are often able to make predictions about people's behavior. This is not only fun and interesting, but when things are going wrong, it also helps us to diagnose *why* things may be going wrong. It also helps us in the development and fine-tuning of new institutions that can expand economic opportunity. For example, game theory has been instrumental in the understanding and continued development of group-lending schemes, such as those operating in Guatemala. This and many other applications begin in the next chapter.

CHAPTER 2
Games

No man is an island . . .

– John Donne, *Meditation XVII*

ADAM SMITH'S CONCEPTION of the "invisible hand" postulated that a market consisting of self-interested individuals would yield an outcome that was best for society simply through the natural course of free exchange. One of the most striking contributions of game theory has been to demonstrate that the benevolence of the "invisible hand" is merely a special case, rather than a general truth about the fruits of economic self-interest. We will observe a number of cases, in fact, where the invisible hand can become an angry, malevolent hand, punishing players for their selfish behavior. What we will see is that self-interest is sometimes good for society, but often it is not. Indeed, self-interest may yield very poor economic outcomes outside the discipline of well-functioning institutions.

Game Theory

The origins of game theory are fascinating, and they help us to understand how such important insights came about. The work of French economist Augustin Cournot revealed the earliest glimpses of a formalization of strategic behavior in the 1830s. Cournot developed a famous model of strategic competition between two firms that foreshadowed some of the later insights of game theory. But Cournot was never able to generalize his concept of an equilibrium solution to other contexts, and for many decades, his results were regarded as insightful as applied to only a restricted type of competition between two firms.

The seminal work in game theory is considered to be *Theory of Games and Economic Behavior* (1943) by Princeton mathematicians John Von Neumann and Oskar Morgenstern. Von Neumann and Morgenstern are considered to be the founding fathers of game theory. They proved that there is an equilibrium solution to any zero-sum game, a class of two-player games in which a victory by one player implies an equivalent loss to the other. (French mathematician Emile Borel had argued that such games do not necessarily have a solution.)

Yet arguably, the most important consequence of Von Neumann and Morgenstern's seminal work was that it laid the foundation for the far-reaching insights of

John Nash and others who followed him. Nash, whose celebrated life and work are brilliantly portrayed in Sylvia Nassar's biography *A Beautiful Mind* (1998) and in the 2002 Academy Award–winning movie of the same title starring Russell Crowe, was a graduate student at Princeton University when he derived the greatest single result in the theory of games and formal modeling of social behavior. His 1950 and 1951 papers "Equilibrium Points of N-Person Games" and "Non-Cooperative Games" contain his now famous Nash equilibrium. His pathbreaking insight generalized the result of Von Neumann and Morgenstern to include a much broader category of social interaction that is not necessarily zero sum.

Part of the power of Nash's solution is its almost childlike simplicity. To begin to understand the Nash equilibrium, remember that every game contains three elements: (1) two or more players, (2) a set of potential strategies for each player, and (3) payoffs, a function of the combination of strategies employed by each player. *A set of strategies is a Nash equilibrium if the strategy by each player in the game is a best response to the strategies of all of the other players.* That is, given what every other player is doing, no player wants to do anything else. (For readers unfamiliar with the Nash equilibrium concept, a more detailed introduction to the Nash equilibrium and other concepts in game theory used in this book is provided in the appendix.)

A simple example of the Nash solution concept is a game in which two cars simultaneously approach an intersection, one from the West, the other from the North.[1] Suppose the strategies available to each are to Proceed or Yield. If both Proceed, they get into a wreck, and both receive a low payoff. If each Yields, then both drivers waste time making frantic hand gestures at one another, deciding who should go through the intersection first. There are two Nash equilibria in the game: one in which North Yields while West Proceeds, and a second in which West Yields while North Proceeds. Both are Nash equilibria because both constitute a best response, given the behavior of the other.[2]

Why do we expect that a solution to any game should be a Nash equilibrium? The first and most important argument is a simple proof by contradiction: If a particular outcome were not a Nash equilibrium, then it would be in the interest of someone to deviate from it. In addition, if a game has a single Nash equilibrium, it forms an intuitive outcome to a game that well-reasoning players are likely to anticipate. Such anticipations then create a focal point for play and become self-reinforcing. The Nash equilibrium can also be justified as a stable "prescription" for play. If, for example, a social norm, a tradition, or a third party suggests a behavior for players, creating an expectation about play, neither player will want to deviate from these prescriptions. Last, if players experiment with strategies over time on a trial-and-error basis, the final settling point in the game should constitute a Nash

[1] I will use capitals to delineate players and strategies in games throughout the book.
[2] It makes sense to codify one of the two Nash equilibria into law. In the United States and many other countries, West would have the right-of-way since it approaches to the right of North, an arbitrary distinction but one that induces the efficient behavior by fostering behavioral expectations that promote safer and quicker transitions at intersections.

equilibrium in which players develop a mutually reinforcing best response to one another's behavior.

