Managerial Economics & Business Strategy

Chapter 10

Game Theory: Inside Oligopoly

Revised 2/12 by DF

McGraw-Hill/Irwin

Overview

I. Introduction to Game Theory
II. Simultaneous-Move, One-Shot Games
III. Infinitely Repeated Games
IV. Finitely Repeated Games
V. Multistage Games

Normal Form Game

- A Normal Form Game consists of:
  - Players, at least 2.
  - Strategies or feasible actions: at least 2 for each player.
  - Payoffs for each player, for each strategy combination.

A Normal Form Game

Player 2

Player 1

Strategy	A	B	C
a	12,11	11,12	14,13
b	11,10	10,11	12,12
c	10,15	10,13	13,14

Normal Form Game: Scenario Analysis

- Suppose 1 thinks 2 will choose "A".

Player 2

Player 1

Strategy	A	B	C
a	12,11	11,12	14,13
b	11,10	10,11	12,12
c	10,15	10,13	13,14

Normal Form Game: Scenario Analysis

- Then 1 should choose “a”.
  - Player 1’s best response to “A” is “a”.

Player 2

Player 1

Strategy	A	B	C
a	12,11	11,12	14,13
b	11,10	10,11	12,12
c	10,15	10,13	13,14

Normal Form Game: Scenario Analysis

- Suppose 1 thinks 2 will choose “B”.

Player 2

Player 1

Strategy	A	B	C
a	12,11	11,12	14,13
b	11,10	10,11	12,12
c	10,15	10,13	13,14

Normal Form Game: Scenario Analysis

- Then 1 should choose "a".
  - Player 1's best response to "B" is "a".

Player 2

Player 1

Strategy	A	B	C
a	12,11	11,12	14,13
b	11,10	10,11	12,12
c	10,15	10,13	13,14

Normal Form Game Scenario Analysis

- Similarly, if 1 thinks 2 will choose C…
  - Player 1's best response to "C" is "a".

Player 2

Player 1

Strategy	A	B	C
a	12,11	11,12	14,13
b	11,10	10,11	12,12
c	10,15	10,13	13,14

Dominant Strategy

- Regardless of whether Player 2 chooses A, B, or C, Player 1 is better off choosing “a”!
- “a” is Player 1’s Dominant Strategy!

Player 2

Player 1

Strategy	A	B	C
a	12,11	11,12	14,13
b	11,10	10,11	12,12
c	10,15	10,13	13,14

Putting Yourself in your Rival's Shoes

- What should player 2 do?
  - 2 has no dominant strategy!
  - But 2 should reason that 1 will play "a".
  - Therefore 2 should choose "C".

Player 2

Player 1

Strategy	A	B	C
a	12,11	11,12	14,13
b	11,10	10,11	12,12
c	10,15	10,13	13,14

The Outcome

Player 2

Player 1

Strategy	A	B	C
a	12,11	11,12	14,13
b	11,10	10,11	12,12
c	10,15	10,13	13,14

- This outcome is called a Nash equilibrium:
  - "a" is player 1's best response to "C".
  - "C" is player 2's best response to "a".

Key Insights

- Look for dominant strategies.
- Put yourself in your rival's shoes.
- At Nash equilibrium, every player is best responding to the other players' strategies.

A Market-Share Game

- Managers of two rival firms want to maximize market share.
- Strategies are pricing decisions.
- Simultaneous moves.
- One-shot game.
  - [Owners might prefer for them to maximize profits, but the managers are empire builders…]

The Market-Share Game in Normal Form

Manager 2

Manager 1

Strategy	P=$10	P=$5	P = $1
P=$10	.5, .5	.2, .8	.1, .9
P=$5	.8, .2	.5, .5	.2, .8
P=$1	.9, .1	.8, .2	.5, .5

Market-Share Game Equilibrium

Manager 2

Manager 1

Strategy	P=$10	P=$5	P = $1
P=$10	.5, .5	.2, .8	.1, .9
P=$5	.8, .2	.5, .5	.2, .8
P=$1	.9, .1	.8, .2	.5, .5

Nash Equilibrium

Comment

- Game theory can be used to analyze situations where "payoffs" are non monetary
  - The bar scene in "A Beautiful Mind" is a (bad) example
- We will usually focus on situations where businesses want to maximize profits.
  - Hence, payoffs are measured in monetary units.
  - Expected NPV in $millions, say.

Examples of Coordination Games

- Industry standards
  - size of floppy disks.
  - size of CDs.
  - Etc.
- National standards
  - electric current.
  - traffic laws.
  - Etc.

A Coordination Game in Normal Form

Player 2

Player 1

Strategy	A	B	C
1	0,0	0,0	\$10,\$10
2	\$10,\$10	0,0	0,0
3	0,0	\$10,\$10	0,0

A Coordination Problem: Three Nash Equilibria!

Player 2

Player 1

Strategy	A	B	C
1	0,0	0,0	$10,$10
2	$10,$10	0,0	0,0
3	0,0	$10, $10	0,0

Comments.

- Not all games are games of conflict.
- Communication can help solve coordination problems.
- Sequential moves can help solve coordination problems.
- We'll play some games in class that are mainly coordination and others that involve conflicts of interest.

An Advertising Game

- Two firms (Kellogg's & General Mills) managers want to maximize profits.
- Strategies consist of advertising campaigns.
- Simultaneous moves.
  - One-shot interaction.
  - Repeated interaction.

A One-Shot Advertising Game

General Mills

Kellogg's

Strategy	None	Moderate	High
None	12,12	1, 20	-1, 15
Moderate	20, 1	6, 6	0, 9
High	15, -1	9, 0	2, 2

Equilibrium to the One-Shot Advertising Game

General Mills

Kellogg's

Strategy	None	Moderate	High
None	12,12	1, 20	-1, 15
Moderate	20, 1	6, 6	0, 9
High	15, -1	9, 0	2, 2

Nash Equilibrium

Can collusion work if the game is repeated 2 times?

General Mills

Kellogg's

Strategy	None	Moderate	High
None	12,12	1, 20	-1, 15
Moderate	20, 1	6, 6	0, 9
High	15, -1	9, 0	2, 2

No (by backwards induction).

- In period 2, the game is one-shot, so High Advertising is the equilibrium in the last period.
- This means period 1 is "really" the last period, since everyone knows what will happen in period 2.
- Equilibrium entails High Advertising by each firm in both periods.
- The same holds true if we repeat the game any known, finite number of times.

Can collusion work if firms play the game each year, forever?

- Consider the following "trigger strategy" by each firm:
  - "Don't advertise, provided the rival has not advertised in the past. If the rival ever advertises, "punish" it by engaging in a high level of advertising forever after."
- In effect, each firm agrees to "cooperate" so long as the rival hasn't "cheated" in the past. "Cheating" triggers punishment in all future periods.

Suppose General Mills adopts this trigger strategy. Kellogg's profits?

$$\Pi_{Cooperate} = 12 + 12/(1+i) + 12/(1+i)^2 + 12/(1+i)^3 + \ldots$$
$$= 12 + \boxed{12/i}$$

Value of a perpetuity of \$12 paid at the end of every year

$$\Pi_{Cheat} = 20 + 2/(1+i) + 2/(1+i)^2 + 2/(1+i)^3 + \ldots$$
$$= 20 + 2/i$$

General Mills

Kellogg's

Strategy	None	Moderate	High
None	12,12	1, 20	-1, 15
Moderate	20, 1	6, 6	0, 9
High	15, -1	9, 0	2, 2

Kellogg's Gain to Cheating:

- $\Pi_{Cheat} - \Pi_{Cooperate} = 20 + 2/i - (12 + 12/i) = 8 - 10/i$
  - Suppose $i = .05$
- $\Pi_{Cheat} - \Pi_{Cooperate} = 8 - 10/.05 = 8 - 200 = -192$
- It doesn't pay to deviate.
  - Collusion is a Nash equilibrium in the infinitely repeated game!

