CHAPTER 11 Collective-Action Games

TEACHING SUGGESTIONS

A good way to introduce the topic of coordination games is to have the students play one. There are two suggestions below. One can be used to lead into a general discussion of the issues surrounding games of this type; the other can be used as a numerical example for a game with a prisoners' dilemma structure. Another way to play such a game can be used if you give frequent quizzes; you can prepare the class by including one of the game questions as the last question on the quiz the week before.

Another way to start the topic is to ask the class why, with so many different styles of dress available, all students are dressed pretty much alike (these days you will find most male students and many females wearing reversed baseball caps, jeans, and flannel shirts with shirttails' hanging outside). The answer will usually be some variant of "conformity to the group norm" or "seeking peer approval." You can develop these suggestions into the ideas that conformity creates a positive feedback, uniformity is the equilibrium outcome of such behavior, or some other chance development could have led to a different equilibrium where the common dress style was something else. It is then possible to develop a diagram like the PC–Mac one in the text out of this discussion and to talk about the different equilibria that might arise in different situations.

Ask the students for stories of attempts, successful or otherwise, to get volunteers in their high school class or their community for some worthy project such as cleaning up a local beach. Relate the arguments given for participating or shirking, and the reasons for the success or failure of the project to the conceptual ideas in this chapter. You can make connections here to the second game described below which is essentially a test of player willingness to contribute to a public good or to the third game which deals with the problem of a common resource.

Many examples of prisoners' dilemma–type collective-action games can be found. Here is one about a group of college students and their decision to participate in a dorm cleanup: Suppose that there are 100 residents of the dorm. If n of them choose to work on the cleanup, then the benefit to each one, measured in dollars, is $B = n - (1/200)n^2$. For each student the cost of the approximately 5-hour cleanup is \$40. Then each student gets a net payoff of 0 if no one works and a net payoff of 50 – 40 = 10 if everyone works.

To analyze this collective-action game, you need to look for the equilibrium participation choices of the students. If n other students are working, then an individual student's payoff from choosing to work with the group is

$$(n+1) - \frac{(n+1)^2}{200} - 40$$

and his payoff from choosing not to work (choosing to shirk) is

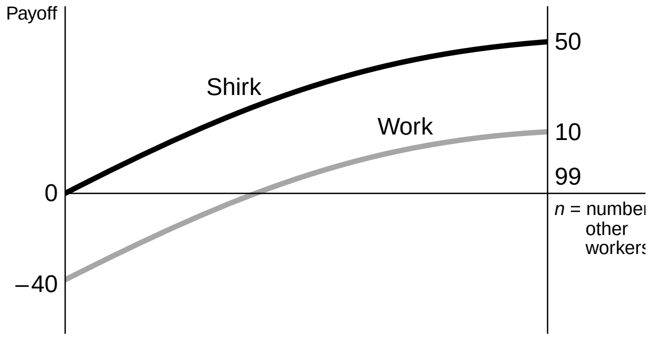
$$n - \frac{n^2}{200}$$

Then the student will shirk if

$$(n+1) - n - \frac{(n+1)^2 - n^2}{200} - 40 < 0$$

or if $-(2n + 1)/200 - 39 < 0$, which is always true. Every student will want to shirk.

Another way to illustrate this outcome is with a diagram showing the payoffs to an individual student from working and shirking given different numbers of other students who have chosen to work. Such a diagram for this example is shown below:



Note that the payoff from shirking is always higher than the payoff from working, regardless of how many other students are already working. This game fits the description of a multiperson prisoners' dilemma.

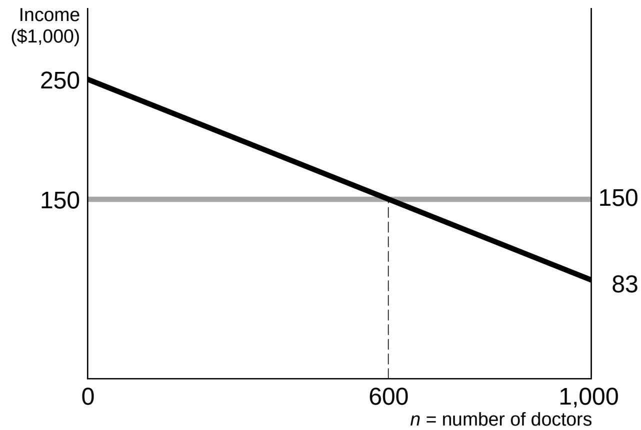
Consider how to resolve this dilemma: (1) Use the repeated (ongoing) relationship among dorm residents and punish shirkers (through ostracism or exclusion). (2) Establish a social norm of participation; then shirkers entail a cost—shame, and so on. (3) Reward workers with money, an office, and so on. (4) Take advantage of the existence of people who have larger benefit (or smaller cost) who take the lead in organization, and so on. (5) Resort to external enforcement (administration or government), but the enforcing institution may be poorly informed. The same type of analysis applies to natural resource management.

