

The Strategy of Sovereign Debt Renegotiation ¹

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Abstract

The standard economic theory of perfect competition assumes that there are many buyers and many sellers, all possessing the same information, so that no one can act strategically. This standard theory is clearly not appropriate for analyzing debt renegotiation, where buyer and seller are bound to deal with each other and information is asymmetric. Game theory is a set of techniques developed to analyze economic situations that, like games, involve few players and strategic behavior. This theory has been greatly developed in the past fifteen years, and is useful for understanding some of the paradoxes of debt renegotiation.

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1. Introduction.

The influence of game theory on economics has been ballooning since the 1970's because it provides a way to attack the problem of strategic behavior in economic interaction. Not only is game theory widely used in mainstream economics, it has also penetrated finance, corporate strategy, and political science. Once the preserve of mathematicians, the subject is by now well enough understood that it is beginning to be taught to undergraduates and to MBA students in the leading business schools.

Debt renegotiation is an obvious area for application of economic models of strategic behavior. As historical studies such as Aronson (1979) and Cizauskas (1979) show, debt renegotiation has always been marked by the complicated interaction of self-interest with the fear of pushing one's bargaining partner into some mutually damaging action. The basic model of standard economics is perfect competition, the market condition under which each participant is so small that he can ignore his effect on the behavior of the others. The market for sovereign debt already departs from perfect competition in its relatively small number of participants. Debt renegotiation departs even further, since the participants have no choice but to deal with each other and they must carefully decide how far to push their demands. Outside competition having become a minor force, it is bilateral bargaining between the debtor country and the rescheduling committee of the lenders that determines the outcome.

Game theory originated with Von Neumann & Morgenstern's 1944 book, *The Theory of Games and Economic Behavior*, a book mostly concerned with zero-sum games with perfect information. In **zero-sum games** what one player gains, another player must lose; and under **perfect information** neither player has an informational advantage and there is no uncertainty over the future. These assumptions rule out informational asymmetry and the possibility of mutually advantageous contracting—a positive-sum outcome—which are two distinctive features of debt negotiation. Later work in game theory does address these features, especially work in the tradition of Thomas

Schelling's 1960 book on precommitment and strategy, *The Strategy of Conflict*. This book is nonmathematical, and remains well worth reading, but for more recent and technical treatments one may wish to consult the books by Shubik (1982) and Rasmusen (1989). More specialized treatments of game theory as applied to international economics also exist: in particular, Clifton (1982) on debt, Dixit (1987) on small countries, and McMillan (1989) on trade negotiations. McMillan has also written an excellent book (McMillan, 1986) entirely on the application of game theory to international economics, and Crawford (1987) is a very clear survey of the literature on reputation and credit relationships that gives special attention to international lending.

Academic research on debt problems has been making much use of game theory in recent years. The first article to attack the problem of how reputation might prevent repudiation of sovereign debt was Eaton & Gersovitz (1981). Their work was followed by a variety of articles on reputation and the form of contracts, of which I will mention only a few. Bulow & Rogoff (1989a, 1989b) have more recently analyzed the Eaton-Gersovitz problem of how reputations operate, and they look in detail at the renegotiation of debt agreements. Chowdhry (1991) attacks the problem from a different angle, emphasizing the syndicated nature of debt. Grossman & Van Huyck (1988) point out that borrower and lender may have an implicit contract that allows default without punishment in bad states of the world, thus shifting risk efficiently from the borrowing country to the lending banks. Most recently, Fernandez & Rosenthal (1990) apply game theory to the issue of bargaining power in debt renegotiations where repayment improves the country's access to international markets, rather than just preventing diminished access.

Rather than surveying the academic literature of the past few years, however, this chapter will try to show how the basic ideas of game theory—concepts such as payoff-maximizing players, strict stylization of the facts, careful delineation of informational advantages, and the ability to precommit—can be used to understand debt negotiations. The approach will be to teach the tools of game theory using examples from debt strategy rather than to describe the conclusions reached by frontier game theory models of reputa-

tion and negotiation. The aim will be to show how game theory can be used by a corporate analyst, a bank regulator, or a central banker to capture the essence of a situation when a he must formulate policy.

2. The Rules of the Game.

One of the biggest contributions of game theory is its ability to focus the analyst's thought when he is confronted by an unorganized set of facts. The purpose of the analyst, *qua* analyst, is to simplify; he takes the data available to him, pulls out what is essential, and shows the policymaker how to manipulate those essential forces. Complexity may be realistic, but simplicity is more useful, and it is the analyst's duty to seize upon the central features and discard the rest. The way the game theorist does this is to start by determining the relevant players, their possible actions, and the payoffs resulting from different combinations of their actions. He must also specify the order of the actions and the information available to each player. This done, he can begin to decide which actions are optimal for each of them, and how their decisions interact, but the first step is description, which requires considerable care.

The essential descriptive elements of a game are "players," "actions," "information," "outcomes," and "payoffs." From these, one can find "strategies" and "equilibria." The players, actions, and outcomes are collectively referred to as the "**rules of the game,**" and the modeller's objective is to use the rules of the game to predict and perhaps to change the equilibrium.

