SUPPLEMENTAL CLASS NOTES

Unit 3D. Competition Economics

Part 2. Markets and Market Equilibria

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Markets and Market Equilibria

Price formation models

- Standard assumptions in the neo-classical model
  - Consumers
    - Individually maximize preferences (utility) subject to their individual budget constraints
    - Yields a consumer demand function, which gives the quantity demanded $q_i^{demanded}$ by consumer *i* for a given market price *p*
  - Firms
    - Individually maximize profits subject to their available production technology (production possibility sets)
    - Yields a production function that gives the quantity produced $q_j^{produced}$ by firm *j* for a given market price *p*
  - Equilibrium condition
    - No price discrimination (all purchases are made at the single market price)
    - Market clears at the market price (i.e., demand equals supply):

$$\sum_i q_i^{demanded} = \sum_j q_j^{produced}$$

$\sum$ simply means to add up the *q*'s. So if $q_1 = 10$, $q_2 = 7$, and $q_3 = 5$, then $\sum q_i = 10 + 7 + 5 = 22$.

Perfectly Competitive Markets

Perfectly competitive markets

- *Definition*: A market in which no single firm can affect price, meaning—
  - The firm perceives its residual demand curve as horizontal
  - The firm perceives that it can sell any amount of product without affecting the market price
  - $\frac{dp}{dq} = 0$ (as perceived by the firm)
  - $p = \frac{dc}{dq}$ (i.e., price = marginal cost)

These four bullets are just different ways of saying exactly the same thing

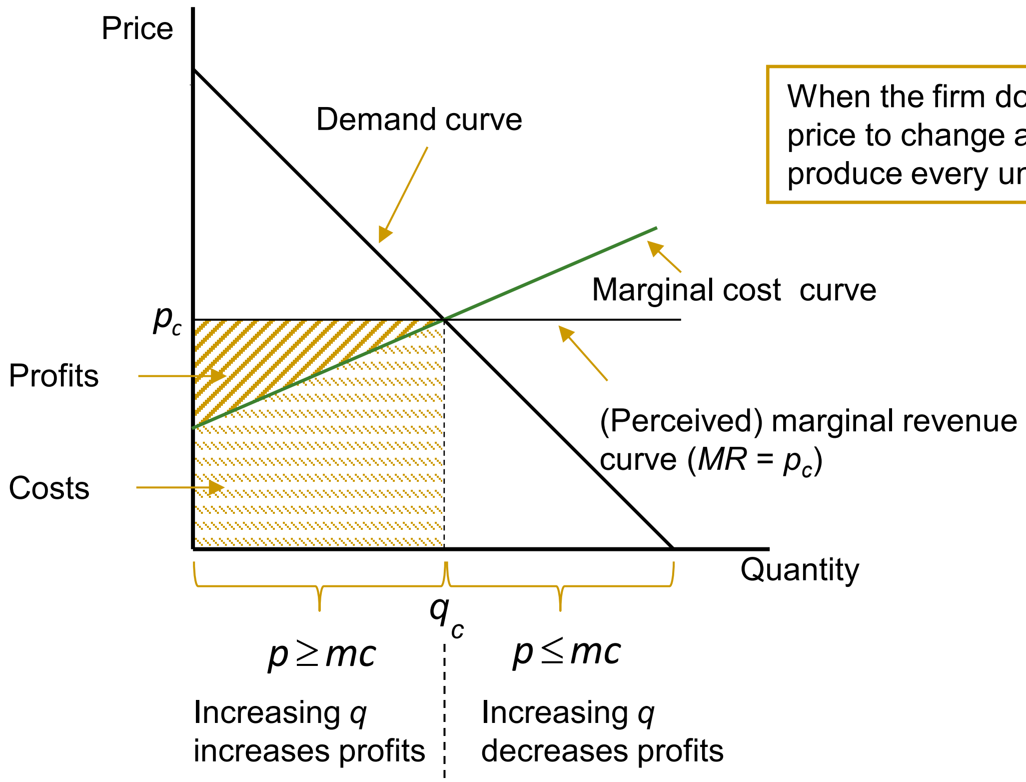
- Some more definitions
  - *"Price taking":* Competitive firms are called *price-takers*, that is, they take price as given and not something that they can affect
  - *Perfectly competitive equilibrium*: A market equilibrium where:
    - Aggregate supply equals aggregate demand, *and*
    - Each firm chooses its level of production so that the market-clearing price is equal to the firm's marginal cost of production

Perfectly competitive markets

- What could cause a market to be perfectly competitive?
  - *Traditional theory*: Each individual firm's production is very small compared to aggregate demand at any price, so that individual production changes cannot move significantly along the aggregate demand curve
    - This implies that there are a very large number of firms in the market
  - *Modern theory*: Competitors in the marketplace react strategically but non-collusively to price or quantity changes by a firm in ways that maintain the perfectly competitive equilibrium

Competitive firms

- Competitive firms take prices as given
  - Each individual firm perceives that its output decision does not affect the market-clearing price
  - This means that the firm acts *as if* $mr = p_c$



When the firm does not expect the market-clearing price to change as the firm expands output, the firm will produce every unit for which $p \geq mc$

Rule: As always, the FOC is $mr = mc$. If the firm is competitive, then $mr = p_c$ and so FOC is $p_c = mc$.

Competitive firms

- Three take-aways
  1. Competitive firms do not perceive that their output decisions affect the market-clearing price
     - That is, each firm perceives that it faces a horizontal residual demand curve
     - In fact, their individual output decisions do affect the market-clearing price but because the effect is so small no individual firm perceives this
       - In the aggregate, the sum of the output of all competitive firms determines the market-clearing price
  2. Competitive firms chose their output so that *p* = *mc*
     - Competitive firms, like all other firms, choose output so that marginal revenue is equal to marginal cost (*mr* = *mc*)
     - Since a competitive firm does not perceive that its output decisions affect the market-clearing price, the firm does not perceive that there is any downward adjustment in market price when it expands its output
     - Therefore, the firm perceives—and makes its output decision—on the premise that its marginal revenue is equal to the market price
     - Hence, the firm selects an output level so that *p* = *mc*
     - Mathematically:

$$mr(q_i) = p + q_i \frac{\Delta p}{\Delta q_i} = mc(q_i)$$

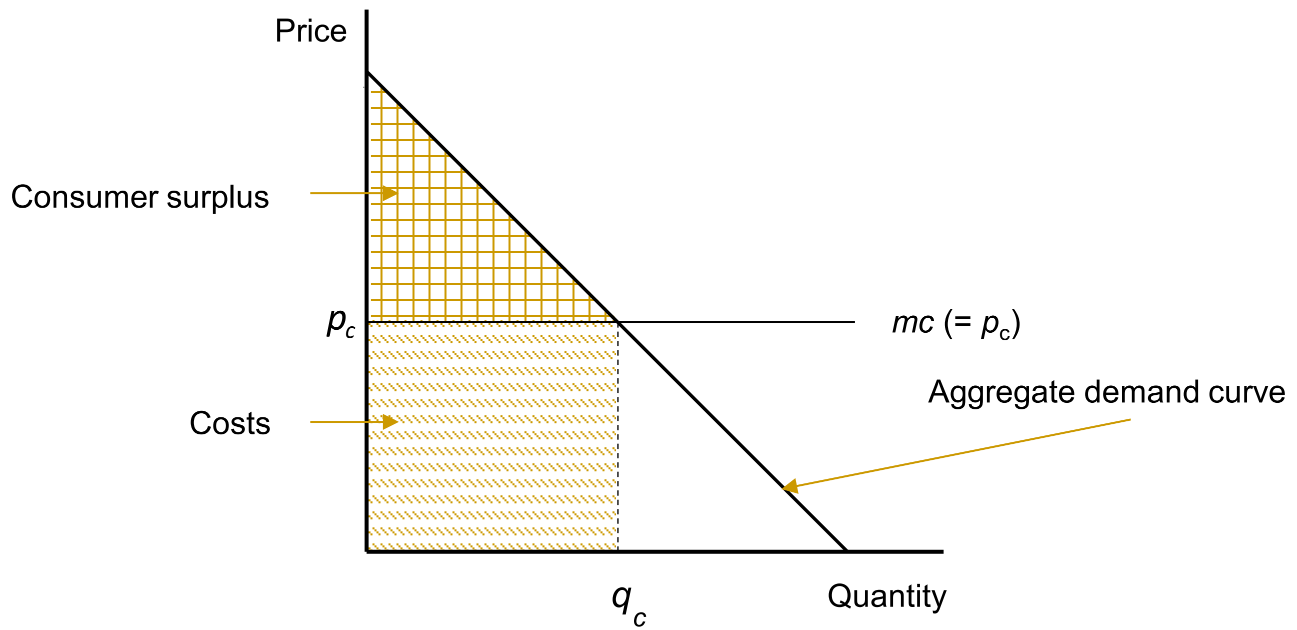
Perceived to be zero since the firm is a price-taker and does not believe that its choice of output affects market price

So:

$$p = mc$$

Competitive firms

- Three take-aways
  3. A competitive market maximizes consumer surplus[1]
     - A competitive market exhausts all gains from trade



[1] We are assuming a simple market where there is only one product that sells at a single uniform price (i.e., there is no price discrimination).

Perfectly Monopolized Markets

Perfect monopoly

- Basic concepts
  - In a perfect monopoly market, there is only one firm that supplies the product
    - This is an economic concept
    - In law, a monopolist need not control 100% of the market

> In economics and in law, a firm that faces a downward-sloping residual demand curve and therefore has some power to influence the market-clearing price for its product is said to have *market power*. In antitrust law, a firm that has very significant power over the market-clearing price is said to have *monopoly power*. In economics, a monopolist is the only firm in the market.

  - The aggregate demand curve defines the residual demand curve facing the firm
    - The demand curve is still downward-sloping (as opposed to vertical), so that there are some substitutes for the monopolist's product—just not very good ones

Perfect monopoly

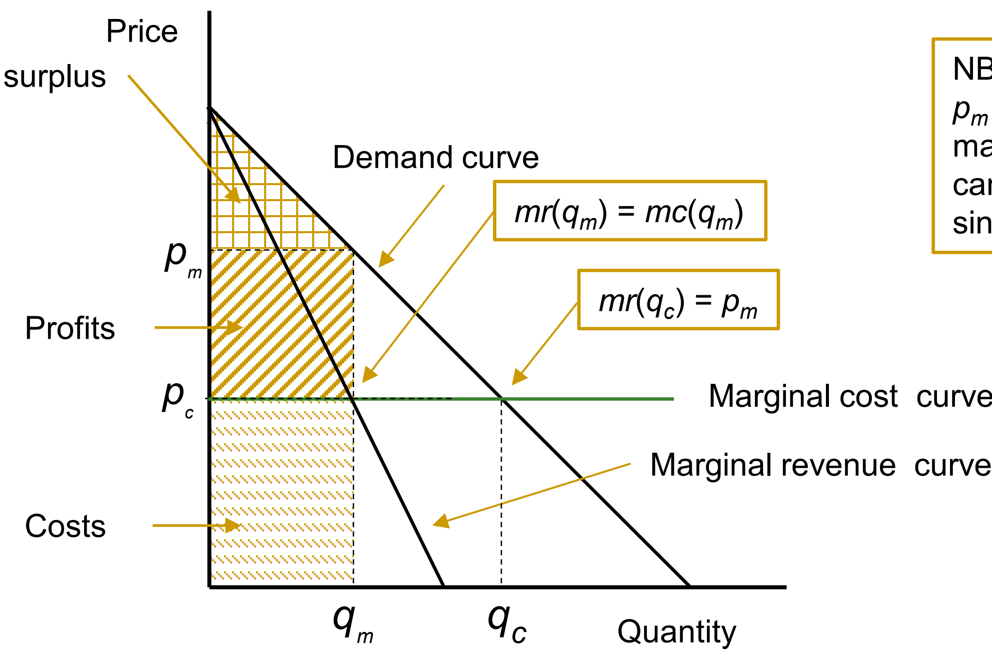
- A monopolist chooses output q_m so that $mr(q_m) = mc(q_m)$
  1. A monopolist charges a higher price than a competitive firm

     $$p_m > mr(q_m) = mc(q_m) = mc(q_c) = p_c$$

     where marginal costs are constant[1]

  2. A monopolist produces a lower output than would a competitive firm facing the same residual demand curve ($q_m < q_c$)

NB: $q_m = ½\ q_c$, where the monopolist and the firms in the competitive market face the same aggregate demand curve and have the same constant marginal costs.



NB: The monopolist price p_m is the price at which the maximum available profits can be drawn from a single price market.

[1] But true whenever marginal costs are constant or increasing.