Where is the aggregate optimum in this game? You need to find the n that maximizes

$$100[n - (1/200\ n^2)] - 40n = 60n - (1/2\ n^2)$$

That n solves $60 - (1/2)2n = 0$; $n = 60$. Each worker's payoff is $60 - 3{,}600/200 - 40 = 2$, and each shirker's payoff = 42. There is an additional problem of distributive justice of this optimum; who should be allowed to be a shirker? You can solve this problem in a repeated game using a rotation scheme; in a one-shot game, the problem can be solved with side payments (from shirkers to workers).

The other most easily constructed examples are those involving externalities. Consider an example based on career choice decisions of students in your class: Suppose there are 1,000 students in the class (or college). Let n represent the number who choose to become doctors, so $1{,}000 - n$ is the number who choose to become lawyers. Each doctor's income is a function of the number of others who choose to be doctors: $250 - n/6$ (thousands of dollars); each lawyer's income is a constant 150 (thousand dollars). In the equilibrium with free choice, 600 students will choose to become lawyers as can be seen in the diagram at the top of the next column:

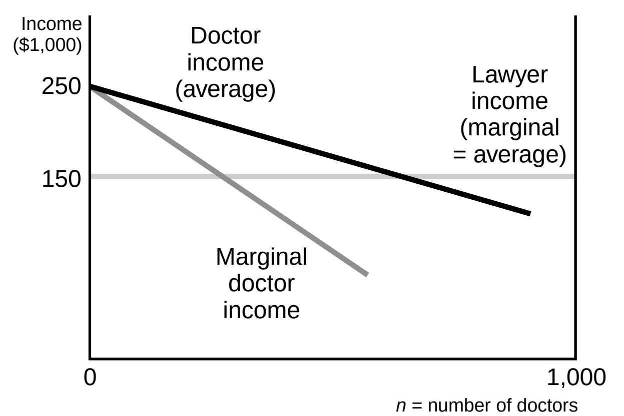


But what is the socially optimum outcome here; what number of doctors would maximize total class income? You want to find the value of n that maximizes

$$n(250 - n/6) + (1{,}000 - n)150$$

Taking the derivative with respect to n shows that the optimal n must satisfy $260 - (1/6)2n - 150 = 0$, or $n = 300$. Thus the optimal number of doctors is only one-half the number that arises in the free choice equilibrium.

You can interpret this story with additional economic jargon if you are so inclined. In this case, the doctors' total income is $n(250 - n/6)$. An average doctor earns $250 - n/6$, but the marginal doctor earns $250 - n/3$. For lawyers, the total income is $150(1{,}000 - n)$; the average and marginal incomes for lawyers are also 150.



You can use the diagram above to show that maximizing the total income of the group requires equating the marginal income of a doctor to the marginal income of a lawyer. The free choice equilibrium is attained from equating the average incomes.

For a collection of additional examples that are different from the ones in the book, see Dixit and Nalebuff, *Thinking Strategically*, Chapter 9.

GAME PLAYING IN CLASS

GAME 1 Check Marks

Prepare a handout or cards and ask students to place *either* a blank line *or* a check mark on the paper Tell them that if less than half of the class answers with a check mark, 5 points (if you count experiment points toward the grade or if this is included on a quiz) will be added to the score of each person who makes the check mark. But if more than half of the class answers with a check mark, then 5 points will be taken away from the score of each person who makes the check mark. (You can achieve the same incentive structure in a variety of ways.) Collect the cards or quizzes and collate the answers to the question.

Consideration of the results from this game can lead to an interesting discussion. The game has asymmetric Nash equilibria in pure strategies and a symmetric Nash equilibrium in mixed strategies. Which one (if any) would you or the students expect to emerge? What kind of coordination would be needed to achieve a particular asymmetric pure-strategy outcome? What ethical or redistributive issues would arise if the students did act in coordination? Should students who did badly on previous quizzes be allowed to get the extra points here, or should the allocation be made by a lottery that gives an equal chance to everyone? If a plan of joint action is devised, would anyone try to cheat? And so on.