These descriptive elements will be defined using a game called "Mexican Debt I." First, let us postulate a situation for the analyst to model. The year is 1990, and a group of banks are considering making loans to Mexico, whose exports of oil are sold at a high price that may or may not be sustained over the decade. Mexico may choose to pay the interest on any loan it obtains, or it may accumulate arrears. It can pay interest without great difficulty if oil remains high-priced, but if the price drops, repayment would require a cutback in government spending that would have serious political consequences. If Mexico does accumulate arrears, its trade will be hampered and it will not be able to borrow again for many years.

*The **players** are the individuals who make decisions.*

For “Mexican Debt I,” let us specify the players to be Mexico and a bank.

*An **action** or **move** by a player is a choice he makes.*

*A player’s **action set** is the entire set of actions available to him.*

*An **action combination** is a set of one action for each of the players in the game.*

In “Mexican Debt I,” the action set of the bank will be whether to lend or not lend, and the action set of Mexico will be whether to pay the interest or accumulate arrears in each of two five-year periods following the loan.

***Nature** is a pseudo-player who takes random actions with specified probabilities at particular points in the game.*

Often it is useful to introduce uncertainty into a model, where by “uncertainty” is meant random changes in the environment caused by influences outside the game. Uncertainty is introduced by means of a pseudo-player called Nature (“pseudo” because Nature moves mechanically rather than strategically). In “Mexican Debt I,” assume that the price of the oil that Mexico exports can take one of two values: *High* or *Low*. At the beginning of the game the price is *High*, but after five years it might drop to *Low*. At that point Nature randomly decides whether the price will be *High* or *Low*, assigning, let us say, probabilities of 70 and 30 percent. This random move means that the model yields more than just one prediction, so there are different “**realizations**” of a game depending on the results of random moves.

The specification of *when* particular actions are available to the players, the “**order of play**,” is crucial to the analysis. It is convenient to summarize the order of play by writing it in list form.

Mexican Debt I

- (1) The bank decides whether to lend or to not lend.

- (2) Mexico decides whether to pay interest or accumulate arrears in 1990.
- (3) Nature chooses the price of oil to be high with probability 0.7 and low with probability 0.3.
- (4) Mexico decides whether to pay interest or accumulate arrears in 1995.

The information available to different players is specified as their knowledge of past moves. The order of play just given, for example, implicitly assumes that neither player knows what the future price of oil will be until after the bank has decided whether to lend and Mexico has decided whether to repay in 1990. Suppose instead that the bank has expert forecasters who can perfectly predict the price of oil, but Mexico will not know the price until later. The order of play then becomes:

Mexican Debt II

- (0) Nature chooses the price of oil to be high with probability 0.7, and low with probability 0.3. The price is observed only by the bank.
- (1) The bank decides whether to lend or not lend.
- (2) Mexico decides to pay interest or to accumulate arrears in 1990.
- (3) Mexico observes the price of oil.
- (4) Mexico decides to pay interest or to accumulate arrears in 1995.

Notice that the word “observe” is used for the players’ knowledge of the price of oil. Observation refers to knowledge obtained directly, rather than by deduction. If, for example, Mexico *observes* that the bank chooses *Not Lend*, then Mexico might *deduce* that the bank had observed a low price for oil. What a player can observe is part of the rules of the game, but what a player can deduce depends on the equilibrium, since it depends on what behavior is inspired by the rules.

The order of play places Nature’s move at the point where it is observed by one of the players, which may not be the temporal point at which it takes place. A tree that falls unseen in the forest may or may not make a sound, but the sound cannot influence behavior, and so game theory would ignore it. In Mexican Debt I, the future price of oil might have been determined by events prior to the original loan, but since neither player knows that,

Nature's move is listed as move (3). Also, the order of play represents the order in which actions are taken or become known, which may be separated by widely varying lengths of time. It could be that actions (0) and (1) in "Mexican Debt II" take place in December 1989, action (2) takes place in January 1990, event (3) takes place in 1992 and action (4) takes place in 1995.

We now come to the final member of the trio of Players, Actions, and Payoffs.

A player's payoff is the utility he receives after the game has been played out.

Let us make the following assumptions on payoffs in Mexican Debt I. The payoffs are zero for each player if the bank chooses *Not Lend*. It costs the bank 160 to make a loan, but in each period that Mexico pays interest the bank receives $X = 100$. Mexico receives a benefit of $W = 700$ from the loan. In a period in which it pays interest, Mexico loses 100 if the price of oil is High and 300 if it is Low (the domestic discontent caused by paying X is greater when Mexico's GNP is lower). If Mexico ever chooses to accumulate arrears, it loses $D = 250$ (the same whether it does this twice, or only once).

Table 1: Payoffs for "Mexican Debt I" if the Bank Lends.

		Nature	
		High Price (0.7)	Low Price (0.3)
	Arrears in 1990 only	350, -60	150, -60
	Arrears in 1995 only	350, -60	350, -60
Mexico:	Arrears in both years	450, -160	450, -160
	Full payment	500,40	300,40

Payoffs to: (Mexico, Bank). Equilibrium payoffs are boldfaced.

Each cell of the matrix shown in Table 1 contains the payoffs for Mexico and the bank from a different action combination given that the bank chooses to lend. The first two columns show payoffs depending on the two possible actions of Nature, *High Price*, which has probability 0.7, and *Low Price*, which has probability 0.3. A typical set of payoffs is the (350, -60) in the northwest corner. Mexico's payoff of 350 is composed of the 700 benefit from the loan minus 100 from the interest payments in 1995, minus 250 from the arrears in 1990. The bank's payoff of -60 is composed of the cost of the loan (-160) plus 100 in interest paid in 1995. At this point, the analyst does not ask whether or not it is advisable for Mexico to accumulate arrears or for the bank to make the loan; the first step is just to calculate payoffs.

