiation. Thereafter, the player should simply mimic the "opponent's" move in the previous round of negotiations. Axelrod [2] asserts that "Tit-for-Tat" as a bargaining strategy has the advantage of clarity; niceness (it never is the first to cheat); provocability (it never ignores cheating by one's opponent); and forgiveness (it does not punish cheating too long). Further, Axelrod performed a simulation study in which he invited other game theorists to submit strategies to be pursued in a "Prisoner's Dilemma" game repeated 150 times. Then, he tested the submitted strategies in pair-wise contests. Although "Tit-for-Tat" could, by design, beat none of the strategies (the best it could do is tie), when Axelrod looked at the total performance of each strategy, "Tit-for-Tat" proved superior to the others. His work established "Tit-for-Tat" as a strategy against which others must be compared.

Dixit and Nalebuff [3], while recognizing the virtues of "Tit-for-Tat," find that it has a flaw when applied to human behavior rather than computer simulation. In particular, they assert that Axelrod's simulations [2] do not account for the possibility that one party might misperceive a move by the other. For example, if one party in a negotiation perceives a cooperative move as non-cooperative, then if each party follows a strict "Tit-for-Tat" strategy, what ensues is a round of negotiations in which one party is cooperative and the other is non-cooperative; that is, one party victimizes the other. In the next round, the victim retaliates by becoming non-cooperative while the original party cooperates. Dixit and Nalebuff [3] use the example of the feud between the Hatfields and the McCoys where the families alternate by attacking one another. The only way in which this series of events would change is if there is a second misperception.

One tactic that has been used with increasing frequency by employers in their negotiations with unions is the firm's lack of ability to pay either current wages or any wage increase. As Kochan and Katz [4] note, "Thus, the ability to pay is an important criterion to employers, but one that traditionally has met strong union opposition, except in severe financial crises and in smaller firms that are less likely to pose a threat to a union-negotiated wage pattern."

In the past several years, General Motors (GM), the National Hockey League (NHL), and several airlines (among others) have used financial distress, frequently with the explicit or implicit threat of bankruptcy proceedings and/or mass layoffs, as a bargaining ploy to wrest concessions in wages and benefits from their unions. The question that then faces the union is to what extent is the employer's claim of financial exigency justified and to what extent is the firm overstating its difficulty simply to obtain opportunistic advantage over the union.

Elkouri and Elkouri [5] note that while the management of a firm is required to submit credible evidence to support their claim of inability to pay, such evidence is likely to receive close, critical scrutiny by the other party. If the evidence is found lacking in any way, the other party will hotly contest it and the possibility of a cooperative solution will be reduced. For example, prior to locking out its players in 2004, the NHL hired Arthur Levitt, a former Securities and Exchange Commission (SEC) Chairman, Lynn Turner, former Chief Accountant of the SEC, and Eisner LLP, an independent accounting firm, to audit the profitability of the NHL's 30 teams. Levitt [6] reported that, in aggregate, the teams lost \$273 million for the 2002-2003 season. Yet, as noted by Ozanian [7], when Forbes.com did its own audit, it found that the league's losses over the same period were only \$123 million, less than half as much. Needless to say, the union cried foul, finding management's figures less than credible. This lack of credibility, in part, contributed to the breakdown of negotiations and to a work stoppage that wiped out an entire season of hockey.

The example illustrates that, in the course of labor negotiations, claims made by one party can be of uncertain validity. There is the possibility, then, that the other party may misperceive the claim. It may simply regard a credible claim as uncooperative or aggressive. The object of this inquiry is to examine the effects on the welfare of the participants in a labor negotiation if each participant pursues a "Tit-for-Tat" strategy in the face of some probability that their moves may be misperceived by the other participant.

METHODS

The incentives created in a single game of "Prisoner's Dilemma" are commonly analyzed within the context of a two-player game matrix which depicts the payoffs or rewards given to each player as a result of the interaction between them. Here, labor and management are assumed to be the two players. Each has the choice of pursuing a cooperative (conciliatory) or non-cooperative (aggressive) strategy in bargaining. The payoff received by one player, however, depends on the strategy pursued by the other. Although the object is to analyze their interaction through numerous rounds of negotiation, the payoffs in each round are structured in the manner portrayed in Table 1.