GAME 2 Investment Game

This game starts with each person's receiving an imaginary $5 from the instructor. Students are each asked to divide the $5 between two different investment opportunities, Asset A and Asset B. Asset A is a riskless investment with a zero rate of return; any money invested in this asset is returned intact at the end of the game. Asset B works in the following way. Each student chooses to invest some amount between $0 and $5 (inclusive) in Asset B. These amounts will be added together, and the sum will become the Asset B investment pool. The size of this investment pool will be increased by 50%. The money in the investment pool will then be divided *equally* among all the participants in the game. (In other words, an individual's share of the Asset B investment pool depends only on the total amount invested in the pool and not on how much the individual personally invested in Asset B.)

You might want to give your students an example of how the game could proceed: Suppose that there are 25 people who participate in the game, that Sarah Student invests $2 in Asset A and $3 in Asset B, and that the total amount invested in Asset B (from all 25 people) is $60. In this case, the Asset B pool is increased to $90 after the investment decisions are made, and $90 is then divided equally among the 25 participants. Each player collects $3.60 from the Asset B investment pool. Sarah Student ends the game with her $2 from Asset A and $3.60 from the Asset B pool for a total of $5.60.

Ask students to divide the $5 between the two assets in any way they choose. After thinking about this game for a few moments, ask them to indicate how much of the $5 they wish to invest in each asset and have them indicate this on a card or handout.

This game is a multiperson prisoners' dilemma game or a collective-action game with a payoff structure resembling a prisoners' dilemma. Those who invest in A defect while those who invest in B cooperate. You can calculate the amount of free-riding that takes place in the game by taking the proportion of the dollars invested in Asset A to the total number of dollars available to be invested and discuss the implications of the outcomes observed.

You can also use a slightly simpler version of this game in which students can put their entire $5 either into Asset A or into Asset B. This case is easier to analyze, and you can draw a simple diagram showing payoffs from cooperation (this payoff is (7.5 × number investing in B)/number in class) and defection (this payoff is 5 + (7.5 × number investing in B)/number in class). Defection is a dominant strategy for each player, but the class as a whole would be better off if all cooperated.

There are many versions of this public goods game that appear in the literature. For some ideas about ways to vary this game see http://www.marietta.edu/~delemeeg/expernom/s93.html.

GAME 3 Fishing Game

Here are directions for the students to be written on a handout: Imagine that you own a fleet of boats that are used to catch fish in a particular lake. There is one other fleet of fishing boats that also operates in this lake. On any given single day, the amount of fish caught by your fleet depends both on the number of boats you sent out and on the number the other fleet sent out. The following table shows the number of pounds of fish caught by each fleet in a day, depending on how many ships each fleet sent out. (Your catch is shown first.) Suppose that a pound of fish can be sold for $1 and that it costs $10 to send out a fishing boat for a day.

		OTHER FLEET					
		0 Boats	*1 Boat*	*2 Boats*	*3 Boats*	*4 Boats*	*5 Boats*
YOUR FLEET	0 Boats	0, ***0***	0, ***32***	0, ***60***	0, ***84***	0, ***104***	0, ***120***
	1 Boat	32, ***0***	30, ***30***	28, ***56***	26, ***78***	24, ***96***	22, ***110***
	2 Boats	60, ***0***	56, ***28***	52, ***52***	48, ***72***	44, ***88***	40, ***100***
	3 Boats	84, ***0***	78, ***26***	72, ***48***	66, ***66***	60, ***80***	54, ***90***
	4 Boats	104, ***0***	96, ***24***	88, ***44***	80, ***60***	72, ***72***	64, ***80***
	5 Boats	120, ***0***	100, ***22***	100, ***40***	90, ***54***	80, ***64***	72, ***72***

If you want to send out the number of boats that will maximize your own profit (bearing in mind that the owner of the other fleet will also be picking a number of boats to maximize profit), how many of your boats would you send out?

Now, suppose that you can pick the number of boats that both your fleet and the other fleet send out (but, to be fair, you have to allow the other fleet to send out exactly the same number of boats that you send out). Again assuming that you are interested in maximizing your profit, how many of your boats would you send out in this case?

You may also want to show students the following tables showing how many fish are caught for a given number of boats on the lake and showing the profits gained for the different combinations of boats sent out by each fleet:

Total boats	Fish caught
1	32
2	60
3	84
4	104
5	120
6	132
7	140
8	144
9	144
10	144

The original matrix was produced by allocating the number of fish caught proportionally among all the boats sent out.