General Mills

Kellogg's

Strategy	None	Moderate	High
None	12,12	1, 20	-1, 15
Moderate	20, 1	6, 6	0, 9
High	15, -1	9, 0	2, 2

Benefits & Costs of Cheating

- $\Pi_{Cheat} - \Pi_{Cooperate} = 8 - 10/i$
  - 8 = Immediate Benefit (20 - 12 today)
  - 10/i = PV of Future Cost (12 - 2 forever after)
- If Immediate Benefit - PV of Future Cost > 0
  - Pays to "cheat".
- If Immediate Benefit - PV of Future Cost ≤ 0
  - Doesn't pay to "cheat".

General Mills

Kellogg's

Strategy	None	Moderate	High
None	12,12	1, 20	-1, 15
Moderate	20, 1	6, 6	0, 9
High	15, -1	9, 0	2, 2

Main Idea

- Cooperation can be sustained as a Nash Eq. even when there is a conflict of interest.
  - E.g., collusion in oligopoly
- Requires repeated interaction into the indefinite future.
  - Won't work if everyone knows the end date.
- Works better given:
  - Ability to monitor actions of rivals
  - Ability (and reputation for) punishing defectors
  - Low interest rate
  - High probability of future interaction

Real World Examples of Collusion

- Garbage Collection Industry
- OPEC
- NASDAQ
- Airlines

Garbage Collection Industry

- Homogeneous products
- Bertrand oligopoly
- Identity of customers is known
- Identity of competitors is known

