Networks, Telecommunications Economics and Strategic Issues in Digital Convergence

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Basic Market Structure Slides

The Structure-Conduct-Performance Model

- **Basic conditions**: technology, economies of scale, economies of scope, location, unionization, raw materials, substitutability of the product, own elasticity, cross elasticities, complementary goods, location, demand growth

- **Structure**: number and size of buyers and sellers, barriers to entry, product differentiation, horizontal integration, vertical integration, diversification

- **Conduct**: pricing behavior, research and development, advertising, product choice, collusion, legal tactics, long term contracts, mergers

- **Performance**: profits, productive efficiency, allocative efficiency, equity, product quality, technical progress

- **Government Policy**: antitrust, regulation, taxes, investment incentives, employment incentives, macro policies

Costs

Total costs: $C(q)$ or $TC(q)$

Variable costs: $V(q)$

Fixed costs: $F(q) = F$, constant

$$C(q) = F + V(q)$$

Average total cost: $ATC(q) = C(q)/q$

Average variable cost: $AVC(q) = V(q)/q$

Average fixed cost: $ATC(q) = F/q.$

$$ATC(q) = F/q + AVC(q)$$

Marginal cost: $MC(q) = C'(q) = dC/dq = V'(q) = dV/dq$

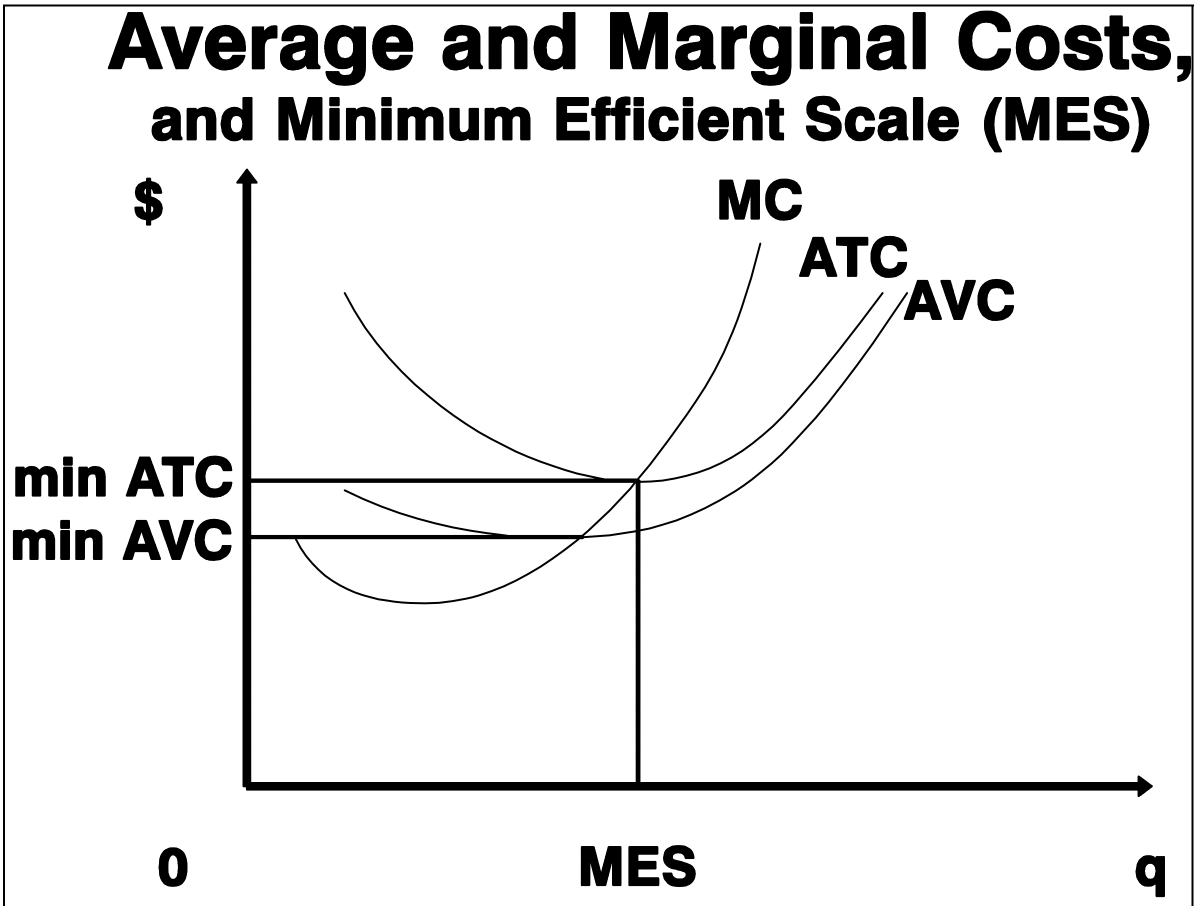


Figure 1

The marginal cost curve MC intersects the average cost curves ATC and AVC at their minimums. Remember, MC is the cost of the last unit. When MC is <u>below</u> average cost (ATC or AVC), it tends to drive the average cost down, i.e. the slope of ATC (or AVC) is negative. When MC is <u>above</u> average cost (ATC or AVC), it tends to drive the average cost up, i.e. the slope of ATC (or AVC) is positive. AC and MC are equal at the minimum of AC. The corresponding quantity is called the minimum efficient scale, MES.

