LECTURE 4
SEQUENTIAL GAMES

Introduction

- Lecture 1-3: Simultaneous games:
  - Prisoner's dilemma (Ad, No Ad):
    - Unique PSNE, both players defect.
  - Games without PSNE (shirk/monitor):
    - MSNE is the intuitive outcome.
  - Coordination games:
    - 2 PSNE & 1 MSNE. Players may try to coordinate.

Introduction

- Lecture 4-5: Sequential games.
  - Games where players move one after another. Sequential games are asymmetric.
  - Games we play: chess
  - Games businesses play: entry, pricing…
- L4: Subgame perfect equilibrium.
- L5: Experimental evidence, and an application to bargaining.

Sequential games

- Looking forward: Players, when make moves, have to consider how other players will react.
- Reasoning backward: Given other players' reaction, what is my optimal strategy?
- Asymmetry in order of play causes asymmetry in payoffs. It matters who plays first and who plays second.

Entry game

- Two restaurant chains must choose whether to open or no to open a restaurant in a new shopping area.

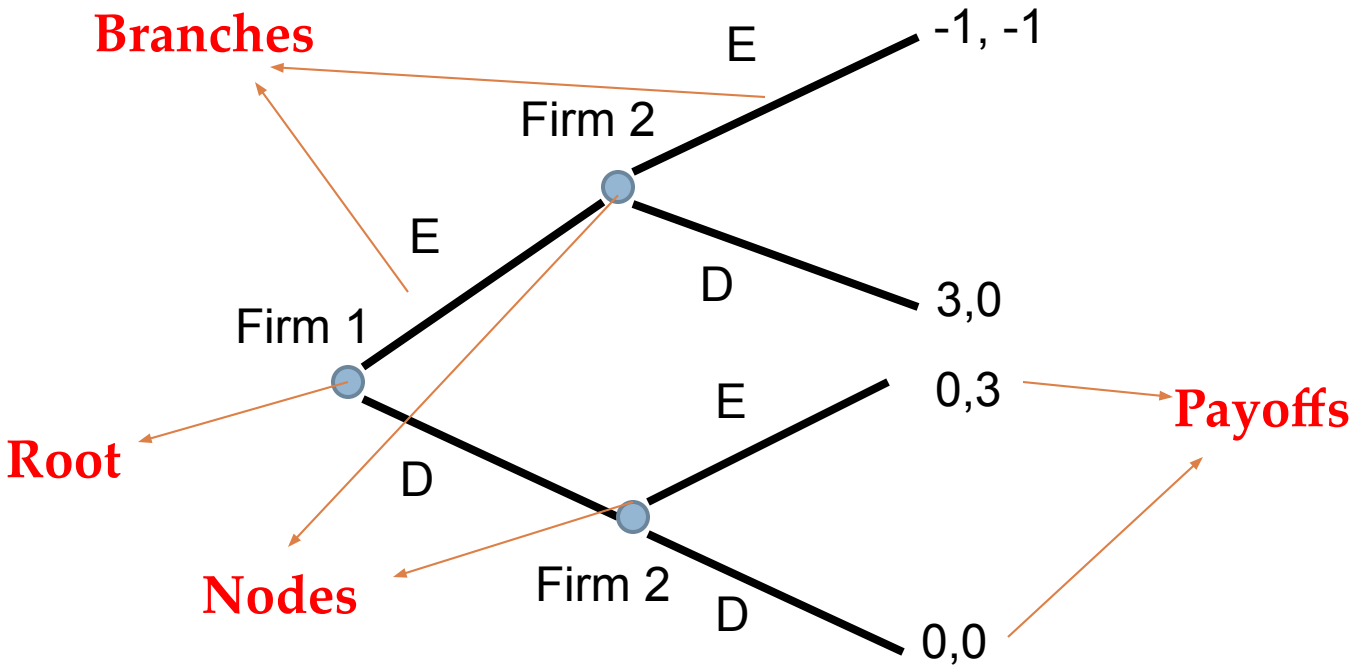
Firm 2

Firm 1	Enter	Don't
Enter	-1, -1	3, 0
Don't	0, 3	0, 0

- If the game is simultaneous: 2 PSNE, 1 MSNE.

Entry game

- What if Firm 1 is first mover, and Firm 2 the follower?
- Game Trees: all possible moves, and all possible outcome and payoffs.



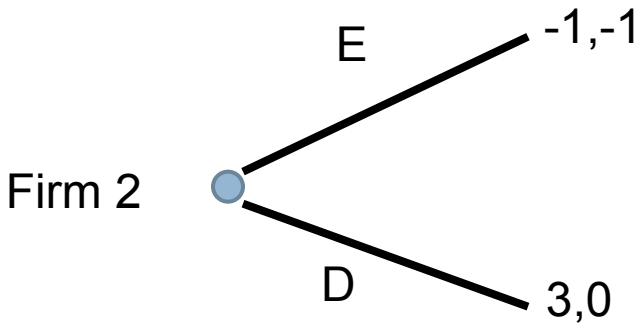
Solving the Game Tree

- Method use to solve game tree:
  - Backward Induction, or rollback
  - Start from the end, and rollback until the root

- Difference with simultaneous game
  - Drop the concept of joint best response
  - There is a hierarchy of actions, of players