Perhaps not coincidentally, as Nash languished in a schizophrenic haze for several decades after his major breakthrough, game theory also languished, with few major advances in interesting economic applications. Thomas Schelling's *The Strategy of Conflict* (1960) and Garret Hardin's application of Albert Tucker's now-famous Prisoners' Dilemma in the *Tragedy of the Commons* (1968) are two major exceptions. By the 1980s, however, economists had begun to understand the power and generality of the Nash equilibrium concept. In fact, much of modern microeconomic theory by then was beginning to be recast in the language of game theory. This has continued such that in economics today, there is hardly an issue of any mainstream academic journal that does not contain the phrase "Nash equilibrium." Almost miraculously, by the late 1980s Nash began to emerge from mental illness. Moreover, in recognition of his revolutionary solution concept (as well as his work on bargaining models), Nash received the Nobel Prize in 1993 with Reinhard Selten and John Harsanyi, who extended the Nash equilibrium to include dynamic games and games with imperfect information, respectively. The 2005 Nobel Prize in Economics was also given for work in game theory, to Thomas Schelling and Robert Aumann, who pioneered important extensions and applications of Nash's basic solution concept.

The Nash equilibrium is a powerful tool for understanding development problems. As is now commonly understood, most economic behavior is not zero-sum. For example, economic exchange nearly always falls into the category of "win-win" (though some may not "win" as much as they would like). Other phenomena, such as environmental degradation or economic corruption, are often ultimately "lose-lose." As a result, the Nash equilibrium is helpful for understanding the incentive structures that end up producing unhappy outcomes.

Let us now return to our five vignettes from Chapter One . We can model each of these as a simplified two-player, two-strategy, normal-form game. A game in normal-form (sometimes called *static* form) uses a payoff matrix with one horizontal player, Player 1, choosing strategies by row, and a vertical player, Player 2, choosing strategies by column. In the normal form, players choose strategies simultaneously or at least independently of the other's knowledge. The payoffs in the lower left of each cell are to Player 1 and those in the upper right of each cell are to Player 2.

Coordination Games: The Battle of the Sexes and the Stag Hunt

Consider a Businessman from the bribery and corruption story in Chapter One. A model of this game in normal form appears in Figure 2.1. Suppose that he needs to get a business license to open a branch office in the capital city. Arriving at the window at which such licenses are issued, he must choose between an Honest Behavior and a Corrupt Behavior. Either he can expect the official to process his application expeditiously without a bribe or knowing that a little speed money will help grease the wheels of the bureaucracy, he can slip a fifty-dollar bill under the window with his application. The Public Official likewise can dutifully process the

		Public Official: Honest Behavior	Public Official: Corrupt Behavior
Businessman	Honest Behavior	3 / 1	0 / -2
	Corrupt Behavior	-2 / 0	1 / 3

Figure 2.1. Battle of the Sexes/Corruption Game

permit application or suggest to the businessman that the permit can be "expedited" for a special "rush fee" of $50.

A culture of corruption contains reinforcing behaviors that form a Nash equilibrium in the cell located in the intersection of the bottom row and right column. The Public Official expects a bribe and the Businessman comes prepared to oblige. The Businessman receives the payoff of 1 in the lower-left corner of this cell, and the official receives the payoff of 3 located in the cell's upper right. Neither will choose to deviate given the behavior of the other. Failing to obtain a permit leaves the Businessman with a payoff of zero, whereas he receives a payoff of 1 through bribing. The Public Official receives a payoff of 3 by taking an offered bribe and zero if he does not. If either player were to act honestly in the face of dishonesty by the other player, it would increase the chance of prosecution to the dishonest player so that the latter's payoff falls to −2. But the payoffs do not dictate such a response because the inconvenience of this action reduces the payoff of the honest player to zero. Thus cultural expectations can create an outcome in which people expect to pay bribes and officials expect to receive them, producing a Nash equilibrium of (Corrupt; Corrupt).

However, another equilibrium also exists in this game: the corruption-free Nash equilibrium, (Honest; Honest). The Businessman approaches the window expecting to pay the normal processing fee and no more. The Public Official has little reason to expect that the Businessman will offer him a bribe; perhaps bribes have seldom been offered in the past. A bribe may be regarded as out of the norm or, possibly, as an insult. No fifty-dollar bill changes hands. The Businessman's payoff is 3 and the Public Official's payoff is 1. If either were to deviate from honesty, then his payoff would fall to −2, hence the outcome is self-sustaining.

Consequently, two Nash equilibria are possible in the game.[3] This is true in all two-strategy Coordination games. In the general case of m players in an n-strategy Coordination game, there are typically n Nash equilibria (not m). Which Nash equilibrium actually occurs is often difficult to predict, but past play tends to govern

[3] There is actually a third Nash equilibrium that occurs in "mixed strategies," in which players are honest some of the time and corrupt some of the time. We will consider only "pure strategy" Nash equilibria for now, until we examine the mixed strategy case in Chapter Nine.

future play. All that we know for certain about a Coordination game is that players will ultimately coordinate on a similar behavior. Other examples of Coordination games in everyday life include, time and spatial measurements, currency, different types of software programs, electrical plugs, fashion (e.g., neckties, turbans, droopy pants). The list is endless. The game in which I write this book in English and you read it in English is a Coordination game.