Perfect Competition

- In perfect competition, each firm takes price as given. Its profits are

$$\Pi = pq - C(q)$$

- They are maximized at q^* that is found from

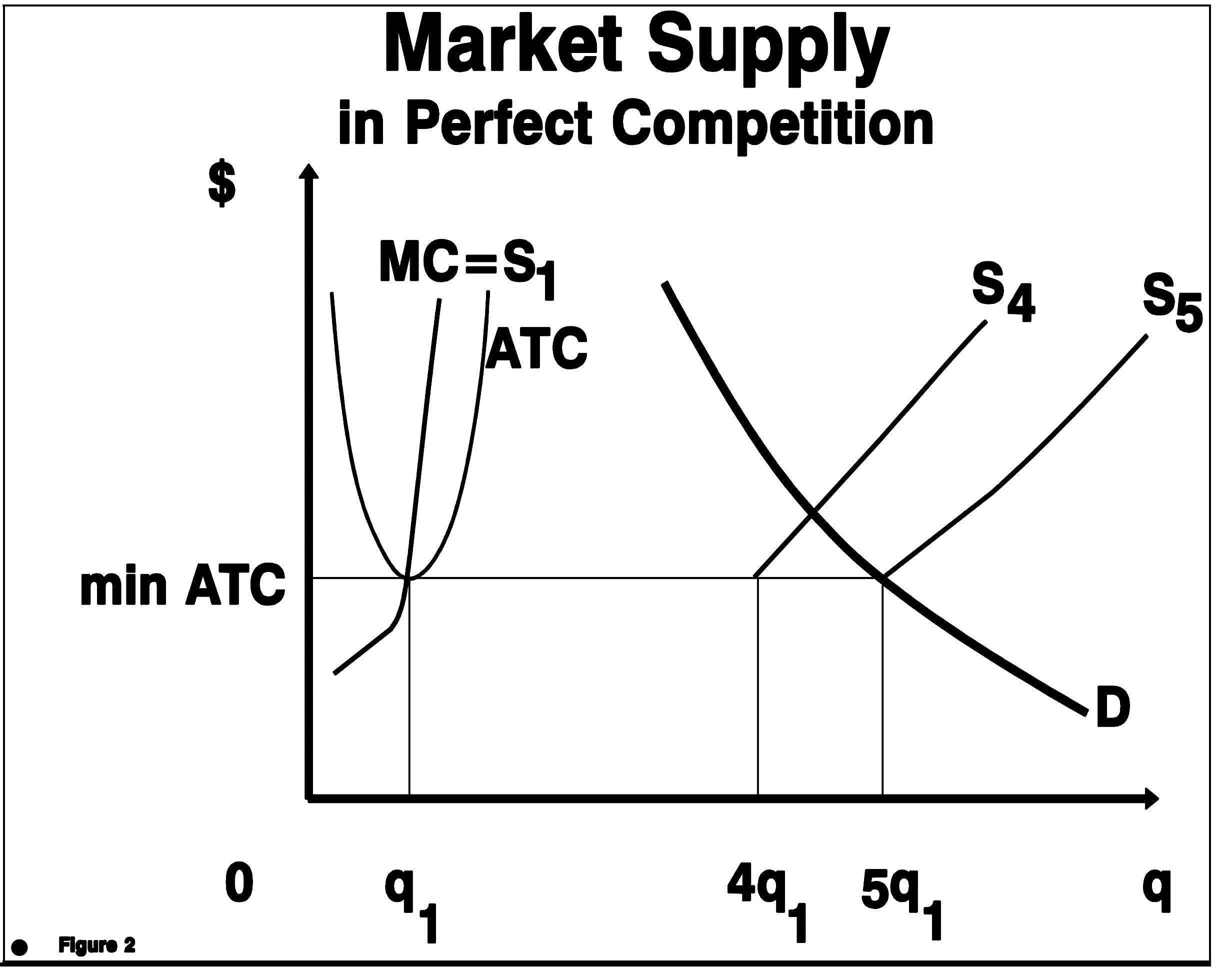
$$p = MC(q^*)$$

- This means that the quantity-price combinations that the firm offers in the market (its supply curve) follow the marginal cost line.

- Note that the firm loses money when it charges a price below min ATC.

- Therefore, for any price below min ATC, the firm shuts down and produces nothing.

- For any price above min ATC, the firm produces according to curve MC.



Market Supply
in Perfect Competition
$
MC=S1
ATC
S4
S5
min ATC
D
0
q1
4q1
5q1
q
Figure 2

Economies of Scale and Scope

- Let the quantity at minimum efficient scale be q_1 = MES, and the corresponding average cost be p_1 = min ATC. See Figure 2. Consider the ratio $n_1 = D(p_1)/q_1$. It shows how many firms can coexist if each one of them produces the minimum efficient scale quantity and they all charge minimum average cost. Since no firm can charge a lower price than min(ATC), $D(p_1)/q_1$ defines the maximum possible number of firms in the market. It defines an upper limit on the number of firms in the industry directly from structural conditions. If n_1 is large (above 20) there is a real possibility for perfect competition. If the number is small, the industry will be oligopolistic or a monopoly.