Solving the Game Tree

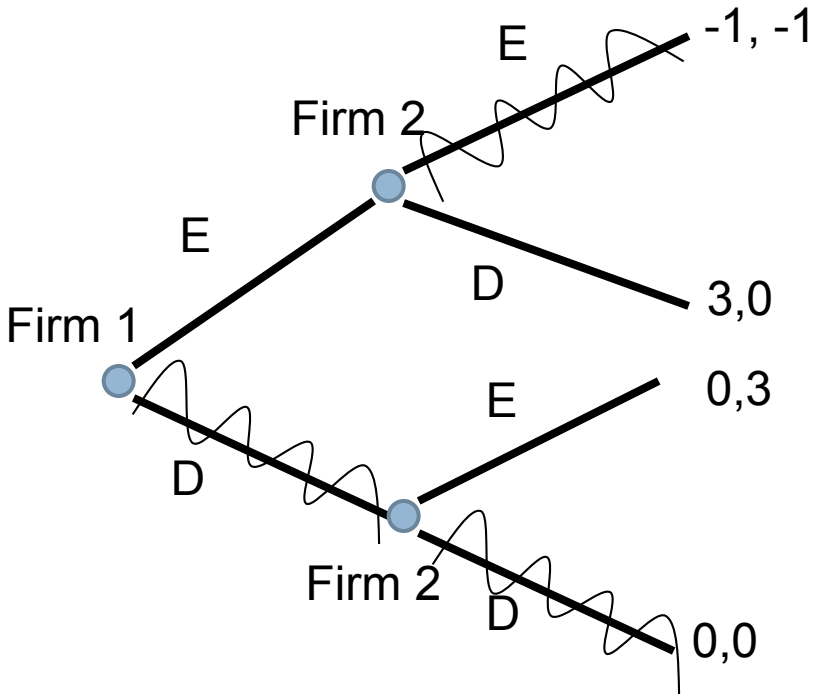
- Subgame: any node with all subsequent nodes:



- **Subgame perfect equilibrium (SPE):**
  - The SPE is the equilibrium in sequential games.
  - The SPE is such that players' strategies constitute a Nash equilibrium in every subgame of the original game
  - Start with terminal nodes and eliminate dominated actions from the game

Looking Forward… And Reasoning Back

- Firm 1 makes the first move, and must take into account how the response of Firm 2:



The SPE is (E,D)

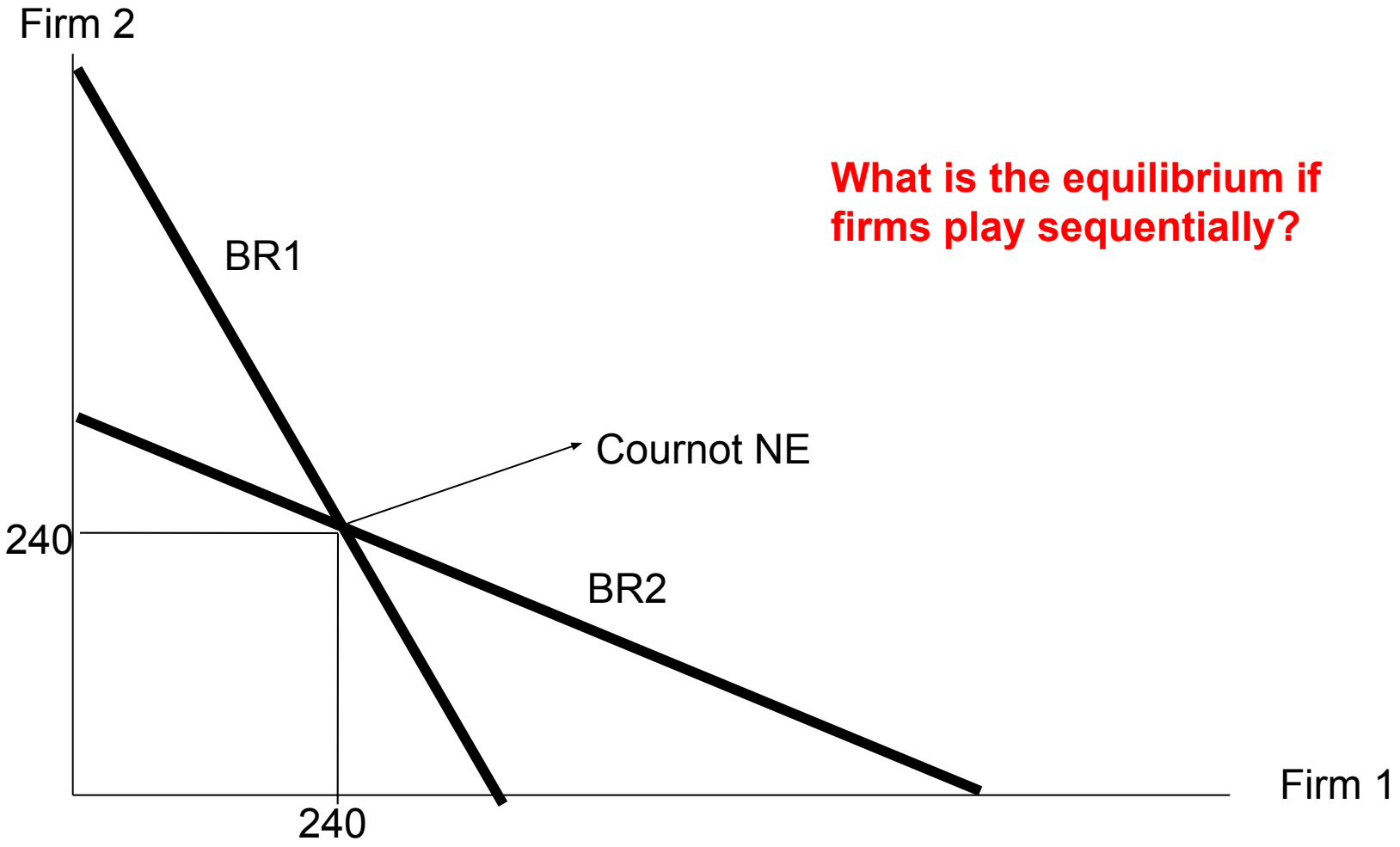
Discussion

- Compared to the simultaneous version of the game,
  - Firm 1 can obtain the outcome that yields the highest payoff (3), whereas Firm 2 obtains a low payoff (0)
- First-mover advantage:
  - Ability to commit oneself to an advantageous position
  - Firm 1 benefits from taking an irreversible action
- Note: not all games have a first-mover advantage
  - e.g. some bargaining games may have a second-mover advantage (see lecture 5).