The game presented in Figure 2.1 is a particular type of Coordination game often called a Battle of the Sexes game. It has this curious title because a common prototype of the game depicts a couple deciding where to go on a date, wherein one activity is favored by the man and the other by the woman. The game assumes that the couple is enamored with one another, so that they prefer to be together even if it means one of them has to endure his or her second-favorite activity.

As a two-player Coordination game, the Battle of the Sexes has two Nash equilibria, but each is favored by one of the two players. If I wrote this book in English even though you would have preferred to read it in Spanish (but will read it in English anyway), we have a Battle of the Sexes game. It would have taken longer for me to write it in Spanish, but this might have made life easier for you. (Although given the level of my written Spanish, this is clearly questionable.) In the corruption game in Figure 2.1, the businessman is better off in the honest equilibrium, and the public official is better off when there is corruption.

Let's turn now to the migration story discussed in Chapter One. Contrast the Nash equilibria in the corruption game with the migration game depicted in Figure 2.2. In the migration game, consider two peasants, Ronny and Jaime, lured by the lucrative wages of *el norte*. They consider migration to the United States, where currently few of their countrymen have settled. If they Stay, they both earn low rural wages in their home country and receive a payoff of 1. If they both Go (migrate), they can form a small network in which they can share living expenses, help each other to find jobs, and have somebody to talk to in their own language. The payoff when they both migrate is 3. If only one Goes, lonely times dictate a payoff of −2 for him who Goes and one for him who Stays.

Like the corruption example, this is also a Coordination game with two Nash equilibria, (Stay; Stay) and (Go; Go). However, unlike the corruption example in which the businessman prefers the (Honest; Honest) Nash equilibrium and the official prefers (Corrupt; Corrupt), in the migration example *both* prefer (Go; Go) over (Stay; Stay). The migration example is also a particular type of Coordination

		Jaime: Go	Jaime: Stay
Ronny	Go	3 / 3	-2 / 1
	Stay	1 / -2	1 / 1

Figure 2.2. Stag Hunt/Migration Game

game called a *Stag Hunt* (sometimes called an Assurance game). The game gets the Stag Hunt name from Jean-Jacque Rousseau's reflection on two hunters deciding whether to individually pursue a Hare (safe, but a small meal) or jointly pursue a Stag (dangerous, but more filling). Stag Hunts capture strategic interdependence when coordinated cooperation between players yields a superior equilibrium, but a safer equilibrium exists in which players pursue their independent interests; that is, a solitary hunter is more likely to be speared by the stag but is unlikely to be overwhelmed by a hare.

Stag Hunts have one Nash equilibrium that is better than the others, but players will choose it only if they believe that the other player(s) will do the same. Otherwise, by choosing it, the player may get burned with a low payoff. For example, in the migration game in Figure 2.2, if one player Goes while the other Stays the migrating player gets burned with a payoff of -2. Yet in the same game, if both players Go, they receive a payoff of 3, which is better than the payoff of 1 if they both Stay.

In economics, we say that the strategy pair (Go; Go) is *Pareto superior* to (Stay; Stay). This means that (Go; Go) is best for all the players, or at least one player is better off while the other is no worse off than the alternative. (Here both happen to be better off.) Any set of payoffs that is not Pareto inferior to another set of payoffs is said to be *Pareto efficient*. Pareto efficiency is a critical idea in applying game theory to economic development because Pareto inefficient equilibria are often associated with development traps.

In other types of Coordination games like a Battle of the Sexes game, the Nash equilibria cannot be Pareto ranked, or ranked in terms of Pareto superiority. In the corruption game in Figure 2.1, for example, if we move from the (Corrupt; Corrupt) equilibrium to the (Honest; Honest) equilibrium, the businessman is better off, but the official is worse off. Because one Nash equilibrium is preferred by each player in the game, the equilibria cannot be Pareto ranked. In such cases, there remain *n* Nash equilibria in games with *n* strategies available to each player, and each Nash equilibrium may be Pareto efficient; that is, no equilibrium will be Pareto superior to the others.

A third type of Coordination game is one of *pure coordination*, in which payoffs to players are equal in the different Nash equilibria. One example from the previous list might be language: Can one say that coordinating on Romanian as a common language is better or worse than Swedish? If a society emerges all speaking one or the other, the payoff is essentially the same. Unlike when there is one Nash equilibrium that is Pareto superior to others, in a game of pure coordination there is no a priori reason to expect one particular Nash equilibrium as more likely than the rest. Other Coordination games fall into none of these categories but still have as many equilibria as there are strategies.

Nash equilibria in any type of Coordination game are often "focal points" that evolve around social norms. The term *focal point* was originally used by Nobel Laureate Thomas Schelling to describe the way people gravitate toward one particular coordinated type of behavior. In an experiment reported in *The Strategy of Conflict*, Schelling polls a large number of East Coast college students, asking them where

and when they would meet someone in New York City if no prior place or time had been arranged. An overwhelming number in the sample gave the same answer: at noon under the big clock in Grand Central Station. The point is that "noon at Grand Central Station" may be no better than anywhere else in New York. It is simply a best response given the conjecture of players regarding where they think others think that they would show up to meet them.