While players, actions and payoffs are the basic elements of the game and jointly determine what happens, it may be that the modeller is not directly interested in any of them. Instead, he may just wish to use them to predict the value of some other variable or variables more interesting to him, a variable or set of variables that we call the *outcome*.

*The **outcome** of the game is a set of interesting elements that the modeller picks from the values of actions, payoffs, and other variables after the game is played out.*

The definition of the outcome for any particular model depends on what variables are of interest to the modeller. In "Mexican Debt I" the interesting variable might be whether Mexico accumulates arrears, so the outcome would be one of the following:

- "Arrears only in 1990-1995,"
- "Arrears only in 1995-2000,"
- "Arrears in neither period,"

- “Arrears in both periods.”

The outcome could be defined differently (for example, as whether Mexico accumulates arrears *and* what payoff each player receives). The best definition depends on what question the analyst is trying to answer.

Another way to depict the order of play is the game’s **extensive form** or **game tree**. Figure 1 shows the extensive form for “Mexican Debt I.” The decisions are called **branches** and the points at which decisions are taken are called **nodes**. The decisions start at the left, with the bank’s choice between the branches labeled *Lend* and *Not Lend*. If the bank chooses the *Lend* branch, then Mexico in turn has a choice between two branches, and the game continues until at the right-hand side the game concludes. The numbers at the right-hand side of the diagram show the payoffs (in an extensive form) or the outcomes (in a game tree).

In trying to determine which actions are chosen, it is convenient to recast the decision set, not in terms of the particular actions, but in terms of contingent action rules called *strategies* that instruct the players on what moves to make at each node of the game tree.

*A player’s **strategy** is a rule that tells him which action to choose at each instant of the game, given his available information.*

*A player’s **strategy set** or **strategy space** is the set of strategies available to him.*

*A **strategy combination** is an ordered set consisting of one strategy for each of the players in the game.*

*A game’s **normal form** is a table showing the payoffs associated resulting from different strategy combinations.*

Since a player’s information can include the previous actions of other

Figure 1:

players, the strategy tells him how to react to their actions. The concept of the strategy is useful because only rarely can we predict a player's action unconditionally; but we can often predict how he will respond to Nature and the other players. In Mexican Debt I, the bank has no history on which to base its strategy, so its strategies are the same as its actions *Lend* or *Not Lend*. Mexico, however, can observe Nature's move before its 1995 choice of *Pay* or *Arrears*. An example of a strategy combination for Mexican Debt I is

Bank. Lend.

Mexico. Pay in 1990; Pay in 1995 if Nature chooses *High*, Pay in 1995 if Nature chooses *Low*.

There are, of course, many different strategy combinations, but at this point in the analysis the modeller does not worry about whether the play-

ers' behavior makes sense; he cares only about discovering all the possible strategies and making sure that each strategy covers all contingencies.

A player's strategy is a function only of observed history, not of current actions or of another player's strategy. The bank's strategy cannot be specified to depend on Mexico's strategy. Also, a player's strategy is a complete set of instructions for him, which tells him what action to pick in every conceivable situation, even if he expects some situations never to arise. Strictly speaking, even if a player's strategy instructs him to drop out of the game in 1995, it ought also to specify what actions to take if he is still in the game in 1996. The strategies, unlike the actions, are unobservable, because a complete description describes the world that might have been as well as the world that was. A strategy is a thought process; an action is a physical act.

The Equilibrium of the Game.

To predict the outcome of a game, the modeller focuses on the possible strategy combinations, since it is the interaction of the different players' strategies that determines what happens. The goal of each player is to maximize his payoff by his choice of a strategy. An equilibrium is a strategy combination such that every player has chosen his strategy to maximize his payoff. Definitions of equilibrium differ in how they define "maximize his payoff." By far the most common definition (the most common "**equilibrium concept**") is Nash equilibrium.

*A **Nash equilibrium** is a strategy combination such that no player can raise his payoff by unilaterally altering his strategy.*

The following is a Nash equilibrium for "Mexican Debt I."

Bank. Lend.

Mexico. Pay in 1990. Pay in 1995 if the price of oil is high and if Mexico paid

in 1990; otherwise, accumulate arrears.

Notice how this strategy combination tells each player how to pick actions under every possible contingency. In particular, it tells Mexico how to behave if somehow the game reaches the node at which Mexico has accumulate arrears in 1990, even though that node is never reached in equilibrium (it is “**off the equilibrium path**”).

The equilibrium is a strategy combination, a set of contingent actions. What actions actually are played out? The bank lends, and Mexico pays interest in 1990. With probability 0.7, Nature picks a high price, and Mexico pays in 1995; with probability 0.3, Nature picks a low price, and Mexico accumulates arrears in 1995.

Having used the strategies to discover the probabilities of different actions, we can calculate the expected equilibrium payoffs. With probability 0.7, Nature picks a high price and Mexico pays in both periods, so the payoffs from Table 1 (which are boldfaced there) are 500 for Mexico and 40 for the bank. With probability 0.3, Nature picks a low price, and Mexico accumulates arrears in 1995 only: then the payoffs from Table 1 are 350 for Mexico and -60 for the bank. If we multiply each payoff by its probability, the **expected payoffs** are 455 for Mexico ($= 0.7 \cdot 500 + 0.3 \cdot 350$) and 10 for the bank ($= 0.7 \cdot 40 - 0.3 \cdot 60$).