Sequential games and oligopoly

- Cournot model of oligopoly:
  - Simultaneous game.
  - Producers have market power (profits>0), but less than the monopolist.
  - Producers would be better off if they could cooperate (e.g. OPEC oil cartel), however cooperation is not a stable outcome.
- Decisions of how much to produce can also be sequential **Stackelberg model** of oligopoly

Sequential games and oligopoly



What is the equilibrium if firms play sequentially?

The Stackelberg model

A Cournot game with sequential actions

- Two producers, Firm 1 and Firm 2.
  - Produce the same goods, and sell on the same market.

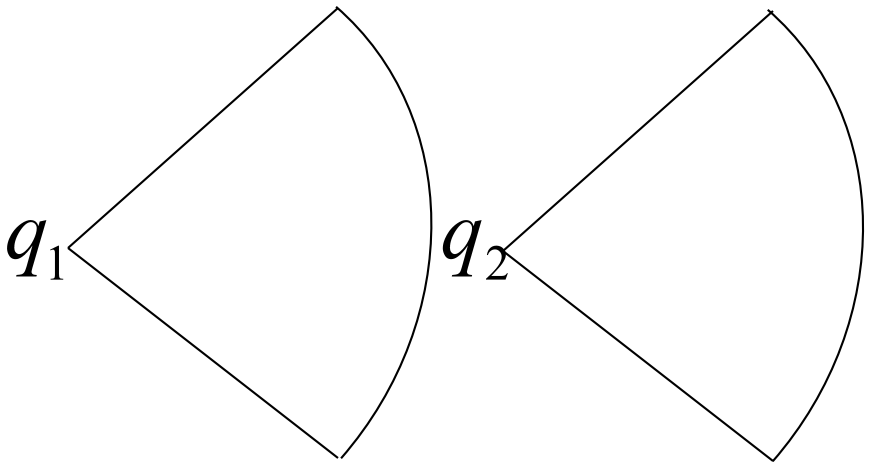
$$P(q_1 + q_2) = 1 - 0.001(q_1 + q_2)$$

$$C_1(q_1) = 0.28 \times q_1$$

$$C_2(q_2) = 0.28 \times q_2$$

The Stackelberg model

- Rather than assuming that producers choose quantity simultaneously, the Stackelberg model identifies a leader (who chooses quantity first), and a follower.
- The follower will observe the leader's quantity level before choosing his own quantity.



The Stackelberg model

- The leader can predict the follower's choice, and will take it into account when making its decision.

$$\Rightarrow \pi_1 = q_1 \times (1 - 0.001 \times (q_1 + q_2)) - 0.28 q_1$$

$$\Rightarrow \begin{cases} \pi_1 = 0.72 q_1 - 0.001 q_1^{\,2} - 0.001 q_1 q_2 \\ \pi_2 = 0.72 q_2 - 0.001 q_2^{\,2} - 0.001 q_1 q_2 \end{cases}$$

The Stackelberg model

Backward induction

- In a sequential game, Firm 2's output will be its best response to Firm 1's output decision. Best response of Firm 2:

$$q_2 = 360 - 0.5q_1$$

- Substitute into Firm 1's profit function:

$$\pi_1 = 0.72q_1 - 0.001q_1^2 - 0.001q_1(360 - 0.5q_1)$$
$$= 0.36q_1 - 0.0005q_1^2$$

The Stackelberg model

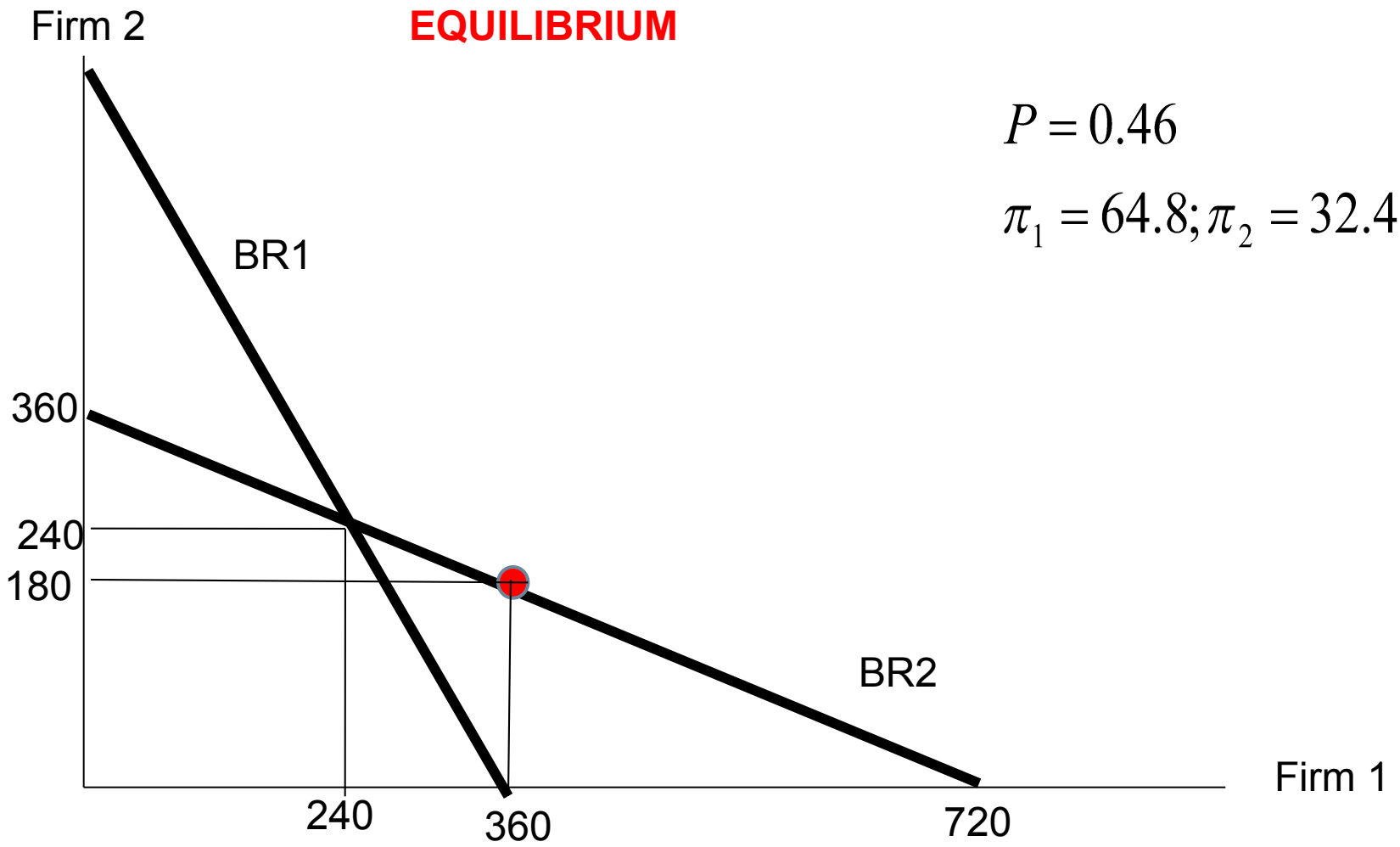
- Derive the optimal output for Firm 1:

