Efficiency-Enhancing Partnership Protocols for Two-Person Games: Laboratory Analysis

(extended abstract)

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Efficiency is a central concern in economics. In the study of strategic behavior in interactive decision theory (non-cooperative game theory), the Nash equilibrium and various refinements of Nash equilibrium are of primary importance as guidance for predicting behavior . But the inefficiency of many Nash equilibria is a concern in many contexts, both because of the sometimes extreme wastefulness implied, and because the equilibria often appear implausible as a prediction of real human behavior. The prisoners' dilemma is a well known and simple game that we will use for illustration, but the principles outlined here apply to two-person games generally, including (Bayesian) games of incomplete information. We will propose here an experimental analysis of two-person games to investigate the efficacy of various "protocols" for enhancing efficiency in games. These protocols range from simply allowing players to communicate with one another prior to play ("cheap talk") to well-specified mechanisms that players may voluntarily "opt into" in order to ensure more efficient outcomes. (the mechanism approach is based on recent theoretical work by Kalai and Kalai (2010)). The analysis is potentially important in many real-world contexts, such as collective bargaining and many kinds of bilateral bargaining situations in business and politics.

The standard prisoners' dilemma can be illustrated as follows:

PRISONERS' DILEMMA	Not Rat	Rat
Not Rat	100, 100	0, 150
Rat	150, 0	1, 1

The row player can either “Not Rat” or “Rat” and same for the column player, where “Not Rat” means not confessing your guilt and also implicating the other player, while “Rat” means confessing. If neither player rats out the other player, then both do well with a payoff of 100. But the payoff to each player is better playing Rat than Not Rat. If you rat out your partner, then you get a good payoff of 150 and your partner gets 0. Since the strategy Rat is a dominant strategy for each player, (Rat, Rat) is the unique Nash equilibrium for the game, and the players get a payoff of 1 each in this equilibrium.

This game perfectly illustrates the issues mentioned at the outset. The Nash equilibrium of this game is wildly wasteful. Payoffs 100 times larger for both players are available, but evidently are not enforceable as an equilibrium of the game. If one player believes the other will Not Rat, then it is in his or her interest to Rat. Would real players in a game with real payoffs (say, in dollars) actually both Rat out the other player? Experimental studies (from my own work and many others) show mixed results. The unique Nash equilibrium is surely not the unique behavioral outcome. Many players will attempt to achieve the cooperative outcome in early trials of a repeated version of the Prisoners’ Dilemma game (i.e., (Not Rat, Not Rat)), but more play will tend to be non-cooperative (Rat-ing) in later trials, for randomly matched subjects (i.e., in each trial players are randomly re-matched. The analysis here does not apply to repeated play between the same two players).

We now illustrate the two main *partnership protocols* (the term comes from Kalai and Kalai (2010)) that we propose to study, for the prisoners’ dilemma. The first is simply to allow subjects to discuss the situation prior to making their decisions. This is not the same as making a binding commitment, which would, obviously, solve the problem and make it easy for players to achieve the efficient solution where each gets a payoff of 100. The question is whether such “cheap talk,” which does not guarantee that the other player will do as he or she says, is sufficient to achieve the efficient outcome. My own recent work in other contexts suggests that such talk may be effective. For example, (with Ebru Isgin, a graduate student) I have studied the following labor market situation in the laboratory. Employers make wage offers that employees may accept. Upon accepting an offer, the employee then chooses an effort level. Effort is costly to the employee, but increases the overall profitability of the relationship. We find that when employers and employees can engage in “cheap talk” (via computer “chat boxes” on the computer screen) prior to contracting, wage levels and effort levels are significantly higher and outcomes are much nearer to the efficient level. There is nothing forcing subjects in these experimental labor markets to do as they say, but nonetheless then tend to do what they say, and they tend to be believed.

This simple kind of partnership protocol may work well in simple games of complete information, such as the prisoners' dilemma, but with games of incomplete information things are much more complicated. Kalai and Kalai (2010) have proposed formal partnership protocols for such games, and our analysis follows directly from their work. I will first illustrate the principles with the prisoners' dilemma, and then discuss the implementation of a protocol for one of the games of incomplete information that we propose to study.

First, observe that any two person non-cooperative game can be decomposed into two simpler-to-solve games, consisting of a cooperative "team game" with an obvious solution and a competitive zero-sum game, which also has a relatively straightforward solution. The team game is constructed simply by adding up the payoffs in each cell, dividing the total by 2, and giving each player that amount. For the prisoners' dilemma, as above, the corresponding team game is given by:

TEAM GAME:	Not Rat	Rat
Not Rat	100, 100	75, 75
Rat	75, 75	1, 1

The obvious solution is to choose the cell with the highest payoffs for both players, and this is self-enforcing—there is no reason to deviate from this solution. In fact, Not Rat is a dominant strategy for both players in the team game. The competitive game is constructed by taking the difference between the row and column player payoff, and the difference between the column and row player payoff, in each cell, and dividing each by 2. For the prisoners' dilemma, the corresponding game is given by:

COMPETITIVE GAME	Not Rat	Rat
Not Rat	0, 0	-75, 75
Rat	75, -75	0, 0

Notice that summing up the payoffs in the team game and the competitive game cell by cell gives the original payoff matrix for the prisoners' dilemma. The solution for the competitive game is the "min-max" solution: choose the strategy that will minimize the maximum that your partner can achieve. It also happens to be the Nash equilibrium in this game (Rat is a dominant strategy for both players in the competitive game). The solution is for the row player to choose Rat and for the Column player to choose Rat.