To check that this strategy combination is a Nash equilibrium, it is necessary to test whether either player can gain by unilaterally deviating to another strategy. Table 1 shows the payoffs from different strategy combinations, and the expected payoffs can be calculated using the probabilities of Nature’s two different moves.

First, test the bank. Taking Mexico’s strategy as given, the bank’s payoff is 10 from following the strategy *Lend*, as was calculated two paragraphs above. If the bank were to choose not to lend, it would earn 0, which is less than 10. So the bank will not deviate from the proposed equilibrium.

Second, test Mexico. In equilibrium, Mexico's payoff from following its strategy of paying interest in 1990 but paying in 1995 only if the price of oil is high is 455. Since the penalty for arrears in both periods is no greater than for just one period, it is pointless for Mexico to deviate by just running arrears in 1990. If, on the other hand, Mexico were to deviate by not paying interest in either year, regardless of the price of oil, then its payoff would be (using numbers from Table 1)

$$\pi_{Mexico} = 0.7(450) + 0.3(450) = 450.$$

If Mexico were to deviate by paying interest regardless of the price of oil, then its payoff would be

$$\pi_{Mexico} = 0.7(500) + 0.3(300) = 440,$$

which is still inferior to the equilibrium payoff of 455. Finally, if Mexico were to deviate by paying interest in 1995 when the price of oil was low, but not when it was high, the payoff would be

$$\pi_{Mexico} = 0.7(350) + 0.3(100) = 335.$$

Hence Mexico never has incentive to deviate from the suggested strategy combination, which is indeed a Nash equilibrium. The prediction of the model is that the bank will lend and Mexico will accumulate arrears only if the price of oil drops. This suggests that there is scope for mutually profitable lending but that the bank should consider trying to break out of the structure of this game by making the terms of lending contingent upon real exports, something not in the current strategy set of "Mexican Debt I."

Note that it is the expected payoff, not the realized payoff, that is relevant for decisionmaking. Rational decisions demand sensible choices *ex ante*; what happens *ex post* is a matter of luck. In this example, the bank's rational choice is to make the loan, since the expected payoff is 10 from that action; but if Nature picks a low price, and the bank's realized payoff is -40 instead of the 0 it could have gotten by not lending, that says more about the bank's luck than its decisionmaking ability.

3. Asymmetric Information and the Cost of Arrears.

Most research in game theory nowadays explores games of asymmetric information, games in which one player has an informational advantage. “Mexican Debt I” is a game of *symmetric* information, because despite the uncertainty introduced by Nature’s move, both players are equally ignorant of the future price of oil. “Mexican Debt II” is a game of *asymmetric* information, because the bank is able to take its action having observed Nature’s move but Mexico must take its action in ignorance.

Mexican Debt I and II are just two of the many possible models of Mexican debt. Both of them focused on the effects of changes in the price of Mexico’s main export. For contrast, another game representing a similar situation is presented below, “Mexican Debt III,” which focuses on the lenders’ ignorance of the cost to the Mexican government of accumulating arrears. In the situation it models, many banks compete to lend to Mexico, but none of them know exactly how much the Mexican government would be damaged by the economic turmoil following arrears in interest payments, although the government itself knows. Competition between banks can be modelled by specifying just two banks as players, who simultaneously choose the interest rates on their loans. If there were really just two banks, this would be an unrealistic way to model them, because their decisions would interact in complicated ways; but the assumption of two sellers who simultaneously choose prices—**Bertrand competition**—achieves the same cocompetitive outcome as a more complicated model of many sellers.

Mexican Debt III

Players:

Mexico, Bank A, and Bank B.

Actions and Events:

- (0) Nature chooses Z_1 , the cost of arrears for Mexico, Z , to be low ($Z = Z_1$) with probability 0.2, or high ($Z = Z_2$) with probability 0.8. Mexico

observes Z but the banks do not.

- (1) Banks A and B simultaneously choose interest rates r_a and r_b for their offers of loans to Mexico of amount X . Each bank's cost of capital is r .
- (2) Mexico accepts either one or neither loan. The variable m_i equals 1 if bank i 's loan is accepted and 0 if it is rejected. Mexico derives benefit $(m_a + m_b)W$ from the loan.
- (3) Mexico decides whether to pay interest or accumulate arrears.

Payoffs:

If Mexico refuses both loans,

$$\pi_{Mexico} = 0, \pi_a = 0, \text{ and } \pi_b = 0.$$

If Mexico chooses to pay,

$$\pi_{Mexico} = W - r_a X m_a - r_b X m_b, \pi_a = (r_a - r) X m_a, \text{ and } \pi_b = (r_b - r) X m_b.$$

If Mexico chooses to accumulate arrears,

$$\pi_{Mexico} = W - Z, \pi_a = -r X m_a, \text{ and } \pi_b = -r X m_b.$$

Let us use as parameter values $X = 100$, $W = 200$, $r = 1.1$, $Z_1 = 108$, and $Z_2 = 150$. The game tree is shown in Figure 2. It is more complicated than the game tree in Figure 1 for two reasons. First, since the banks' move consists of the choice of an interest rate from a continuous action set, rather than from just two possibilities, the move is depicted by a single branch. Second, dotted lines enclose certain nodes to indicate the banks' imprecise information. Bank A does not know how Nature moved, so it does not know exactly which node the game has reached; all it knows is that the game has reached some node within the dotted lines. Bank B is ignorant not only of

Figure 2:

how Nature moved but of how Bank A moved, which amounts to the same thing as Banks A and B moving simultaneously.

