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1 THE MOST FAMOUS GAMES

Many strategic interactions one may encounter in any discipline can be seen as variations of a few basic games. It is then convenient to know them by their name and to understand the questions they address.

Strategic interactions typically involve situations with room for both common interests and conflict among the various players. Our first examples will start with a game of pure common interest in Section 1.1 and end up with some of pure conflict in Sections 1.6 and 1.7; in the middle, we will show different balances between these two aspects. Along the way, we will also introduce a few other ideas, like the role of the model and its interaction with reality, the implications of having multiplicity of equilibria, and the assumptions of selfishness and rationality. All will be extensively discussed throughout the rest of the book.

1.1 The coordination game

Let us begin with the simplest of games. It is so simple that the reader may say that we do not need a theory to talk about it. That being true, the important thing is not what the theory says in this particular example, but the fact that with its help we can introduce some of the concepts that will be useful in more complicated cases.

This is the game. Lisa and Bart each rent an apartment in the same building. Both apartments share a garage with a door wide enough to accommodate one car entering and the other exiting at the same time. There is a strategic decision to make, though, as every time one enters the garage they must decide which side to use to make room for the other neighbor in case he or she is exiting at the same time. If they both drive on their right or both drive on their left there will be no problem, but if they drive on different sides they will have to maneuver to avoid collision when they use the door at the same time. The situation can be represented as seen in Figure 1.1.

		Bart	
		Left	Right
Lisa	Left	1, 1	0, 0
	Right	0, 0	1, 1

Figure 1.1 Coordination game

The way to understand the information in the figure is as follows. Lisa must choose between “Left” and “Right,” which are the two rows of the table. Bart does the same with the columns. If both adopt the same driving convention they both will be better off compared to the case in which they do not. The first number in each cell is the payoff for Lisa, and the second number is the payoff for Bart. We have assigned a value of 1 to the outcome in which both coordinate in the same rule, and 0 to the case where each

one drives on a different side. The only thing that matters is that 1 is greater than 0, indicating that coordinating is better than not coordinating. We could have written any other numbers, like 100 and -16, and the game would have been the same. Also, we are saying that both ways of being coordinated are equally good, and both ways of being uncoordinated are equally bad.

If both Lisa and Bart could talk to each other, it is reasonable to assume that they would easily reach an agreement. Neither the details of the story nor the analysis of the game allow us to say which agreement that would be, beyond that they will decide on one of the two possible ways of coordinating. We can safely say that they will not agree on “you use your right and I will use my left” or “every time we coincide at the garage door we flip a coin to decide whether to use the right or the left side.”

But say that they cannot talk to each other. For instance, they just moved in the day before, never met, and today they have to use the garage. Then, there is not much that we can say. The first time they meet at the garage door, either one of the four combinations may occur (Left-Left, Left-Right, Right-Left, Right-Right). However, not all the possibilities have the same properties. If, for whatever reason, they drove on their right, we have a situation in which none of them regrets their choice, as they managed to coordinate. Even if there is no communication between them in the future, it will not come as a surprise to see them both driving on their right from there after. A similar thing will happen if the first time they meet they drive on their left, but not if they drive on different sides. In this latter case we do not know what will happen in the future, but we can say that going uncoordinated is an unstable situation. Perhaps only Bart will change his choice of side and they will both be coordinated in the future, or perhaps no one will change and they will be uncoordinated also the next time they meet. It may even happen that they both change and will be annoyed to see they are still uncoordinated the next time they meet. The important thing to understand is that we can detect two stable situations in this game and the analysis of the game goes around them, regardless of what could happen.

The previous two paragraphs show two ways to reach the coordination, but we can say more. The analyst studying the game will find that there are two stable situations and then will be able to start a research line suggested by this multiplicity in the theoretical game. For instance, he can gather information about whether this building is located in a left or right driving country and propose as an hypothesis that the strategic choice of a side to enter or exit the garage will be solved using the same rule.

1.2 Choice of standards

Our next game is a small complication of the coordination game: now, our characters Lisa and Bart enjoy a higher payoff if they coordinate by driving on the right rather than on the left (e.g., they have cars with the steering wheel on the left). In this case, the game changes to be like the one in Figure 1.2.

		Bart	
		Left	Right
Lisa	Left	1, 1	0, 0
	Right	0, 0	2, 2

Figure 1.2 Choice of standards

Again, the numbers 0, 1 and 2 only indicate the ranking of preferences over the different combinations. It is better to coordinate in the preferred rule than in the other one, and any coordination is preferred to being uncoordinated.

If, as we did in the original coordination game, we try to anticipate what the neighbors will do if they talk to each other before choosing a strategy, we will not only anticipate the agreement in one of the sides, but we will be able to be more specific and say that it will be the right side. The fact that both of them agree on the ranking of the options will help us in the prediction.

However, if the neighbors cannot communicate, several things may happen. One is that they are able to identify the game and reason that since the best option for them is to drive on the right, that is what each one should do when deciding individually, hoping that the neighbor reasons the same way. This is a stable situation. As soon as they cross into each other the first time, and see that their expectations are confirmed, no one has an incentive to change their choice. Notice that, for this situation to happen, both players need to know that the other player also prefers that they coordinate on the right (for instance, they are aware of the type of car the other player owns after seeing it parked in the garage). Unless we specify otherwise, in the rest of the book we will assume that the players know the game they are playing.

To be sure, the result above is the most reasonable thing to expect given the way the game was described, but it is not the only possibility. If the players have not analyzed the game and their first coordination was on the left, that would also be a stable situation. Given that we began coordinating on the left, should I change next time once I realize that right is a better option? How do I know that my neighbor has also noticed this? Even if he noticed, how do I know that he will change, trusting that I change too? When do we change the rule? These difficulties are easily resolved if Lisa and Bart talk to each other, but if they cannot do it, they may find themselves in a non-optimal situation from which it may not be so easy to leave.