- **Economies of scope** are exhibited when the existence of one line of production (and the extent of its use) creates savings in the costs of another line of production undertaken by the same firm.

Monopoly

- To maximize profits, every firm tries to choose the quantity of output that gives zero marginal profits, which is equivalent to marginal revenue equals marginal cost.

$$\Pi(q) = R(q) - C(q)$$

$$d\Pi/dq = MR(q) - MC(q) = 0.$$

- Revenue is

$$R(q) = qp(q),$$

where $p(q)$ is the willingness to pay for quantity q.

- Marginal revenue is

$$MR(q) = p + q(dp/dq).$$

- In perfect competition, because a firm cannot influence the prevailing market price (and therefore $dp/dq = 0$), its marginal revenue is exactly equal to price, $MR(q) = p$. However, in monopoly $dp/dq < 0$ (because the demand is downward sloping), and therefore, for every quantity, marginal revenue is below the corresponding price on the demand curve, $MR(q) < p(q)$. Therefore, the intersection of MR and MC under monopoly is at a lower quantity q_m than the intersection of MR (= p) and MC under perfect competition, q_c. It follows that price is higher under monopoly, $p_m > p_c$. Since surplus is maximized at qc, monopoly is inefficient. The degree of inefficiency is measured by the triangle of the dead weight loss (DWL). It measures the surplus difference between perfect competition and monopoly.