$$\frac{\partial \pi_1}{\partial q_1} = 0.36 - 0.001 q_1 = 0 \Rightarrow q_1 = 360$$

- For Firm 2, substitute q1 in the best response function:

$$q_2 = 360 - 0.5 * 360 = 180$$

The Stackelberg model



$$P = 0.46$$

$$\pi_1 = 64.8; \pi_2 = 32.4$$

The Stackelberg model

- Note that the equilibrium is not on Firm 1's Cournot best response function.
  - By playing first, Firm 1 can select the point on Firm 2's best response function that maximizes its own payoff
- First-mover advantage: By committing to a high quantity, Firm 1 can force Firm 2 to produce a low quantity.
- The first-mover has the advantage because his action is irreversible. The Stackelberg leader is the player that makes an irreversible decision first.

Stackelberg vs. Cournot

	Monopoly	Cournot	Stackelberg	Perfect competition
Industry Output	360	480	540	720
Price	0.64	0.52	0.46	0.28
Industry Profit	129.6	115.2	97.2	0

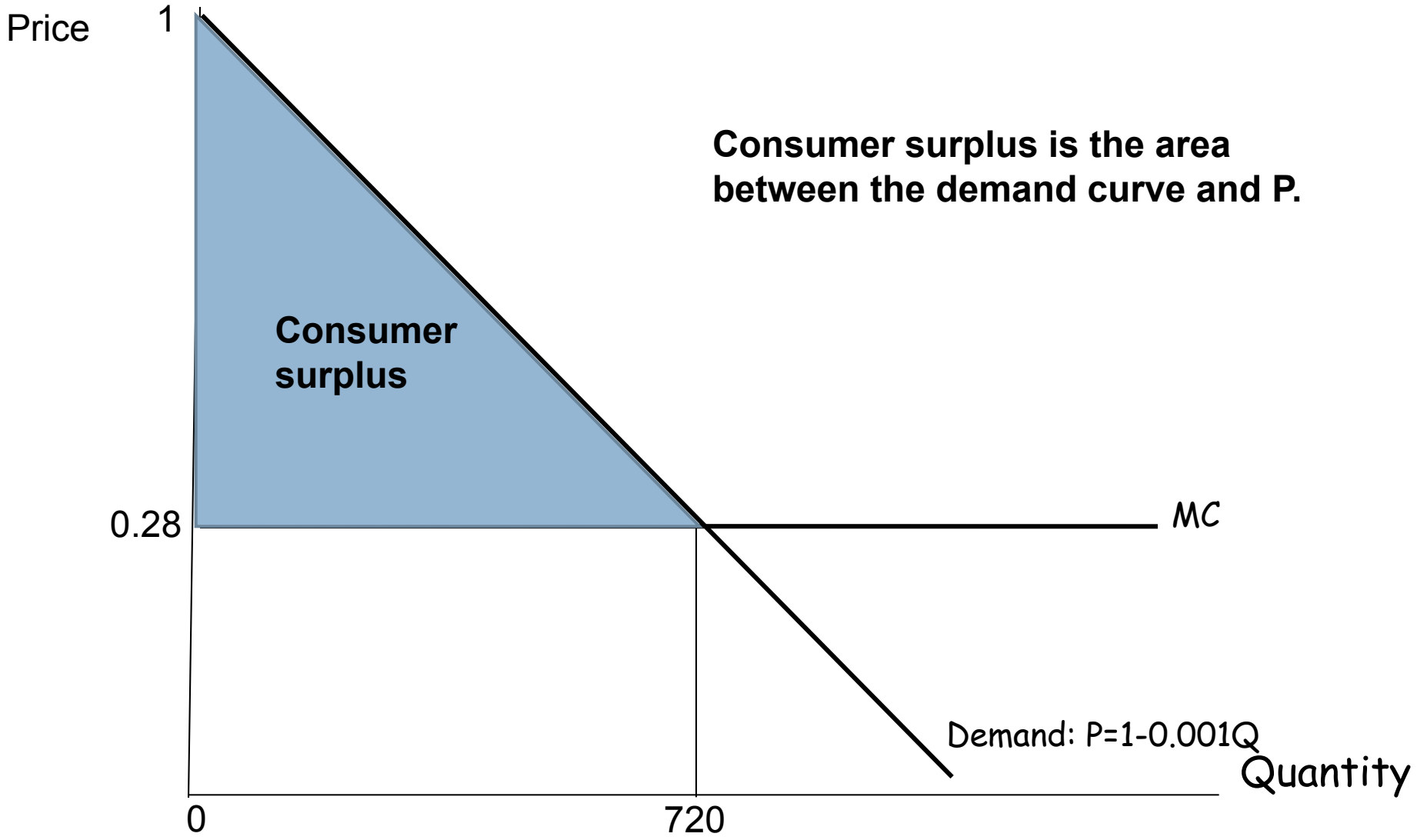
Stackelberg yields a higher total quantity than Cournot.

