Coordination

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Abstract: Many economic games have multiple equilibria, some of which are better than others for everyone involved. Such coordination games are of special interest to economists since they raise the possibility that a group of individuals, or even a whole economy, might become mired in an unfavorable situation. This paper explains how to use playing cards in the classroom to implement an economic game with multiple, Pareto-ranked equilibria. Discussion can focus on policies and institutions that promote coordination on better outcomes.

Use: This experiment can be used in introductory economics to teach concepts of team production and coordination, and in intermediate microeconomics to teach game-theoretic concepts of Nash equilibrium and Pareto-optimality.

Time required: five minutes for reading instructions, twenty minutes for decision making, and about fifteen minutes for discussion.

Materials: You will need one or more decks of playing cards; each deck accommodates twenty-six people. One copy of the instructions should be made for each person. Payment to a randomly selected individual is optional and will require about a dollar or two.

JEL codes: A22, C72, C92

1. Introduction

Coordination problems arise naturally in many economic contexts. For example, in large organizations it is necessary to synchronize specialized divisions in order to avoid production bottlenecks. Low effort on the part of one worker or division can hold up the whole process, and it may not be worthwhile for a particular worker to exert high effort if others are not doing the same. In this sense, the organization may reach an equilibrium in which low effort prevails, even though all would be better off if they could share the gains from a high-effort, high-output situation. A similar problem may arise in macroeconomic contexts where high employment in

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one sector may increase the marginal product of labor in another. Some neo-Keynesians have used coordination games to justify the possible role of macroeconomic policies to move the economy to a better equilibrium.

This paper describes how to use playing cards to set up a series of classroom coordination games, with little advance preparation. Each player must make one of two decisions, which can be interpreted as "high" or "low" efforts, with high effort being more costly but potentially more productive if it is matched by others. There is an equilibrium in which all choose low efforts, and there is a better equilibrium in which all choose high efforts. These equilibria are not affected by noncritical changes in the cost of effort or in the number of participants. In contrast, intuition suggests that coordination on the high-effort outcome would be more difficult with more participants and higher effort costs. The classroom game helps students discover the essential tension in a coordination game between safe (e.g. low-effort) decisions and risky attempts to reach a better (e.g. high-effort) outcome. In more advanced classes, you can discuss the presence of multiple, Pareto-ranked Nash equilibria, and the sensitivity of behavior to payoff parameters like effort costs or group size that do not affect this set of equilibria. Depending on the level and nature of applications discussed, these games are appropriate for undergraduate and M.B.A. courses in microeconomics or macroeconomics, and for any course that uses applied game theory, such as industrial organization, law and economics, or managerial economics.

2. Procedures

This exercise takes about thirty-five to forty-five minutes to read instructions, play the game, and discuss results. Start by giving each student a copy of the instruction sheet and two playing cards, one red (Hearts or Diamonds) and one black (Clubs or Spades). Thus each deck of cards can accommodate up to 26 participants. The instructor should begin by reading the instructions out loud to the class, which turns out to be a good way to anticipate questions and establish the appropriate atmosphere. In fact, an effective way for the instructor to prepare before class is to read the instructions in order to envision how the setup will appear from the students' point of view.

As explained in the instructions, each student is matched with another person, and each chooses a card to play, red or black. A person who plays the red card earns $1 no matter what the other chooses. In contrast, a person who plays the black card earns $4 if the other also plays black, but earns nothing if the other plays red. In this sense, playing the black (high-effort) card is riskier but potentially more profitable. Since only the colors of the cards matter, it is better to use decks with cover patterns that are neither red nor black. The use of the playing cards avoids suggestive terms like "high effort," which emphasizes the basic incentive structure of the game. Finally, it helps to write the payoff rules (in words and dollar amounts) on the blackboard or on a transparency, perhaps using colored markers. We do not show a payoff matrix at this stage, since its construction can arise naturally from the discussion that follows (see below).