Normal Form Bertrand Game

Firm 2

Firm 1

Strategy	Low Price	High Price
Low Price	0,0	20,-1
High Price	-1, 20	15, 15

One-Shot Bertrand (Nash) Equilibrium

Firm 2

Firm 1

Strategy	Low Price	High Price
Low Price	0,0	20,-1
High Price	-1, 20	15, 15

Potential Repeated Game Equilibrium Outcome

Firm 2

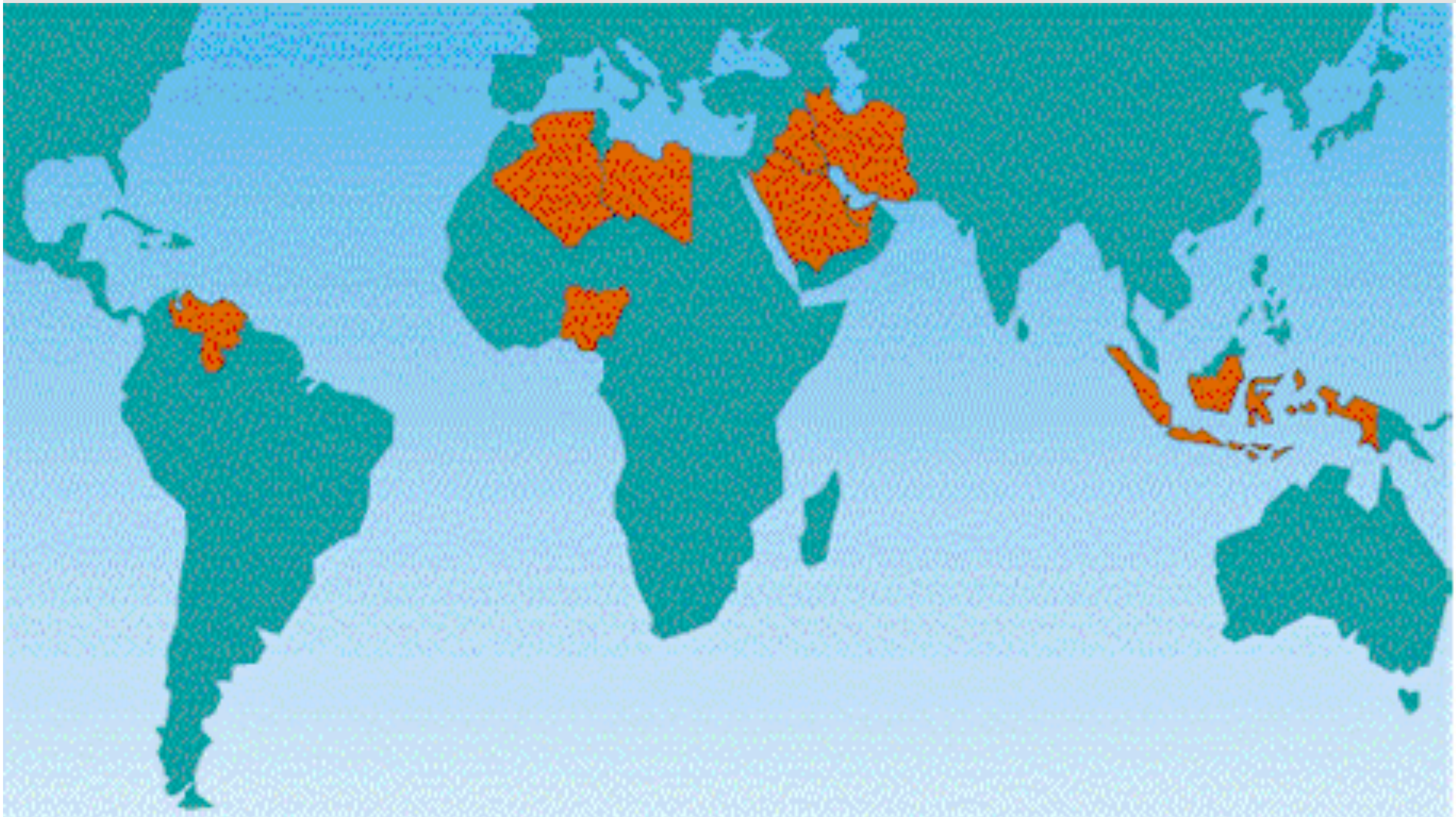
Firm 1

Strategy	Low Price	High Price
Low Price	0,0	20,-1
High Price	-1, 20	15, 15

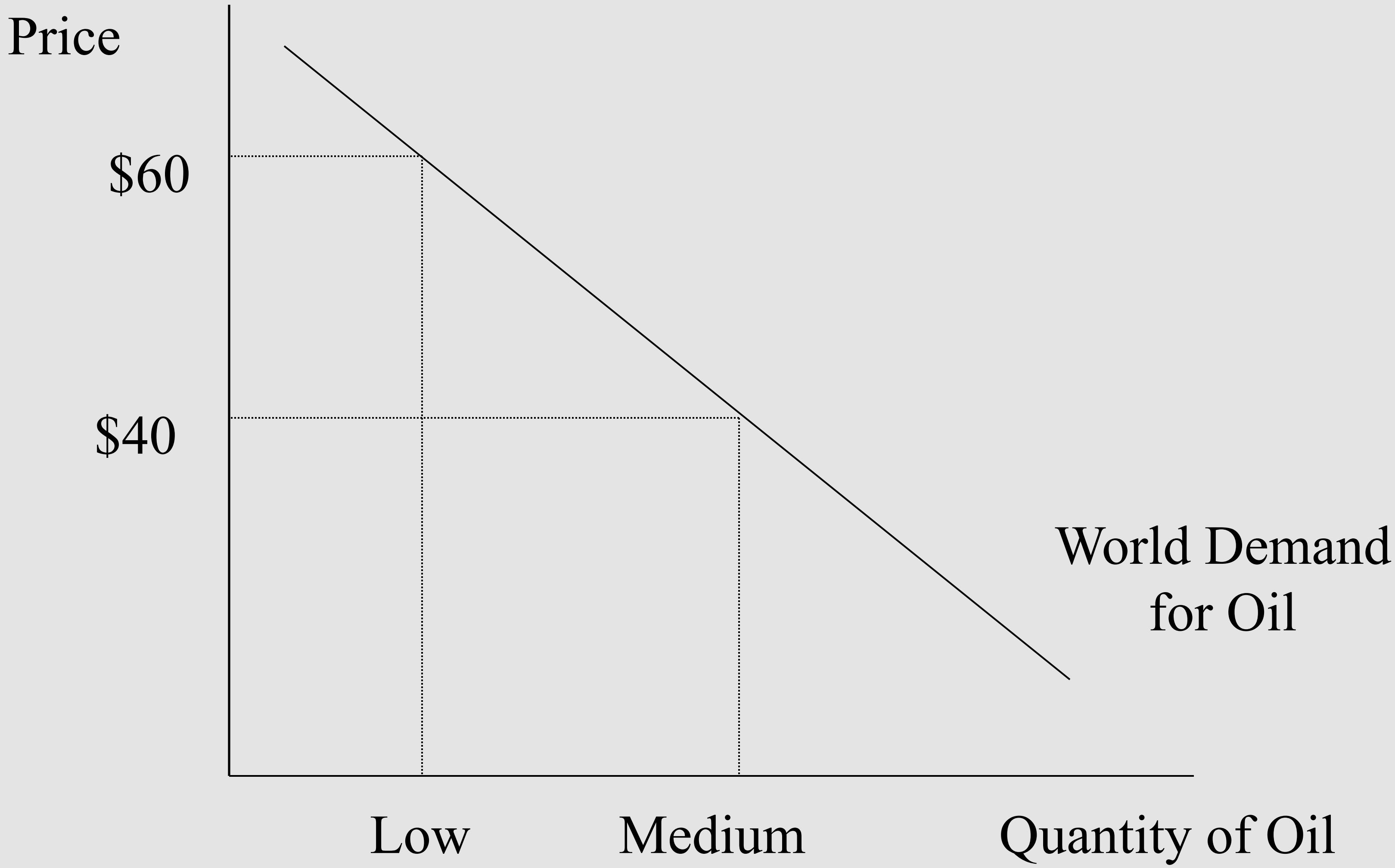
OPEC

- Cartel founded in 1960 by Iran, Iraq, Kuwait, Saudi Arabia, and Venezuela
- Currently has 11 members
- "*OPEC's objective is to co-ordinate and unify petroleum policies among Member Countries, in order to secure fair and stable prices for petroleum producers…*" (www.opec.com)
- Cournot oligopoly
- Absent collusion: $P^{Competition} < P^{Cournot} < P^{Monopoly}$

Current OPEC Members



Effect of Collusion on Oil Prices



Cournot Game in Normal Form

Venezuela

Saudi Arabia

Strategy	High Q	Med Q	Low Q
High Q	5, 3	9,4	3, 6
Med Q	6, 7	12,10	20, 8
Low Q	8, 1	10, 18	18, 15

One-Shot Cournot (Nash) Equilibrium

Venezuela

Saudi Arabia

Strategy	High Q	Med Q	Low Q
High Q	5, 3	9,4	3, 6
Med Q	6, 7	12,10	20, 8
Low Q	8, 1	10, 18	18, 15

Repeated Game Equilibrium*

Venezuela

Saudi Arabia

Strategy	High Q	Med Q	Low Q
High Q	5, 3	9,4	3, 6
Med Q	6, 7	12,10	20, 8
Low Q	8, 1	10, 18	18, 15

* *(Assuming a Low Interest Rate)*

Caveat

- Collusion is a felony under Section 2 of the Sherman Antitrust Act.
- Conviction can result in both fines and jail-time (at the discretion of the court).
- Some NASDAQ dealers and airline companies have been charged with violations
- OPEC isn’t illegal; US laws don’t apply

Simultaneous-Move Bargaining

- Management and a union are negotiating a wage increase.
- Strategies are wage offers & wage demands.
- Successful negotiations lead to $600 million in surplus, to be split among the parties.
- Failure to reach an agreement results in a loss to the firm of $100 million and a union loss of $3 million.
- First consider simultaneous moves: only one last shot at making a deal due to impending deadline.

The Bargaining Game in Normal Form

Union

Management

Strategy	W = $10	W = $5	W = $1
W = $10	100, 500	100, 500	100, 500
W=$5	-100, -3	300, 300	300, 300
W=$1	-100, -3	-100, -3	500, 100

Three Nash Equilibria!

Union

Management

Strategy	W = $10	W = $5	W = $1
W = $10	100, 500	100, 500	100, 500
W=$5	-100, -3	300, 300	300, 300
W=$1	-100, -3	-100, -3	500, 100

Fairness: The "Natural" Focal Point

Union

Management

Strategy	W = $10	W = $5	W = $1
W = $10	100, 500	100, 500	100, 500
W=$5	-100, -3	300, 300	300, 300
W=$1	-100, -3	-100, -3	500, 100

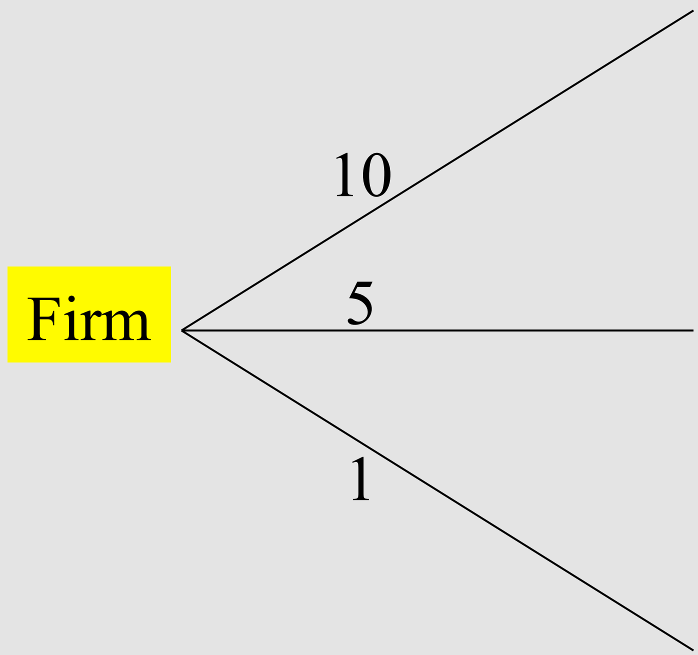
Lessons in Simultaneous Bargaining

- Simultaneous-move bargaining results in a coordination problem.
- Experiments suggests that, in the absence of any “history,” real players typically coordinate on the “fair outcome.”
- When there is a “bargaining history,” other outcomes may prevail.