The coordination in driving on the right side to enter and exit the garage may not seem a big problem, but in the real world there are situations that share the same strategic structure and that definitely are a big problem. For instance, imagine that different users must choose one out of two computer systems that are incompatible with each other, making it difficult to share files or programs. Even if the users agree that one of them is better, if everyone else is using the other system it may be rational to buy the worst one to avoid the problem of incompatibility. To change driving sides is a trivial matter in the case of the neighbors, but it is quite costly in the case of a whole country. In 1967 Sweden did just that to be on the same side as the rest of continental Europe and to favor its automotive industry, that until that time had to manufacture two versions of each car. They did it before cars were as numerous as today. If the British wanted to change their driving side today, the cost would be much greater. Other examples of inefficient coordination include the choice of technology for the development of colour TV, the different standards for video tapes, and different choices for office automation. The coordination of a group of friends or members of a family in a social network is a modern example.

There is a case of inefficient coordination that has some special interest. Say that a country has both a right-wing party (RP) and a left-wing party (LP). Lately, the RP has been involved in many corruption cases, and some citizens decide to start a new, corruption-free right-wing party (CP). Now, all right-wing voters agree that CP is a

better option than RP. Will they all vote for it? If they prefer any right-wing party to a left-wing one, they may not want to risk dividing the vote between RP and CP and, thus, facilitating the possibility of a left-wing government. This may be enough for many voters to continue voting the RP. In the real world, not all voters will have the same motivations. Some right-wing voters may prefer a left-wing government to a corrupt right-wing one, or may be willing to risk losing the elections to build support for CP. What our analysis says is that, in addition to all these considerations, one should not disregard the coordination issues, which allow a more complete diagnosis of the political scene beyond just saying that the voters of the RP are clueless or just do not mind the corruption.

1.3 The battle of the sexes

In the previous games there was no disagreement about the best way to coordinate actions. Let us change this in our new game. Sylvie and Bruno are a couple in the time before cell phones, and they go out every Friday evening. Today is such a day, and yesterday they talked about two alternative plans, going to the movies or to the football game, but did not say anything definitive. This morning they left to their respective jobs and now are unable to communicate during the day. After work each of them has to decide whether to go to the movie theater or to the stadium. They prefer going together to the same place, but Sylvie likes football better, while Bruno prefers movies. If they mismatch and go to different places, their evening is ruined regardless of where they go. Figure 1.3 shows the game.

		Bruno	
		Football	Movies
Sylvie	Football	2, 1	0, 0
	Movies	0, 0	1, 2

Figure 1.3 Battle of the sexes

Like in the previous examples, there are two stable situations that, from now on, will be called equilibria: they both go to see the football match or they go to the movie theater. In either case, there will be no regrets. For instance, if they met in the movie theater, Sylvie will be satisfied with her decision, as it allowed her to meet Bruno. Of course, she prefers to watch the football game, but had she gone to the stadium she would have been alone. Recall that Sylvie can only decide for herself, and she cannot choose the equilibrium because she cannot decide for Bruno. We have a similar situation in case they went to the football game. We do not know which equilibrium, if any, will prevail. Contrary to the other games we have seen so far, talking may not solve the problem. We may anticipate that they will agree on one plan, but we cannot forget that besides the coordination problem there is a conflict that was absent in the coordination or in the choice of standards games.

The multiplicity of equilibria may be telling us that our game model is incomplete and that we might want to obtain more relevant data from the real-life situation. The game can give us some hints about what to look for; we must find details which we did not take into consideration at first glance, and that may determine the equilibrium

selection. We can check whether Sylvie and Bruno live in a patriarchal society where women always do as men say or whether they live in a patriarchal society where women are treated as girls that need to be pleased. If the society is patriarchal of the first type, they will go to the movies; if it is patriarchal of the second type, they will go to the football game. There are other possible solutions. If the couple lives in an egalitarian society, or if this couple in particular is that way and alternates plans every week to satisfy the preferences of both of them, and, further, if we know that the previous week they went to Bruno's most preferred place, now we can safely predict that they will go to Sylvie's.

It is important to distinguish between the model and the real-life situation. The game model in Figure 1.3 has two equilibria, and we cannot put one above the other. The real world, as we saw in the previous paragraph, may be more complicated and at the same time may give us clues about how to resolve the equilibrium selection. The analysis should not end here; if there are some features of the relation between Sylvie and Bruno that may be relevant to their strategic decision, they should be included in the description of the game. Doing so, we will end up with a more complicated game compared to the one in Figure 1.3, and as such it should be analyzed. In the rest of the book we will see how to add more details and how to analyze them.

The players themselves may learn something from the analysis. The problem of equilibrium selection has arisen because the decisions had to be made without the knowledge of what the other player was doing. If one of them, say Sylvie, can decide first where to go, she can get her way. If she already went to the stadium, or has made a credible commitment to go, and Bruno knows that, he would have no choice but going to the stadium as well. To accept this line of reasoning, it has to be the case that what happens today will not affect the future. For instance, it cannot be the case that Bruno wants to gain a reputation of not allowing Sylvie to win with this kind of stratagem.

This last consideration opens the door to more possibilities. If Sylvie can send a one-way message to Bruno, she will say that she is going to the stadium. A phone call may work:

-Darling, we'll meet at the stadium gates.

-What? No. I prefer to go to the movies.

-Sorry, I can't hear you. It seems we have a bad connection. Bring scarves and sandwiches. See you!

-What? No! I want the movies! Can you hear? Hello?

-...

1.4 The chicken game

In the Nicholas Ray film *Rebel without a Cause*, with James Dean playing the main character, a group of bored, young people, not knowing what to do with their lives, have an interesting way of having fun: a car race. This is not any car race; two drivers take their respective stolen cars and speed up towards a cliff (that is why they needed stolen cars). The first one to jump out of the car loses this "chicken game." The last to jump will be the winner who, full of testosterone and adrenaline, will enjoy a higher status within the group. In the movie, one of the boys, Buzz, challenges Jim, the newcomer played by James Dean, to play the game.