The process begins when students are asked to play a card by holding it against their chests. This guarantees that they do not observe others' decisions. Moreover, the instructor can see who has already made a choice and who needs more time. Once students make their choices, the instructor can select pairings more or less randomly by pointing at two students spontaneously and saying: "You and you, please reveal your choices." If the class has fewer than twenty students, ask everyone to make choices at the same time before the random matching. With larger classes, pool people in groups, perhaps composed of one or two rows of seats, so that they can be paired with someone else in the same group after making their choices.

One variation that stimulates a lot of discussion is the use of more than two people in each matching, in order to evaluate coordination problems among larger numbers of people. To proceed, select groups of about ten people. Ask students to make their choices in the same way as previously, but note that earnings depend on the choices of all people in a given group. Playing the red card results in a $1 earning regardless of others' choices (as before), but playing the black card yields $4 only if all people in the same group choose black; otherwise, it yields $0. The instructions in the Appendix are set up for two-person matchings in periods 1 and 2, followed by games with larger numbers of participants in periods 3 and 4. There are two additional rows in the instructions for recording earnings for periods 5 and 6, in case the instructor tries a variation in which the gains from coordination on black are reduced from $4 to $2 (as discussed below).

Although earnings may be hypothetical, small monetary payments help to increase interest, especially in a game like this where market competition is not a factor. You can announce, in advance, that you will pick one person at random, *ex post*, and pay that person ten percent of their total earnings in cash, as explained in the parenthetical sentence in the instructions appendix. The cash required would be between $1.00 and $2.00 for a ten percent payout rate over four-six periods.

To summarize, the only advance preparation involves copying an instruction sheet for each person and securing enough playing cards to give each person one red card and one black card. Distribute these materials, read the instructions out loud, ask groups of students (by row) to make decisions, and pair them randomly until all in a given group have revealed their choices. This can be repeated until each person has made two decisions. Then read the second part of the instructions that explains payoffs when students are playing in larger groups. The large-group games can be repeated once, before moving on to a change in the incentive to coordinate (if desired) and the discussion of results.

3. Discussion

About 91 percent of the students in an introductory class coordinated on the high-payoff equilibrium (black/black) in two-person matchings. These same students later chose black only about 66 percent of the time when placed in groups of six to eight students (seated in their own row). In the final period, all 28 students were placed in the same group, and the rate of black choices fell to 14 percent. One way to initiate discussion is to find people who played black in the two-person matchings and switched to red in the large-group variation, and then ask them to explain their choices. Most recognize that it is riskier to attempt coordination in larger groups because the gains from doing so require that all make the same choice. In this card game, it only takes a single red card choice to destroy the potential benefits from playing black.

Another approach is to ask whether playing black is a stable or self-enforcing situation. In this manner, you can let students try to figure out the notion of an equilibrium in which nobody has an individual incentive to change his or her behavior, given that the others do not change their decisions. In the end, you may have to ask the direct question: "If you knew that the other person would play black, which card would you play? And if the other person knew that you would play black, which card do you think he or she would play? In what sense is it an equilibrium for both people to play black? What if you think the other will play red and the other thinks you will play red?" Then ask whether a change in the group size prevents all playing black from being an equilibrium. Only after some discussion should you point out that it is a Nash equilibrium for all to play black, regardless of group size. Students may have difficulty with this conclusion, citing the increased risk of someone switching to red in a large group. Here it is useful to make a distinction between the stability of an equilibrium once it is reached and the process of learning and adjustment that may or may not converge to such an equilibrium.