Under these parameters, the following strategy combination is a Nash equilibrium:

Bank A. $r_a = 1.375$.

Bank B. $r_b = 1.375$.

Mexico. Accept the cheapest loan, at rate r_i (choose either loan if $r_a = r_b$). If $Z = 150$, pay if $r_i \leq 1.5$; otherwise, accumulate arrears. If $Z = 108$, pay if $r_i \leq 1.08$; otherwise, accumulate arrears.

To test that this is indeed a Nash equilibrium, one must begin by checking whether Mexico has any incentive to deviate unilaterally.

Mexico ought to accept the loan regardless of the interest rate and the state of the world, because the loan brings a benefit of 200, and the greatest cost it can bring is the *High* cost of accumulating arrears, which is 150. If Z takes the value of 108, then Mexico wishes to accumulate arrears if the interest rate is anything above 1.08; the cost of doing so is 108 and the benefit is the avoidance of a payment of $100r_i$. Similarly, if $Z = 150$ then Mexico wishes to accumulate arrears if the interest rate is anything above 1.5.

Mexico's expected payoff from the equilibrium strategy is composed of a 20 percent probability of $\pi_{Mexico} = W - Z$ and an 80 percent probability of $\pi_{Mexico} = W - r_a X m_a - r_b X m_b$, resulting in

$$\pi_{Mexico} = 0.2(200 - 108) + 0.8(200 - 1.375 \cdot 100) = 68.4.$$

If Mexico were to deviate by paying interest when the cost of accumulating arrears was low, its payoff would fall from 92 to 62.5 ($= 200 - 1.375 \cdot 100$) in the low-cost state of the world. If Mexico were to deviate by accumulating arrears when the cost of doing so was high, its payoff would fall from 62.5 to 50 in the high-cost state of the world. So Mexico has no incentive to deviate.

The other test to perform on this equilibrium is to discover whether either bank would want to change its interest rate from 1.375. The bank whose loan is refused gets a payoff of zero, and the other bank's payoff is, if $r = 1.375$

$$\pi_{bank} = 0.2(0 - 1.1)(100) + 0.8(1.375 - 1.1)100 = 0.$$

A bank has no incentive to raise its interest rate above 1.375 unilaterally, because Mexico would turn to the other bank. Lowering the interest rate would also be unprofitable, because it would lower the interest payment without reducing Mexico's temptation to accumulate arrears. Hence, the banks are content to offer exactly 1.375.

The outcome changes dramatically if we specify the parameter values differently. To be sure, some parameters do not matter much—the benefit from the loan, W , could be increased from 200 to 400 without making any difference, for example. But if we raise the minimum cost of arrears, Z_1 , to 110 instead of 108, the equilibrium interest rate changes drastically. The new equilibrium is

Bank A. $r_a = 1.1$.

Bank B. $r_b = 1.1$.

Mexico. Accept the cheapest loan, at rate r_i (choose either loan if $r_a = r_b$). If $Z = 150$, pay if $r_i \leq 1.5$; otherwise, accumulate arrears. If $Z = 110$, pay if $r_i \leq 1.1$; otherwise, accumulate arrears.

Mexico's expected equilibrium payoff is now

$$\pi_{Mexico} = 0.2(200 - 1.1 \cdot 100) + 0.8(200 - 1.1 \cdot 100) = 90.$$

The interest rate falls from 1.375 to 1.1 because Mexico is no longer tempted to accumulate arrears in the *Low* state of the world and the banks do not need to build in a premium for the risk of non-payment. The interest rate falls to the cost of capital to the banks, because the bank no longer need compensation for the risk of non-payment. The paradoxical lesson is that a small increase in Mexico's cost of arrearages can lower the interest rate dramatically. Moreover, while the increase in cost leaves the banks' expected payoffs unchanged at 0, it helps Mexico, raising its payoff from 68.4 to 90. Mexico benefits substantially from its own higher cost.

This result is counterintuitive at first, but it makes sense after some thought. Mexico benefits from the higher cost of accumulating arrears because it is only a *potential* cost, and it encourages the banks to lower their risk

premia. Suppose a recently graduated MBA had the option of being publicly exempted from the laws against embezzlement. Would he take the option? He would be foolish to do so, because once he had the exemption no business would hire him. This kind of reasoning applies to institutional arrangements such as the U.S. Foreign Sovereign Immunities Act of 1976, which exempted the commercial activities of foreign governments from sovereign immunity. Since the Act allowed banks to pursue sovereign borrowers in U.S. courts, it helped foreign nations to obtain loans, and this was not a law passed to hurt foreigners, but to encourage trade. One of the lessons of game theory is that players often wish to commit themselves to future behavior, and public sanctions against one's own future misbehavior are a good form of precommitment.