Note that management's (Player A's) bargaining stance determines the row of the matrix, and labor's (Player B's) stance determines the column. The payoffs are represented as ordered pairs with the first element of each pair representing A's payoff from a set of strategies and the second element B's payoff. Consequently, the total payoffs in each round are such that if both parties cooperate, the total joint payoff is 20; if one side is cooperative but the other isn't (to the detriment of the cooperative side), the total joint payoff is 10; and if both sides don't cooperate, their total joint payoff is 0.

Each player is assumed to play a strict "Tit-for-Tat" strategy, initially cooperating and subsequently following the opponent's move in the previous round. A random element is introduced to allow for the possibility of misperception. Beyond the initial round and with fixed probability, a player will either perceive the opponent's previous cooperative move as non-cooperative or the opponent's previous non-cooperative move as cooperative. In the simulation, the average total joint payoff is calculated over the rounds. Further, the probability of misperception is varied. Because the authors wished to examine the effects of even small probabilities of misperception, the probability was varied from one-tenth of one percent to one percent in increments of one-tenth of one percent (i.e., $p = .001$ to

Table 1. Joint Payoff Matrix

Player B / Player A	Don't cooperate	Cooperate
Don't cooperate	(0, 0)	(+20, –10)
Cooperate	(–10, +20)	(+10, +10)

p = .01 in increments of p = .001). The simulation was conducted repeatedly over a large number of rounds. At each probability, the computer simulation was run 10 different times over 100,000 rounds (10 × 100,000), 100 times over 10,000 (100 × 10,000) rounds, and 1,000 times over 1,000 rounds (1,000 × 1,000). The details of the programming of the simulation are discussed below.

Programming

The goal was to develop a mathematical model of "Tit-for-Tat" in a repeated "Prisoner's Dilemma" game that could handle millions of rounds. Microsoft Excel™ spreadsheet software[1] was used, with an add-on Bernoulli Binary Random Number Generator to simulate the players' mistakes in perception in the games. In the first round of the repeated game, each player begins by cooperating with the other. If there is no possibility of misperception in subsequent rounds, then each player following a "Tit-for-Tat" strategy would cooperate indefinitely. Thus, the Bernoulli Generator produces the mistakes that set off the periods of retaliation in the standard game of Prisoner's Dilemma presented in Table 1.

To simulate "Tit-for-Tat" mathematically, we used 1's (ones) and 0's (zeros) to represent moves and mistakes. Players using "Tit-for-Tat" simply play the same move their counterpart played last turn. So, if Player A (management) cooperated at the last turn and Player B (labor) misperceived that move, then Player B would not cooperate this turn, and vice versa. When the possibility of misperception is introduced, then the players' moves are simulated by the following formulae:

$$A_t = |(B_{t-1})-(\delta_{tA})|$$
$$B_t = |(A_{t-1})-(\delta_{tB})|$$

Where: $$A_t = \begin{cases} 1\_\ if\_\ A\_\ cooperates\_\ at\_\ time\_\ t \\ 0\_\ if\_\ A\_\ does\_\ not\_\ cooperate\_\ at\_\ time\_\ t \end{cases}$$

$$B_t = \begin{cases} 1\_\ if\_\ B\_\ cooperates\_\ at\_\ time\_\ t \\ 0\_\ if\_\ B\_\ does\_\ not\_\ cooperate\_\ at\_\ time\_\ t \end{cases}$$

$$\delta_{tA} = \begin{cases} 1\_\ if\_\ A\_\ misperceives\_\ B's\_\ move\_\ at\_\ time\_\ t-1 \\ 0\_\ if\_\ A\_\ correctly\_\ perceives\_\ B's\_\ move\_\ at\_\ time\_\ t-1 \end{cases}$$

$$\delta_{tB} = \begin{cases} 1\_\ if\_\ B\_\ misperceives\_\ A's\_\ move\_\ at\_\ time\_\ t-1 \\ 0\_\ if\_\ B\_\ correctly\_\ perceives\_\ A's\_\ move\_\ at\_\ time\_\ t-1 \end{cases}$$

Table 2 below illustrates Player B's moves under each possible contingency. Player A's moves are analogously constructed.

[1] Microsoft Excel is a registered trademark product of the Microsoft Corporation.