To exploit the first-mover advantage, the leader should produce more output than in Cournot. This results into higher total output, and a lower price.

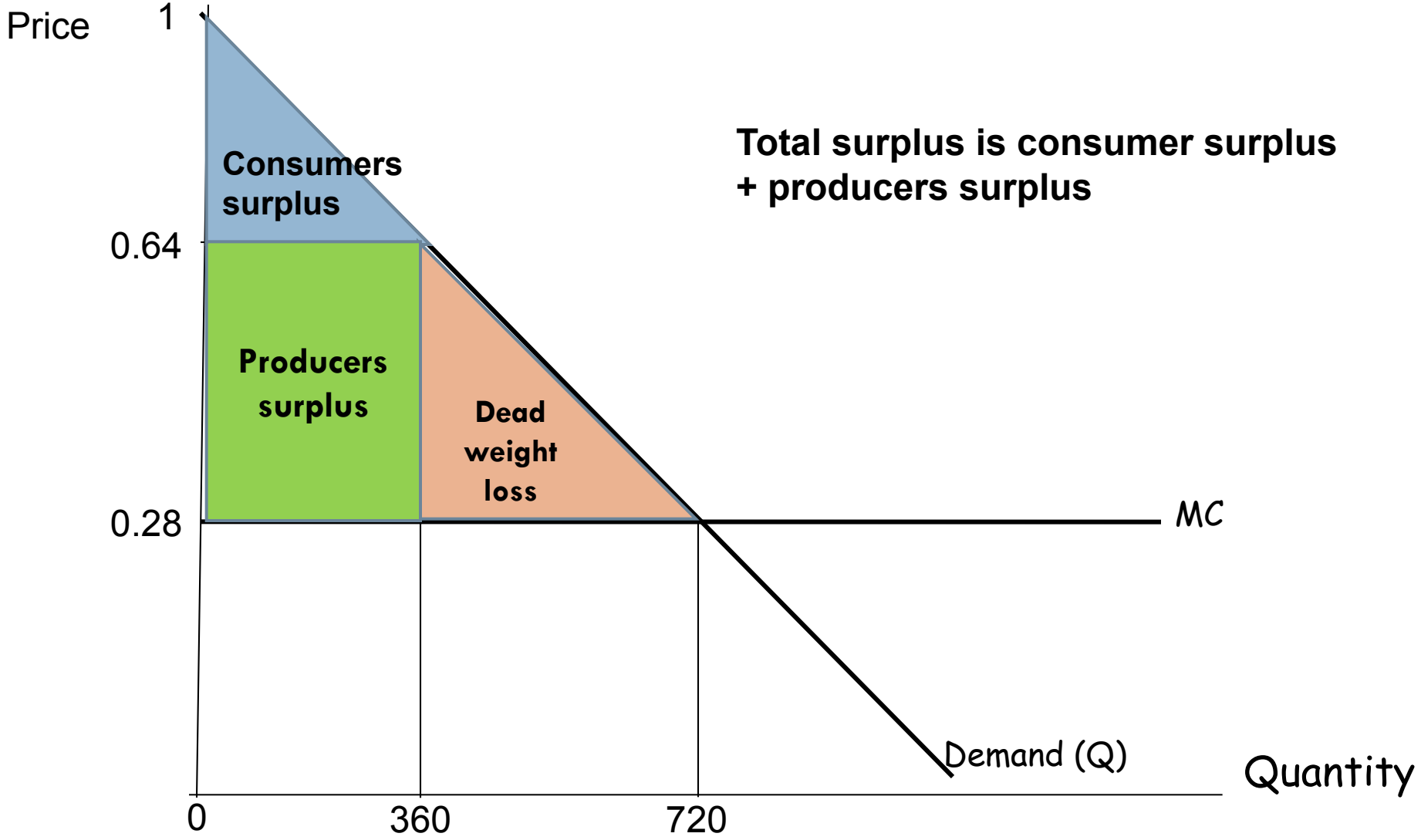
Stackelberg in the pharmaceutical industry

- Patents for new drugs last up to 20-30 years. During the patent period, the firm that invented the drug has a monopoly and can sell the drug at a high price.
- Once the patent expires, anyone is allowed to produce generic version of drug and sell at a low price.
- Just before the patent expires, brand name pharmaceutical companies enter into the generic drug competition by marketing their brand name drug with a pseudo-generic label before the generic drug manufacturers can enter the generic market.
- This allows the pseudo-generic drug to attain most of the market share and establish itself as the market leader.