To make the game a little more interesting, let us change the rule of driving towards a cliff with the rule of driving against each other on a collision course. Now, the first one swerving is the chicken, and the one keeping his way will be the winner. If they both swerve they are both chickens, but the stigma will not be as high as in the case one is the only coward. The worst-case scenario occurs if they both keep going and crash into each other. They would have been very brave, but also lost their lives. Figure 1.4 summarizes the game.

		Buzz	
		Swerve	Keep going
Jim	Swerve	2, 2	1, 4
	Keep going	4, 1	0, 0

Figure 1.4 The chicken game

The face-saving outcome, where both drivers swerve, is not an equilibrium. If, for whatever reason, they agree on doing that, any one will have an incentive not to swerve. If Jim follows the agreement, Buzz would be better off by not honoring it. The agreement is not stable. In other words, the assumption that the agreement is an option that the players will be willing to follow leads to the contradiction that they will want to do otherwise. One can object that if Jim thinks as Buzz does, and both break the agreement, they will be both worse off. That is true, but this only illustrates that the agreement is very unstable, and that the outcome after the agreement is unpredictable.

There are two equilibria, two stable situations from which no one wants to deviate: one swerves and the other one keeps going. As we saw in the previous games, to know which one will swerve we better take a closer look at the group. If one of the two drivers already has a reputation of never swerving, it will be difficult for the other one to win the game. Again, remember that a player only chooses his strategy, not the equilibrium. In the film, Buzz has this reputation, while Jim’s reputation is unknown to everyone in the group. In the film, as they speed toward the cliff, Buzz’s jacket gets caught on the door’s handle, and he cannot jump out of the car. We see Jim jumping out, but we do not know what would have happened if Buzz could have jumped.

As in the battle of the sexes, one of the players could try committing to a strategy, but how?

-Darling, you better swerve.

-??!!

No. That is not going to work. We need something more dramatic, an action that shows a real commitment not to swerve or one that shows that the payoffs in the table are different. Here are two possible strategies: (i) arrive at the racing place conspicuously drunk and (ii) in the middle of the race, pull out the steering wheel and throw it out the window, also conspicuously. The key to the strategy is, it was easy to notice, the word “conspicuously.” This is an example of how being, or pretending to be, irrational puts a player in a winning situation, leading to the paradox of calling irrational a behavior that makes you win.

Like in the other games, the equilibria in the chicken game can be viewed as a pair of fulfilled beliefs. For instance, in the equilibrium (Swerve, Keep going), Jim swerves

because he believes that Buzz will keep going, and Buzz keeps going because he believes Jim is going to swerve. As we argued before, why this equilibrium is selected and, therefore, why these beliefs prevail are questions that cannot be answered with the level of detail of this particular mathematical game model as a representation of the real-life situation (although a more complicated game may incorporate more details that explain the selection). A system of compatible beliefs can help to select an equilibrium, but the source of those beliefs may be different at different moments. When players observe the actions in the equilibrium they get confirmation of their beliefs that, at this point, may become independent of the reason they had those beliefs to begin with. This is an important point if one wants to understand some behaviors.

For instance, a young couple decides to live together and he has the expectation that she will do most of the housekeeping. It may not be something she wants, but if she knows that she is expected to do that, it will be very hard to fight against the assumption of the classical roles. Say the expectations came from a social norm in the society where they live and that later on they understand that they do not need to follow the norm. But now, given that they are established in the equilibrium, neither of them continues in their roles because of the social norm, or at least not only because of that. They have a strong incentive to follow the equilibrium because their belief that she will do the housekeeping, and that he will not, is confirmed by the actions of both of them and not dictated externally by a norm. She does the housekeeping because he does not, and he does not do it because she does. This does not mean that they can do nothing to change it, it means that they have to do more than just realizing that they do not need to obey the social norm.

The chicken game was made famous by many analysts at the time of the negotiations between the Greek government and the Troika during the financial bailouts in 2015. While Greece demanded soft conditions to accept the bailout, the European institutions and the IMF wanted to impose stronger ones. Each party thought that its conditions were the best for Greece to overcome the crisis and pay the loans back. For the strategic analysis, what matters is not who is right, but what each party thinks it can win in the different scenarios. The strategies are “concede” or “hold.” The worst-case scenario is that no one concedes, which constitutes a disaster for Greece (leave the euro, devaluation, bankruptcy, etc.) and also for the EU (a backing out of the common currency, disaffection for the European project, etc.). Each party thinks that the best outcome is that the other one concedes. If both concede, there will be an intermediate agreement that does not fully satisfy anyone but that is better than the lack of an agreement. In Chapter 10 we analyze this game in detail.

1.5 The prisoners’ dilemma

Two suspects are arrested and accused of committing a crime. The police put them in separate cells and tell them the following:

We know you committed the crime but we don’t have enough on you for a conviction. You know that too. But if you confess and your partner does not, your partner takes all the blame (5 years in prison) and you go free for helping us. If you both confess, you share the punishment and serve 4 years each. If no one confesses, we will make sure that you still go to jail for 1 year, accused of a minor crime (illegal possession of firearms, for instance).

This game might be better understood with the help of Figure 1.5a, which represents the number of years to be spent in prison. Such an unpleasant prospect is prefaced with a minus sign, with zero being greater than -1, indicating that zero years in prison is better than one year.

		2	
		Do not confess	Confess
1	Do not confess	-1, -1	-5, 0
	Confess	0, -5	-4, -4

Figure 1.5a The prisoners' dilemma

Now the prisoners must decide what to do. If they could talk, reach an agreement and then make a joint decision, they would almost surely decide not to confess. But the catch here is that they must decide individually, and each one will see that, no matter what the accomplice does, it is best to confess: "If my partner confesses, I better confess myself (four years in jail are better than five), and if my partner does not confess, I still better confess (going free is better than one year in jail)." This way they both confess and enjoy four years in the slammer. This is a stable situation, as no one can do anything to improve his situation given what the other prisoner is doing.