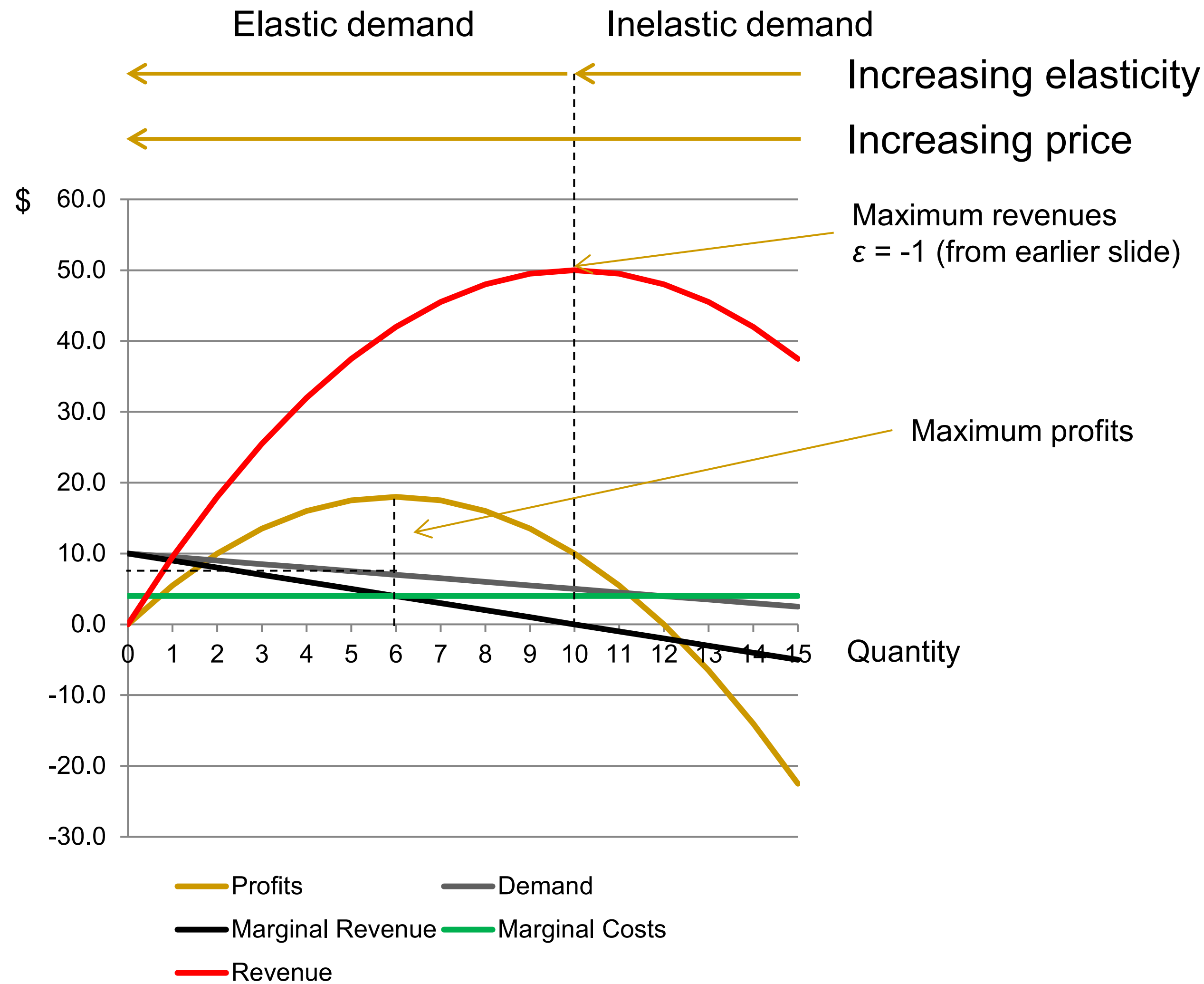
Monopolists and elasticities

- Proposition
  - A monopolist will not operate in the inelastic portion of its demand curve

Remember:

$$\varepsilon = \frac{\Delta q_i}{\Delta p_i}\frac{p_i}{q_i}$$

Important: The same rule applies to profit-maximizing firms generally: A profit-maximizing firm will not operate in the inelastic portion of its residual demand curve



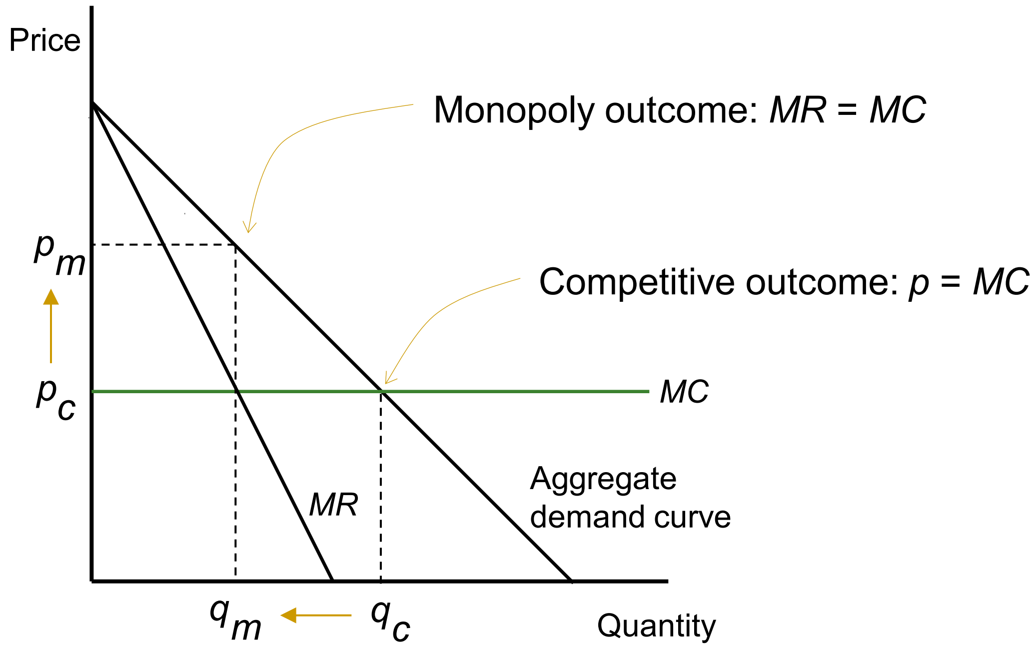
Review: Public policy on monopolies

- Modern view on why monopolies are bad:
  1. Increase price and decrease output
  2. Shift wealth from consumers to producers
  3. Create economic inefficiency (“deadweight loss”)

  - May (or may not) have other socially adverse effects
    - Decrease product or service quality
    - Decrease the rate of technological innovation or product improvement
    - Decrease product choice