In Coordination games, communication can be vital. Taking the previous example, the ability of two people to communicate before choosing a rendezvous point and time helps the players to reach a Nash equilibrium in a game of pure coordination. Thus, in Coordination games, and particularly in Stag Hunts in which Nash equilibria can be Pareto ranked, leadership is key and involves communicating the Pareto-superior strategy to all players. In a Battle of the Sexes game like the corruption example, one player may try to make the other player *believe* that he will play the strategy that corresponds with his own preferred Nash equilibrium outcome. For example, an official may try to convey to a businessman that "nothing ever gets done around here" without a little tip.

Nash equilibria in all types of Coordination games are also notoriously "sticky." Once a Nash equilibrium in a Coordination game is established, it is often difficult to move to another equilibrium, even if the alternative is Pareto superior. In economic development, this is called a *coordination failure*, an idea that will be explored more thoroughly in Chapter Three. A simple and well-known example is the QWERTY key arrangement on computer keyboards. Why should relatively rarely used letters like *j* and *k* (not to mention ";") be situated in the most convenient locations, whereas one needs to reach for important vowels like *e* and *i*?

Paul David, a well-known economic historian at Stanford, chronicles the answer in a 1985 article. In the earliest days of the typewriter, salesmen would impress potential customers by rapidly hammering out the word *typewriter* on the machine. The typewriter keys were placed such that the hammers would not jam as "typewriter" was quickly typed. (Notice that the letters in "typewriter" are located along a single row on the QWERTY keyboard.) In the days before we were all forced to do our own typing on computers, firms hired typists from typing schools, where the QWERTY arrangement had been adopted and taught. Thus, it made no sense for firms to stock any other type of keyboard as an alternative. This is ironic given the existence of the Dvorak keyboard, developed back in 1932, which contains vowels and other common letters in handy places, which some have claimed to type up to 30 percent faster.[4] The QWERTY keyboard continues as an example of a coordination failure to this day, a result of a historical accident and is an example of a lock-in process that has created a Pareto-inferior Nash equilibrium.

[4] The unquestioned superiority of the Dvorak keyboard has been challenged in "The Fable of the Keys," a well-known article by Stan Leibowitz and Stephen Margolis (1990) who argue that Navy tests documenting Dvorak's superiority were flawed, and even that Dvorak himself had a financial stake in the results. Still, nearly everyone acknowledges the QWERTY design to be less than optimal and its perpetuation attributed to some degree of path dependence.

We will see that games in economic development can take societies down a path in which their level of development ends up resembling a QWERTY keyboard. A combination of strategic interdependence, historical processes, and deeply rooted social norms can cause societies to become entrenched in a Nash equilibrium that is inferior to what could be achieved – as shown in the example of Mexican corruption and elsewhere.

Hawk-Dove Games

Many games in economics involve a conflict over something. The particular something may be a piece of land, food, a potential spouse, or a private good that only one person or one group of people can possess, enjoy, or consume. The essence of such conflicts is captured in a Hawk-Dove game (sometimes called "Chicken"). In Coordination games, the more people engaged in a certain behavior, the more attractive that behavior becomes to the individual player. Hawk-Dove games are precisely the opposite. The more that other players are devoted to a given type of behavior, the more the individual player wants to do something else. Suppose that two (fastidious) backpackers suddenly discover that they have only one toothbrush between them. Both would like to use the toothbrush but not if the other is using it. What is certain is that the toothbrush will be used by someone. However, a toothbrush is a personal hygienic tool. Although each backpacker would ideally like to use the toothbrush exclusively, each would also prefer that the other use it than to share it. In the Nash equilibrium, only one person will use the toothbrush.

Consider the numerous other situations like the toothbrush: Two oncoming cars approach a one-lane bridge; which should defer and which should proceed? A pair of firms would each like to enter a market of limited size, but with high fixed costs of entry. Given the limited size of the market, there is only room for one profitable firm. Which firm will enter? A government agency agrees to provide a village with a well if the villagers can decide where the well should be sunk; which families will get the well closest to their property? The common element in Hawk-Dove games is conflict over a scarce resource.

Conflict over land tenure is a classic and common problem in development. Land is most productive when it is worked by an individual or individual household. Rights to land have been the source of innumerable civil wars in developing countries, especially in nations with a legacy of colonialism. Well-defined property rights were a common feature of many European societies before, during, and after colonization, from the sixteenth to nineteenth centuries. Many indigenous societies, in contrast, traditionally viewed land as held in common, something inappropriate for individuals to own. Consequently, during the colonial era, Europeans and their descendants often laid claim to vast areas of land that had no apparent "owner." Since that era, descendants of those who first *occupied* the land have often viewed the early European claims as illegitimate. Such has been the genesis of conflicts over land tenure in less-developed countries, especially throughout Central and South America and in many parts of Africa.