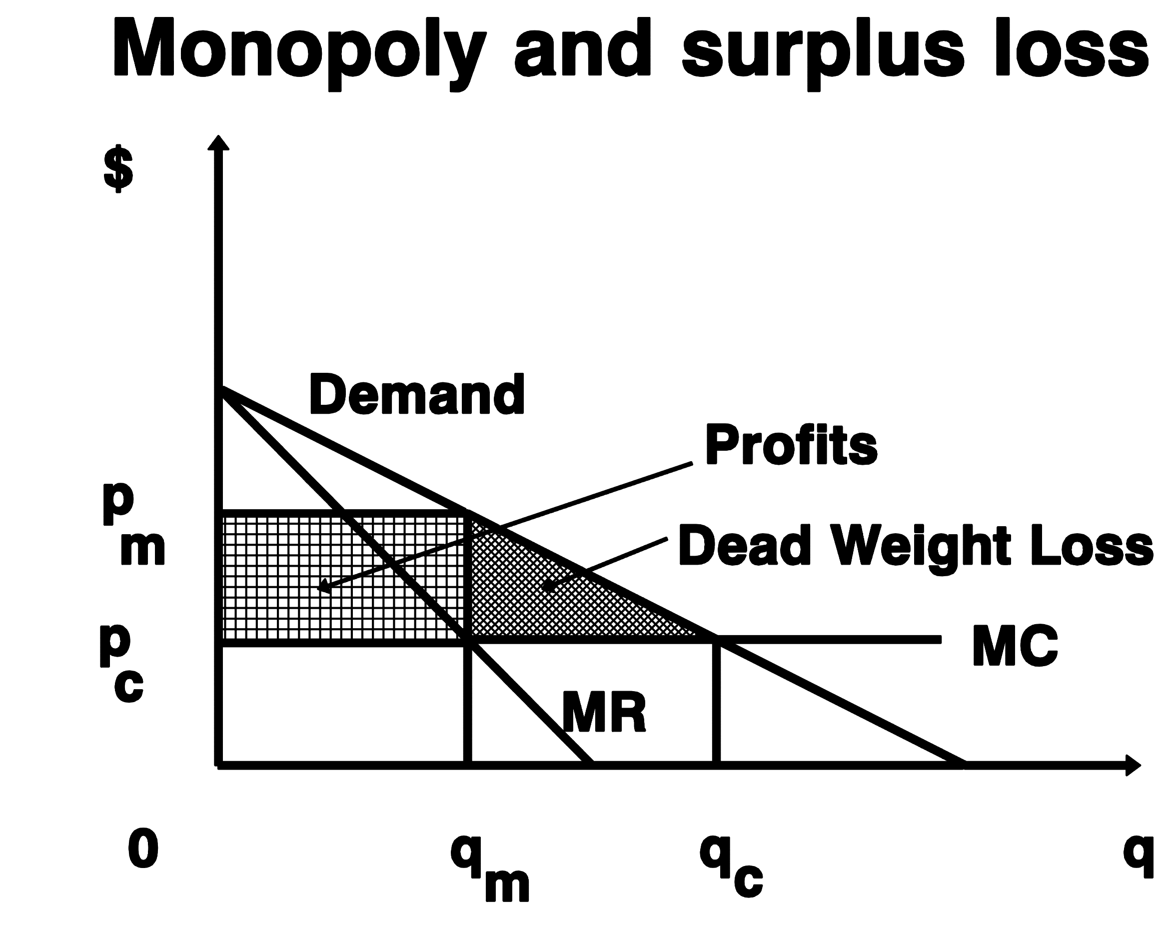


Figure 3

Elementary Game Theory
Games in Extensive and in Normal (Strategic) Form

- **Games** describe situations where there is potential for conflict and for cooperation. Many business situations, as well as many other social interactions have both of these such features.