The following matrix shows the profit earned by each firm as a function of the number of boats sent out by each fleet. The table below was constructed from the original table by subtracting the $10 cost of sending out each fishing boat; students often do this calculation for themselves as they play the game if they are not provided with the table below.

This game shows that a good individual outcome may be inversely related to a good outcome for the other player so that some type of coordination is necessary to get a jointly optimal outcome. When each player pursues a course of action designed only to better his payoff, the final outcome may be bad for him. This game has an externality; putting more of your boats on the lake hurts the other fleet's potential catch (and potential profit). From a societal perspective (total profit), an outcome with two fleets and three boats each is better (132 fish and a total of 72 profit) than a single fleet sending out all five of its boats (120 fish and 70 profit).

To analyze the game from an individual's perspective, you could derive best-response curves showing each fleet's best number of boats (the number of boats that gives each fleet the most profit) given the number of boats sent out by the other fleet. To analyze the game from a social perspective, you can graph total profits (to both fleets) as a function of the number of boats sent out (from 1 to 10). You will want to ask the class about solutions to the externality problem

		OTHER FLEET					
		0 Boats	*1 Boat*	*2 Boats*	*3 Boats*	*4 Boats*	*5 Boats*
YOUR FLEET	0 Boats	0, ***0***	0, ***22***	0, ***40***	0, ***54***	0, ***64***	0, ***70***
	1 Boat	22, ***0***	20, ***20***	18, ***36***	16, ***48***	14, ***56***	12, ***60***
	2 Boats	40, ***0***	36, ***18***	32, ***32***	28, ***42***	24, ***48***	20, ***50***
	3 Boats	54, ***0***	48, ***16***	42, ***28***	36, ***36***	30, ***40***	24, ***40***
	4 Boats	64, ***0***	56, ***14***	48, ***24***	40, ***30***	32, ***32***	24, ***30***
	5 Boats	70, ***0***	60, ***12***	50, ***20***	40, ***24***	30, ***24***	22, ***22***

here and get them to think about how the externality might be internalized in this case.

ANSWERS TO EXERCISES FOR CHAPTER 11

1. (a) This game is a prisoners' dilemma since $s(n)$ is greater than $p(n + 1)$ for all n. Any single player can always raise his payoff by switching from participating to shirking.

   (b) $T(n) = n^2 + (100 - n)(4 + 3n)$

   (c) Plugging the appropriate values into the text's Eq. (11.1) yields

$$\begin{aligned} T(n+1) - T(n) &= n + 1 - 4 - 3n + n(n + 1 - n) \\ &\quad + (100 - n - 1)(4 + 3n + 3 - 4 - 3n] \\ &= -3 - 2n + n + 3(100 - n - 1) \\ &= 294 - 4n \end{aligned}$$

   This formula is positive for all n up to $n = 73$, but turns negative for $n = 74$ and higher. Thus, the last time the change in total social payoff expression is positive is for $T(74) - T(73)$ T is thus maximized at $n = 74$.

   (d) When $n = 74$, each participant receives a benefit $p(74) = 74$. If one participant were to switch to shirking, he would receive a benefit $s(73) = 4 + 3(73) = 223$. Each participant thus has an private incentive to become a shirker (as is always the case in a prisoners' dilemma).

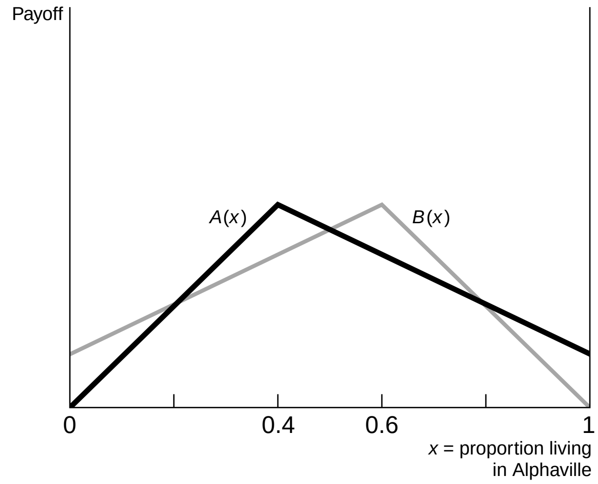
   (e) If the game is repeated, the players can take turns playing the role of shirker (and receiving the higher private benefit). Social norms of the threat of future punishment might keep each player in his assigned role for that game. A similar procedure might work even if the players' future interaction was in a different game.