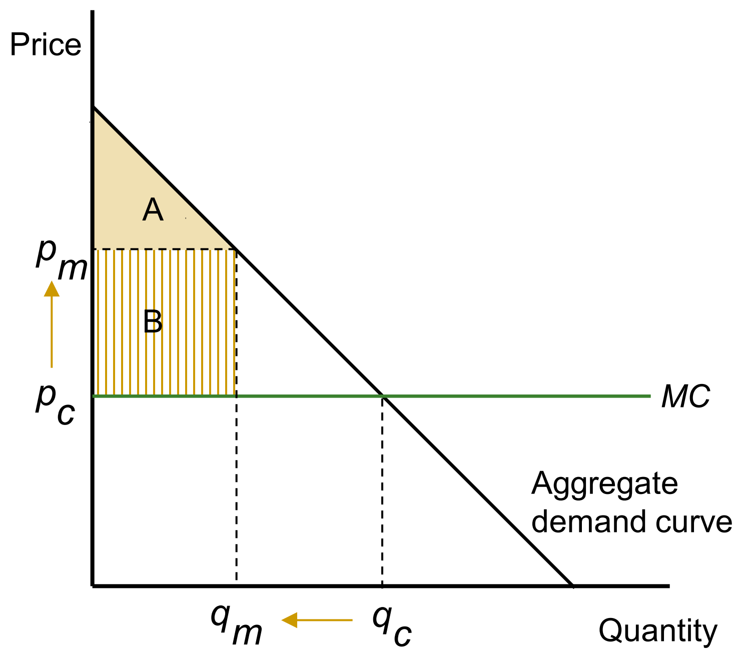
Review: Public policy on monopolies

1. Adverse effect on output and prices
   - Output decreases: $q_c > q_m$
   - Prices increase: $p_c < p_m$



Review: Public policy on monopolies

2. Shift in wealth from inframarginal consumers to producers*
   - Total wealth created ("surplus"): A + B
   - Sometimes called a "rent redistribution"

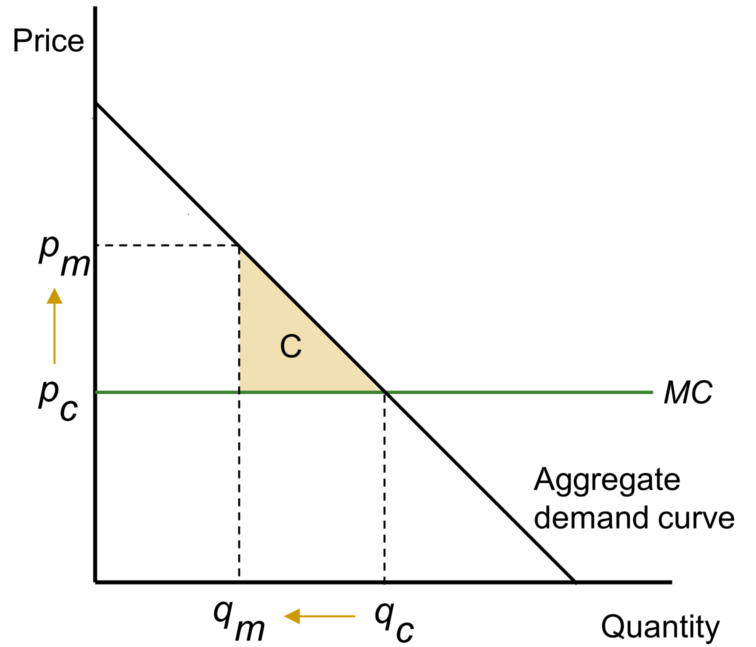


	Competitive	Monopoly
Consumers	A + B	A
Producers	0	B

* Inframarginal customers here means customers that would purchase at both the competitive price and the monopoly price

Review: Public policy on monopolies

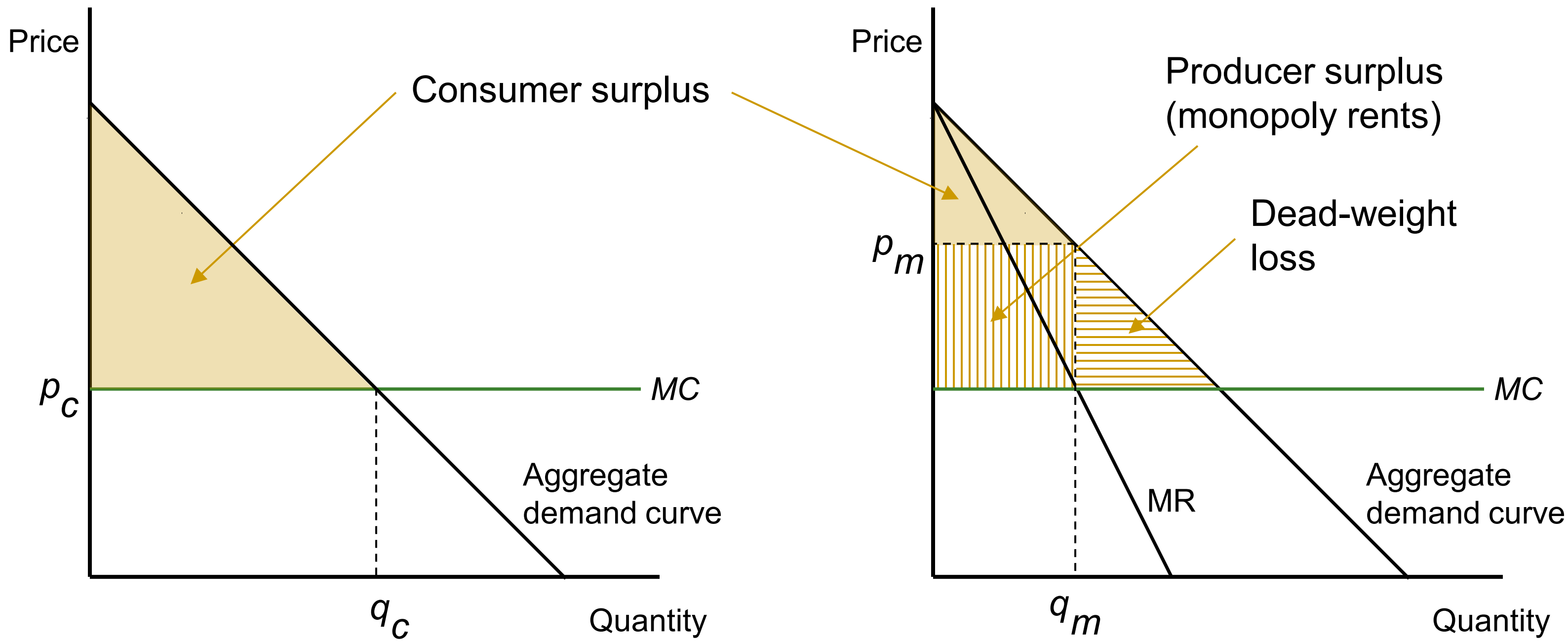
3. "Deadweight loss" of surplus of marginal customers*
   - Surplus C just disappears from the economy
   - Creates "allocative inefficiency" because it does not exhaust all gains from trade