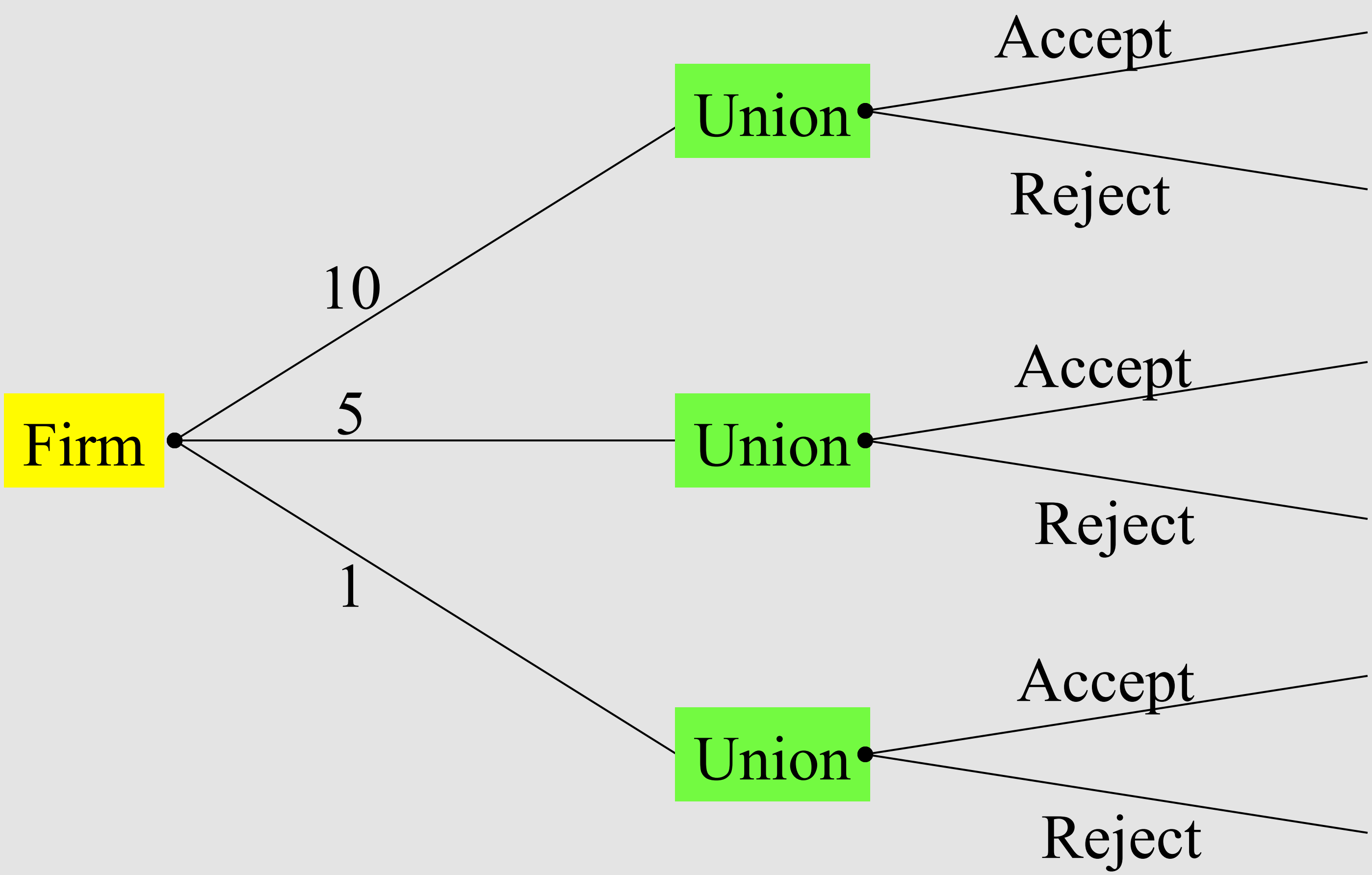
Single Offer Bargaining

- Now suppose the game is sequential in nature, and management gets to make the union a "take-it-or-leave-it" offer.
- Analysis Tool: Write the game in extensive form
  - Summarize the players.
  - Their potential actions.
  - Their information at each decision point.
  - The sequence of moves.
  - Each player's payoff.