2. (a) Let x be the proportion of the population in Alphaville. Then the payoffs to living in the towns are:

   For Alphaville: $A(x) = \begin{cases} x & \text{if } x < 0.4 \\ 0.6 - 0.5x & \text{if } 0.4 < x < 1 \end{cases}$

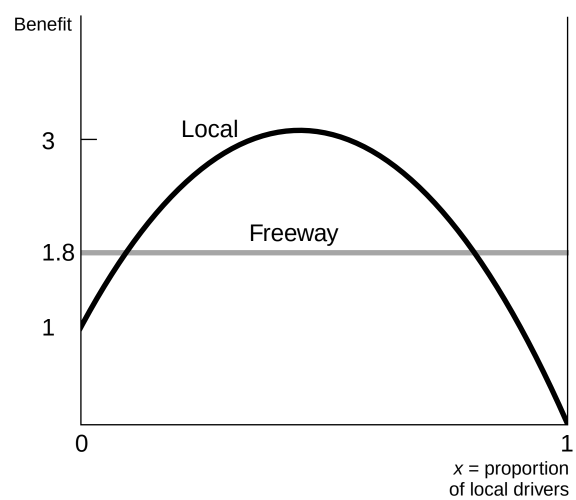
   For Betaville: $B(x) = \begin{cases} 0.1 + 0.5x & \text{if } x < 0.6 \\ 1 - x & \text{if } 0.6 < x < 1 \end{cases}$

   (b) The graph below shows that there are five equilibria. Three exist where $A(x)$ and $B(x)$ cross: at $x = 0.2[A(x) = B(x) = 0.2]$, at $x = 0.5[A(x) = B(x) = 0.35]$, and at $x = 0.8[A(x) = B(x) = 0.2]$. There are also two equilibria at the end points. At $x = 0$ (when nobody lives in Alphaville), $B(x) = 0.1 > A(x) = 0$, so nobody will move into Alphaville. Similarly, at $x = 1$, $A(x) = 0.1 > B(x) = 0$, so nobody will move into Betaville.



   (c) For $0 < x < 0.2$, $B(x) > A(x)$; for $0.2 < x < 0.5$, $A(x) > B(x)$; for $0.5 < x < 0.8$, $B(x) > A(x)$; and for $0.8 < x < 1$, $A(x) > B(x)$. Given these relationships, if x is just below 0.2, people will move to Betaville and x will fall. If x is just above 0.2, people will move to Alphaville and x will rise. Thus, the $x = 0.2$ equilibrium is unstable. Similar analysis shows that the $x = 0.8$ equilibrium is also unstable. The equilibria at $x = 0$, $x = 0.5$, and $x = 1$ are stable since x moves toward those values.

3. (a)



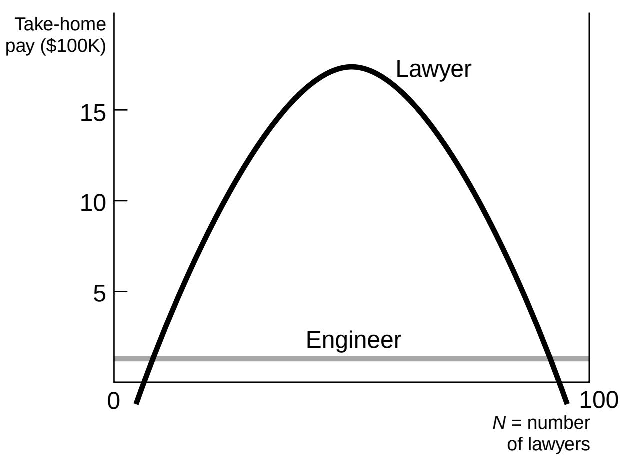
   (b) There are three possible equilibria. At $x = 0$ (nobody on the local roads), the benefit on the highway exceeds the benefit on local roads; nobody will switch to a local road. At $x = 0.1$, the benefits are equal. This is, however, an unstable equilibrium, since if $x < 0.1$, the number of people driving the local road will fall, while if $x > 0.1$, local road usage will rise. At $x = 0.8$, benefits are again equal. This is a stable equilibrium: for $0.2 < x < 0.8$, local usage rises, for $x > 0.8$, local usage falls. Note that the other endpoint ($x = 1$) is not an equilibrium. When everybody is on the local roads, any driver could help himself by switching to the highway.

(c) Total benefit = $x(1 + 9x – 10x2) + 1.8(1 – x)$. Trial and error shows that $x = 0.55$ maximizes this expression.