		Landlord: Put Cows on Land ("Hawk")	Landlord: Put Cows Elsewhere ("Dove")
Peasant	Live and Work on Land ("Hawk")	-10 / -10	-5 / 5
	Live and Work Elsewhere ("Dove")	5 / -5	0 / 0

Figure 2.3. Hawk-Dove/Land Tenure Game

The essence of the conflict over land rights as presented in Chapter One can be illustrated through the Hawk-Dove game shown in Figure 2.3.

Like Coordination games, two-player, two-strategy Hawk-Dove games are characterized by two pure Nash equilibria. The "Hawk-Dove" name refers to the idea that players can play either aggressive (hawkish) or passive (dovish) strategies. The difference between the two types of games lies in the pattern of their Nash equilibria. With Coordination games, Nash equilibria occur when all players do the same thing. In Hawk-Dove games, the equilibrium occurs with players each doing different things. In the example in Figure 2.3, Nash equilibria occur between the Peasant and the Landlord on (Live and Work on Land; Put Cows Elsewhere) and (Live and Work Elsewhere; Put Cows on Land).

With the payoff so low to players in the conflicting strategy profile (i.e., (Live and Work on Land; Put Cows on Land)), how does one ensure that one of the two Pareto efficient Nash equilibria will occur? Robert Sugden (1986, 2004) in his celebrated work *The Economics of Rights, Co-operation and Welfare* suggests that disputes in the Hawk-Dove games over goods such as property are resolved through the establishment of "conventions." Conventions are established in games through the exploitation of *asymmetries* in the roles of players. For example, consider a conflict over a piece of land in which one player has possessed the land for a number of years but is faced by a challenger who wants the same piece of land. The convention "if Possessor, play Hawk; if Challenger, play Dove" always leads to one of the two Pareto-efficient Nash equilibria of the game. Seldom does a player take the same role of Possessor or Challenger in all conflicts. Typically, a player will take different roles in different situations; the convention prescribes the proper strategy for each role that facilitate a (Hawk; Dove) or (Dove; Hawk) Nash equilibrium. These conventions prevent the conflict associated with (Hawk; Hawk) and the economic waste associated with (Dove; Dove). Irrespective of what role a player takes in a particular situation, provided that his opponents follow the convention, then it is in each player's interest to follow it. Sugden, moreover, argues that formal law emerges from such conventions (perhaps from which comes the idea that possession is 9/10 of the law!).

Children, for example, learn even as toddlers about two types of conventions that can give them claim over a toy. We can call these *possession* and *sharing*. A child may be told that she has claim over a toy if she "had it first" but also if it is "her turn" to play with it, sometimes even if the toy is in the possession of the other child. Conflict occurs between children when one convention butts up against another, such as when one child has been playing with the toy for a long time while the other has coveted it. In such cases, the child without the toy is likely to invoke the latter convention, claiming "It's MY turn!" while the child with the toy will invoke the former convention, "I had it FIRST!".

Like the toy example, conflict occurs similarly in developing countries when different groups have different views of what convention should apply. Another convention, for example, might dictate that land ownership should be egalitarian. Under an egalitarian convention, asymmetry in the game would occur between those with more and those with less land, those with less land being prescribed to play Hawk, and those with more land to play Dove. Thus conflict, in the form of Pareto inefficient (Hawk; Hawk) play, could occur between one party who favors a "first-possession" convention and another party who favors an "egalitarian" convention.

Nevertheless, even when there is a shared understanding over a particular convention such as first-possession, arguments may linger concerning which party is indeed the rightful first-possessor. A group of people of indigenous ancestry may dispute the convention that the first to claim property rights over a piece of land should occupy the role of Possessor if land was previously possessed, perhaps communally, before formal property rights were bestowed on a later claimant. The Israeli-Palestinian conflict also seems to apply here. Does first-possession in modern history trump first-possession in ancient history? We will explore the subject of conflict more closely in Chapter Ten.

Conventions help determine how a broad array of resources is allocated in society: Should a given lump of government expenditure be spent where it is most efficiently utilized or where poverty is greatest? A limited number of tickets are available for sale at a counter. Should they be allocated to those first waiting in a line or to those who can most aggressively shove themselves toward the window? A business started by a member of a poor extended family becomes lucrative. Who is entitled to share in the good fortune? Economic development is hampered when a consensus over basic conventions has failed to emerge in society, creating an atmosphere of conflict and unpredictability.

The Prisoners' Dilemma

The story of deforestation in Haiti and the Dominican Republic in Chapter One is but one of the countless instances of environmental degradation in the developing world. Insight into the vexing problem of environmental degradation is one of the many applications of the famous Prisoners' Dilemma game.[5] The Prisoners'

[5] Albert Tucker at Stanford University is credited with the original Prisoners' Dilemma game in an unpublished manuscript. In his game two suspects are charged with a joint crime, and are held separately by the police. Each prisoner is told the following: If one prisoner confesses and the other one does not, the

		Rochelle-Marie: Restrain Cutting	Rochelle-Marie: Cut Down Maximum
Jean-Pierre	Restrain Cutting	3, 3	-1, 4
	Cut Down Maximum	4, -1	0, 0

Figure 2.4. Prisoners' Dilemma/Deforestation Game

Dilemma illustrates how individually rational people can collectively do irrational things, and it has vast applications across the social sciences. The game has yielded insights into issues as diverse as arms races, marital cooperation, commodity cartels, price wars, bidding strategy, voter participation, cooperatives, international trade policy, and the provision of public goods, as well as the degradation of natural resources. Some scholars such as Robert Axelrod (1984) have even used the game to develop general theories about the emergence of social order from anarchy.