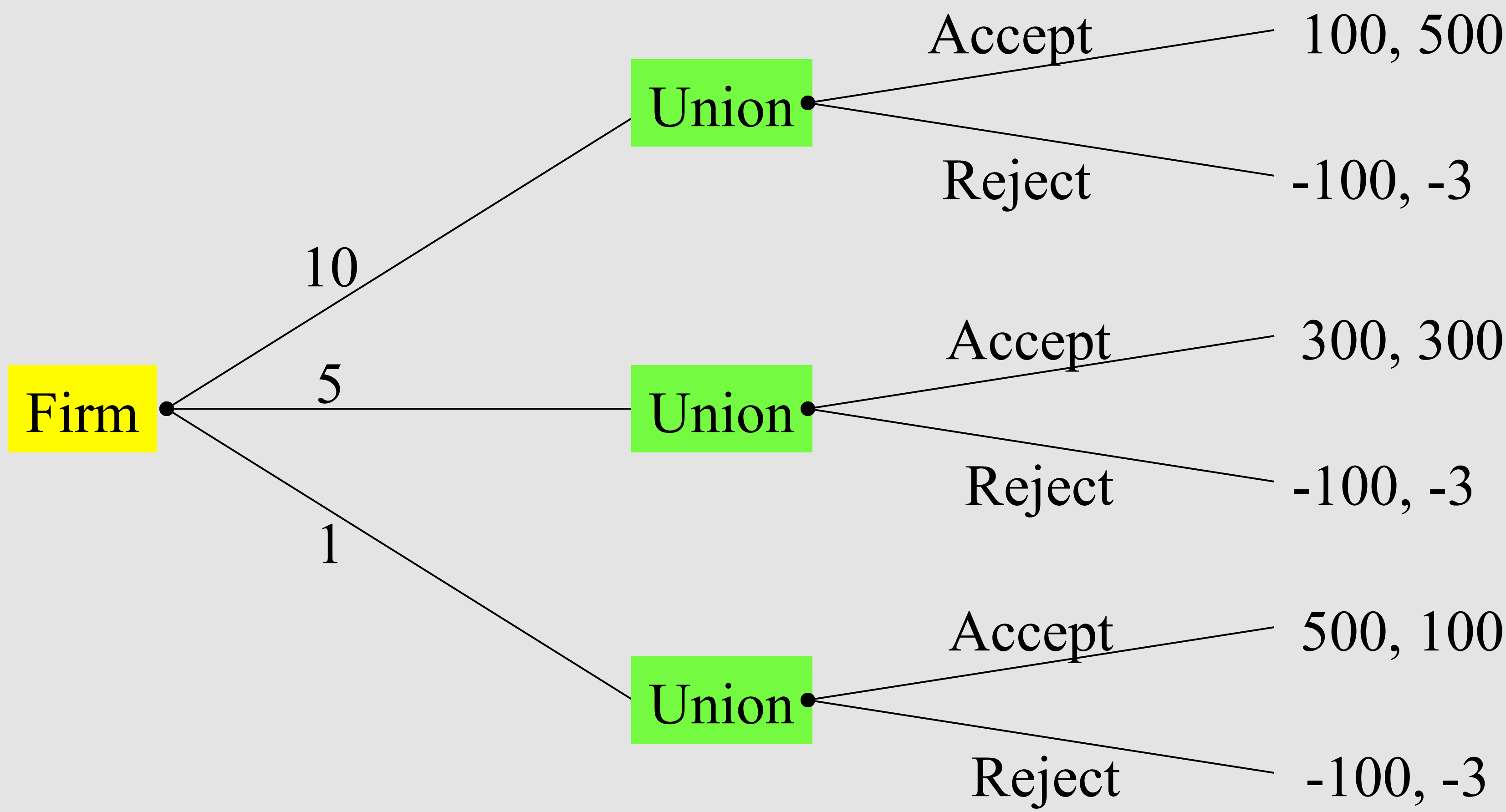
Step 1: Management's Move



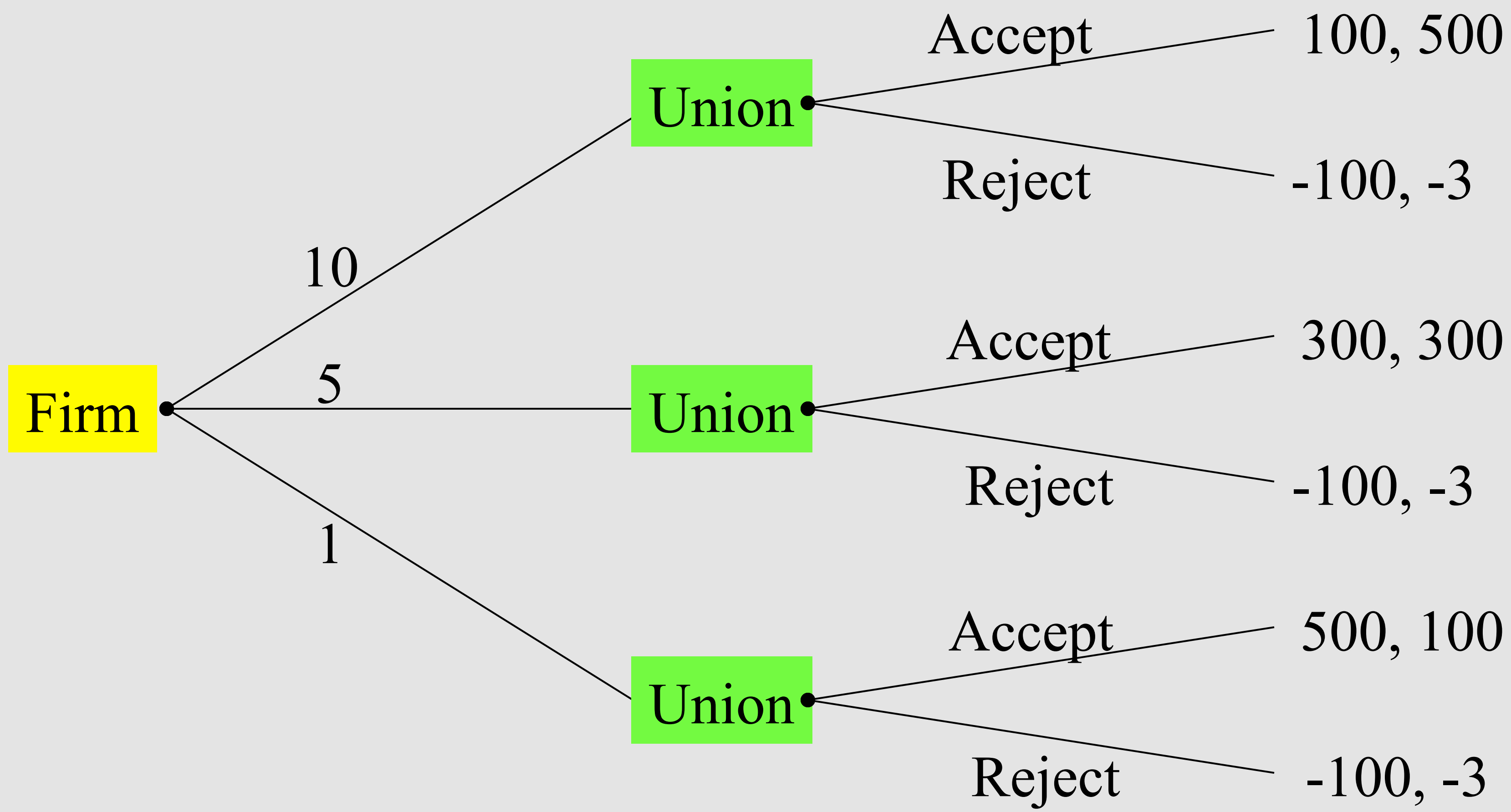
Step 2: Add the Union's Move



Step 3: Add the Payoffs



The Game in Extensive Form



Step 4: Identify the Firm's Feasible Strategies

- Management has one information set and thus three feasible strategies:
  - Offer $10.
  - Offer $5.
  - Offer $1.

Step 5: Identify the Union's Feasible Strategies

- The Union has three information sets and thus eight feasible strategies:
  - Accept $10, Accept $5, Accept $1
  - Accept $10, Accept $5, Reject $1
  - Accept $10, Reject $5, Accept $1
  - Accept $10, Reject $5, Reject $1
  - Reject $10, Accept $5, Accept $1
  - Reject $10, Accept $5, Reject $1
  - Reject $10, Reject $5, Accept $1
  - Reject $10, Reject $5, Reject $1

Step 6: Identify Nash Equilibrium Outcomes

- Outcomes such that neither the firm nor the union has an incentive to change its strategy, given the strategy of the other.

Finding Nash Equilibrium Outcomes

Union's Strategy	Firm's Best Response	Mutual Best Response?
Accept $10, Accept $5, Accept $1	$1	Yes
Accept $10, Accept $5, Reject $1	$5	Yes
Accept $10, Reject $5, Accept $1	$1	Yes
Reject $10, Accept $5, Accept $1	$1	Yes
Accept $10, Reject $5, Reject $1	$10	Yes
Reject $10, Accept $5, Reject $1	$5	Yes
Reject $10, Reject $5, Accept $1	$1	Yes
Reject $10, Reject $5, Reject $1	$10, $5, $1	No

Step 7: Find the Subgame Perfect Nash Equilibrium Outcomes

- Outcomes where no player has an incentive to change its strategy, given the strategy of the rival, and
- The outcomes are based on “credible actions;” that is, they are not the result of “empty threats” by the rival.

Checking for Credible Actions

Union's Strategy	Are all Actions Credible?
Accept \$10, Accept \$5, Accept \$1	Yes
Accept \$10, Accept \$5, Reject \$1	No
Accept \$10, Reject \$5, Accept \$1	No
Reject \$10, Accept \$5, Accept \$1	No
Accept \$10, Reject \$5, Reject \$1	No
Reject \$10, Accept \$5, Reject \$1	No
Reject \$10, Reject \$5, Accept \$1	No
Reject \$10, Reject \$5, Reject \$1	No

The "Credible" Union Strategy

Union's Strategy	Are all Actions Credible?
Accept $10, Accept $5, Accept $1	Yes
Accept $10, Accept $5, Reject $1	No
Accept $10, Reject $5, Accept $1	No
Reject $10, Accept $5, Accept $1	No
Accept $10, Reject $5, Reject $1	No
Reject $10, Accept $5, Reject $1	No
Reject $10, Reject $5, Accept $1	No
Reject $10, Reject $5, Reject $1	No

Finding Subgame Perfect Nash Equilibrium Strategies

Union's Strategy	Firm's Best Response	Mutual Best Response?
Accept \$10, Accept \$5, Accept \$1	\$1	Yes
Accept \$10, Accept \$5, Reject \$1	\$5	Yes
Accept \$10, Reject \$5, Accept \$1	\$1	Yes
Reject \$10, Accept \$5, Accept \$1	\$1	Yes
Accept \$10, Reject \$5, Reject \$1	\$10	Yes
Reject \$10, Accept \$5, Reject \$1	\$5	Yes
Reject \$10, Reject \$5, Accept \$1	\$1	Yes
Reject \$10, Reject \$5, Reject \$1	\$10, \$5, \$1	No