4. (a) A person will voluntarily contribute if his benefit from so doing exceeds the $100 cost. Assuming that n other people are already contributing, a person's benefit from beginning to contribute is the difference between his benefit when there are $n + 1$ contributors and when there are n contributors: $(n + 1)^2 – n^2$. Once there are 50 other contributors, this benefit is 512 – 502 = 101 > 100. So once the mayor convinces 50 people to contribute, the rest will join in voluntarily.

(b) There are two stable Nash equilibria in this game. When $n = 0$, no one is contributing, and no one wants to. When $n = 100$, everybody is contributing, and each person receives a private gain from so doing. (With 100 discrete individuals, there is no unstable equilibrium in the middle. When 50 other people are contributing, everybody wants to contribute; when 49 others are contributing, nobody gains from becoming contributor number 50. There is no division at which the next possible contributor is indifferent about his choice.)

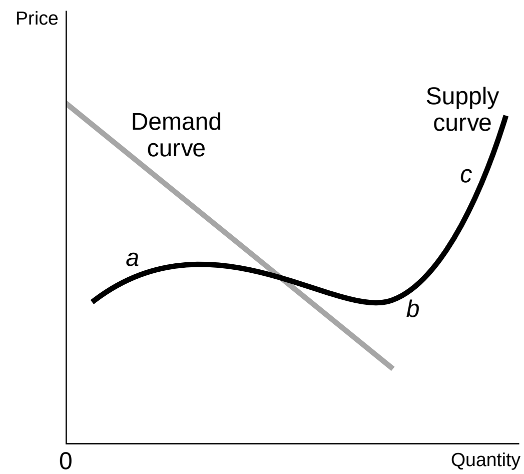
5. (a)



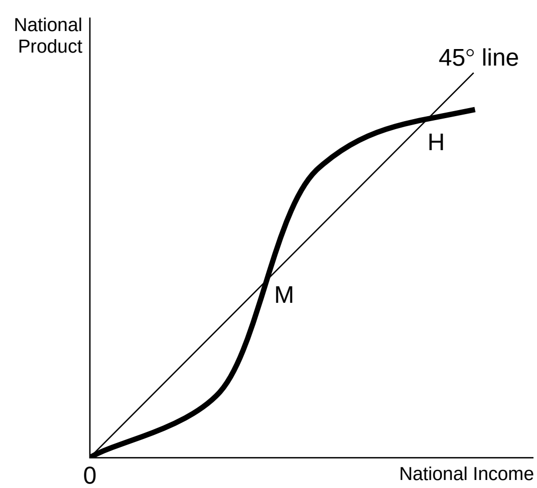
(b) There are two possible equilibria: (1) When $N = 10$, a lawyer receives $[100(10) – 10^2 - 800]$ thousand = 100 thousand, which equals an engineer's pay. This equilibrium is unstable. (2) When $N = 90$, a lawyer receives $[100(90) – 90^2 – 800]$ thousand = 100 thousand. This equilibrium is stable.

(c) The function to be maximized is $N(100N – N^2 – 800) + (100 – N)100 = 10{,}000 – 900N + 100N^2 – N^3$. The function is maximized at $N = 61.8133$. Once the number of lawyers exceeds 61.8, any increase in their number creates a marginal spillover effect that outweighs the marginal private gain.

6. Here is one possible account. The diagram below shows a possible configuration of industry-level supply and demand. Demand has the normal downward-sloping shape. For supply, over the range from point *a* to point *b* there are industry-level scale economies, so quantity rises more than one for one as demand shifts to the right. Beyond point *c* capacity constraints bite and supply rises rapidly.



On the macroeconomic level, we see a function relating national product to national income (demand) with the shape shown below.



Equilibria occur at the points where this curve crosses the 45% line (the line where national product = national income). Here, point *O* represents a stable collapse equilibrium, point *H* represents a stable good equilibrium, and point *M* represents an unstable middle equilibrium.

7. Answers should include careful descriptions of the (usually two) strategies available to the group of players and of the benefits derived from the two different choices. Good descriptions of benefits should allow a simple graph to be sketched. From the graph, one should go on to analyze the various possible equilibria in the game and predictions regarding which of the potentially multiple equilibria might be obtained in actual play. Comparisons of the predicted outcome to the optimal outcome (that which maximizes the total group benefit) should be included.