* *Marginal customers* here means customers that would purchase at the competitive price but not the the monopoly price

Review: Public policy on monopolies

1. Increases prices and decreases output
2. Shifts wealth from consumers to producers
3. Creates a deadweight economic loss



Perfectly Competitive Market

Perfect Monopoly Market

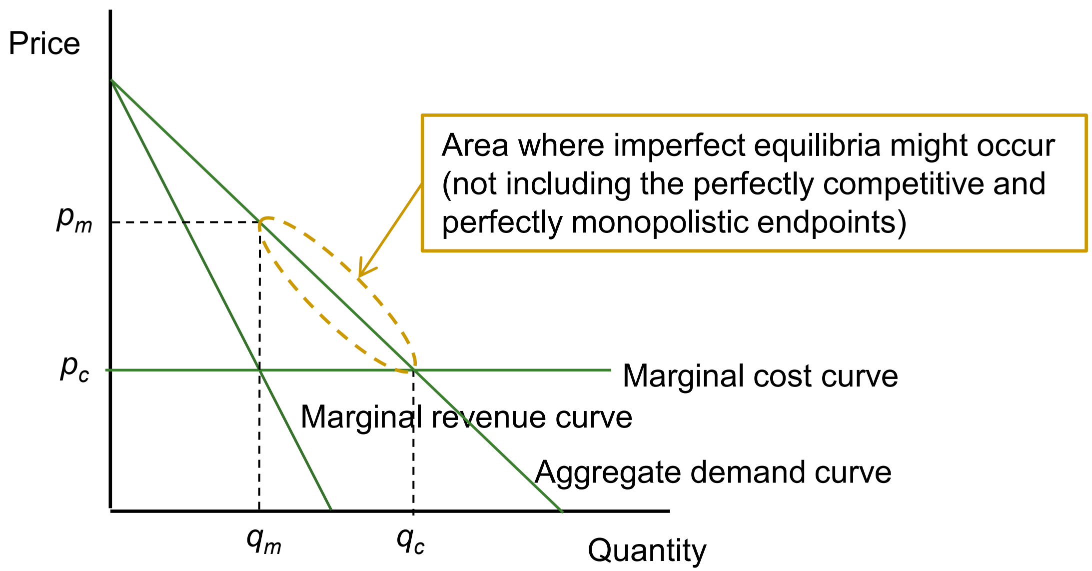
May also:

4. Decrease product or service quality
5. Decrease the rate of technological innovation or product improvement
6. Decrease product choice

Imperfectly Competitive Markets

Imperfectly Competitive Markets

- Range of imperfect equilibria
  - An imperfectly competitive equilibrium occurs when the equilibrium price and output on the demand curve falls strictly between the perfect monopoly equilibrium and the perfectly competitive equilibrium

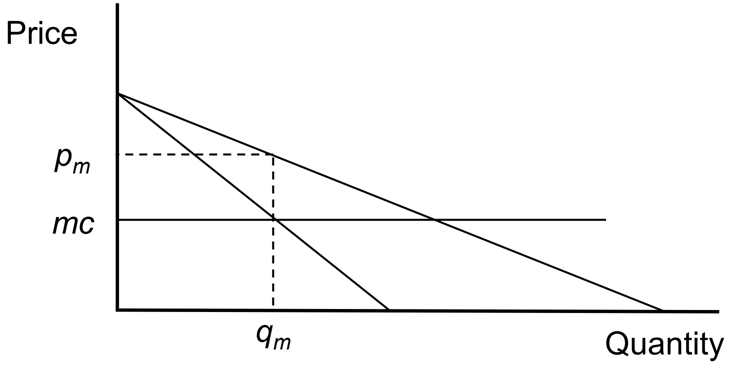


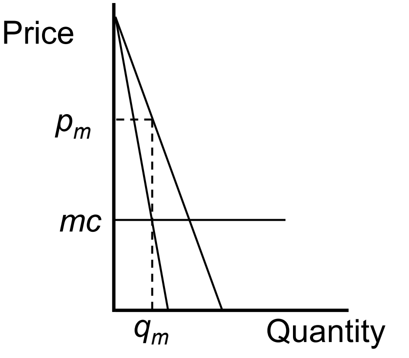
Market power

- Measuring market power
  - Economically, market power is the power of the firm to affect the market-clearing price through its choice of output level
  - The traditional economic measure of market power is the *price-cost margin* or *Lerner index L*, which is a measure of how much price has been marked up as a percentage of price:

$$L = \frac{p - mc}{p}$$

    - In a competitive market, *L* = 0 since because *p* = *mc*
    - In a perfectly monopolized market, *L* increases as the aggregate demand curve becomes steeper (and so price increases)





Market power

- The Lerner index for an imperfectly competitive market
  - The Lerner index is usually used as a measure of the market power of a single firm
  - The market Lerner index is defined as the sum of the Lerner indices of all firms in the market weighted by their market share:

$$L \equiv \sum_{i=1}^{n} L_i s_i,$$

where there are *n* firms in the market, with each firm *i* having a Lerner index L_i and a market share s_i:

$$L \equiv \sum_{i=1}^{n} L_i s_i = \sum_{i=1}^{n} s_i, \frac{p - c_i}{p}$$

Measures of market concentration

- The Herfindahl-Hirschman Index (HHI)
  - *Definition*: The Herfindahl-Hirschman Index (HHI) is defined as the sum of the squares of the market shares of all the firms in the market:

$$HHI \equiv s_1^2 + s_2^2 + \cdots + s_n^2 = \sum_{i=1}^{n} s_i^2$$

The HHI is the principal measure of market concentration used in antitrust law in all markets (not just Cournot markets)

where the market has *n* firms and each firm *i* has a market share of s_i.