Table 2. Player B's Moves

1 = |1-0|	A cooperates at time t-1. B correctly perceives that move. B cooperates at time t.
0 = |1-1|	A cooperates at time t-1. B mistakenly perceives that move. B does not cooperate at time t.
0 = |0-0|	A does not cooperate at time t-1. B correctly perceives that move. B does not cooperate at time t.
1 = |0-1|	A does not cooperate at time t-1. B mistakenly perceives that move. B cooperates at time t.

The following equations of movement are used to convert the possible contingencies into the payoffs (denoted by π) for each player:

$$\pi(A_t) = (20 * B_t) - (10 * A_t)$$

$$\pi(B_t) = (20 * A_t) - (10 * B_t)$$

The possible payoffs for Player B at time t are illustrated in Table 3.

Again, Player A's payoffs are similarly constructed. Note that payoffs generated in this manner will yield the payoffs for each player in the Joint Payoff Matrix of Table 1.

Hypotheses

At the outset, there are two hypotheses that are tested here. The first is that for tests conducted over a given number of rounds, the probability of misperception and the average total payoffs to the players are inversely related. The rationale for the negative correlation is seemingly intuitive. A higher probability that a player will misperceive his opponent's move should, over time, lead to more misperceptions that should reduce the average payoff received by each player and, hence, the average total payoff. The second hypothesis is that for a given level of probability of misperception, the number of rounds over which the simulation is run is inversely related to the average total payoff. The rationale here is again intuitive. Given that the players begin by cooperating with each other, the only time that the total joint payoff is less than 20 is if one or both of the parties mistakes the other's move. The level of the probability of misperception then determines the length of a period over which the average payoff is 20. For example, if the probability of misperception of any individual move is one in a thousand, then the expected number of rounds before any misperception occurs is

Table 3. Player B's Payoffs

Player B's payoff	Players' moves at time t
(1*20) = (1*10) = 10	When both A and B cooperate
(0*20) – (1*10) = –10	When A does not cooperate, but B cooperates
(1*20) – (0*10) = 20	When A cooperates, but B does not cooperate
(0*20) – (0*10) = 0	When both A and B do not cooperate

approximately five hundred. As the number of rounds in the simulation increases, the length of what is called here the "honeymoon period" (during which the joint payoff in each round is 20) relative to the total number of rounds in the simulation decreases and so, consequently, should the average joint payoff.

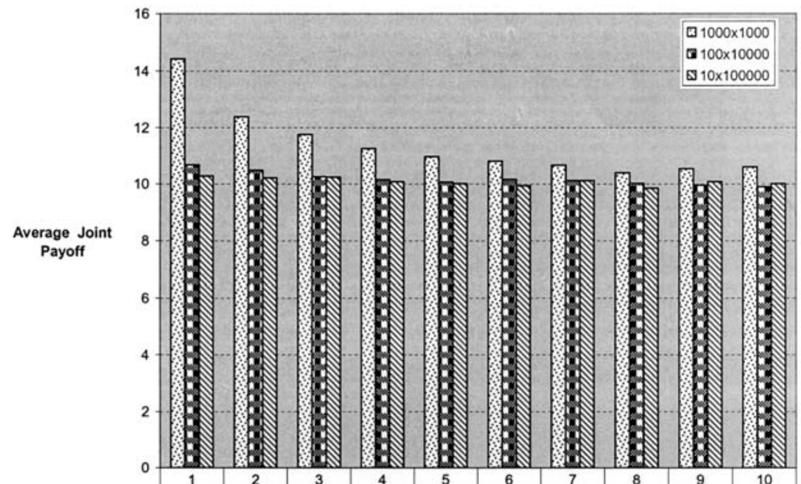
RESULTS

The average joint payoffs at different levels of probability of misperception are presented in Figure 1. A superficial examination of Figure 1 lends support to both hypotheses. With small exceptions, for a given set of runs, as the probability of misperception increases, the average total payoff to the players decreases for all three sets of runs. In addition, for a given probability of misperception and again with small exceptions, the more times the simulation is run, the lower the average total payoff to the players.

