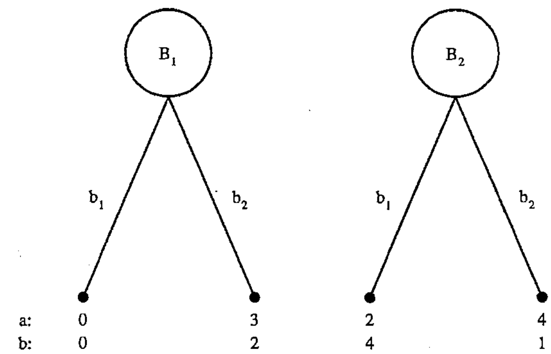
Figure 9-14 Subgames



for *every* subgame. For example, we have already seen that the strategy combination (a_1, {b_2, b_1}) is a Nash equilibrium for the complete game, and it is also a subgame-perfect Nash equilibrium. Player B's strategy {b_2, b_1} specifies that he chooses b_2 at the B_1 node and b_1 at the B_2 node, and he has no incentive to deviate from these choices. Thus, the strategy combination (a_1, {b_2, b_1}) involves rational behavior *at every node of the game.* In contrast, the strategy combination (a_2, {b_1, b_1}) is not a subgame-perfect Nash equilibrium since it specifies that at the subgame beginning at the B_1 node, Player B chooses b_1, and this is not a Nash equilibrium for that subgame.

The attentive reader may ask at this point: With the Nash equilibrium (a_2, {b_1, b_1}), who cares what Player B chooses at the B_1 node if Player A is choosing a_2 as his equilibrium strategy? What happens at a subgame, however, even if that subgame is never reached during the course of play, can determine the final outcome of a game. With the Nash equilibrium (a_2, {b_1, b_1}), let's carefully examine why Player A has no incentive to deviate from a_2. If Player A decides to choose a_1, *given Player B's strategy of* {b_1, b_1}, A expects to end up with a payoff of 0. Therefore, A prefers to choose a_2 and end up with a payoff of 2. But why should Player A believe that B will stick to his equilibrium strategy? Player A knows that if he were to choose a_1, the game would be at the B_1 node and Player B would rationally choose b_2. The important point here is that B's strategy {b_1, b_1} is not **credible;** that is, the only way the Nash equilibrium (a_2, {b_1, b_1}) can be maintained is if Player A believes that B will choose b_1 if the game progresses to the B_1 node. A subgame-perfect Nash equilibrium, such as (a_1, {b_2, b_1}), does not require that any incredible threat be believed. In the final section of this chapter, we will examine an economic application of the importance of making threats credible.

9.5 ENTRY DETERRENCE

Let us once again return to the Coke/Pepsi advertising example, but now we tell a different story. Assume that Coke is a monopolist in a market, and

Entry Cost = 10

Pepsi is deciding whether or not to enter the market. In this case, we refer to Coke as the **incumbent,** and to Pepsi as the **entrant.** Figure 9-15 presents the extensive form of this entry deterrence game. At the initial node P_1, Pepsi has two actions to choose from—stay out of the market or enter the market at an entry cost of 10. If Pepsi stays out, it earns zero profit, and Coke, the incumbent, earns monopoly profit equal to 100. If Pepsi enters the market, we are at the C_1 node, and we assume that Coke can then choose between two actions—collude with Pepsi and share the monopoly profit, or fight Pepsi by undertaking a malicious advertising campaign at a cost of $k = 25$. If Coke decides to collude with Pepsi, Coke's payoff is 50 and Pepsi's payoff is 50 minus the entry fee, that is, 40. If Coke decides to fight Pepsi, Coke's payoff is $70 - k$ and Pepsi's payoff is -10 (that is, Pepsi loses the entry fee).

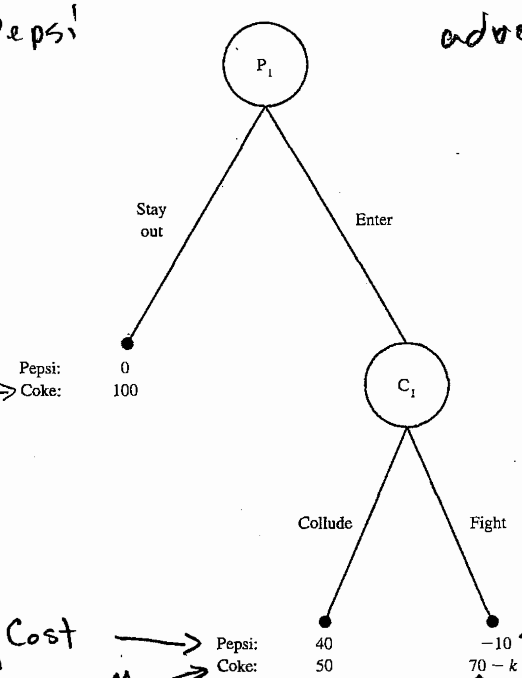
In this game, can Coke deter Pepsi from entering the market? If Coke's strategy is to fight Pepsi upon entry, Pepsi will not enter, since it prefers a profit of 0 to a profit of -10. Thus, the strategy combination (Stay Out, Fight) is a Nash equilibrium.[6] But is Coke's threat credible? Using backward induc-

Figure 9-15 Entry Deterrence Game

k = cost of malicious advertising campaign

P_1 = Pepsi

C_1 Coke



π^M → Coke

½π^M − Entry Cost → Pepsi

½π^M → Coke

← Pepsi gets 0 sales & Pays Entry fee

smaller sales

cost of ads

6 When Pepsi's strategy is Stay Out, Coke does not get to move in this game; therefore, Coke is indifferent between its two actions.