Welfare and perfect competition

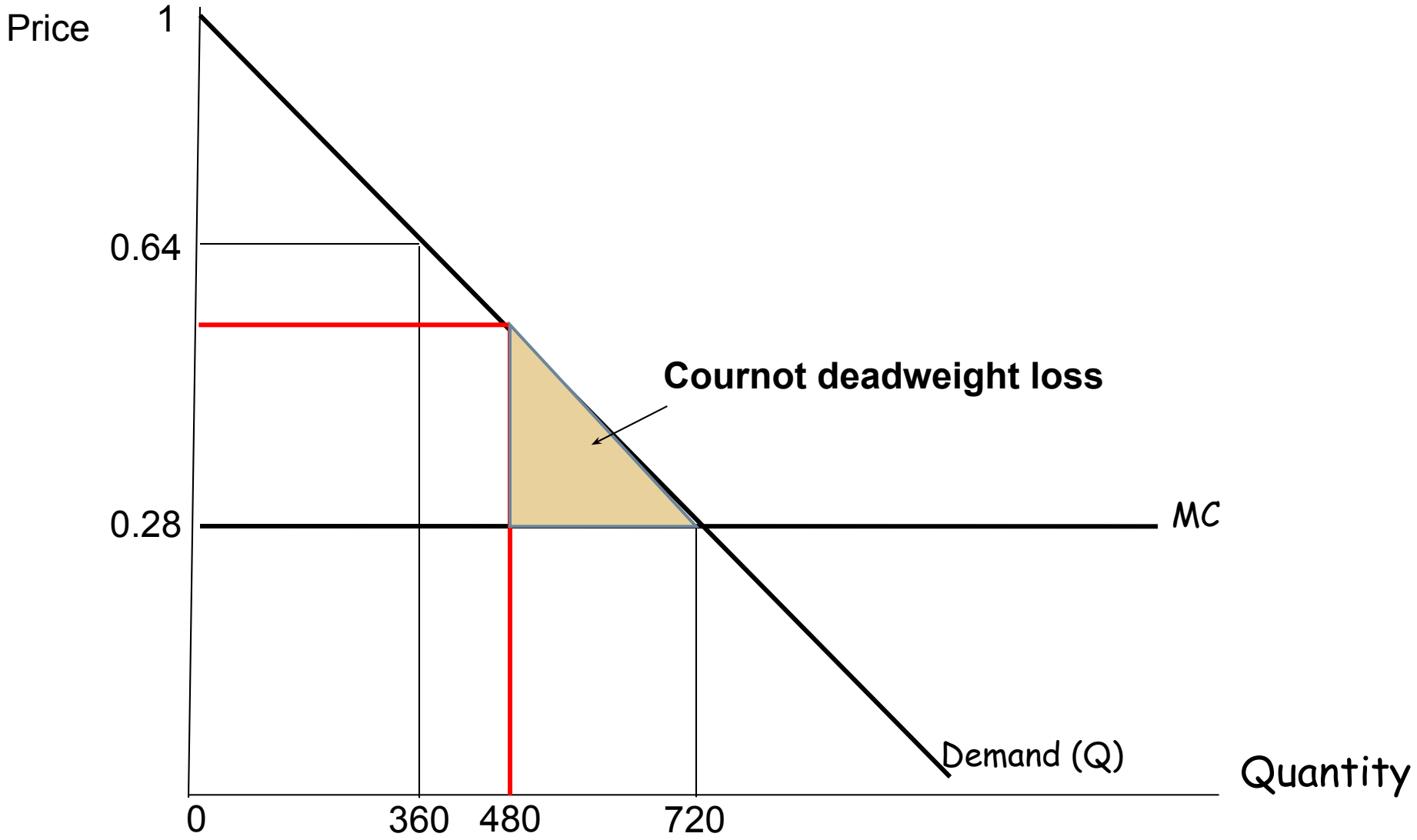


Welfare and monopoly

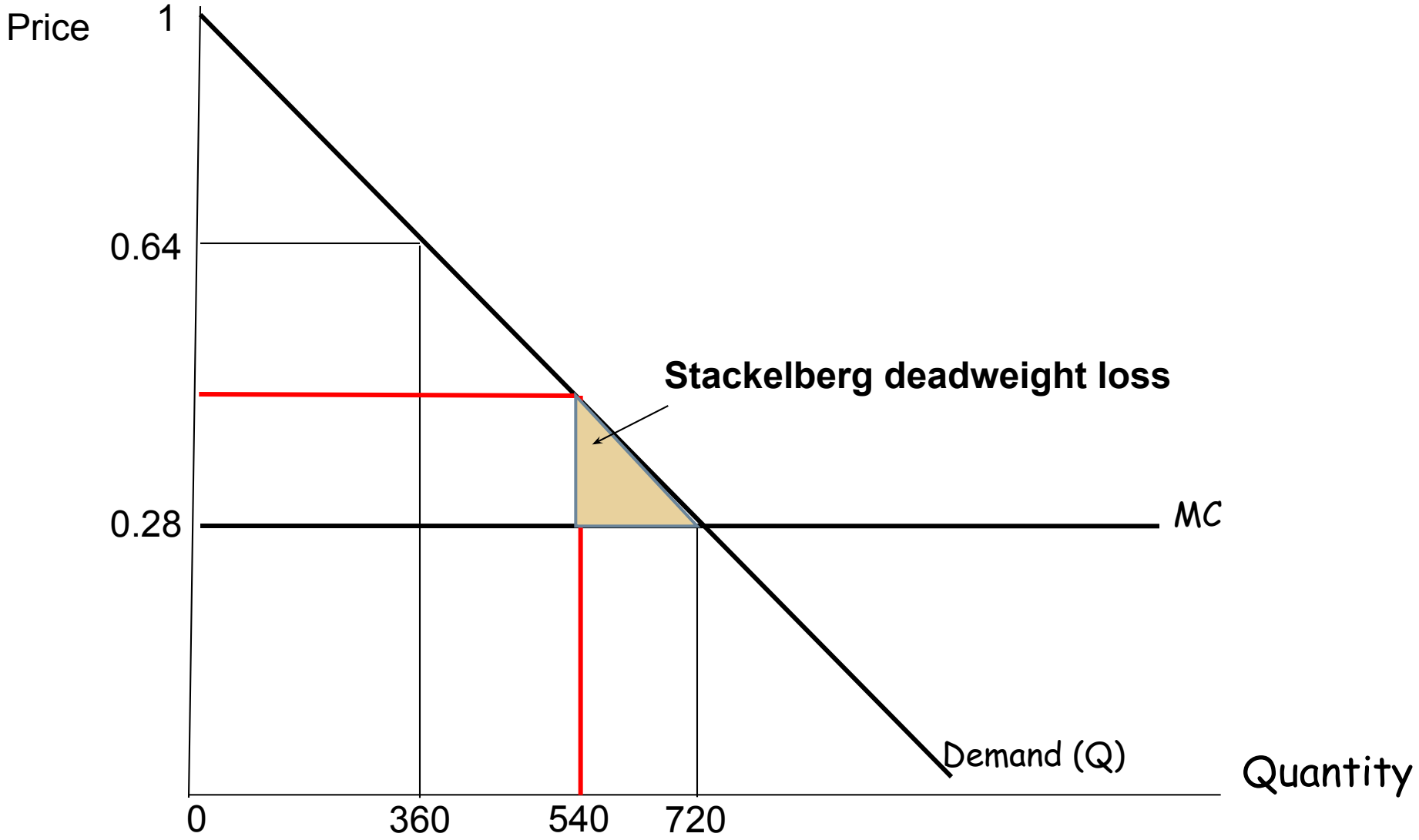


Total surplus is consumer surplus + producers surplus

Welfare and Cournot



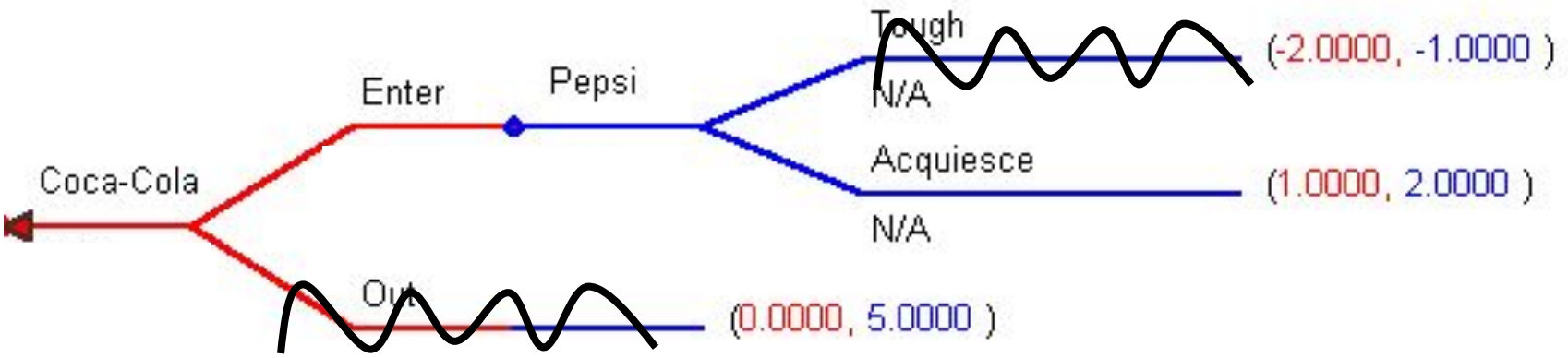
Welfare and Stackelberg



Entry game with incumbent

- Suppose that Pepsi (the incumbent) is already in the local market, and Coca-Cola is deciding whether to **Enter** or stay **Out**.