When one is exposed to the prisoners' dilemma for the first time, the natural reaction is to reject the conclusion. How can it be that, knowing the consequences of confessing, the two prisoners are unable to take an action that substantially reduces their sentence time? Very often the reason is that we forget that the choice is unilateral and individual; it is taken with no attachments to what the other person is doing. At other times we might tend to think that the game ends differently. For instance, the two prisoners may be friends that care about each other. This would mean that the numbers in Figure 1.5a do not adequately reflect the consequences of the prisoners' actions. Suppose that each prisoner suffers when his friend is in prison. Specifically, say that every year spent by one prisoner in jail causes remorse in his friend equivalent to half a year of jail. In this case, the numbers would be similar to those in Figure 1.5b. For example, if no one confesses, each suspect not only suffers his own year of pain but also the equivalent of another half year caused by remorse at his partner's year in jail.

		2	
		Do not confess	Confess
1	Do not confess	-1.5, -1.5	-5, -2.5
	Confess	-2.5, -5	-6, -6

Figure 1.5b Prisoners' dilemma with empathy

Now the only equilibrium situation is that no one confesses. If one of the prisoners deviates from this situation, he does go free but his friend's five years in jail will cause this prisoner pain equivalent to two and a half years in jail, which is more pain than the one and a half years if no one confesses.

There are other ways out of the prisoners' dilemma. Even if the prisoners are indifferent to the suffering of their accomplices, it may happen that they are

members of a criminal gang that punishes traitors with death. If one of the prisoners betrays the other, his payoff will be zero years in jail plus certain death, a grimmer prospect than five years in prison. The game would be something similar to the one in Figure 1.5c.

		2	
		Do not confess	Confess
1	Do not confess	-1, -1	-5, -100
	Confess	-100, -5	-100, -100

Figure 1.5c Prisoners' dilemma with punishment

The number -100 indicates something very bad (death). The choice of this particular number is not important; it is enough that it is worse than -5 , the number corresponding to five years in jail. Again, the option "Do not confess" is now more attractive.

There are many more ways to escape the logic of the prisoners' dilemma, and one may be tempted to think that any one of them would always be able to prevail. The fact is that in real life there are indeed situations that may be represented by the game in Figure 1.5a and which offer no easy way out or, at least, one that has not yet occurred.

The problem of pollution is just one of these situations: we are all better off if we pollute less, but if I go green, my action will be hardly noticed and I will be paying a cost. No matter what others do, it is better for me to avoid this cost and keep polluting. The result is that we contaminate too much, which is something that we definitely see in the real world. An advertising campaign to make people conscious of the problem might reduce some types of contamination – the ones that are cheap to solve – but in general it would not achieve optimal results. For this to occur, the polluter would also need to pay the cost of polluting. Penalties, taxes per unit of contamination or markets for emission permits are different ways to face the problem. In some cases, such as when we want to have a clean communal park, both social pressure and education may be enough; however, if we are talking about industrial pollution, transport emissions or agricultural contamination, things are very different. When we face a prisoners' dilemma, it is better to understand, rather than ignore, its logic. A correct diagnosis will help to solve the problem better and in a shorter time.

Other real-life examples with the structure of a prisoners' dilemma game are voluntary contributions to financing public goods, environmental degradation, the depletion of natural resources, greenhouse gas emissions, traffic congestion in the inner city, noise pollution, basic research and cartel formation, among many others. One example dearest to the author of this book is the opera *Tosca*, by Puccini, which we explain here.

We are in Italy at the end of the 18th century when the Royalists and Republicans are at war. The troops of the Kingdom of Naples occupy Rome, where both Cavaradossi, the church painter, and his beloved Tosca live. As always in opera, things are fine for the two lovers but circumstances plot against them. In this case, Cavaradossi is arrested after helping to hide a Republican sympathizer and, for this, he will be shot the next morning. The chief of police, the evil Scarpia, calls Tosca to his quarters and tells her about the situation. He can give the order to replace the real bullets with fake ones to save Cavaradossi, but in return Tosca has to spend the night with him. Tosca

accepts and Scarpia leaves the room to give the order. While he is out, Tosca sees a knife on the table and starts thinking:

-If Scarpia has indeed given the order, I can kill him in case he changes his mind and also to avoid being with him. If he did not give the order I will be avenging my lover.

At this time, the reader may already guess Scarpia's thoughts:

-If Tosca has already accepted my conditions, there is no point on me giving the order and risking being caught by my superiors. She will know nothing until everything is over.

The terms of the agreement are reasonably good for both of them. Tosca keeps her lover alive at the price of spending one terrible evening, while Scarpia enjoys a good time at the price of saving Cavaradossi. Of course, Tosca prefers not to be with Scarpia (for that she has to kill him) and Scarpia prefers not to get into trouble with his superiors (and for that reason he has to let Cavaradossi die). But if they follow their rationality, they both will face a bad outcome: the first one living without her lover, the second one being killed. It is not my intention to spoil the opera for the reader. Suffice it to say that the plot goes according to the logic of the prisoners' dilemma.

Many smart people have had trouble in their first analysis of the prisoners' dilemma and have tried to find a better logic. Perhaps the following paragraphs by cognitive science researcher Douglas Hofstadter in his book *Metamagical Themas* (Hofstadter, 1985) are the best illustration of this (to his honor, he later changed his mind after he understood the game)¹:

Now, if reasoning dictates an answer, then everyone should independently come to that answer. . . . Once you realize this fact, then it dawns on you that either all rational players will choose D or all rational players will choose C. This is the crux. . . .