- Example 1: Company X would like to be the only seller of a product (a monopolist). The existence of competing firm Y hurts the profits of firm X. Firms X and Y could cooperate, reduce total production, and increase profits. Or they could compete, produce a high quantity and realize small profits. What will they do?

- Example 2: Bank 1 competes with bank 2 for customers. Many of their customers use Automated Teller Machines (ATMs). Suppose that each bank has a network of its own ATM machines which are currently available only to its customers. Should bank 1 allow the customers of the other bank to use its ATMs? Should bank 1 ask for reciprocity?

- Example 3: Computer manufacturer 1 has a cost advantage in the production of network «cards» (interfaces) of type 1. Similarly manufacturer 2 has an advantage in network «cards» of type 2. If they end up producing cards of different types, their profits will be low. However, each firm makes higher profits when it produces the «card» on which it has a cost advantage. Will they produce «cards» of different types? Of the same type? Which type?

- A **game in extensive form** is defined by a set of players, i = 1, ..., n, a **game tree**, **information sets**, **outcomes**, and **payoffs**. The game tree defines the sequence and availability of **moves** in every **decision node**. Each **decision node** is identified with the player that decides at that point. We assume there is only a finite number of possible moves at every node. Each branch of the tree ends at an event that we call an **outcome**. The utility associated with the outcome for every player we call his **payoff**. **Information sets** contain one or more nodes. They show the extent of knowledge of a player about his position in the tree. A player only knows that he is in an information set, which may contain more than one nodes. Information sets allow a game of simultaneous moves to be described by a game tree, despite the sequential nature of game trees. A game where each information set contains only one point is called a game of **perfect information**. (Otherwise it is of **imperfect information**.) For example, in the «Incumbent-Entrant» game, at every point, each player knows all the moves that have happened up to that point. All the information sets contain only a single decision node, and the game is of perfect information. In the «Simultaneous Incumbent-Entrant» game, player I is not sure of player E's decision. He only knows that he is at one of the two positions included in his information set. It is as if players I and E move simultaneously. This is a game of imperfect information. Note that this small change in the information sets of player I makes a huge difference in what the game represents -- a simultaneous or a sequential decision process.

- When the utility functions associated with the outcomes are known to both players, the game is of **complete information**. Otherwise it is of **incomplete information**. You may not know the opponent’s utility function. For example, in a price war game, you may not know the value to the opponent firm (or the opponent manager) of a certain loss that you can inflict on them.

- A **game in normal form** is a summary of the game in extensive form. This is facilitated by the use of **strategies**. *A strategy for player i defines a move for this player for every situation where player i might have to make a move in the game*. A strategy of player i is denoted by s_i, and it belongs in the set of available strategies of player i, S_i. By its nature, a strategy can be very complicated and long. For example, a strategy for white in chess would have to specify the opening move, the second move conditional on the 20 alternative first moves of the black, the third move conditional on the many (at least 20) alternative second moves of the black, and so on. The advantage of using strategies is that, once each player has chosen a strategy, the outcome (and the corresponding payoffs) are immediately specified. Thus, the analysis of the game becomes quicker.