Nash and Credible

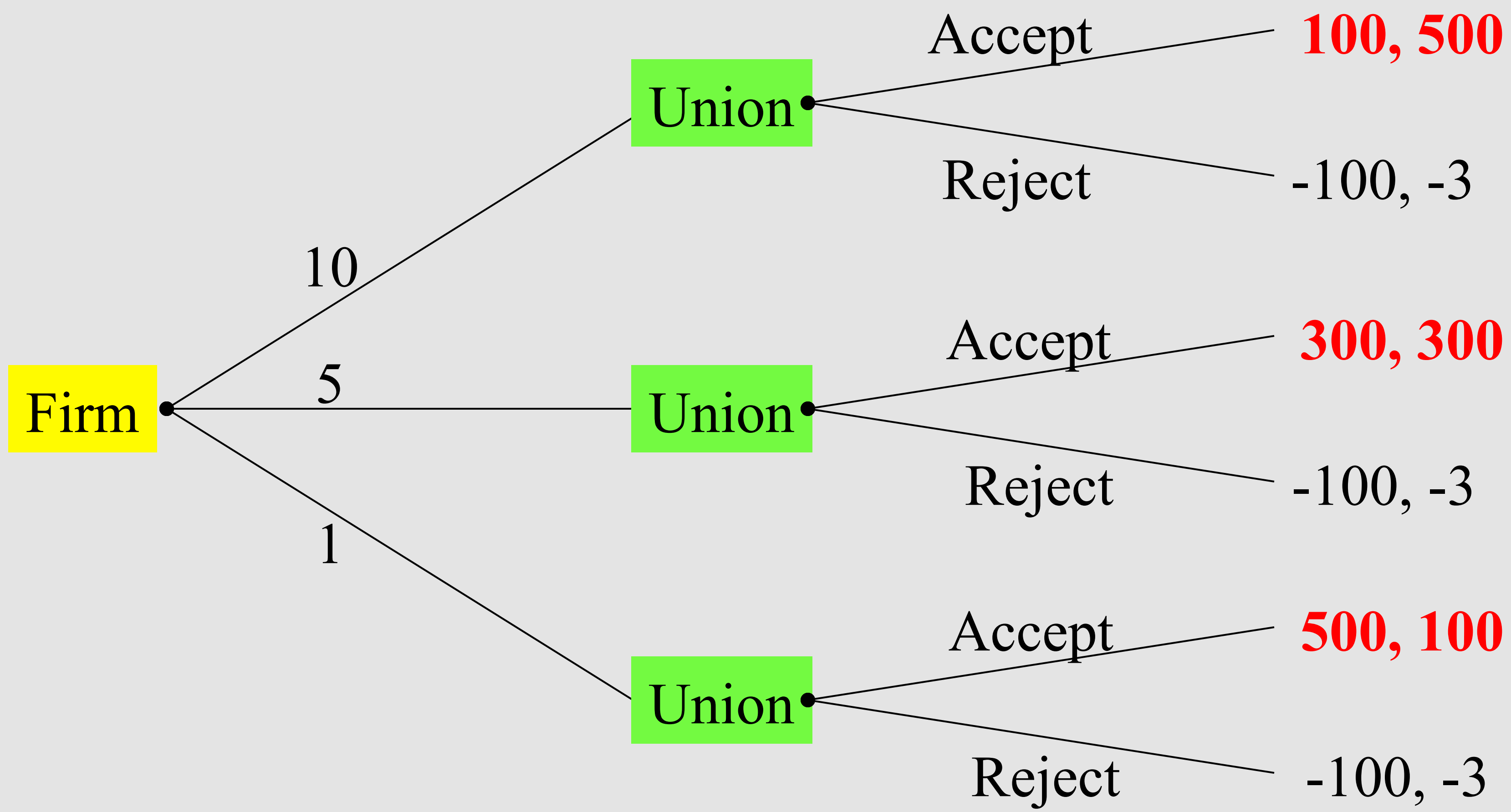
Nash Only

Neither Nash Nor Credible

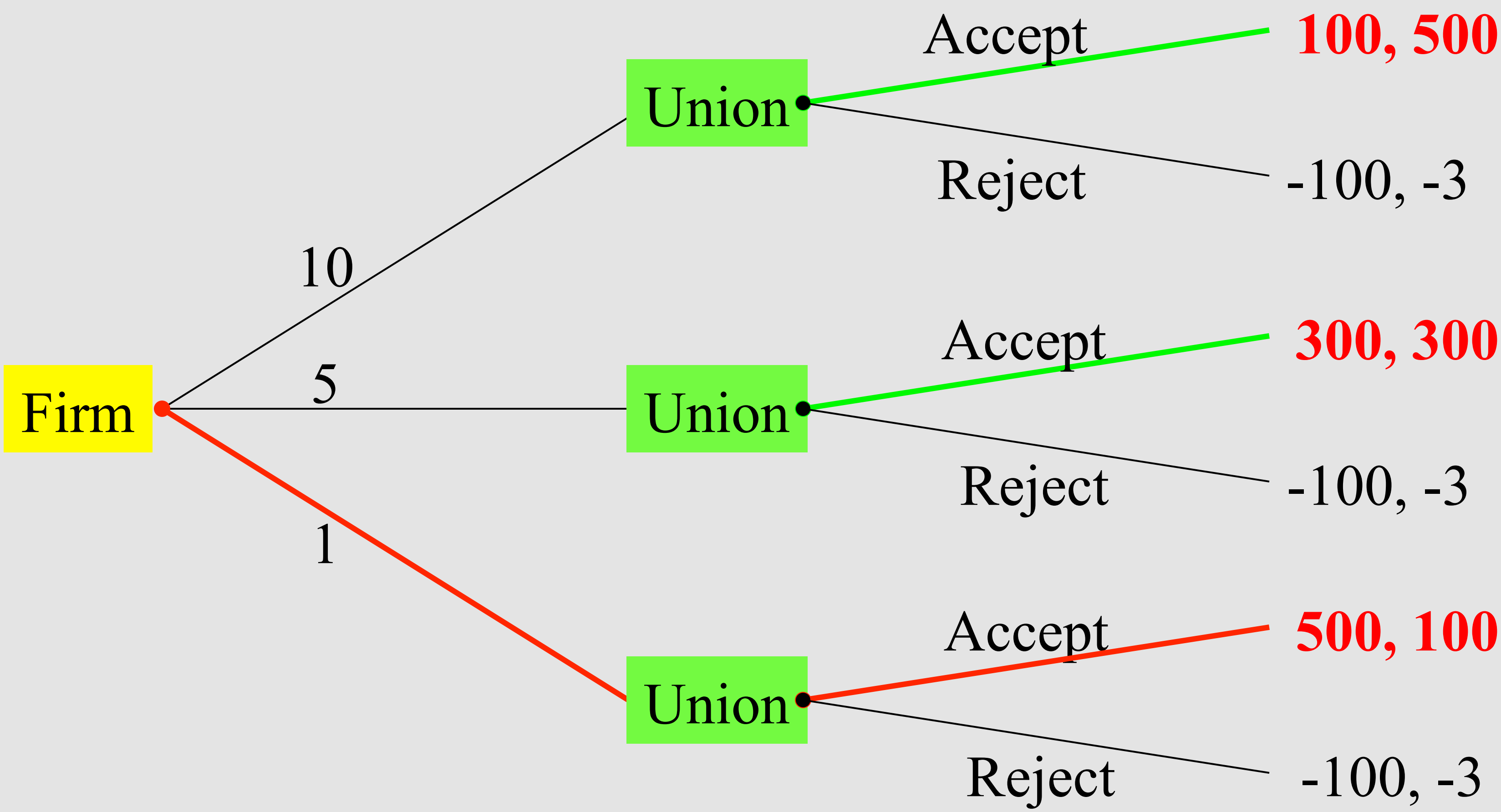
To Summarize:

- We have identified many combinations of Nash equilibrium strategies.
- In all but one the union does something that isn't in its self interest (and thus entail threats that are not credible).
- Graphically:

There are 3 Nash Equilibrium Outcomes!



Only 1 Subgame-Perfect Nash Equilibrium Outcome!



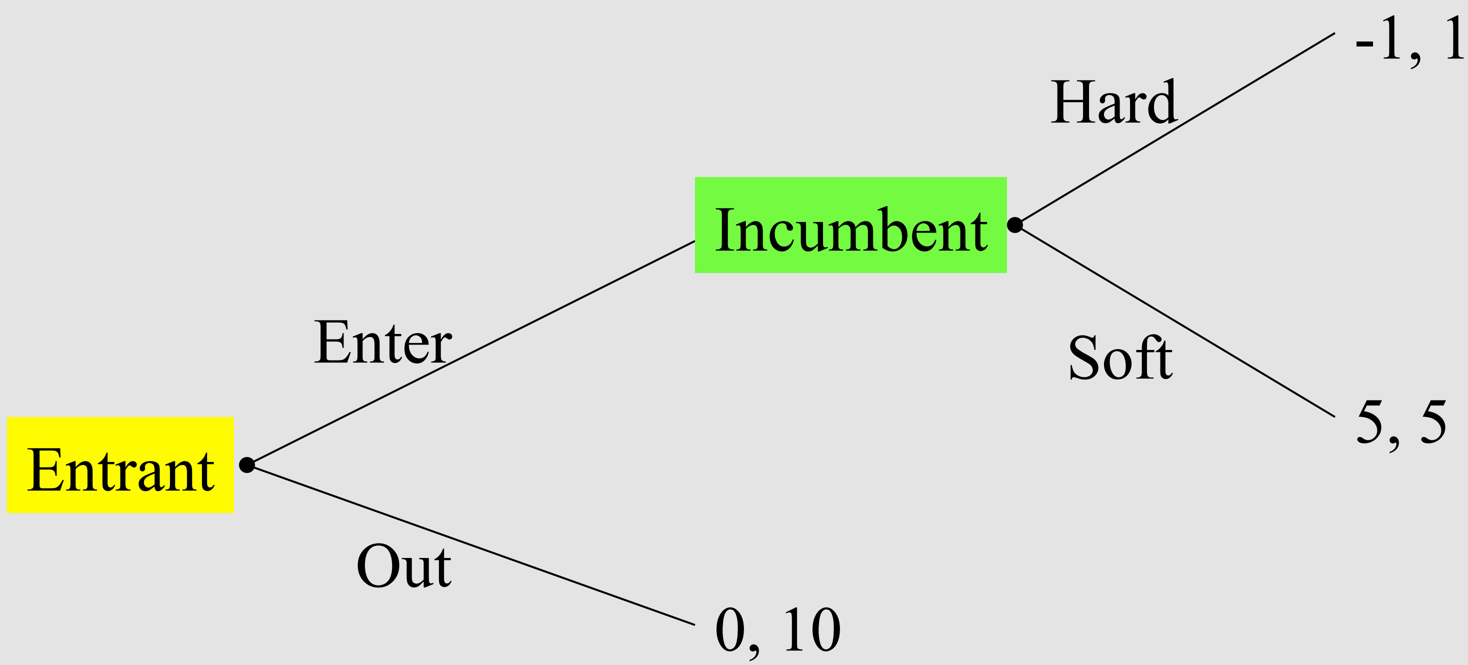
Bargaining Re-Cap

- In take-it-or-leave-it bargaining, there is a first-mover advantage.
- Management can gain by making a take-it-or-leave-it offer to the union. But...
- Management should be careful; real world evidence suggests that people sometimes reject offers on the the basis of "principle" instead of cash considerations.