DISCUSSION

The results above tend to confirm our hypotheses, at least on a superficial level. A better understanding of these results, however, can be obtained by further analysis. At the outset of this discussion, it is profitable to construct a benchmark against which to view the simulations. In particular, if the probability of misperception was 50 percent ($p = .5$), then one player's actual move is perceived by the other correctly half the time and incorrectly the other half. Thus each party, adhering strictly to a "Tit-for-Tat" strategy, will cooperate half the time and not cooperate the other half. After the first round of the simulation, the pattern of cooperation would be entirely random. Each cell in the game matrix would have equal probability of occurring. Consequently, when the probability of misperception is 50 percent, the expected average joint payoff is 10.

What is striking about the results is that, even at low probabilities of misperception, the average joint payoffs differ little from the random result. Particularly



	1	2	3	4	5	6	7	8	9	10
1000x1000	14.4172	12.3881	11.762	11.2554	10.9665	10.8034	10.6668	10.3906	10.5352	10.5979
100x10000	10.6711	10.4811	10.2524	10.1484	10.0574	10.1563	10.1192	10.0174	9.94815	9.90097
10x100000	10.2761	10.217	10.242	10.0749	10.004	9.93049	10.1174	9.84789	10.0777	10.0077

P=.00X (thousandth)

Figure 1. Average joint payoffs

if the game is played enough times, the average joint payoff to the players quickly approximates 10. The explanation for average joint payoffs not differing greatly from that which would be obtained by a random selection of cells is that misperception can cut both ways. That is, in our simulation, it is equally likely that a party will perceive a non-cooperative move as cooperative as it is that the player will perceive a cooperative move as non-cooperative.

The simulations run, therefore, divide into two segments. The first is the initial "honeymoon" segment that occurs with each party cooperating with the other, and joint payoff of 20 in each round. The second segment begins with the first misperception by either party. The conjecture here is that once misperception occurs, the average joint payoff will not differ perceptibly from that which would be obtained from random assignment of cells in the game matrix (i.e., an average joint payoff of 10). Further, this average joint payoff in this segment should not vary systematically as the probability of misperception changes. The rationale for this invariance is that, although a lower probability of misperception gives a longer "honeymoon" period, it also creates a longer period over which the effects of misperceptions persist. The more certain that a party is of the moves of its opponent, the longer time it takes before another mistake occurs. If this surmise is correct, then the only reason that average joint payoffs differ from one another systematically is the percentage of each run that is consumed by the "honeymoon" period.

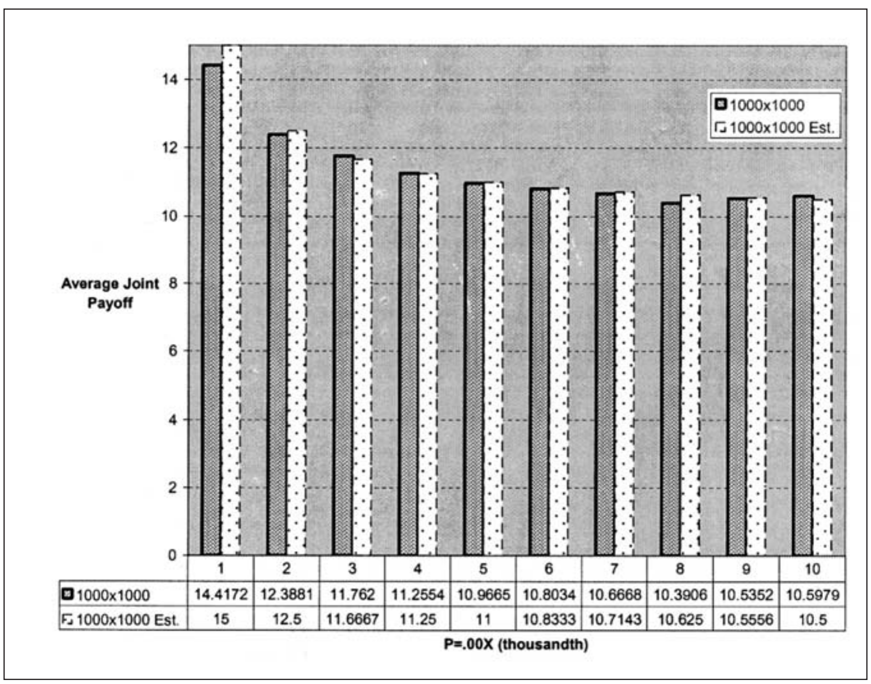
To test the conjecture, the expected average joint payoff was calculated for each probability in each set of simulations according to the formula:

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

where: P = the expected average joint payoff
H = the expected length of the "honeymoon" period
N = the number of rounds in the simulation.