Table 1. A Coordination Game

		Column Player	
		Red	Black
Row Player	Red	(1, 1)	(1, 0)
	Black	(0, 1)	(4, 4)

Only after this type of discussion is it useful to let students construct a payoff matrix for this coordination game, as shown in Table 1. The number before the comma for each payoff pair represents the row player's payoffs. If either person plays black, then the other's best response is to play black too, so black/black is an equilibrium with payoffs of $4 each. On the other hand, the best response to the play of a red card is also red, and this constitutes another equilibrium, with $1 payoffs. The black/black equilibrium is better for both, i.e. it is "Pareto dominant". The effort interpretation can be explained: low effort results in revenue of $2 and an effort cost of $1, for net earnings of $1. A high effort results in an effort cost of $2, but does not raise the revenue if the other person chooses low, in which case the net earnings are zero. If all participants choose high effort, the revenue per person rises to $6, so the net earnings are $4, as shown in Table 1.

Another variation in the game that affects behavior without changing the pure-strategy equilibria (red/red and black/black) is to reduce the gains from successful coordination from $4 to $2, which changes the $4 payoffs to $2 payoffs in Table 1. The rate of black (high-effort) decisions fell from 91 percent in one class with the $4 setup to 71 percent in another class with the $2 setup.[1]

It is important for class discussion to lead students to discover richer economic applications with elements of coordination. You can begin by asking them to think of situations that are similar to coordination games. One effective way to do this is to divide the class into discussion groups of 3-5 students and ask each group to come up with an example. The instructor can walk around and listen to the group discussions and help if necessary. If students cannot come up with examples, ask them to think of coordination problems that they might often face, such as getting together with friends at a restaurant, or studying in groups. If your friends are on time, you would be happier arriving on time; however, if they are late, you would prefer to be late too. You may then relate being on time to working hard in a large organization with specialized production tasks, as discussed in the introduction. Since coordination is harder with large groups, ask why some actual organizations are not small, which raises issues of economies of scale, monitoring, and team incentives.

Economy-wide coordination problems can be stressed in development and macroeconomics classes. Here, you can interpret playing red as production within the household, and playing black as taking goods and services to exchange in the market. Loosely speaking, market exchanges can be very profitable in thick markets that allow specialization of labor and the exchange of a wide variety of goods. But if market activity is low, then the less risky option of household production may be better. Public transportation, day-care subsidies, and good communications and legal infrastructures can promote highly coordinated, developed economies.

It is interesting to compare the coordination game with a prisoner's dilemma. Students may have seen a prisoner's dilemma in other economics or social science classes, and these people are likely to think that the classroom coordination game is a prisoner's dilemma. If you ask how these games differ and the answer is unclear, then follow up with a question about how a prisoner's dilemma could be set up with playing cards. For example, playing the red card

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[1] In a game theory class, you can show that this change in behavior is not explained by resorting to a Nash equilibrium in mixed strategies. Assuming risk neutrality, the mixed equilibrium probability of playing black is .25 in the $4 treatment, and it is .5 in the $2 treatment, which is qualitatively opposite the change in observed behavior.

could correspond to "taking" $1 for oneself, and playing the black card could correspond to "giving" $4 to the other person, so that you always have a selfish incentive to take even if the other gives $4 to you.[2] You can then review the payoffs for a typical prisoner's dilemma and ask how it differs from a coordination game, which leads to discussion of what is meant by an equilibrium. In particular, the highest joint payoffs are self-enforcing in a coordination game but not in a prisoner's dilemma, where each person has an incentive to defect. Duopoly price competition, for example, may be more like a prisoner's dilemma, because sellers typically are tempted to cut price if it becomes too high. Thus the problem for players in a prisoner's dilemma involves both coordination and enforcement, whereas the enforcement problem is not an issue in a coordination game.

4. Further Reading

Macroeconomic applications of coordination models are discussed in Bryant (1983, 1996) and Cooper and John (1988). There have also been a number of laboratory studies of coordination games. In controlled experiments, coordination is enhanced by non-binding pre-play communication in which subjects notify others of intended decisions before making the actual decisions that determine their payoffs (Cooper et al. 1992). In addition, an increase in the number of players or in the cost of effort results in lower effort levels, even in games where these changes do not affect the set of pure-strategy equilibria (Van Huyck, Battalio and Beil 1990; Goeree and Holt 1998). These laboratory results are intuitive: it is riskier to provide a high effort when effort is more costly or when there are more people who must coordinate to make this strategy worthwhile.