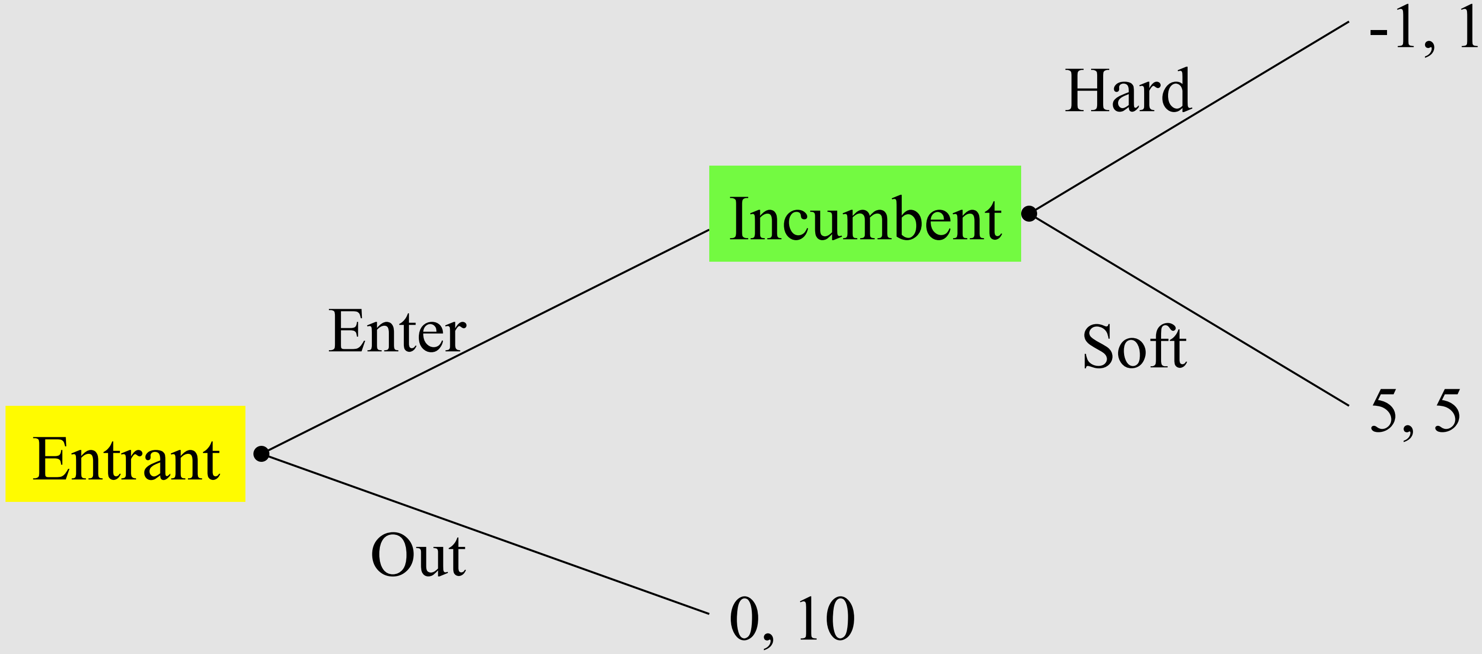
Pricing to Prevent Entry: An Application of Game Theory

- Two firms: an incumbent and potential entrant.
- Potential entrant's strategies:
  - Enter.
  - Stay Out.
- Incumbent's strategies:
  - {if enter, play hard}.
  - {if enter, play soft}.
  - {if stay out, play hard}.
  - {if stay out, play soft}.
- Move Sequence:
  - Entrant moves first. Incumbent observes entrant's action and selects an action.

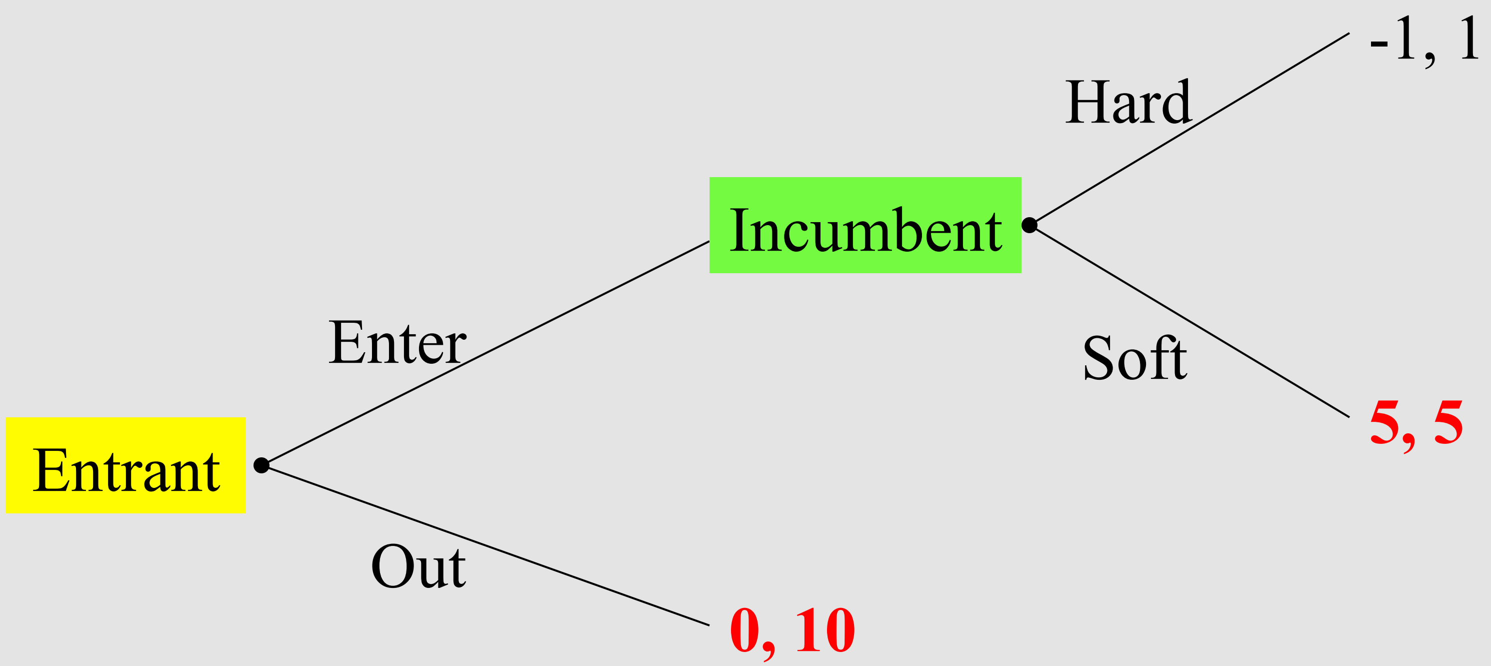
The Pricing to Prevent Entry Game in Extensive Form