4. The Prisoner's Dilemma and Bankruptcy.

Certain games come up over and over again in analysis because their payoff structure applies to a wide variety of situations that are fundamentally the same, however different the situations may appear. Possibly the most useful of these fundamental games is the "prisoner's dilemma." Two criminals, Mr. Row and Mr. Column, have been captured by the police and are being questioned separately about a crime they jointly committed. Each prisoner can either deny that he committed the crime, or confess and implicate his partner in crime. Even if both prisoners deny, enough other evidence has been obtained to send each of them to jail for 1 year, so their payoffs are -1 each. If both confess, they will both go to jail for 8 years. But if one confesses and the other denies, the one that confesses gets off scot free, while the other receives a 10-year sentence.

Table 2: The Prisoner's Dilemma.

		Mr Column	
		Deny	Confess
Mr Row:	Deny	-1,-1 →	-10, 0
	Confess	0,-10 →	-8,-8

Payoffs to: (Mr Row, Mr Column).

This game is unusual in that each player has a “**dominant strategy**,” a strategy that is best for him no matter what the other player does. If Column denies, Row can get a payoff of 0 from *Confess* instead of -1 from *Deny*. And if Column confesses, Row can get a payoff of -8 from *Confess* instead of -10 from *Deny*. Hence, *Confess* is a dominant strategy for Row.

The arrows in Table 2 are a shorthand way of representing how players would deviate from different strategy combinations. The only strategy combination without an arrow pointing away from it either horizontally or vertically is the Nash equilibrium, (*Confess, Confess*), because neither player would unilaterally deviate from it. But if (*Confess, Confess*) is the outcome, each prisoner gets 8 years in jail, whereas the non-equilibrium strategy combination (*Deny, Deny*) gives each a sentence of only 1 year! Both players are strictly worse off in equilibrium (we say it is “**Pareto inferior**” to (*Deny, Deny*)), despite having used their individually dominant strategies.

The prisoner’s dilemma lies hidden in many real-world situations. An example is bankruptcy, and, in particular, the financial distress of a sovereign borrower. Suppose that Allied and Brydcox are two banks that have lent to a financially distressed country. Each bank has a choice between being tough, demanding immediate repayment, and being easy, allowing rescheduling. If both banks are easy, then the country will recover, and the banks’ losses will be slight. If both banks are tough, the country will collapse and pay very little to either bank. But if only one bank is tough, that bank will be able to extract all its funds, while the easy bank will lose everything in a collapse only slightly delayed. The payoffs in Table 3 fit this story.

Table 3: Bankruptcy as a Prisoner’s Dilemma.

		Lender Brydox	
		Easy	Tough
Lender Allied:	Easy	-1,-1	→ -10, 0
		↓	↓
	Tough	0,-10	→ -8,-8

Payoffs to: (Allied, Brydox).

Just as in the original prisoner’s dilemma, the strategies that are best for each player individually result in a jointly bad outcome. The banks would profit if they could somehow break the structure of the game and bind themselves to both be easy on the borrower, instead of acting independently and being tough. Lenders indeed do this, and the bank rescheduling committee, representing the syndicated banks in negotiations with troubled sovereign states, is an institution designed to eliminate the prisoner’s dilemma. In its absence, however, the self-interest of each individual bank would lead to a situation in which every bank would be worse off than if the borrowing country itself chose the policy.

5. The Coordination Game and Bank Runs.

A second paradigmatic game is the coordination game, in which a player wishes to choose the same action as the other players but he must choose independently and guess at what they have chosen. Coordination games take a number of different forms, some with conflict and some without. In the game to be described, the problem is purely one of coordination between the players, with no conflict of interest between them.

Let us suppose that a borrowing nation has fallen into short-run financial difficulties, but the nation’s long-run prospects are excellent if it can borrow enough to maintain economic growth. It can do this only if all its present creditors are willing to increase the size of their loans, which they would be happy to do were they sure that the country would recover from its current difficulties. If, however, a bank thinks that the country will fail to obtain the new loans and will therefore fail to recover, it would prefer to pull out even its old loans.

Table 4 represents this story. The two lenders, Allied and Brydox, each choose between lending more and pulling out. Let us take the point of view of Allied. If both lenders lend more, the debtor country will succeed in recovering from its difficulties, the loans will be repaid, and Allied will receive a high payoff (set equal to 2). If Allied alone lends more, and not Brydox, then the debtor will not recover and Allied will lose its loans, for a low payoff of -2 . If Allied itself pulls out with whatever it can, it receives a payoff of -1 regardless of what Brydox does.

Table 4: Coordination in Runs on Lenders.

		Lender Brydox	
		Lend More	Pull Out
Lender Allied	Lend More	2,2	← $-2, -1$
	Pull Out	$-1, -2$	→ -1,-1

Payoffs to: (Allied, Brydox).

Note that although the payoff from *Lend More, Lend More* is represented by $(2,2)$, this might be the expected value of a further sequence of uncertain events. It might be, for example, that if both lenders lend more, the payoffs will be $(4,4)$ with probability 0.5 and $(0,0)$ with probability 0.5, depending on whether or not there is a world recession. We can reduce this to the expected value of $(2,2)$ because the uncertainty over the recession is only indirectly relevant to today's decision.