- Pepsi: adopt a **Tough** defensive response or **Acquiesce**.
  - Tough: increase production, fight on prices, advertising campaign etc.
  - Acquiesce: no aggressive commercial war with Coca-Cola

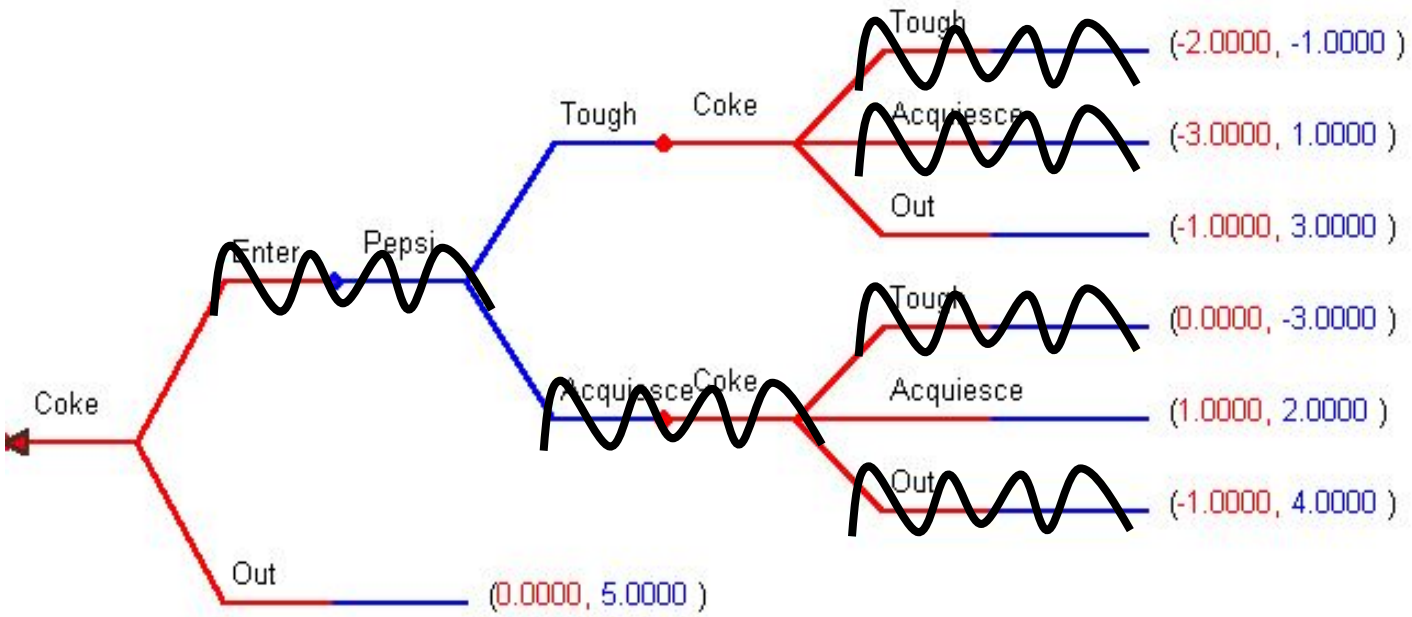
Entry game with incumbent



- Pepsi will choose to acquiesce.
- Since Coca-Cola knows that Pepsi will Acquiesce, its best course of action is to Enter.
- First mover advantage