Identify Nash and Subgame Perfect Equilibria

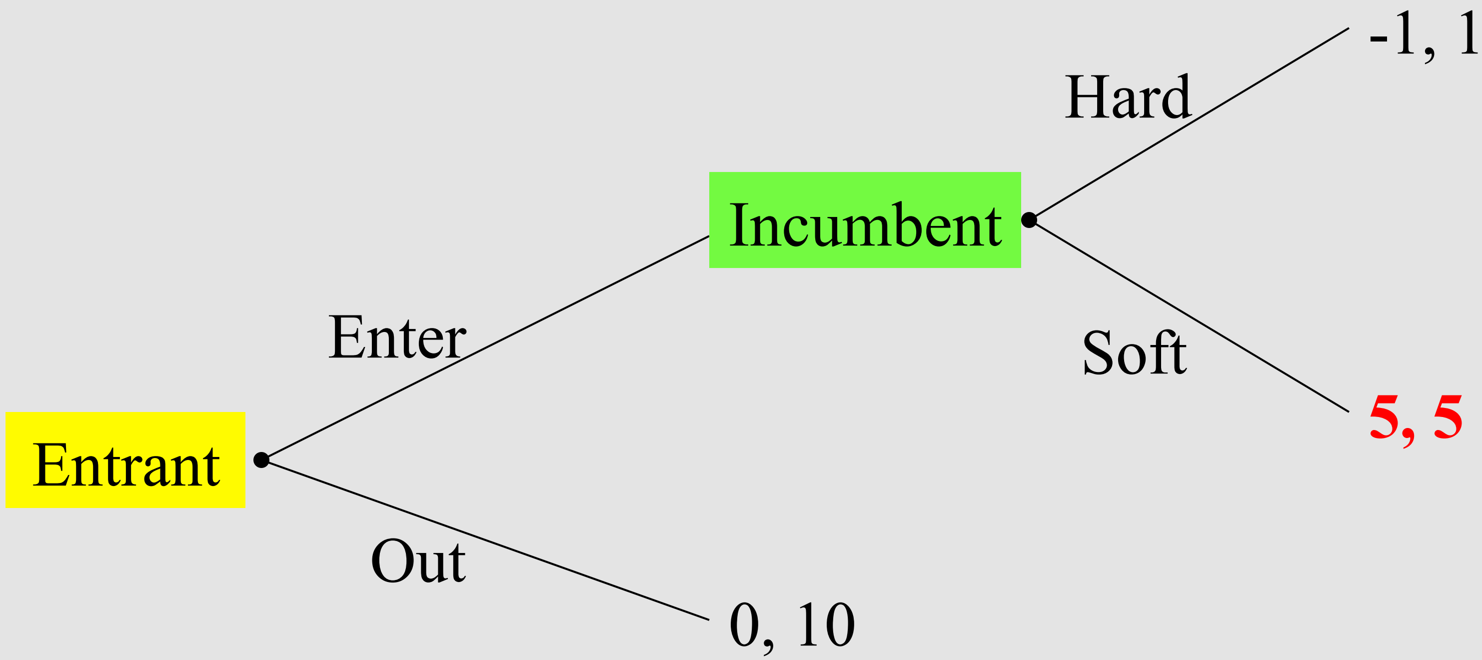


Two Nash Equilibria



Nash Equilibria Strategies {player 1; player 2}:
{enter; If enter, play soft}
{stay out; If enter, play hard}

One Subgame Perfect Equilibrium



Subgame Perfect Equilibrium Strategy:
{enter; If enter, play soft}

Insights

- Establishing a reputation for being unkind to entrants can enhance long-term profits.
- It is costly to do so in the short-term, so much so that it isn't optimal to do so in a one-shot game.

Holdup Problem Revisited

- Sunk cost investments create quasi-rents
  - These can be appropriated
  - This would create a loss on the investment
- Hence the investment might not be made
  - And the opportunity is lost
- Examples include
  - UCSC buys enterprise software from PAS...
  - NASA contracts with Obing Corp..
  - Many Dilbert episodes

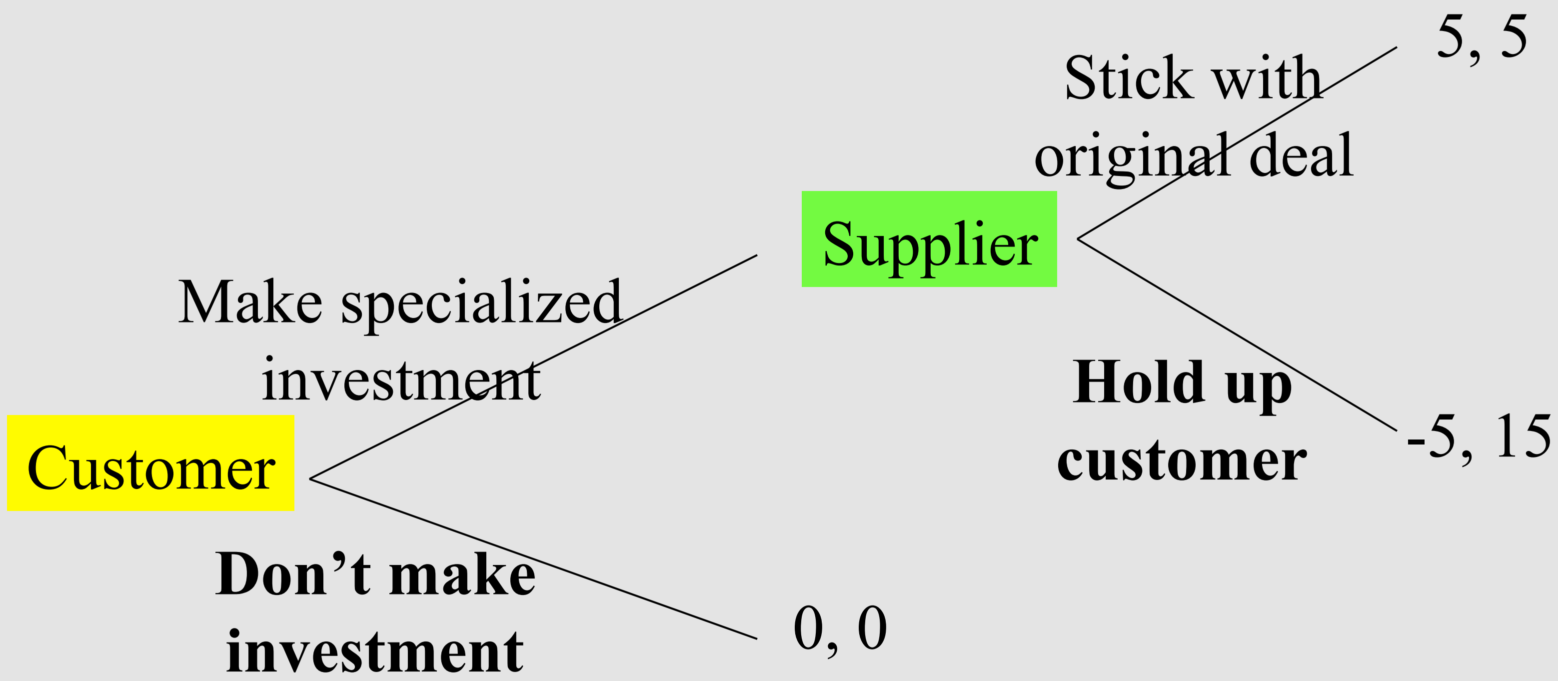
A typical scenario

- Customer can make investment (cost=5) in specialized software that will enhance productivity (benefit=15)
- Original deal: customer keeps 10 of benefit and nets 5, supplier gets the other 5.

A typical scenario

- Customer can make investment (cost=5) in specialized software that will enhance productivity (benefit=15)
- Original deal: customer keeps 10 of benefit and nets 5, supplier gets the other 5.
- **Hold up:** Supplier can later demand an extra amount (at most 10) to keep software working.

The Holdup Problem in Extensive Form



Missing piece of theory: mixed strategies

- It's third down and 4 yards to go for the NY Giants…should they run or pass? Should the NE Patriots stack the defense against the run or pass?
- No Nash equilibrium in pure strategies.
- The NE: mix it up!
- See text for short discussion, and any game theory book for a long discussion.
- Theorem: every "regular" game has at least one NE, but it may involve mixed strategies.