The general characteristic of a Prisoners' Dilemma game is that it consists of two or more players who are each able to engage in either "cooperative" or "defecting" types of behavior. Each player benefits from the cooperative play of others, but individually each has an incentive to defect. The Prisoners' Dilemma is a game rich in irony. Because each player is better off defecting regardless of the behavior of the others, the game yields a unique Nash equilibrium in which *all* defect and are worse off than if each player had played cooperatively. Moreover, agreements between players *not* to defect are notoriously difficult to enforce, particularly in one-shot plays of the game. No matter what they agree to, each player knows that in the end he will be better off by defecting. Therefore, each does defect, to the detriment of everyone. In this regard, the Prisoners' Dilemma represents a divergence between individual and collective rationality.

The structure of the Prisoners' Dilemma can be seen in a representation of the Haitian deforestation problem of Chapter One in Figure 2.4.

Notice that whether or not Rochelle-Marie restrains cutting firewood, Jean-Pierre's best response is to cut as much firewood as he can. Cut Down Maximum is therefore a *dominant strategy* for Jean-Pierre. Since the game is symmetrical, Rochelle-Marie likewise has the same dominant strategy. The ensuing Nash equilibrium is the (Cut Down Maximum; Cut Down Maximum) deforestation payoff, in which the mutual payoff is zero and the hillside is left barren.

As Garret Hardin (1968) famously observes in the *Tragedy of the Commons*, Prisoners' Dilemma problems occur in many, if not most, situations that call for some

former will be given a reward of 1 and the latter will receive a fine equal to 2; if both confess, each will receive a fine equal to 1; if neither confesses, both will be set free. These payoffs establish the basic payoff structure for the game's many applications.

kind of collective sacrificial restraint or action. For example, individual conservation of common-pool resources, such as forests, fisheries, and grazing lands, typically yields a total public benefit that more than compensates each individual for his own restraint. Individual restraint in littering; in air, water, and noise pollution; in respect for private property; even in self-control while resolving disputes, make up only a fraction of other examples. Nevertheless, the underlying incentive in these situations lies in gaining an individual advantage through a lack of individual restraint.

Like individual *restraint*, individual *action* can produce benefits to society and to each individual that more than compensates each individual for his own effort. These are circumstances in which a group of individuals can collectively produce a public good, to be shared by all, that is worth more than the sum of the individual efforts. The Prisoners' Dilemma problem is manifest, for instance, in the incentive structure of cooperatives. A quick numerical example illustrates the point: Suppose a group of n people establish an onion cooperative in which each agrees to work a given number of days planting, weeding, harvesting, and then selling the onions in a local market. All contribute their effort to the onions and then share in the collective bounty. A basketful of onions, selling for $10, is produced for every day each person contributes to the cooperative effort. The incentive for a co-op member to be a slacker is evident: "Calling in sick" for a day reduces a member's take by only $\$10/n$, whereas a person working independently would lose the full $10 for a missed day. If the value of doing something else for a day besides farming onions lies between $\$10/n$ and $10, the co-op member has an incentive to slack off that an individual onion farmer would not have.

The overuse of common-pool resources such as forests or fisheries and the incentive to slack off as a member of a cooperative are symptoms of the "free-rider" problem in collective action. Prisoners' Dilemma games capture a broad class of settings in which the welfare of the individual and the welfare of the group are in conflict with one another. This contrasts with a Coordination game, in which a player may have an incentive to act cooperatively, provided the others do the same.

The relative importance of communication is another difference between the Prisoners' Dilemma and Coordination games. Communication can be vital in a Coordination game, but it is worthless in a single play of the Prisoners' Dilemma. Households in a village may agree that they should restrict tree cutting in a common forest, but the incentive remains to cut as much wood as one needs. Members of a cooperative may agree that each should give 100 percent effort in the work of the cooperative, but the incentive to slack off still exists. "Talk is cheap" in Prisoners' Dilemma games.

The relationship between self-interest and group welfare in a Prisoners' Dilemma also contrasts with normal market exchange. Economists have shown (under a standard set of assumptions[6]) that as individuals pursue their own self-interest in the course of market exchange, they generate an outcome that is Pareto efficient – a result known as the First Theorem of Welfare Economics. This is essentially a proof of the benevolence of Adam Smith's invisible hand, that greed can be harnessed for the common good of society. But in a Prisoners' Dilemma, greed is bad. Unbridled self-interest leads to an outcome that is worse for everyone, that is Pareto *in*efficient.

[6] The conditions include full information between many buyers and sellers, that each consumer's well-being is unaffected by the consumption choices of another, an absence of transaction costs and externalities, and that some technical assumptions about the preferences of buyers and sellers are satisfied.