This coordination game is a two-by-two game, like the prisoner's dilemma, but its payoff structure is fundamentally different. The prisoner's dilemma has a single dominant strategy equilibrium. The coordination game has two Nash equilibria, because each lender's optimal action depends on what the other lender does. The two equilibria are *(Lend More, Lend More)* and *(Pull Out, Pull Out)*. If Brydox chooses *Lend More*, then *Lend More* is the optimal action for Allied. But if Brydox chooses *Pull Out*, then *Pull Out* is the optimal action for Allied. What Allied prefers depends on what Brydox does, and what Brydox prefers depends on what Allied does.

Which of the two equilibria is actually played out depends on the expectations of the two players, which in turn depends on whether they communicate. If Allied assures Brydox that it will lend more, Brydox can expect that Allied will keep its promise, because deception is not in Allied's self-interest. This contrasts with Bankruptcy as a Prisoner's Dilemma, in which Allied's promise to Brydox that it will be easy on the creditor is disbelieved because Allied has a strong incentive to lie. In both situations the lenders might benefit by forming a syndicate. To avoid the prisoner's dilemma, the syndicate needs to have real power over its members to make them choose Easy. To implement the good equilibrium in the coordination game, on the other hand, the syndicate need only set up communication between them: once they announce their policies to each other, they will, if those policies match, be willing to adhere to those policies without any form of compulsion.

6. Mixed Strategies and IMF Aid.

The prisoner's dilemma has one equilibrium, and the coordination game has two, but some games seem to have no strategy combination that is an equilibrium. In these games, the only mutually consistent set of strategies for the different players involves randomizing according to carefully chosen probabilities. Random strategies are known as **mixed strategies** in game theory, in distinction to the nonrandom **pure strategies**.

Random strategies may seem bizarre. But a little thought about sports will lead to the conclusion that mixed strategies are not just theoretical curiosities. In American football, the offensive team's strategies can be roughly divided into passing the ball or running with it. The most important thing is to choose the strategy that the defensive team does not expect, but this means there is no equilibrium in pure strategies. If the defensive team expects the offense to run, the offense will want to pass instead— but the defensive team is aware of this and would change its beliefs. No nonrandom strategy can lead to consistent beliefs. Instead, the offensive team chooses whether to pass or run by randomizing, or, equivalently, by some technique that looks random to the defensive team. But “random” does not mean 50-50 probabil-

ities: the offensive team will choose the proportions of passing and running in light of the possible gains and losses from each strategy. To calculate these optimal probabilities, more formal analysis is needed.

Let us suppose that the International Monetary Fund wants to help a debtor country, but only if the debtor will reform instead of pursuing wasteful policies. The debtor would reform, though reluctantly, if there otherwise were no chance of IMF aid, but if the debtor can rely on an IMF bail-out whether it reforms or not, it would prefer the current wasteful policies.

The payoffs for this story are shown in Table 5. For the IMF, the best outcome is to aid a reforming debtor, for a payoff of 3, and the second-best is to not aid a wasteful debtor, for a payoff of 0. The worst outcomes are to aid a wasteful debtor or not aid a reforming debtor, both of which yield -1 . For the debtor, the best outcome is to receive aid and waste it, for a payoff of 3, and the second-best is to receive aid and reform, for a payoff of 2. If no aid is received, the debtor wishes to reform, for a payoff of 1, in preference to being wasteful, for a payoff of 0. ²

²The game “IMF Aid” is an adaption of the “Welfare Game” (Rasmusen 1989, chapter 3). The game has also been called the “Samaritan’s Dilemma,” by Gordon Tullock, who credits James Buchanan as its originator [Tullock 1983, p. 59].

Table 5: IMF Aid.

		Debtor	
		Reform	Waste
IMF	Aid	3,2 →	-1,3
	No Aid	-1,1 ←	0,0

Payoffs to: (IMF, Debtor).

Each strategy combination must be examined in turn to check for Nash equilibria. The arrows in Table 5 parallel the reasoning in the four points below.

- (1) The strategy combination (*Aid*, *Reform*) is not a Nash equilibrium, because the debtor prefers to respond with *Waste* if the IMF picks *Aid*.
- (2) (*Aid*, *Waste*) is not Nash, because the IMF prefers *No Aid*.
- (3) (*No Aid*, *Waste*) is not Nash, because the debtor prefers *Reform*.
- (4) (*No Aid*, *Reform*) is not Nash, because the IMF prefers *Aid* (which brings us back to the first strategy combination).

“IMF Aid” does have a mixed strategy Nash equilibrium. The debtor selects *Reform* with probability 0.2 and the IMF selects *Aid* with probability 0.5. The realization of the game could be any of the four entries in the outcome matrix, with (*No Aid*, *Waste*) and (*Aid*, *Waste*) having the highest probability of occurrence, each with probability 0.4 (= 0.5[1 - 0.2]).

We must check that these probabilities constitute a strategy combination from which neither player wishes to deviate. Given the debtor’s mixed strategy, the IMF is indifferent between selecting *Aid* with probability 100 percent, *Aid* with probability 0 percent, and any probability in between. That

is because the IMF's expected payoff from *Aid* is $0.2 \cdot 3 + 0.8 \cdot (-1)$, which equals -0.2 , and the expected payoff from *No Aid* is $0.2 \cdot (-1) + 0.8 \cdot (0)$, which also equals -0.2 . Hence, the IMF is indifferent between the two strategies, which means it is willing to pick randomly between them—and, in particular, it is willing to choose 0.5 as the probability of *Aid*. Similarly, the debtor is indifferent between *Waste* and *Reform*, and is willing to pick a probability 0.2 of *Reform*, because the expected payoff from *Reform* is $0.5 \cdot 2 + 0.5 \cdot 1 = 1.5$ and the expected payoff from *Waste* is $0.5 \cdot 0 + 0.5 \cdot 3 = 1.5$.