  - Example
    - Say the market has five firms with market shares of 50%, 20%, 15%, 10%, and 5%. The conventional way in antitrust law is to calculate the HHI using whole numbers as market shares:

$$\begin{aligned} HHI &= 50^2 + 20^2 + 15^2 + 10^2 + 5^2 \\ &= 2500 + 400 + 225 + 100 + 25 \\ &= 3250 \end{aligned}$$

In whole numbers, the HHI ranges from 0 with an infinite number of firms to 10,000 with one firm

    - In some economics applications, however, the HHI is calculated using fractional market shares:

$$\begin{aligned} HHI &= 0.50^2 + 0.20^2 + 0.15^2 + 0.10^2 + 0.05^2 \\ &= 0.25 + 0.04 + 0.0225 + 0.01 + 0.0025 \\ &= 0.3250 \end{aligned}$$

In fractional numbers, the HHI ranges from 0 with an infinite number of firms to 1 with one firm

Homogeneous product models

- Homogeneous product models
  - Characterized by products that are undifferentiated (that is, *fungible* or *homogeneous*) in the eyes of the customer
  - Common examples:
    - Ready-mix concrete
    - Winter wheat
    - West Texas Intermediate (WTI) crude oil
    - Wood pulp
  - Two properties of homogeneous products
    - Customers purchase from the lowest cost supplier → This forces all suppliers in the market to charge the same price
    - Since the goods are identical, their quantities can be added

$$Q(p) = \sum q_i(p)$$

      - Adding all individual consumer demands at price *p* gives aggregate demand
      - Adding all individual firm outputs at price *p* gives aggregate supply

Cournot oligopoly models

A control variable is the variable the firm can set (control) in its discretion

- The setup
  - The standard homogenous product model is the *Cournot model*
  - In a Cournot model, the firm's control variable is *quantity*
    - The (downward-sloping) demand curve gives the relationship between the aggregate quantity produced Q and the market-clearing price p

$$p = p(Q), \text{ where } Q = \sum_{i=1}^{n} q_i,$$

where there are n firms in the market

  - The profit equation for firm i is:

$$\pi_i = p(Q)q_i - c_i(q_i), \quad i = 1, 2, \ldots, n$$

Each firm i choses its level of output q_i, but it is the aggregate level of output that determines the market price

  - First order condition:

$$m\pi_i\left(q_i\right) = mr_i\left(q_i\right) - mc_i\left(q_i\right) = 0$$

This generates n equations in n unknows and can be solved for each q_i

Cournot oligopoly models

- Production levels in Cournot models
  - A simple example
    - Compare the competitive, Cournot, and monopoly outcomes in this example

Demand curve: $Q = 100 - 2p$

	Price	Quantity
Perfectly competitive	5 (= mc)	90
Cournot (n=2)	20	60
Perfect monopoly	27.5	45

  - When demand is linear and there are n identical firms in a Cournot model, then:

$$Q_{Cournot} = \frac{n}{n+1} Q_{Competitive}$$

NB: As the number of firms n gets large, the ratio $n/(n+1)$ approaches 1 and the Cournot equilibrium approaches the competitive equilibrium

$q_{competitive}$	90	90	90	90	90	90	90	90	90
n	9	8	7	6	5	4	3	2	1
$q_{cournot}$	81	80	78.8	77.1	75	72	67.5	60	45

Cournot oligopoly models

- Relationship of the Lerner index to the Herfindahl-Hirschman Index
  - *Proposition*: In a Cournot oligopoly model with n firms, the Lerner index may be calculated from the HHI and the market elasticity of demand:

$$L = \frac{HHI}{|\varepsilon|},$$

    where *L* is the market Lerner index and *ε* is the market price-elasticity of demand
  - This proposition is the reason antitrust law uses the HHI as the measure of market concentration
    - *WDC*: It is not a great reason, but is it generally accepted as better than the alternative measures (especially the four-firm concentration ratios used from the 1950s through the 1970s)
    - The HHI was adopted as the measure of market concentration in the 1982 DOJ Merger Guidelines and by the end of the 1980s has been accepted by the courts

The following slides prove the proposition. The proof is (very) optional, but if you are comfortable with a little calculus, you might find it interesting

Cournot oligopoly models

- Relationship of the Lerner index to the Herfindahl-Hirschman Index
  - *Proof* (optional):
    - Firm *i*'s Lerner index L_i is:

$$L_i = \frac{p(Q) - c_i}{p(Q)},$$

      where $p(Q)$ is the single market equilibrium price (determined by aggregate production quantity Q) and c_i is firm i's marginal cost of production
    - The first order condition for firm i's profit-maximizing quantity is:

$$\frac{d\pi_i}{dq_i} = p(Q) + q_i \frac{dp(Q)}{dq_i} - c_i = 0$$

    - Now

$$\frac{dp(Q)}{dq_i} = \frac{dp(Q)}{dQ}\frac{dQ}{dq_i} = \frac{dp(Q)}{dQ}$$

Equals 1 under the Cournot assumption that all other firms do not change their behavior when firm i changes output

Cournot oligopoly models

- Relationship of the Lerner index to the Herfindahl-Hirschman Index
  - *Proof* (optional) (con't)
    - Substituting and rearranging the top equation:

$$p(Q) - c_i = q_i \frac{dp(Q)}{dQ}$$

    - Dividing both sides by $p(Q)$ and multiplying the right-hand side by Q/Q:

$$\frac{p(Q) - c_i}{p(Q)} = \frac{q_i}{Q} \frac{dp(Q)}{dQ} \frac{Q}{p(Q)} = \frac{s_i}{|\varepsilon|}$$

    - Multiply both sides by s_i:

$$\frac{p(Q) - c_i}{p(Q)} s_i = \frac{s_i^2}{|\varepsilon|}$$

Cournot oligopoly models

- Relationship of the Lerner index to the Herfindahl-Hirschman Index
  - *Proof* (optional) (con't)
    - Summing over all firms:

$$\sum_{i=1}^{n} \frac{p(Q) - c_i}{p(Q)} s_i = \sum_{i=1}^{n} \frac{s_i^2}{|\varepsilon|} = \frac{1}{n} \sum_{i=1}^{n} s_i^2$$

    - The left-hand side is the market Lerner index and the right-hand side is the HHI divided by the absolute value of the market price-elasticity:

$$L = \frac{HHI}{|\varepsilon|}$$

Q.E.D.

Cournot oligopoly models

- Mergers and price increases in Cournot oligopoly
  - From the previous slides:

$$L = \frac{HHI}{|\varepsilon|},$$

  - Then:

$$L^{\text{Postmerger}} - L^{\text{Premerger}} = \frac{HHI^{\text{Postmerger}}}{|\varepsilon|} - \frac{HHI^{\text{Premerger}}}{|\varepsilon|} = \frac{\Delta HHI}{|\varepsilon|}$$

This probably is the justification for the emphasis in the Merger Guidelines on changes in the HHI (the “delta”) resulting from a merger

In other words, the difference in the share-weighted average percentage markup resulting from the merger is $\Delta HHI/|\varepsilon|$

Cournot oligopoly models

- Some final observations on the HHI and Cournot models
  - The HHI and ΔHHI are fundamental to modern merger antitrust law
  - The rationale for using these measures is grounded in their relationship in the Cournot model to percentage price-cost margins measured by the Lerner index