All you need ask now is, "Since we are all going to submit the same letter, which one would be more logical? That is, which world is better for the individual rational thinker: one with all C's or one with all D's?" The answer is immediate: "I get \$57 if we all cooperate, \$19 if we all defect. Clearly I prefer \$57, hence cooperating is preferred by this particular rational thinker. Since I am typical, cooperating must be preferred by all rational thinkers. So I'll cooperate."

All these attempts to convince us, through seemingly logical and rational arguments, could go on for a long time and yet they would still miss the point. To deduce individual incentives from what would be a good deal is a logical fallacy. If they are all in the same situation, each player will arrive at the end of his or her reasoning process to the same conclusions as the others – but only at the end of this process. The symmetry does not need to be carried through the tentative and counterfactual arguments along the deductive process. During the process of reasoning, one prisoner contemplates his best course

¹ Note that Hofstadter was discussing a prisoners' dilemma with money rather than years in jail, and with more than two players. Also, he uses C for cooperate and D for defeat. Just use "one year" and "four years" instead of the number of dollars that Hofstadter used and replace "all" with "both" to translate his version into ours.

of action for every possible thing the other may be doing. For the mathematically inclined reader, in Section 3.6 we conduct a more formal discussion of these symmetry issues. The equilibrium postulates one prisoner's own best response to the other's actions – the key to the equilibrium concept that we will be using extensively in game theory. We will provide a precise definition later and name it in honor of John Nash, who was awarded the Nobel Prize in Economics and the Abel Medal in Mathematics (the highest distinctions in the respective fields) and who proposed and investigated this equilibrium.

Being aware of this logical fallacy has implications for how we examine games. These may be summed up in the following hypothetical dialogue:

-If everyone else chooses not to cooperate, I better not cooperate. In fact, if the others do cooperate, it is also best for me if I do not cooperate.

-True, but if we all cooperate we will be better off compared to the situation in which no one does. If we all think like you do we will be worse off.

-Yes, but the case is that if every one thinks like I do, I am not going to be the only fool that does not think like myself.

The Golden Rule in ethics states that “one should treat others as one would like others to treat oneself.” Regrettably, the rule may not be an equilibrium situation, and individuals may have reasons not to follow it. Improvements of the rule, like Kant's categorical imperative to “act only according to that maxim whereby you can at the same time will that it should become a universal law,”² follow the same fate, even when individuals have the same preferences and agree on what it means to be well treated or on what should become a universal law.

Because of analysis such as this, game theory (and economics) is sometimes accused of defending and promoting selfishness. However, notice that our analysis does not say anything about the ethics of the equilibrium (or of the Golden Rule, for that matter). It just says that in the prisoners' dilemma the actions “Defeat” constitute an equilibrium and the actions “Cooperate” do not, and this fact has consequences for understanding some social interactions. In Section 1.7 we will dedicate some more time to discussing the selfishness assumptions. Throughout this book we will see many more examples and variations of prisoners' dilemma games. One of the most interesting extensions of this theory has to do with the repetition of the interactions and the emergence of cooperation in that context. Chapter 7 is entirely dedicated to this question with extensive discussions on the theory, the historical and field data, and lab experiments.

To finish this first encounter with the prisoners' dilemma, let us see what this game can add to some classical philosophical views of society. The negative vision on the nature of human beings, for example, culminates in Hobbes' *Leviathan* (Hobbes, 1651). The expression *homo homini lupus*, which he borrows from the Roman playwright Plautus, captures this perspective, best expressed in the famous quote in Chapter XIII of his book:

Whatsoever therefore is consequent to a time of war, where every man is enemy to every man, the same consequent to the time wherein men live without other security than what their own strength and their own invention

² Immanuel Kant (1785), *Grounding for the Metaphysics of Morals*.

shall furnish them withal. In such condition there is no place for industry, because the fruit thereof is uncertain: and consequently no culture of the earth; no navigation, nor use of the commodities that may be imported by sea; no commodious building; no instruments of moving and removing such things as require much force; no knowledge of the face of the earth; no account of time; no arts; no letters; no society; and which is worst of all, continual fear, and danger of violent death; and the life of man, solitary, poor, nasty, brutish, and short.

After Hobbes, Locke and, mainly, Rousseau (1762) defended an opposite view, closer to the myth of the Good Savage. Arguably, one of the best alternatives to Hobbes is Adam Smith (1776) and his Invisible Hand, a metaphor to explain how selfishness does not imply Hobbes' view of a society in the absence of a Leviathan. The quote from his book *The Wealth of Nations* is no less famous than Hobbes':

It is not from the benevolence of the butcher, the brewer, or the baker that we expect our dinner, but from their regard to their own interest. We address ourselves, not to their humanity but to their self-love, and never talk to them of our own necessities but of their advantages.

The general equilibrium theory in economics is the theoretical corpus that draws upon ideas established by Adam Smith (Smith, 1776). The first welfare theorem states that if a number of assumptions are satisfied then competitive markets are efficient, which is a keystone of the theory. Needless to say, neither Adam Smith nor neoclassical economists thought that markets were always efficient, and that is why economists emphasize the theorem's assumptions. Game theory, on the other hand, presents a theoretical framework to generalize the concept of competitive equilibrium to many situations that do not fit under the assumptions of the first welfare theorem. Among those situations there is one that appears to be the opposite archetype to the Invisible Hand, and this is the prisoners' dilemma. Notice that it is really a simple game, formed with literally four numbers, and yet it helps to understand relevant real-life problems and to offer a non-trivial analysis. Risking simplification, one may say that game theory along with the general equilibrium theory allow us to say under which circumstances we can see the Invisible Hand at work and when a human being is wolf to another human being.

1.6 Matching pennies

In the prisoners' dilemma there was a strong strategic tension. Even if the conflict prevailed, there was still a cooperative outcome; although, it does not constitute an equilibrium. In our next game, matching pennies, there is no room for cooperation, equilibrium or not. What one player wins is the loss of the other player. Any game in which this happens is called a zero-sum game – a game of pure conflict.