To be sure, this is a **weak equilibrium**: although no player wishes to deviate from the equilibrium probabilities (so the Nash test is satisfied), no player strongly wishes to play them either. But no combination of strategies except the mixed strategies do form an equilibrium, and while we cannot predict exactly which realization of the game will occur, we can at least predict the probabilities of the various outcomes. To an outsider, the players will appear to behave randomly, but a player's apparent randomness is actually the result of a carefully chosen set of probabilities that keep the other player guessing as to what will happen.

7. The Order of Moves and the Credibility of Threats.

An important contribution of Schelling's book, *The Strategy of Conflict*, was to point out the importance of precommitment. In many situations a player would prefer to bind himself in advance rather than have unrestricted freedom of choice. This will be seen here in the game called "Idle Threats." The situation involves an indebted country which asks its creditor bank for a new loan. Assume that the new loan would be unprofitable for the bank, but the country threatens to repudiate its old loan if not granted the new one. If the country carries out the threat, however, it suffers a severe loss of reputation.

Figure 3 is an extensive form that fits this story. It is based on the following parameter values: the country's reputation, which is lost if it defaults, is worth 250; the new loan costs the bank 50 and benefits the country 50;

Figure 3:

and the old loan's repayment costs the country 100 and benefits the bank 100.

This game illustrates an idea that economists call **subgame perfection**: an equilibrium should not include threats that are not credible. In “Idle Threats,” the country's threat to repudiate the old loan if the bank refuses the new loan is not credible. Whatever threat is made, if the bank does refuse the new loan, the situation is now represented by the “subgame” starting with the node *Country*₂ in Figure 3. In this subgame, the country will choose to pay and receive 150 instead of to repudiate and receive 0. The bank therefore can feel safe in refusing the new loan. The only subgame-perfect equilibrium is for the bank to choose *Refuse* and the country to choose *Pay*, resulting in a payoff of 100 for the bank and 150 for the country.

The country would be better off if it could precommit to a strategy in advance. Suppose the country could bind itself to the strategy (*Pay if the*

bank chooses Loan; Repudiate if the bank chooses Refuse). The bank would then respond by choosing *Loan*, for a bank payoff of 50 instead of 0. But how can the country bind itself in this way? In the game just described, the country would wish to pay even if the bank did choose *Refuse*, because once the bank has refused the new loan, it is pointless for the country to carry out its threat. Somehow the country must change the structure of the game. The country's government might put its domestic political reputation on the line by promising voters to repudiate the debt if the bank refuses the new loan, or try purposely to push the economy to the brink of disaster so that only a new loan would make repayment of the old loans possible. By adding these moves to the game, the country could effectively bind itself to carry out its threat of repudiation if the bank refused the new loan. Thus, precommitment to disastrous policies contingent on the loan being refused can actually benefit the country.

The bank, in turn, would like to add a still earlier move to the game and bind itself not to make any new loans before the country has a chance to carry out the precommitment moves just described. The bank might secure legislation from its home country forbidding any increase in foreign debt exposure, for example. In this kind of model it matters to the outcome not only *what* actions are available to the players but *when* they are available. "Idle Threats," like many other games, has a first-mover advantage, so the bank and the country would each like to be the first to commit to a policy and force the other player to react.

8. Conclusion.

The games in this chapter illustrate a number of surprising points. The analysis throughout has assumed that players try to maximize their own payoffs and do not care about those of the other players. But self-interest leads in strange directions. A nation can help itself by increasing its cost of default (Mexican Debt III). Profit-maximizing banks may end up hurting their profits by trying to enforce loans too strictly, but without any incentive for a single bank to be more lenient (Bankruptcy as a Prisoner's Dilemma).

Mere promises exchanged between players can influence actions even when each player is completely selfish and there is no penalty for breaking promises (Coordination in Runs on Lenders). Debtors and relief agencies may deliberately choose policies that are to all outside appearances random (IMF Aid). A country can benefit by increasing its chances of carrying out a disastrous policy (Idle Threats). All of these paradoxes can be simply explained using the tools of game theory.

In illustrating the methods of game theory, this chapter has come to these surprising conclusions, but game theory's most important contribution to the bank negotiator and the debtor-country representative is not just a set of general conclusions, but a framework in which to conduct analysis. Describing a situation in the terminology of game theory—players, actions, information, and payoffs—is an aid to understanding it. A crucial aspect of negotiation is being able to put oneself in the position of the negotiator on the other side of the table, and game theory provides a disciplined way to do this. It also shows that simple intuition is often wrong and that a little further analysis can make a big contribution to understanding. Having learned that an increase in a player's potential costs can redound to his benefit, that independent self-interested action can lead to an outcome that is bad for all players, and that identity of interests may not be enough to guarantee agreement, the analyst will be more wary in his predictions. A good negotiator may learn these things through experience, but game theory shows how even a novice can formally analyze them and recognize what is happening while there is still time to change the rules of the game.

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List of Diagrams.

Figure 1: The Extensive Form for “Mexican Debt I”

Figure 2: The Game Tree for “Mexican Debt III”

Figure 3: “Idle Threats”