Cournot oligopoly models

- Some final observations on the HHI and Cournot models (con't)
  - BUT—
    - Price-cost margins typically cannot be calculated directly
      - Prices, while seemingly observable, can be empirically difficult to measure given the existence of discounts, variations in the terms of trade, and price and quality changes over time
      - Marginal costs are even more difficult to measure
        - *Time period*: There is the conceptual issue of the time period over which to assess marginal cost. As the time period becomes longer, some fixed costs such as real estate rents or workers' salaries become marginal costs. There is nothing in the theory that tells us what is the proper time period.
        - *Complex production processes*: In the real world, production functions are often joint and are used to produce multiple products. The is a conceptual problem of how to allocate costs associated with joint production to each individual product type.
        - *Dynamic market conditions*: Marginal costs can fluctuate rapidly in dynamic markets due to changing supply and demand conditions, input price volatility, or disruptions in the production process.
    - The Cournot oligopoly model is an abstraction that may not (and probably does not) accurately characterize any real-world market
      - NB: The Merger Guidelines use the HHI and ΔHHI as critical statistics even in markets where the Cournot model does not apply

Cournot oligopoly models

- Some final observations on the HHI and Cournot models (con't)
  - HHIs to some extent allow us to infer the magnitudes of percentage price-cost margins and how these margins may change with changes in market structure
  - BUT—
    - Antitrust law tests just look at the HHI and ΔHHI—antitrust law does not modulate its HHI tests for market elasticity of demand as the Cournot model indicates it should
      - So two mergers in a Cournot model may have the same HHI and ΔHHI but have dramatically different premerger postmerger percentage price-cost margins
        - A higher aggregate elasticity of demand yields lower percentage price-costs margins than a less elastic demand even with the same HHI and ΔHHI.
      - In any event, there are no accepted "thresholds" in antitrust law when percentage price-margins become "anticompetitive"

Bertrand oligopoly models

- The setup
  - In a Bertrand model, the firm's control variable is *price*
    - Compare with the Cournot model, where the firm's control variable is *quantity*
    - The (downward-sloping) residual demand curve gives the relationship between the firm's choice of price and the quantity consumers will demand from the firm at that price
  - The profit equation for firm *i* is:

This is the demand function

$$\pi_i(p_i) = p_i \overbrace{q_i(p_i)} - C_i(\overbrace{q_i(p_i)}), \quad i = 1, 2, \ldots, n$$

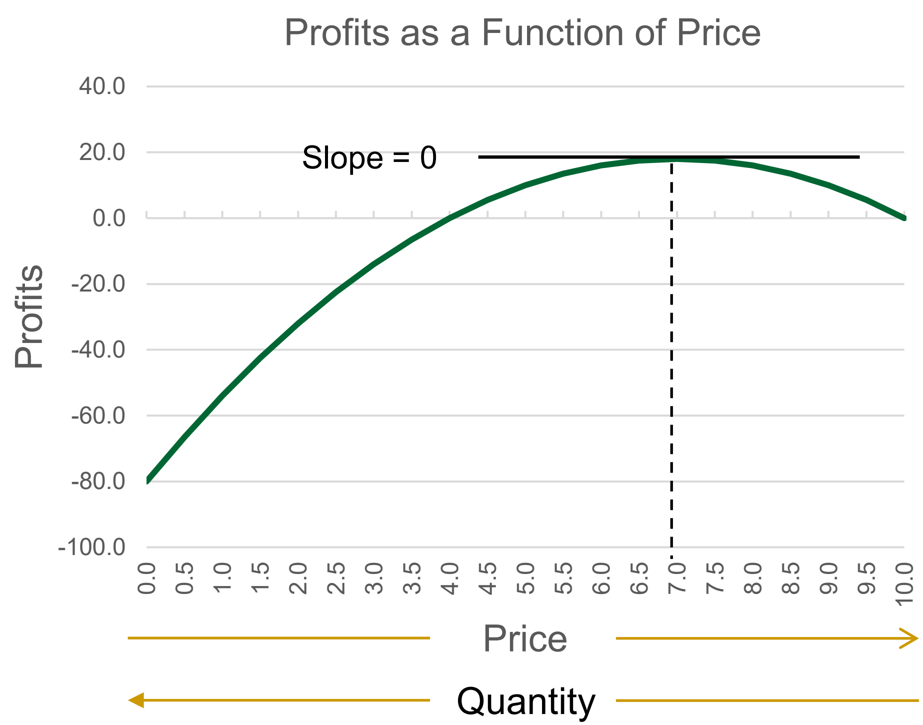
To see the first order conditions in operation, let's first look at profit-maximization for a monopolist whose control variable is price

Bertrand oligopoly models

- Profits as a function of price: Example for a monopolist

Price p	Quantity q	Revenues r	Costs C	Profits Π
0.0	20	0.0	80	-80.0
0.5	19	9.5	76	-66.5
1.0	18	18.0	72	-54.0
1.5	17	25.5	68	-42.5
2.0	16	32.0	64	-32.0
2.5	15	37.5	60	-22.5
3.0	14	42.0	56	-14.0
3.5	13	45.5	52	-6.5
4.0	12	48.0	48	0.0
4.5	11	49.5	44	5.5
5.0	10	50.0	40	10.0
5.5	9	49.5	36	13.5
6.0	8	48.0	32	16.0
6.5	7	45.5	28	17.5
7.0	6	42.0	24	18.0
7.5	5	37.5	20	17.5
8.0	4	32.0	16	16.0

Demand: $q = 20 - 2p$
Fixed costs = 0
Marginal costs = 4



Bertrand oligopoly models

- Observations
  - The profit curve as a function of price is a parabola
    - Although different in shape than the profit curve as a function of quantity
  - The profit maximum is when the slope of the profit curve is zero
  - So:

Marginal profits (as a function of price)	=	Marginal revenues (as a function of price)	-	Marginal costs (as a function of price)
	=	0 at the firm's profit maximum		

Bertrand oligopoly models

- Profit-maximization when a monopolist sets price: Example

Demand: $q = 20 - 2p$ Marginal costs ($mc(q)$) = 4
Fixed costs = 0

- Revenues:

$$\pi(p) = pq(p)$$
$$= p(20-2p)$$
$$= 20p - 2p^2$$

This describes the parabola on the prior slide

- Marginal revenues:

$$mr(p) = 20 - 4p$$

Remember, if $y = ax + bx^2$ is the function, then the marginal function is $a + 2bx$

- Cost

$$mc * q(p) = mc(20-2p)$$
$$= 4(20-2p)$$
$$= 80 - 8p$$

Constant marginal cost

Note: If $y = a + bx$ is the function, then the marginal function is b

- Marginal cost:

$$mc(p) = -8$$

NB: This is marginal cost as a function of p (not q). Why is it a negative number?