The game is played as follows. Two players decide casting lots to select a winner (e.g., who starts an activity or who keeps some money they bet). Each player has to show one side of a coin (a penny). If the sides match, because they both showed heads or both showed tails, Player 1 wins. Otherwise, Player 2 wins. Figure 1.6a shows the game.

We immediately observe that this game has no equilibrium. If both players played “heads” or both played “tails,” Player 2 regrets her choice. If they chose different sides, it is Player 1 who has regrets. There is no stable situation: Player 1 wants the sides to match, while Player 2 wants them to mismatch. However, as anyone who has played this game or a similar one knows, there is a way to play: you need to be unpredictable by choosing “heads” sometimes and “tails” some other times. Any deterministic rule to choose between the two strategies is likely to be detected by the opponent and used in her favor. For instance, if Player 2 alternates between “heads” and “tails,” Player 1 will soon react by playing the same choice made by Player 2 in the previous turn. The best way to be unpredictable is to choose one option at random and, in this precise game, with odds 50–50.

		2	
		Heads	Tails
1	Heads	1, -1	-1, 1
	Tails	-1, 1	1, -1

Figure 1.6a Matching pennies

It is not always the case that the best way to be unpredictable is playing the different options with equal probabilities. This is shown in the next game, that strategically is just a version of the matching pennies, played between the two best tennis players ever according to the rankings. Say that, at some point in a Grand Slam match, Nadal serves and Federer returns. Nadal has to decide whether to aim to the right or to the left, and Federer has to decide whether to anticipate the ball coming to the right or to the left. Right and left are always defined from the perspective of the server. It is important to understand that Federer cannot just wait and see where the ball is coming, as its speed is so high that the time it takes to cross the court is less than the reaction time of any human being. Thus, to all effects, the decisions of both Nadal and Federer are simultaneous.

Let us write some numbers. For instance, if Nadal serves to the left and Federer mistakenly anticipates that the ball is going to the right, then Nadal has a great advantage to win the point. Say that in this circumstance he wins the point 90 percent of the time. Also, if Nadal serves to the right and Federer anticipates the left, then Nadal wins 70 percent of the time. Finally, if Federer anticipates the side correctly, the odds of Nadal winning are 50–50. In this example, we have made up the numbers, but we can use real numbers studying the historical averages in the matches between the two players. Figure 1.6b summarizes all this.

		Federer	
		Left	Right
Nadal	Left	50, 50	90, 10
	Right	70, 30	50, 50

Figure 1.6b Nadal-Federer game

What is the best course of action for Nadal? And for Federer? Notice that Federer wants to match Nadal’s choice, while Nadal wants the opposite. They are in exactly the same situation as the players in the matching pennies game. Should they try to be unpredictable choosing their strategies with probabilities 50–50? Let us see.

Consider that Federer observes that Nadal serves with those probabilities. If Federer returns from the left, he will win the point 50% of the time when Nadal plays “Left” and 30% of the time when Nadal plays “Right.” Since Nadal is playing “Left” and “Right” 50% of the time, on average, Federer will win $1/2 \times 50\% + 1/2 \times 30\% = 80/2 = 40$ percent of the time. Similarly, if Federer returns from the right, he will win $1/2 \times 10\% + 1/2 \times 50\% = 60/2 = 30$ percent of the time. Thus, Federer is better off if he always returns from the left, and therefore he does not want to play randomly. Of course, if Federer reacts this way, now Nadal will reply by playing always “Right”; however, going beyond this is not important at this point. We have just seen that if Nadal chooses sides with probabilities 50–50, this cannot be a stable situation.

What is then the best way to be unpredictable? We will show that Nadal has to choose “Left” one third of the time. If Federer returns from the right, he will win $1/3 \times 50\% + 2/3 \times 30\% = 110/3 = 36.66$ percent of the points; if he returns from the left, he will win $1/3 \times 10\% + 2/3 \times 50\% = 110/3 = 36.66$ percent of the time. In other words, Federer does not have a preferred side to return. Notice that, for Nadal, 33.66% is better than the 40% we found before with the 50–50 play (he wins the points that Federer does not).

Now we will show that the best way for Federer to randomize is playing “Left” two thirds of the time. To see this is indeed the case, notice that if Nadal serves to the left he will win the point $2/3 \times 50\% + 1/3 \times 90\% = 190/3 = 63.33$ percent of the time, and if he serves to the right he will win $2/3 \times 70\% + 1/3 \times 50\% = 190/3 = 63.33$ percent of the time.

To summarize: Nadal has a strategy that guarantees that he wins at least 63.33 percent of the points, while Federer has a strategy that guarantees that Nadal wins at most 63.33 percent of the points. Since both numbers coincide, no one has an incentive to do otherwise, and the situation is stable. Nadal cannot do better with any other strategy as long as Federer plays this way, and vice versa.

The analysis was a little hard, but we have learnt that we can find an equilibrium using random strategies and that this randomization does not need to put equal probabilities in the different options. The reader can repeat the analysis to prove that, in the original matching pennies game, the randomization 50–50 is indeed an equilibrium. Recall that we just learned to check whether a given randomization is an equilibrium, but we do not know yet how to find the equilibrium. We leave this task for the next chapter.

It seems then that, game theory in hand, we can advise tennis players to optimize their play. Well, not really. According to some studies,³ professional players have already learned the best strategies for serving and returning against different rivals. Most likely they did it by trial and error, and not by using game theory. Nevertheless, it is remarkable that we can model this equilibrium behavior.

1.7 The ultimatum game

Our last game is also a zero-sum game. We include it in the list for two reasons. First, to provide one example in which players play sequentially rather than simultaneously and, second and more importantly, because the game has become famous for its use

³ An example is Walker and Wooders (2001).

in the literature of behavioral economics in the study of the hypotheses of selfish and altruistic behaviors, among others.