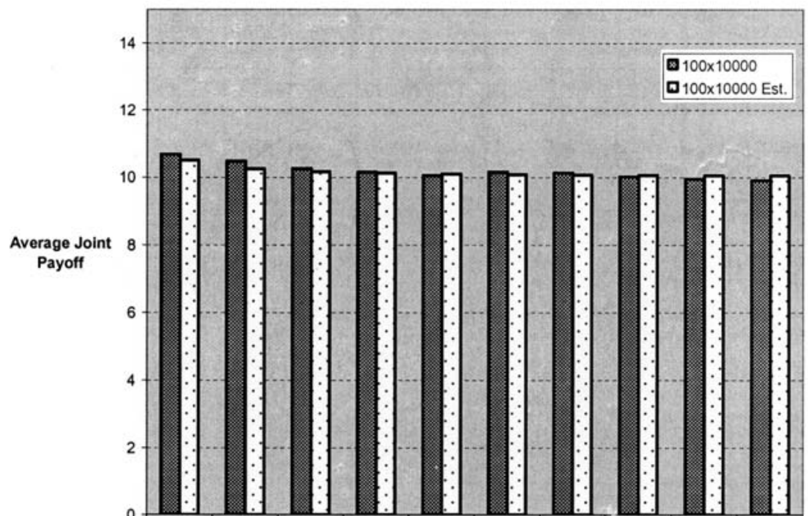
Figures 2, 3, and 4 compare the actual average joint payoff with the expected average joint payoff for each set of simulations.

The difference between the observed and the expected average joint payoffs was not statistically significant at the $\alpha = 0.05$ level. Moreover, the magnitude of those differences was relatively small in all of the cases, with the largest absolute value of the mean deviation approximating 0.13 of a point as can be seen in Table 4. Setting aside the initial "honeymoon period," it is unclear, then, that players pursuing a "Tit-for-Tat" strategy are materially better off than if they simply randomized their moves. In fact, in the one case where the absolute mean



	1	2	3	4	5	6	7	8	9	10
1000x1000	14.4172	12.3881	11.762	11.2554	10.9665	10.8034	10.6668	10.3906	10.5352	10.5979
1000x1000 Est.	15	12.5	11.6667	11.25	11	10.8333	10.7143	10.625	10.5556	10.5

Figure 2. 1000 × 1000 actual vs. expected average joint payoff.



	1	2	3	4	5	6	7	8	9	10
100x10000	10.6711	10.4811	10.2524	10.1484	10.0574	10.1563	10.1192	10.0174	9.94815	9.90097
100x10000 Est.	10.5	10.25	10.1667	10.125	10.1	10.0833	10.0714	10.0625	10.0556	10.05

P=.00X (thousandth)

Figure 3. 100 × 10000 actual vs. expected average joint payoff.

deviation is greatest (the 1,000 × 1,000 case), the average payoffs were worse in absolute terms.

IMPLICATIONS AND CONCLUSIONS

The close similarity between the conjectured distribution of expected average joint returns and the returns actually observed gives some credence to Dixit and Nalebuff's [3] observation that the possibility of misperception can wreak havoc on joint payoffs to players pursuing a "Tit-for-Tat" strategy. The findings of our simulations are that, once the initial period of joint cooperation ends with the first misperceived move, the subsequent average joint payoffs are neither substantially nor statistically better than random behavior would predict. The only effect that a decreasing probability of misperception has on the average joint payoffs is to increase the average length of the initial "honeymoon." A low probability of misperception, however, becomes a two-edged sword. Once the initial cooperative period ends, the smaller the chance of one party mistaking the move of the other, the longer the periods of non-cooperation will be.