ADDITIONAL EXERCISES WITH ANSWERS

1. The broken-window theory (Wilson and Kelling, 1982) was originally based on a research project conducted by Stanford professor Philip Zimbardo. In his research, "an automobile without license plates [was] parked with its hood up in a street in the Bronx and a comparable automobile in a street in Palo Alto, California." The Bronx car was attacked almost immediately. Within one day almost everything of value was stripped; the rest of the car was soon vandalized. The Palo Alto car was untouched for a week. Once Zimbardo himself broke one window, however, the car was wrecked within one hour.

   Some police departments have used ideas based on this theory to justify a policy of cracking down on lifestyle crimes, such as vandalism, graffiti, loitering, and so on. Relate the lessons of the broken-window theory and the associated (sometimes controversial) police strategy to the discussion of sanctions and norms in this chapter. (For a quick update on this theory, see http://www.hel.fi/tietokeskus/brokenwi.html and http://eagle.unr.com/onpatrol/wilsonint.html.)

   ANSWER The police are attempting to use sanctions in order to reestablish a norm to treat society's "common areas" with respect; if the norm becomes established, it may help to deter the commission of more serious crimes as well.

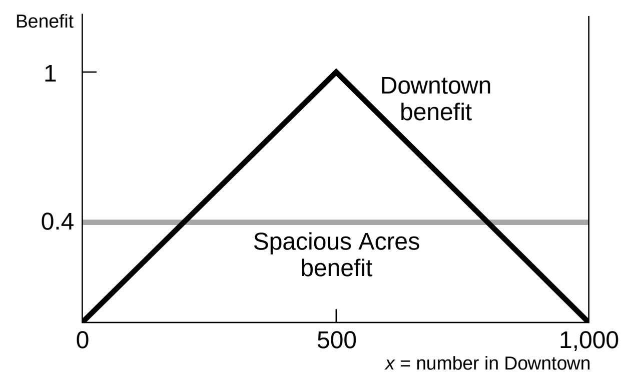
2. Consider a school choice program in which each student (or the parents of each student) can choose the school that he or she will attend. Assuming that there is no limit on student body size, how would a school that was originally thought to be better compare with the other school(s) in equilibrium?

   ANSWER In equilibrium, all schools will offer the same payoff; the better school's advantage will be dissipated as students crowd into it.

3. Consider a situation in which 1,000 people independently decide where to locate. For simplicity assume the following. One possible location is in a very spread-out area; there is no benefit or cost to having additional people locate there. Each person who locates in this area (call it Spacious Acres) receives a payoff of 0.4. The other area is more compact; additional people are, at first, a benefit (more activity, more things to do), but after some point, additional people become a burden (more congestion). The benefit received by each person who locates in this area (call it Downtown) is given by the following formulas. Let x represent the number of people who locate in Downtown.

$$\text{Benefit} = \begin{cases} 0.002x & \text{for} \quad x \le 500 \\ 2 - 0.002x & \text{for} \quad x \ge 500 \end{cases}$$

   When graphed, these benefit functions look as follows:



   (a) (i) Including both stable and unstable equilibria, state how many equilibria there are in this location-choice game; (ii) give the numeric value of x at which each equilibrium occurs; and (iii) for each of these x, state whether the equilibrium at it is stable or unstable.
   (b) Write down the formula that would be used to determine the total benefit received by all 1,000 people in this situation.
   (c) Find the total benefit received in each of the equilibria you described in part a.
   (d) Is it possible to find some value of x other than those found in part a that produces a total benefit that exceeds those found in part c? If so, find one such value of x, and compute the total benefit at that x.

   ANSWER (a) Three equilibria. A stable one at $x = 0$, an unstable one at $x = 0.2$, and a stable one at $x = 0.8$. (b) For $x \le 500$, total benefit = $x(0.002x) + (1{,}000 - x)(0.4)$; for $x \ge 500$, total benefit = $x(2 - 0.002x) + (1{,}000 - x)(0.4)$. (c) In each equilibrium, each person receives benefit = 0.4, so total benefit = 400. (d) One example is $x = 500$; total benefit = 500(1) + 500(0.4) = 700.