A benefactor gives Lisa and Bart the possibility of winning €100 between the two of them. They only need to agree on how to share the money. The benefactor sets the following rules: Lisa will propose how to divide up the €100 and then Bart must decide whether or not to accept. In case he does, they share the money according to Lisa's proposal, but if he does not accept, they both get nothing and that will be the end of the game.

If Lisa and Bart only care about money, Lisa will propose to keep almost all of it and leave Bart with just one euro. As one euro is better than nothing, Bart should accept. Before discussing the realism of this solution, let us dedicate some time to the formalities of the game. The first thing to notice is that, because choices are not made simultaneously, we will need to change the way we represent the game. Instead of using a table, we will draw a tree as seen in Figure 1.7.

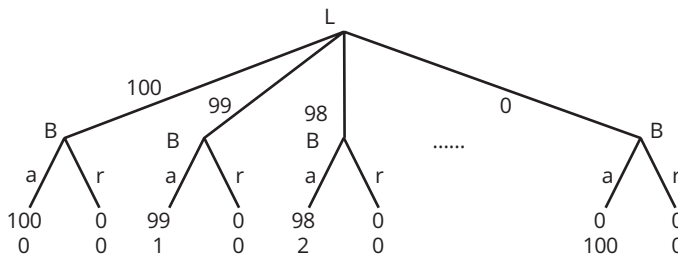


Figure 1.7 The ultimatum game

Lisa plays first and is represented with the letter L. She can propose to keep for herself any quantity between 100 and zero euros (for simplicity we assume that no offers with cents can be made), a fact that is represented with all the branches that depart from the point where Lisa decides. Bart is represented with the letter B and he can accept (a) or reject (r) each offer. The numbers at the end are the payoffs; the first one corresponds to Lisa and the second to Bart. For instance, if Lisa proposes to keep €98 for herself and Bart accepts, the payoffs are €98 and €2, respectively; if Bart rejects, they both get zero.

In the tree, we can repeat the informal analysis above. In every possible contingency, Bart has to decide one of two branches, and the one labeled “a” is always better, except when he is offered to get zero, in which case he is indifferent between accepting and rejecting the offer. In this latter case, if Bart rejects zero, Lisa will propose to keep €99 for herself, Bart will accept €1 and this would be an equilibrium of the game. There is another equilibrium, though, in which Lisa proposes to keep the €100 and Bart accepts all offers, including this one (see that he does not gain anything by rejecting zero). We could discuss how plausible it is that Bart accepts nothing in this second equilibrium, but the discussion would be quite irrelevant: both equilibria say practically the same thing, namely, that Lisa has a huge advantage with these sharing rules.

This simple game, known as the ultimatum game, is of great interest in understanding the status of game theory, as many lab experiments have shown that what

usually happens is that the “Lisas” of the games offer to keep around 60 percent of the money, and the “Barts” tend to reject offers that give them less than 40 percent. It is clear that in this game the selfishness assumption is not satisfactory. However, before discarding it, it is worth noting that there are some other situations in which it is a good assumption.

Take the case of oligopolistic markets, normally studied with the tools of game theory. If firms are selfish, these markets are not efficient and the firms will produce too little at a too high price, and further still, their benefits will be disproportionate when compared to those of consumers. This coincides with what we actually observe. Firms could be less selfish and sell more at a lower price, as if they were in a perfectly competitive market. However, if we want to write a theory of oligopolies to explain real markets and simulate the consequences of different types of regulation, should we rely on the assumption that firms are altruistic or selfish? We have every reason to believe we would obtain a better description with the second assumption.

We thus have an array of different scenarios, each with its own behavior by the players. What does all this imply for the selfishness assumption? There are at least two options here:

1. Substitute the selfishness postulate with another one that explains all the cases studied using game theory, and not only some of them (e.g., oligopolies).
2. Keep the selfishness postulate in the models where it works better and replace it with another one when it does not work.

The first of these options would be the best if only we had this other postulate that is more general than that of selfishness and that improves the existing models. Unfortunately, we are far from having such a thing and must keep our expectations to something closer to the second option.

So does this mean that we keep the selfishness postulate in the theory of oligopolies but give it up in the theory that studies the ultimatum game? Not quite. Even if experimental subjects are not selfish, the study of the selfish equilibrium is still important, as it establishes a baseline with which we can compare observed behavior. For instance, we can define a measure of altruism depending on how much the observed behavior departs from the selfish equilibrium. It is also important because in some variations of the game, subjects get increasingly closer to the equilibrium. When experimental players play against a computer, or when they play in teams, they tend to accept small offers (see the works by van't Wout, Kahn, Sanfey and Aleman, 2006, and by Robert and Carnevale, 1997). Furthermore, the observed behavior gets even closer to the selfish equilibrium when the situation is described as an anonymous interaction in a market and when the experiment is conducted using a double blind so that the subjects have warranties that no one, not even the persons conducting the experiments, will know their actions (Hoffman, McCabe and Smith, 1996). Finally, comparing observed behavior and the selfish postulate across various types of games may help establish whether those two behaviors differ because of altruism, reciprocity or spitefulness, among other possibilities.

Thus, the problem with the selfishness postulate is not whether it is true in general (it is not), but whether we use it properly in the adequate models. To say that game theory, or economics for that matter, is wrong because it uses this postulate is a bad

criticism. To point out that here and there some practitioners abuse the postulate and use it where they should not is a good criticism.

Exercises for Chapter 1

- 1.1 Two car companies are planning to launch an electric car to the market at the same time. Each of them is considering whether it should offer credit to the buyers in order to reach a larger share of customers. However, offering credit would imply incurring some costs. Both companies prefer not to offer credit, but they are afraid that the other one will do so and will, therefore, attract more clients. Suppose that the expected benefits for both companies are the following: If both offer credit, each gets 40 million euros. If none of them offers credit, they get 60 million each. If one offers credit and the other one does not, the first one will earn 80 million while the other will obtain 30.
 - (a) Represent the game in the normal form; that is, represent the players, strategies and payoffs in a table, following the examples in the chapter.
 - (b) Which game in the chapter is closer to this one?
 - (c) Which equilibrium situations can you find?