Entry game with incumbent

- Sequential games may have more than two rounds. After observing Pepsi's stance, Coca-Cola can itself choose to be Tough, Acquiesce, or go Out of the market.



Entry game with incumbent

- Coca-Cola looks at Pepsi's Tough play and should choose to go Out of the market since it then only loses -$1. If Coca-Cola sees Pepsi Acquiesce then it should itself Acquiesce and earn $1.
- Pepsi knows that when it plays Tough Coca-Cola will exit. Its best choice is to act Tough to force Coca-Cola to go Out.
- Coca-Cola reasons backwards: if it enters, then Pepsi will play Tough and the best response is to go Out. Hence, Coca-Cola's best play is to Stay Out since it loses 0 instead of -1.

Strategic moves

- Players are rational and know how the game will be played and the subsequent payoff. What can player do to alter the predicted outcome?
  - Strategic moves: Commitment/threat/promise

  - Commitment: Commit to take a particular decision unconditionally on the other player's action.
  - Having fewer choices is typically worse than having many choices. In sequential games, however, having fewer choices can actually increase your payoff.

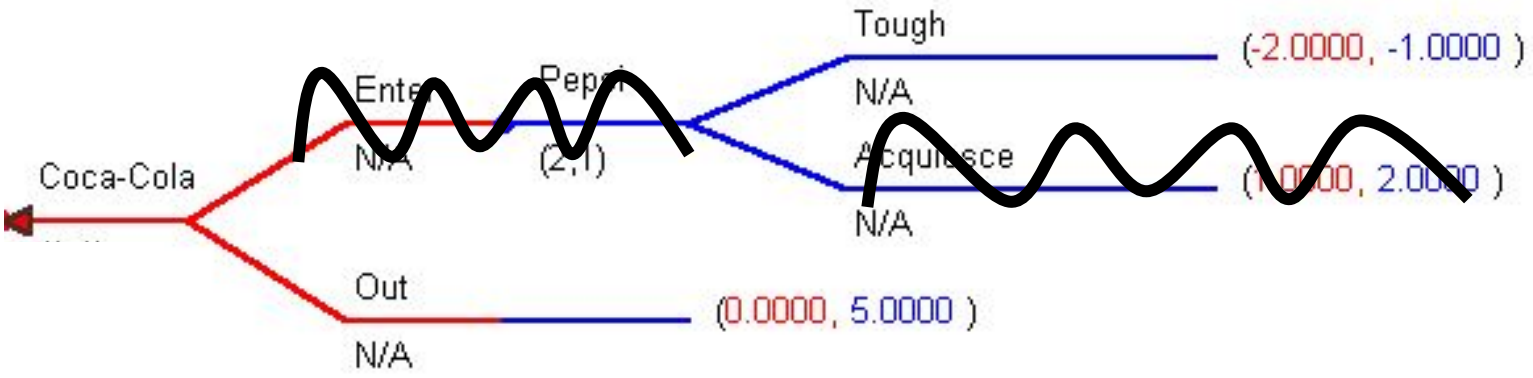
Strategic moves

- Threat: A response rule that leads to a bad outcome for the other player if he acts contrary to your interests.

- Promise: A response rule by which you offer to create a good outcome for the other player if he acts in a way that promotes your interests.

Threat and entry

- Equilibrium without strategic moves: (Enter,Acquiesce)
- What could Pepsi do? Threaten to be tough if Coca-Cola enters:



- Rollback: Coca-Cola stays out!

Threat and entry: Credibility problem

- If Coca-Cola enters, it is in Pepsi's best interest to acquiesce.
- Pepsi's threat to be tough if Coca-Cola enters is not credible.
- Coca-Cola, knowing that, will enter.
- "Talk is cheap"

Credible strategic move

How to make a credible strategic move?

- Binding contract between Pepsi and retailers.
  - We will sell you Pepsi at a lower price than Coca-Cola does.
  - “Tough” becomes credible.
- Decide to expand capacity, in order to reduce the marginal costs of increasing quantity.
- Keep innovating, in order to commit to improve quality and deter entry.

Credible strategic move

How to make a credible strategic move?

- Pepsi can also make threat credible by acquiring a reputation for toughness. By being tough towards potential entrants today, it may deter other firms from entering.
  - Being tough is not subgame perfect, however the entrant may think the incumbent will be tough if he has such a reputation.
  - If a threat is credible, other firms won't enter, and the threat to be tough is never materialized.

Credible strategic move

How to make a credible strategic move?

- Polaroid instant photography
  - Refused to diversify out of its core business. With all its chips in instant photography, it was committed to fight against any intruder in the market.
  - In 1976, after 28 years of a Polaroid monopoly on the instant photography market, Kodak entered the fray.
  - Edwin Land, Polaroid founder:

"This is our very soul we are involved with. This is our whole life…We will stay in our lot and protect that lot."

Summary

- Sequential games
  - Game trees
  - Subgame perfect equilibrium
- Application to oligopoly
  - First mover advantage
- Strategic moves
  - Issue of credibility