All of this seems a bit depressing. How can the Dilemma be resolved? As we will see in many of the following chapters, Prisoners' Dilemma problems are solved principally by two means. In traditional societies where the same people interact frequently, Prisoners' Dilemma problems are often solved through *reciprocity*. In other words, an implicit social contract may prescribe people to help others who have helped them in the past. Likewise, a traditional society may sanction those who fail to help others in the group or who fail to display the proper restraint in using public resources. In such cases, the threat of future punishments will often deter short-term opportunism.

In modern societies, where interaction between individuals is frequently nonrepeated and anonymous, society must devise ways to deter defections in one-shot plays of the Prisoners' Dilemma. A modern society with strong governance structures can impose a series of punishments on certain behaviors (e.g., overfishing, deforestation, littering, making too much noise) that will keep antisocial behavior in check. The establishment of formal laws, police, courts, and prisons helps to deter Prisoners' Dilemma–type defections (at least for most people). A system of penalties for defective behavior can turn a Prisoners' Dilemma into a Coordination game, in which cooperative behavior can be a Nash equilibrium.

Trust Games

In economic transactions, one party often has an opportunity to take advantage of another. A peasant farmer rents a mule from his neighbor, overworks it, and returns it exhausted, limping, and hungry. A woman buys from a merchant on credit and never bothers to repay. A day laborer, paid to herd goats to a remote mountain area for fresh food and water, spends the day in the mountains indeed – taking a nap. Because of the dynamic sequence of many economic transactions, they frequently involve some element of trust.

Stanford game theorist David Kreps (1990) captures this element of second-stage vulnerability in what is now commonly referred to as a Trust game. Trust games involve one player taking a preliminary action in which she is vulnerable to a second player acting in his selfish interest. If the second player were to restrain from selfish behavior, both would benefit from the transaction. But understanding the incentives of the second player, the first player eschews the transaction at the outset. Consequently, unless the incentive problem of the second party can be somehow resolved, the transaction never happens. This results in a Pareto-inefficient outcome in which both players are worse off than if somehow the second player could commit to honoring the transaction.

A credit transaction involves an exchange of money for a promise to repay it back in the future (with interest, of course). A number of problems plague credit

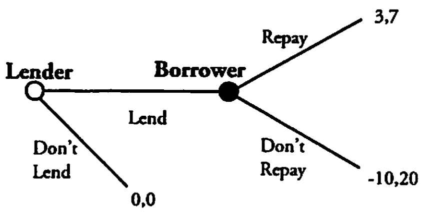

Figure 2.5a. Trust/Lending Game (Extensive Form)

transactions, which we will examine in more detail in Chapter Seven. But one very basic problem is simply the problem of enforcing the promise to repay. Especially in developing countries, where resources are scarce and needs are so often overwhelming (sick children, low crop yields, etc.), there are a thousand decent excuses one could make to justify failing to repay a loan. If it is impossible to enforce loan repayment, then how can a lender lend? If lenders do not lend, how can a low-income economy grow?

The credit transaction in Figure 2.5a illustrates a Trust game, where the game is presented in *dynamic* (sometimes called *extensive*) form. Payoffs are given in order of (first player, second player), in this case (Lender, Borrower). Here we take the example of a $10 loan that is able to generate a 100 percent return on investment. Assume the interest rate is 30 percent, so that $13 is due back to the Lender at payback time. Notice that the Lender is happy to lend the $10 to the borrower, provided the Borrower repays; this yields a payoff of $3 to the Lender, and $7 to the Borrower.

By using a technique appropriate to extensive-form games called *backward induction*, we see that in the second and final stage of the game the borrower has an incentive not to repay. With no recourse against the borrower, the lender in this case would lose not only the interest but also the principal. By backward induction, the lender, understanding the incentives of the borrower in the latter stage of the game, chooses not to lend. This results in a Pareto-inferior (Don't Lend; Don't Repay) solution to the game, and a solution by backward induction is always a Nash equilibrium.

At its most basic level, this story explains one reason so many of the poor in developing countries are left without access to credit. Collateral requirements are one of the most common mechanisms used to solve the Trust game in a lending transaction. But the poor, who arguably have the greatest need for credit, are the least likely to possess the kind of assets needed to secure a loan. (In Chapter Seven, we will see how the lending game can be resolved without collateral!)

Presenting the lending game in normal form in Figure 2.5b shows the similarities and differences between a Trust game and a Prisoners' Dilemma.[7] Both games have

[7] At least, theoretically, every extensive-form game can be represented as a normal-form game and vice versa. However, it is typically more convenient to represent games that involve dynamic play, or sequences of moves in extensive form and to represent static games in normal form.

		Borrower: Repay Loan	Borrower: Don't Repay
Lender	Lend	3, 7	-10, 20
	Don't Lend	0, 0	0, 0

Figure 2.5b. Trust/Lending Game (Normal Form)

a single Pareto-inferior Nash equilibrium. However, in a Trust game, the incentive to defect is one sided. (In fact, some refer to such games, especially when presented in the normal form, as a one-sided Prisoners' Dilemma.) Unfortunately, given the structure of the game, it takes two to play, and an incentive for even one player to defect brings about the sad result. This creates a "market failure" in which two parties each have something to gain in a transaction, but flaws in the market prevent it from happening.