Theorists have become interested in these behavioral patterns that are not explained by a standard Nash equilibrium analysis, and a number of explanations have been proposed. Crawford (1991) introduces evolution and learning into the analysis of coordination; the idea is that people will tend to move towards high (or low) effort levels if they see others doing the same. Anderson, Goeree, and Holt (1996) propose an equilibrium model with logistic decision

[2] Holt and Capra (1997) describes how to use playing cards to set up classroom prisoner's dilemma games. A number of economic applications are discussed.

error that provides a remarkably accurate prediction of "final period" effort levels in the Goeree and Holt (1998) coordination experiments. They show that simple learning models with logistic decision error explain the increase in average efforts over time in experiments with low effort costs (and the analogous decrease with high effort costs).[3] Ochs (1995) surveys some of the earlier literature on coordination game experiments, and Romer's (1996) graduate macroeconomics text summarizes both theoretical and experimental work.

[3] These interesting dynamic patterns are not explained by Crawford's (1991) model, since it specifies an adjustment rule that is a linear function of a player's previous decision and the best response to the other decision(s) observed in the previous period. The best response is to match the other's effort (or the minimum of others' efforts) regardless of the effort cost, so the predicted adjustments are independent of the effort cost.

Appendix

We are going to play a card game in which everybody will be matched with someone else in the room. Each of you should now have a pair of playing cards, one red card (Hearts or Diamonds) and one black card (Clubs or Spades). The numbers or faces on the cards will not matter, just the color. You will be asked to play one of these cards by holding it to your chest (so we can see that you have made your decision, but not what that decision is). Your earnings are determined by the card that you play and by the card played by the person who is matched with you.

If you play your red card, you will earn $1 regardless of what card is played by the other person. If you play your black card, you will receive $4 if the other person also plays a black card, and you will receive $0 if the other plays a red card. To summarize,

your earnings =
$1 if you play a red card
$4 if you play a black card and the other plays a black card
$0 if you play a black card and the other plays a red card.

All earnings are hypothetical, except as noted below.

After you choose which card to play, hold it to your chest. Then we will you who you are matched with, and you can each reveal the card that you played. Record your earnings in the space below. (Optional cash payout method: After all periods are finished, one person will be selected with a random draw to receive 10% of his or her total earnings, in cash. All earnings for everyone else are hypothetical.)

To begin: Would the people in the group (or row) that I designate please choose which card to play. Show that you have made your decision by picking up the card you want to play and holding it to your chest. Now, I will pair you with another person, ask you to reveal your choice, and calculate your earnings. You should record decisions and your earnings in the space provided below. Finally, please note that in each period you will be matched with a different person.

period	your card (R or B)	other's card (R or B)	your earnings
1.	_____	_____	_____
2.	_____	_____	_____

In the next period, you will make your decision at the same time as those in your group (e.g. your row). As before, you earn $1 if you play your red card, regardless of what cards are played by the other people in your group. If you play your black card, you will receive $4 if all of the others in your group also play a black card, and you will receive $0 if one or more of the others play a red card. I will tell you in advance which members of the class are in your group. To summarize,

your earnings =
$1 if you play a red card
$4 if you play a black card and all others play their black cards
$0 if you play a black card and someone else plays a red card.

period	your card (R or B)	all black cards (B) or at least 1 red card (R) (R or B)	your earnings
3.	_____	_____	_____
4.	_____	_____	_____

In the final two periods, you will be paired with only one other person, as was the case originally. But the payoffs for playing a black card have been changed;

your earnings =
$1 if you play a red card
$2 if you play a black card and the other plays a black card
$0 if you play a black card and the other plays a red card.

period	your card	other's card	your earnings
5.	_____	_____	_____
6.	_____	_____	_____
		total earnings for all periods:	_____

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