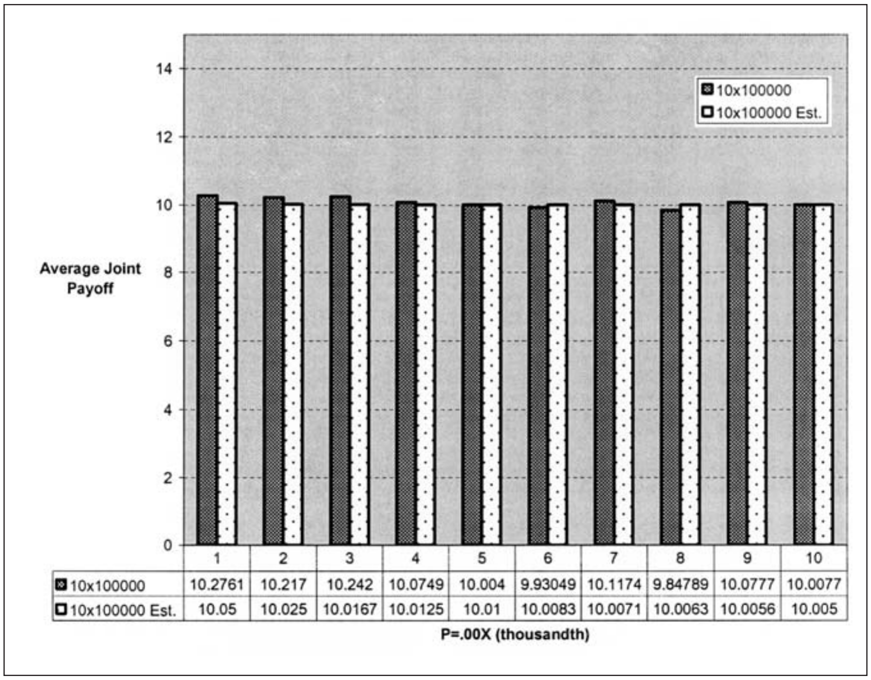


Figure 4. 10 × 100000 actual vs. expected average joint payoff.

Table 4. Deviation of Expected from Actual Distribution

Simulation run	*t*-Statistic	*p*-Value	Mean deviation	Absolute mean deviation
1,000 × 1,000	–1.370	0.102	–0.086180	0.125900
100 × 10,000	0.765	0.232	0.02792	0.097628
10 × 100,000	1.594	0.0725	0.064868	0.113312

If "Prisoner's Dilemma" is played over a sufficient number of rounds, then, the results for each player would not be substantially better than those obtained from random behavior. Before proceeding further, however, several comments are in order. First, recall that, in any round, the dominant strategy in "Prisoner's Dilemma" is not to cooperate. If both parties pursued that strategy continually, the average joint payoff would be zero instead of the 10 that the "Tit-for-Tat" strategy (with misperception) would yield. Thus, if both parties play "Tit-for-Tat" even when there is misperception, then the results will be intermediate between the continually cooperative strategy and the continually non-cooperative strategy. Second, when there is misperception, a pattern of alternating retaliation will frequently develop. As a result, one can expect a good deal of variation in each player's returns. Finally, one should not infer that a single party pursuing a "Tit-for-Tat" strategy will obtain the same payoffs as if he or she had pursued a random strategy. They are not equivalent. The case in which *both* players pursue a random strategy is simply used as a benchmark here.

Aside from the initial period of cooperation, the result that a mutually applied "Tit-for-Tat" strategy yields payoffs not discernibly different from a random strategy gives one occasion to doubt the utility of "Tit-for-Tat" as a panacea for the evolution of cooperative labor relations. In view of this difficulty, Dixit and Nalebuff [3] call for parties to pursue a more patient strategy because of the possibility of misperception, sometimes ignoring moves that they perceive as unfriendly in hopes of avoiding long periods of alternating retaliation. Clearly, if both parties were to trust the other sufficiently to write off seemingly unfriendly moves, then cooperative solutions would much more likely result. Dixit and Nalebuff's proposed strategy, however, discounts the danger of a single party adopting patience. Once the patient strategy of a player is perceived by the other, the other party has every incentive to test that patience to its limits. For example, once management knows that labor may not respond negatively to its moves for wage concessions, management will be far more aggressive in seeking those concessions. In short, a strategy that ignores moves that are perceived to be unfriendly leaves the party adopting that strategy vulnerable to being victimized.

Given that the intentions of each party to a business negotiation are not necessarily known to the other, the existence of misperception in those negotiations is commonplace. The question remains open as to whether a strategy exists that in the long run promotes cooperative solutions at least to the extent that the payoffs to the participants are better than would be obtained by a completely random strategy. Until such a strategy is found, contract negotiations will remain more art than science.

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