- 1.2 Two states compete for a plan that will offer tax reductions in an effort to attract firms. If both offer the same reductions, the tax rate and the tax revenues decrease with no guarantees of new firms establishing in the state. In such a case, the states would have preferred higher taxes. The idea is to attract firms even if it implies tax reductions.
 - (a) Represent the game in the normal form. Use numbers that fit the case as explained in the text.
 - (b) Which game in the chapter is closer to this one?
 - (c) Which equilibrium situations can you find?

- 1.3 The city council has to decide whether to build a high school or a nursery in a particular zone of the city. It does not have budget to carry out both projects. The person in charge of managing these matters has spoken with two indispensable companies that can make any of these two projects: one construction company and one carpentry company. Due to the composition of the population, the high school would be bigger than the nursery (it requires more construction), but the nursery will need a children's play park (it requires more carpentry). In addition, each one of the companies is interested more in participating in a certain project than in the other (the construction company prefers the high school and the carpentry company prefers the nursery), but both prefer signing the same contract to signing different contracts, since the city council would not carry out any project if different contracts are signed. The city council asks them to present a project. As none of the companies has sufficient personnel available to process both projects, they must concentrate on just one of them without knowing the project chosen by the other company.
 - (a) Represent the game in the normal form. Use numbers that fit the case as explained in the text.
 - (b) Which game in the chapter is closer to this one?
 - (c) Which equilibrium situations can you find?

- 1.4 Freedonia is a country that needs financial aid, and it can only obtain that aid from the Pangean Union (PU), an economic union of countries to which it belongs. As a condition for the aid, the PU requires that Freedonia make some deep fiscal reforms. The government of Freedonia makes a counterproposal with a different package of conditions (basically, minor reforms). Each side believes that its proposal is the best and that the other one will imply a disaster. They can hold their position or make some concessions to the other party. If they both make concessions, negotiations will end up with a result that is unsatisfactory for either of them but still better than if no one makes concessions and holds their position (which would be the worst possible outcome for both of them). Of course, each one would prefer to hold while the other party is the only one making concessions.
- Represent the game in the normal form. Use numbers that fit the case as explained in the text.
 - Which game in the chapter is closer to this one?
 - Which equilibrium situations can you find?
- 1.5 Two electors, A and B, must vote among three alternatives, X, Y and Z. If both vote for the same one, that alternative is chosen. In case of a tie between X and any other alternative, X is chosen, while in case there is a tie between Y and Z, Y is chosen. The preferences of the electors are ranked according to the following table:

A	B
X	Z
Y	X
Z	Y

- Represent the game. Hint: Notice that now the players have three strategies, rather than just two as in all previous games.
 - Find the equilibria.
- 1.6 Consider the prisoners' dilemma game in Figure 1.5a.
- Change the payoffs to reflect the case in which one year in prison suffered by the partner causes as much pain as half a year suffered by oneself, but only if the partner did not confess.
 - Find the equilibria.
 - How much pain should a year in prison by the partner cause (always only in case he did not confess) for the game to have only an equilibrium in which no one confesses?
 - Repeat (a) and (b) for a case in which only Player 1 has the altruistic preferences described in (a), while Player 2 has the original preferences in the prisoners' dilemma.
- 1.7 Consider the ultimatum game in Figure 1.7, but now with the players having only €10 to share. As in the text, proposals cannot contain fractions of euros.

Now consider also that Lisa's preferences show empathy for Bart. In particular, one euro that Bart earns is worth half a euro to Lisa.

- (a) Represent the game tree. Include all the branches.
 - (b) What offers will Bart accept? What will Lisa offer?
 - (c) Repeat the exercise for the alternative case in which one euro that Bart earns is worth one euro to Lisa.
- 1.8 Consider the ultimatum game in Exercise 1.7, but now make Lisa's preferences regarding the well-being of Bart a bit more complicated. If Bart earns an amount between 6 and 10 euros less than Lisa, each of these euros gives Lisa as much satisfaction as 2 of her own euros. If Bart earns between 1 and 5 euros less than Lisa, each of the first 2 euros Bart earns gives Lisa as much satisfaction as 2 euros of her own, and each one of the next euros will give Lisa as much satisfaction as one and a half euros. Lisa gets no satisfaction for Bart's money if Bart earns the same as or more than she does.
- (a) Represent the game tree. Include all the branches.
 - (b) What offers will Bart accept? What will Lisa offer?
- 1.9 The popular game rock-paper-scissors is played between two players. Each player has to choose one of the three objects, and they win according to these rules: rock beats scissors, scissors beats paper and paper beats rock. In case they choose the same object, they are tied. Write the normal form of the game.
- 1.10 In a penalty kick, the player can aim to the left or to the right. The goalie can move to the left, stay put, or move to the right, but she must make the decision before waiting to see the ball coming, as there is not enough reaction time. Represent the situation as a game and explain the payoffs you use.
- 1.11 Represent a coordination game between three players, where each one has to choose between "Left" and "Right." If only two players coordinate, the payoff of these two players is higher than the payoff of the player left uncoordinated. Payoffs are the highest if the three of them coordinate. Hint: You will need two tables, each one with two rows and two columns. Player 1 chooses the row (the same in both tables), Player 2 chooses the column (also, the same in both tables) and Player 3 chooses the table.
- 1.12 Two firms compete in a market. Now each one is making one million euros of profits. Firm A is considering whether to contract an advertisement campaign that will increase its profits to €1.2 million (after subtracting all the costs of advertising), while the profits of the rival, Firm B, will decrease to €650,000. The problem is that Firm B is also considering its own campaign, with similar consequences if it is the only one advertising. If they both advertise, each one will have €850,000 profits.
- (a) Represent the game in the normal form.
 - (b) Which game in the chapter is closer to this one?
 - (c) Which equilibrium situations can you find?

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