We will explore in Chapter Six how rural labor and land markets in developing countries are often characterized by traditional institutions that have evolved to solve Trust games. Distribution of land ownership is often highly unequal, creating a substantial demand for labor among large landowners and a substantial supply of labor among landless or near-landless peasants. A natural solution would be for peasants to sell their agricultural labor at a fixed wage to landowners. However, once a worker is promised a fixed wage, he has an incentive to shirk if his wage doesn't depend on what he produces for the landowner, creating the underlying incentives of a Trust game. One alternative would be for workers to rent parcels of land from the landowner, taking a surplus from the land equal to the revenue from the crop minus land-lease and other costs. But because of the uncertainty of crop yields, a land rental contract may burden a peasant with an unacceptable level of risk. We will see that the common solution to this problem is sharecropping, a contractual mechanism that mitigates the problem of shirking (though not completely) while saddling a peasant with less risk than a land rental contract.

Three factors can help curtail the enforcement problem in Trust games. First, as in Prisoners' Dilemma games, repeated interaction can be crucial. In developed and developing economies alike, reputation matters. The desire to maintain access to credit may induce a borrower to repay a loan. The desire to remain employed may be enough to keep workers from shirking their responsibilities. The desire for repeat business is often enough to keep shops from passing off shoddy goods to their customers. We will study the importance of repeated games repeatedly in this book, beginning in Chapter Four.

Second, legal systems play a pivotal role in facilitating economic transactions because, like Prisoners' Dilemma games, Trust games are also games of "cheap talk." Holding payoffs constant, promises and pregame communication are ineffective since they do not eliminate Player 2's incentive to cheat. However, a credible threat of civil action can alter the payoffs in a Trust game enough to make the second player's promises credible. In the frequently one-shot and anonymous transactions in advanced industrialized economies, legal systems are critical for dealing with the enforcement issues in a Trust game. For example, a firm may have a short-term incentive to hawk shoddy merchandise and make off with a customer's money. But in industrialized societies, buyers are made to feel reasonably confident about even first-time purchases of goods and services. Volumes of tort law, reasonably efficient courts, and an abundance of lawyers sharpening their fangs for lucrative civil lawsuits provide ample incentive for most suppliers to make their goods and services conform to their claims. Paradoxically, the ability of the first player to take civil action against the second player results in a benefit to the second player as well as the first: It may allow for a mutually beneficial transaction to occur that would not occur otherwise. The importance of well-functioning legal systems, until recently, has been a long-neglected component of economic development, and is a subject that we will examine in Chapter Nine.

Third, a strong and broadly based set of ethical norms is critical. Most people don't cheat others, not for fear of being thrown in jail, but because they genuinely feel bad about cheating. Ethical norms help to internalize a concern for the welfare of those aside from the self and are typically established through religious institutions, the community, and the family. The importance of this to economic development will be discussed in more detail when we analyze the importance of *social capital* in Chapter Eleven.

CHAPTER 3

Development Traps and Coordination Games

Just then there was a strong wind. It blew Toad's list out of his hand. The list blew high up into the air. Help! Cried Toad. "My list is blowing away. What will I do without my list?" "Hurry!" said Frog. "We will run and catch it." "No!" shouted Toad. "I cannot do that." Why not?" asked Frog. "Because," wailed Toad, "running after my list is not one of the things that I wrote on my list of things to do."

– Arnold Lobel, *Frog and Toad Together*

ECONOMIC DEVELOPMENT, AS we know it, is a relative newcomer to human society. For most of history, the world languished in a kind of economic limbo. Centuries after the early Roman era, world per capita income hardly changed, lingering around $400 per year in both the rich and poor areas of the world.[1] (Ironically, for centuries it remained slightly higher in what is now considered the "developing world.") The world economy was dormant, technological change was slow, and advances in human welfare were virtually imperceptible, bringing to mind the ageless and changeless millennia of J. R. R. Tolkien's *Middle Earth*. By the time of the Renaissance, however, per capita income in Europe slowly began to grow – to around $700 by 1500, creeping to $1,100 by the eve of the Industrial Revolution, the beginning of a spectacular economic takeoff.

What finally got the economic ball rolling? The answer, according to many, was the Big Push. The Big Push idea was originally conceived by Paul Rosenstein-Rodan (1943) as he pondered the economic fate of postwar Eastern Europe. However, the first Big Push took place during the Industrial Revolution in Great Britain, later spreading to parts of Western Europe and the United States. Among other factors, such as important innovations in technology and education, the American Big Push involved a combination of investments in key industries – steel, textiles, coal, and railroads. Feeding off one another, investments in these interlinked sectors generated the economic momentum necessary to escape the gravitational pull of the low-equilibrium trap.

Central to the Big Push is the idea of strategic interdependence among the economy's different players. Investment and growth in one area of the economy depend on the actions of other economic players and, equally importantly, on *expectations*

[1] Madison (2001).