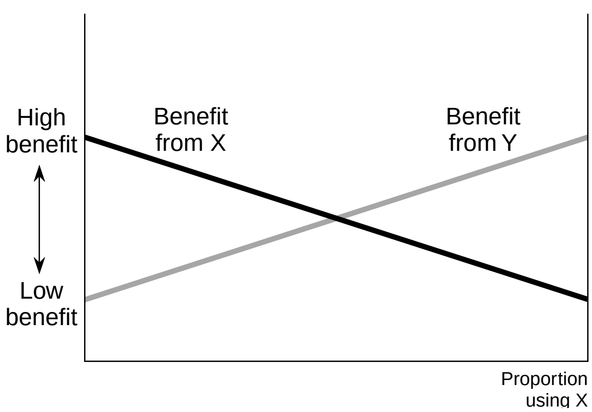
4. The coach of football team A says: "The style of play we use has been successful so far partly because few

other teams use it; our opponents therefore haven't learned how to play against it. If many other teams started using plays like ours, I'm sure that our plays would become less successful than they are now."

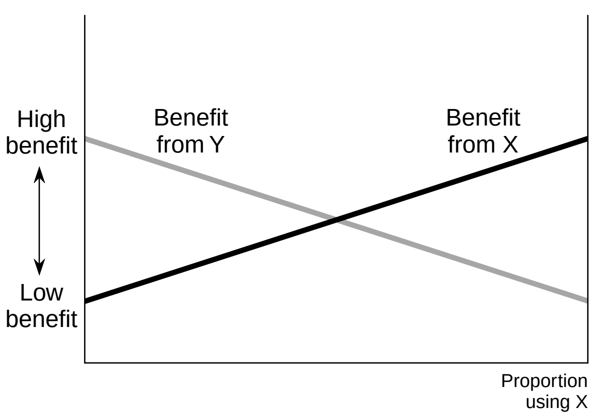
A member of social group B says: "When I wear clothing of a different style than that worn by the other members of my group, I feel uncomfortable. I'm happier when I wear a style that matches what the other group members wear."

For convenience, suppose that football coaches and members of this social group both choose between two possible actions—X and Y (where X and Y are either styles of offenses or styles of clothing). Suppose also that all coaches and all group members are identical and that we wish to analyze the choice between actions X and Y. On the two accompanying graphs, the horizontal axis measures the proportion of the full group choosing action X, the heavy diagonal line illustrates the benefit from performing action X, and the light diagonal line illustrates the benefit from performing action Y.

GRAPH 1



GRAPH 2



Complete the following. The choice-of-offense situation is best illustrated by _____; the choice-of-clothing situation is best illustrated by _____.

(a) Graph 1; Graph 1
(b) Graph 2; Graph 2
(c) Graph 1; Graph 2
(d) Graph 2; Graph 1

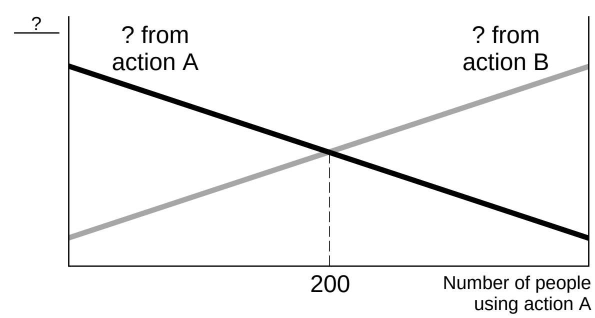
ANSWER (c)

5. Use the pictures in the previous question to answer this question. In both Graph 1 and Graph 2, the benefit lines cross at a point where approximately half of the population is engaging in activity X. In which of those graphs does the crossing point of the benefit lines determine the location of a *stable* equilibrium?

(a) Graph 1
(b) Graph 2
(c) Both Graph 1 and Graph 2
(d) Neither Graph 1 nor Graph 2

ANSWER (a)

6. Suppose that 400 people are choosing between Action A and Action B. The relative payoffs of the two actions depend on how many of the 400 people choose Action A and how many choose Action B. The heavy lines in the following graph show *either* the benefits *or* the costs of these two actions.



Suppose that you know that the outcome in which 200 people choose Action A is an *un*stable equilibrium. This information tells you that if 100 people are currently choosing Action A, it would be most likely that the number choosing Action A would _____ over time. Furthermore, for the graph to be consistent with such behavior, it must be the case that the lines in the graph show the _____ of Action A and Action B.

(a) fall; costs
(b) fall; benefits
(c) rise; costs
(d) rise; benefits

ANSWER (a)

7. Suppose that the game in Exercise 6 is repeated a number of times and that both players use the strategies that make up a mixed-strategy equilibrium. In this situation, we can compute that Player 1 calls out "heads" _____ than half the time and that Player 2 calls out "heads" _____ than half the time.

(a) more; more
(b) less; less
(c) more; less
(d) less; more

ANSWER (b)