tion and starting at the C_1 node, Coke would prefer to collude with Pepsi, since $50 > 70 - k = 45$. Moving up to the P_1 node, if Pepsi chooses to stay out its profit will be 0, but if it enters it will earn a profit of 40, since it is not in Coke's best interest to fight if the C_1 node is reached. In this version of the game, then, Coke can threaten to fight Pepsi, but the threat is not credible, since the outcome (Stay Out, Fight) is not subgame perfect. The outcome (Enter, Collude), however, is a subgame-perfect Nash equilibrium. Intuitively, when an incumbent threatens an entrant *prior* to entry, but the threat will only be carried out *after* entry, the threat must be credible or it will be ignored.

cost of renting space

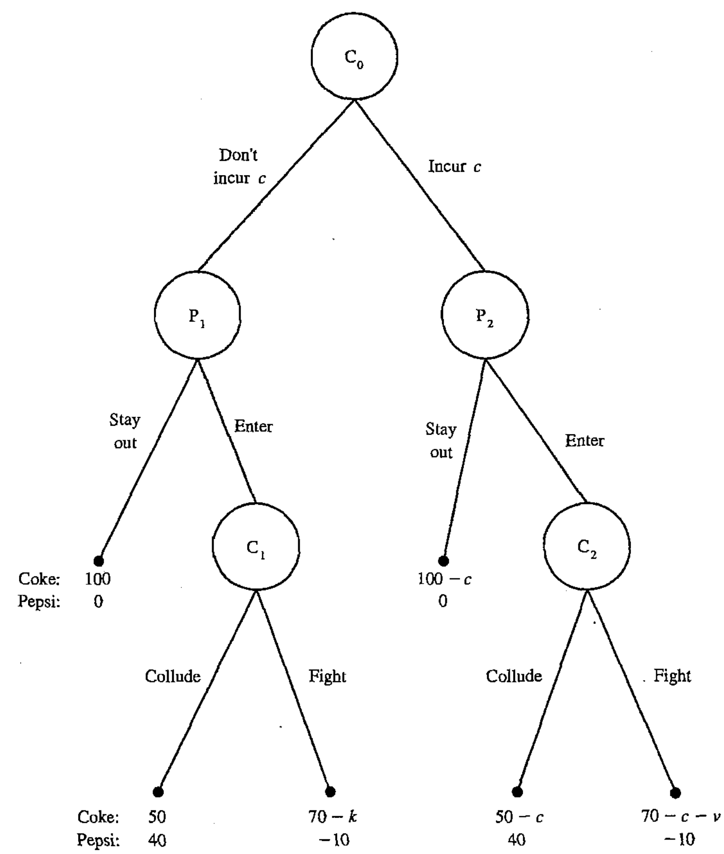
$k = c + v$

cost to make commercial

Can we modify the game in a way that allows Coke to deter entry? Consider a second version of the entry deterrence game shown in Figure 9-16. In this case, we assume that k is made up of two parts: the cost of making the commercial, c, and the cost of purchasing the advertising space, v, (that is, $k = c + v$). This game has three stages. First, Coke must decide whether or not to make the commercial, so that if Pepsi enters and Coke decides to fight, Coke only needs to incur the cost of purchasing the advertising space.

$c = 10$
$v = 15$

Figure 9-16 Entry Deterrence Game



After Coke's initial action, Pepsi must decide whether or not to enter the industry. In the final stage, as in the previous version of the game, Coke must decide whether to collude with Pepsi or to fight Pepsi. If you look closely at the terminal nodes, you will see that the subgame beginning at the P_1 node is exactly the game shown in Figure 9-15 (except the order of the payoffs are reversed, since Coke now moves first). The subgame beginning at the P_2 node is similar to the subgame beginning at the P_1 node, except for a slight adjustment to Coke's payoffs. Since Coke incurs the cost of making the commercial up front, its payoff if Pepsi does not enter is $100 - c$, and if Pepsi does enter Coke's payoffs are $50 - c$ if it colludes, and $70 - c - v$ if it fights. Notice that $70 - k = 70 - c - v$; that is, if Coke ends up fighting Pepsi, its total cost of fighting is the same whether or not it incurred the cost c up front.

The backward induction outcome of this game depends on the values of c and v. We will still assume that $k = 25$, but it is now made up of $c = 10$ and $v = 15$. Let's work through the subgames to find the equilibrium outcome. From the earlier version of the game, we know that if the game progresses to the P_1 node, Pepsi will enter and Coke will collude. Thus, if Coke chooses not to incur c up front, its final payoff will be 50. To find Coke's final payoff if it decides to incur c, we can begin at the C_2 node. If Coke colludes at that node, its payoff is $50 - c = 40$; if it fights, its payoff is $70 - 25 = 45$. Therefore, Cokes decides to fight if Pepsi chooses to enter at the P_2 node, but Pepsi will not enter, because it prefers the payoff of 0 to the payoff of -10. If Pepsi doesn't enter, Coke's payoff from incurring c up front will be $100 - 10 = 90$, which is greater than its payoff of 50 if it doesn't incur c. In all, the backward induction outcome is for Coke to incur c and for Pepsi to stay out of the market.

Here Coke commits early.

Why is the outcome of the second version of the game different from the outcome of the first version? In the first version, Coke can carry out its threat only after Pepsi enters the market, but by then it is too late—Coke's bluff will be called! In the second version of the game, Coke *precommits*; that is, Coke incurs enough of a cost up front to prove to Pepsi that it will credibly incur the rest of the cost if the game reaches the C_2 node. Even though the commercial ends up being wasted (since Coke will never purchase the advertising space), the small cost up front affects Coke's future payoffs in a way that makes fighting a credible threat.

Summary

- **Game theory** is the study of behavior in situations in which each party's payoff directly depends on what another party does.