- FOC:

$$mr(p^*) = mc(p^*)$$
$$20 - 4p^* = -8$$

So $p^* = 7$ and $q^* = 6$

Bertrand oligopoly models

- Homogeneous products case with equal cost functions
  - Consider two firms producing homogeneous (identical) products at constant marginal cost *c* that use price as their control variable
  - Consumers purchase from the lower priced firm; if both firms charge the same price, they split equally consumer demand
  - Profit function for firm *i*:

$$\pi(p_i) \begin{cases} = p_i q_i(p_i) - c(q_i(p_i)) & \text{if } p_i < p_j \\ = \dfrac{p_i q_i(p_i) - c(q_i(p_i))}{2} & \text{if } p_i = p_j \\ = 0 & \text{if } p_i > p_j \end{cases}$$

    - That is, firm *i* gets 100% of market demand at price p_i if p_i is the lower price of the two firms, the two firms split the market demand if their prices are equal, and firm *i* gets nothing if it has the higher price
    - *Equilibrium*: $p_1 = p_2 = mc$, so that both firms price at marginal cost (i.e., the competitive price) and split equally market demand and total market profits

Bertrand oligopoly models

- Homogeneous products case with asymmetric cost functions
  - Now consider two firms producing homogeneous (identical) products but with different cost functions costs, with firm 1 have lower marginal costs than firm 2 (i.e., *mc*(*q*(*p*(1)) <*mc*(*q*(*p*2)))
  - The profit function is the same as before:

$$\pi(p_i)\begin{cases} = p_i q_i(p_i) - c(q_i(p_i)) & \text{if } p_i < p_j \\ = \dfrac{p_i q_i(p_i) - c(q_i(p_i))}{2} & \text{if } p_i = p_j \\ = 0 & \text{if } p_i > p_j \end{cases}$$

  - *Equilibrium*: Firm 1 prices just below firm 2 and captures 100% of market demand
    - *Idea*: firm 1 and firm 2 compete the price down to firm 2's marginal cost as in the symmetric cost case. Then firm 1 just underprices firm 2 and captures 100% of the market demand

Bertrand oligopoly models

- Differentiated products case
  - When products are differentiated, a lower price charged by one firm will not necessarily move all of the market demand to that firm
    - Consider a market with only red cars and blue cars.
    - Some consumers like blue cars so much that even if the price of red cars is lower than the price of blue cars, there will still be positive demand for blue cars
    - Moreover, if the price of blue cars increases, some (inframarginal) blue car customers will purchase blue cars at the higher price, while some (marginal) customers will switch to red cars
    - This means that the demand for red cars (and separately for blue cars) is a function both of the price of red cars and the price of blue cars
    - It also means that the price of blue cars may not equal the price of red cars in equilibrium

Bertrand oligopoly models

- Differentiated products case
  - Simple linear model
    - Firms 1 and 2 produce differentiated products and face the following residual demand curves:

$$q_1 = a - b_1 p_1 + b_2 p_2$$
$$q_2 = a - b_1 p_2 + b_2 p_1$$

NB: Each firm's demand decreases with increase in its own price and increases with increases in the price of the other firm

Assume that $b_1 > b_2$, so that each firm's residual demand is more sensitive to its own price than to the other firm's price

    - Assume each firm has a cost function with no fixed costs and the same constant marginal costs:

$$c_i(q_i) = cq_i$$

    - Firm 1's profit-maximization problem:

$$\max_{p_1} \pi_1 = (p_1 - c)(a - b_1 p_1 + b_2 p_2)$$

NB: This formulation does not take into account firm 2's reaction to a change in firm 1's price. It assumes that Firm 2' price is constant.

    - Solving for the Bertrand equilibrium:

$$p_1^* = p_2^* = \frac{a + cb_1}{2b_1 - b_2}$$

You do not need to know this. What is important is how the model is set up.

Dominant firm with a competitive fringe

- The setup
  - Consider a homogeneous product market with—
    - A dominant firm, which sees its output decisions as affecting price and so sets output so that *mr =mc*, *and*
    - A fringe of firms that are small and act as price takers, that is, they do not see their individual choices of output levels as affecting price and therefore price as competitive firms (i.e., *p* = *mc*)
  - Choice question for the dominant firm: Pick the profit-maximizing level for its output given the competitive fringe
    - The model requires some constraint on the ability of the competitive fringe to expand its output. Otherwise, the competitive fringe will take over the market.
    - The constraint usually is either limited production capacity or increasing marginal costs

Dominant firm with a competitive fringe

- The model
  - At market price p, let $Q(p)$ be the industry demand function and $q_f(p)$ be the output of the competitive fringe.
  - The dominant firm derives its residual demand function $q_d(p)$ starting with the aggregate demand function $Q(p)$ and subtracting the output supplied by the competitive fringe $q_f(p)$ at price p:

$$q_d(p) = Q(p) - q_f(p)$$

  - The dominant firm then maximizes its profit given its residual demand function by solving the following equation for the market price p^* that maximizes the firm's profits:

$$\max_p \pi_D = p \times \left[Q(p) - q_f(p) \right] - T\left(q(p) \right)$$

  - The dominant firm then produces quantity $q^* = q_D(p^*)$

You do not need to know how to solve the dominant firm maximization problem. What is important is how the model is set up.

Dominant firm with a competitive fringe

- Dominant oligopolies
  - The model can be extended to the case where the dominant firm is replaced by a dominant oligopoly
    - The key is to specify the solution concept for the choice of output by the firms in the oligopoly (e.g., Cournot). You then create a residual demand curve for the oligopoly and apply the solution concept to that demand curve.
- Fringe firms
  - As we saw in Unit 2, the DOJ and the FTC typically ignore fringe firms. The dominant oligopoly model with a competitive fringe provides a theoretical justification.

Appendix

Mathematical notation

pq	p times q (equivalently, $p \times q$, $p \cdot q$, and $(p)(q)$)
$p(q)$	p evaluated when quantity is q ("p as a function of q")
$p(q)q$	p (evaluated at q) times q (i.e., pq)
Δq	The change in q to the new state from the old state (i.e., $q_2 - q_1$)
$\sum_{i=1}^{n} a_i$	The sum of the a_i's (i.e., $a_1 + a_2 + \ldots + a_n$)
$\frac{\Delta y}{\Delta x}$	The change in y divided by the change in x
$\|a\|$	The absolute value of a (i.e., a without a positive or negative sign) (e.g., $\|3\| = \|-3\| = 3$)
$\equiv$	Like an equals sign but means a definition

Mathematical notation

- Optional calculus terms

$\frac{dy}{dx}$: The derivative of y with respect to x (where y is a function of x)

$\frac{\partial y}{\partial x}$: The partial derivative of y with respect to x (where y is a function of x)

  - Derivatives
    - If $y = a + bx + cx^2$
      then the derivative of *y* with respect to *x* is:

$$\frac{dy}{dx} = b + 2cx$$