The formal partnership protocol gives the players the choice of opting in. If both players opt in, then the understanding is that they will play the team game and receive payoffs accordingly. They will also, at the time that they choose whether or not to opt in, indicate their strategy choice for the competitive game. If both players opt in, then the competitive game choices will also be implemented for the competitive game. If one or both players do not opt in, then they simply play the original prisoners' dilemma game, using the competitive game strategy choices as the choices for the original game.

While we have motivated this study via game of complete information, our main interest lies in the study of games of incomplete information. I will now outline the analysis of a "double auction," or bilateral trade situation, in which there is one buyer and one seller who may potentially trade at a mutually advantageous price. To make things concrete, suppose there is a buyer who has a resale value for the object to be traded of v, and a seller who can produce the object to be traded at a cost of c. If the object is traded at a price p, then the buyer's profit is v-p and the seller's profit is p-c. But this is a game of incomplete information. The buyer's value v lies somewhere in the interval [0,100] and the seller's cost c lies somewhere in the interval [0,100] as well. The agents each learn their own value or cost parameter prior to trading, but the agents do not know the other agent's parameter. If the value and cost parameters are both independently uniformly distributed, then trade is only feasible half of the time. That is, on average, only half of the time will the buyer have a value that exceeds the cost of production, so that it would, in principle, be possible to find a price that lies in between v and c, giving both agents a positive profit.

The mechanics of the game are as follows. The buyer and seller simultaneously submit an offer price, Po (from the buyer) and an asking price, Pa (from the seller). If Po>=Pa, then trade occurs at the price (Po+Pa)/2. If Po<Pa, then there is no trade, and both players get 0. Theoretical analyses of this game have demonstrated that, although trade is feasible half of the time, it is not possible to ensure that trade occurs whenever it is mutually profitable (Chatterjee and Samuelson (1983) and Myerson and Satterthwaite (1983)). The decomposition outlined

above, as well as the simple “talk only” protocol, seems to hold some promise for this game. There are some subtle issues of information revelation that must be dealt with, which I briefly outline here. We report here on results for initial sessions run for the bilateral trade game, although exactly the same design issues arise in any other Bayesian game of incomplete information, so the experimental plan is quite general.

Buyers and sellers learn their values prior to trade. In a simple talk-only partnership protocol, the talk could occur either prior to the parties having learned their private information, or subsequent to them having learned their private information. Obviously the degree to which one could verbally commit to some particular action is more limited if discussions occur prior to knowing relevant information. But it would still be possible to speak in general terms about the sort of policy one intends to follow (e.g., a buyer could indicate an intention to offer to pay a fixed amount less than whatever the redemption value turns out to be, or the seller could indicate an intention to ask a fixed amount above the cost of production). Similarly, Kalai and Kalai (2010) have proposed formal partnership protocols for *ex ante* (before values and costs are known) contracting and *interim* contracting (after values are known, but before they are revealed to all). In both cases, in order for the mechanisms to work as proposed, it is necessary that both the value and cost is known and revealed to both parties after trade occurs. This is because the formal protocol solutions involve a team game in which the joint proceeds from the partnership, v-c, are shared equally. The competitive part of the decomposition is similar to that illustrated for the prisoners’ dilemma above, in that no actual shifting of payoffs occurs. However, in asymmetric versions of the bilateral trading game, where one or both parties have other outside options for trading, the competitive part of the game can be non-trivial. We plan to investigate further incomplete information games, including these asymmetric versions of the bilateral trade game. At present we have only conducted an experiment for the symmetric bilateral trade game. We have used the design illustrated in the following table:

Design and Efficiency of Trade in the Different Treatments		
	No talk	Talk prior to trade
Trade only, ex ante	73%	81%
Trade only, interim		70%
Ex ante protocol	87%	90%
Interim protocol	82%	84%

There are 7 cells in the design. The "talk only " protocols are achieved by crossing an environment in which players can only trade (no formal mechanism) with a condition in which there is pre-contracting talk via computer chat boxes. For trade-only games, the ex ante and interim distinction is only meaningful in the "Talk prior to trade" column, as players will always have their information prior to actual contracting. The ex ante and interim protocol rows refer to an environment with the formal opt-in choice, executed either prior to or after private information is revealed to traders. We study both an environment in which only the specifics of the protocol are addressed (the left column) and an environment where free-form discussion is possible prior to consideration of the formal protocols (right column).

Initial Results

We have conducted one session for each of the seven cells in the design outlined above, and will later conduct a second session in each cell to ensure that the results we find can be replicated. Each session was conducted with a group of subjects (usually 20 in a session, except for We find that the formal mechanisms significantly increase the efficiency of trade in both the ex ante and interim cases. Specifically, in the baseline game, traders captured 73% of the available surplus (compared to a theoretical maximum of 84% possible with optimal strategies). Efficiency rises to 87% and 82% for the ex ante and interim mechanisms, respectively, and further rises to 90% and 84% when cheap talk is also allowed with the mechanisms. When only cheap talk is allowed, traders capture 81% (for ex ante talk), but only 70% (for interim talk). On average, 55% of trading pairs opt in to mechanisms when they are available. Further analysis will investigate the nature of bidding behavior in the absence of partnership protocols, and the determinants of the opt-in choice when a protocol mechanism is available. We will also analyze the communication that occurred in the games, particularly in light of the evident failure of simple cheap talk to enhance efficiency in the interim case, and the relative success in promoting efficiency in the ex ante case. These can also be contrasted with the nature of communication in the context of formal mechanisms, where communication further enhanced efficiency relative to both the ex ante and interim mechanisms without communication.

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