Sequential Entrant-Incumbent Game

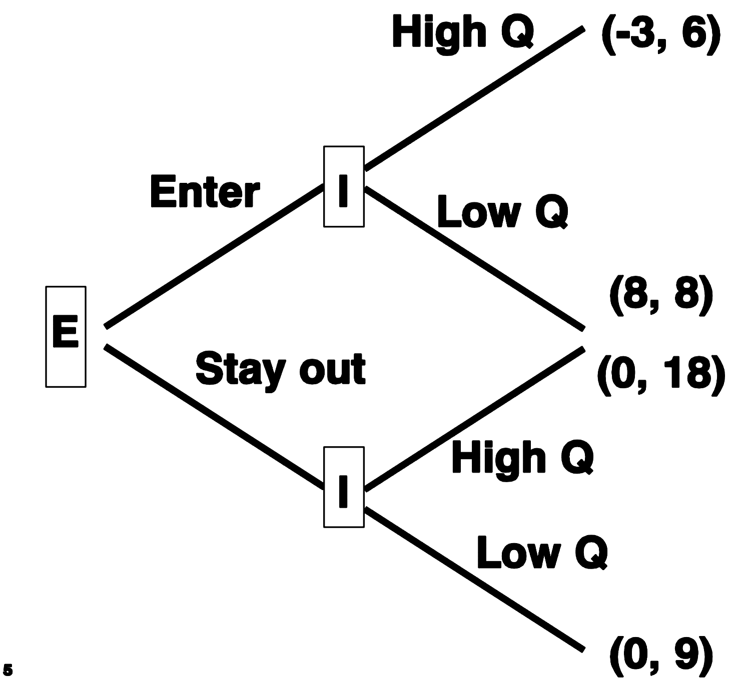


Figure 5

Simultaneous Entrant-Incumbent Game

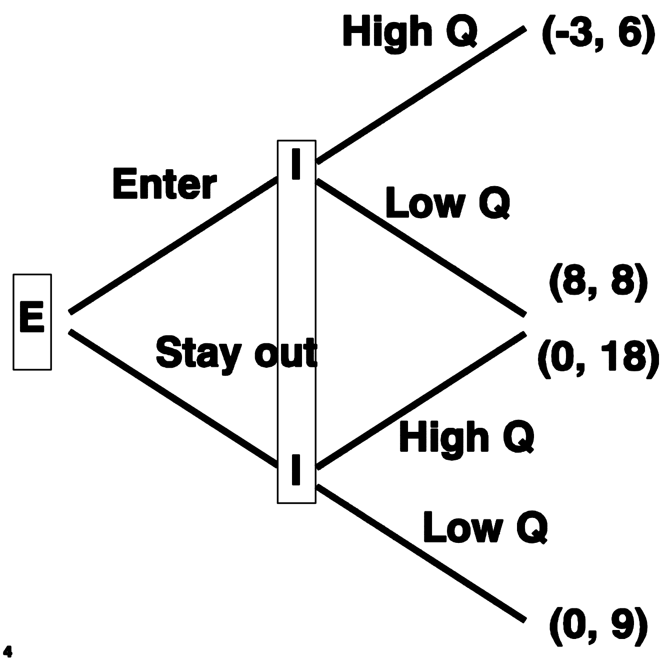


Figure 4

Example 1: **"Simultaneous Incumbent-Entrant"**

		Player 2 (Incumbent)	
		High Q	Low Q
Player 1 (Entrant)	Enter	(-3, 6)	(8, 8)
	Stay out	(0, 18)	(0, 9)

Strategies for player 1: Enter, Stay out. Strategies for Player 2: High Q, Low Q

Example 2: **Prisoners' Dilemma**

		Player 2	
		silence	talk
Player 1	Silence	(5, 5)	(0, 6)
	Talk	(6, 0)	(2, 2)

Strategies for player 1: Silence, Talk. Strategies for player 2: silence, talk.

Non-Cooperative Equilibrium

- A pair of strategies (s, s) is a **non-cooperative equilibrium** if and only if each player has no incentive to change his strategy provided that the opponent does not change his strategy. No player has an incentive to unilaterally deviate from an equilibrium position. This means that

$$\Pi_1(s, s) \geq \Pi_1(s_1, s), \text{ for all } s_1 \in S_1, \text{ and}$$

$$\Pi_2(s, s) \geq \Pi_2(s, s_2), \text{ for all } s_2 \in S_2.$$

Dominant Strategies

- In some games, no matter what strategy player 1 plays, there is a single strategy that maximizes the payoff of player 2. For example, in the Prisoners' Dilemma if player 1 plays «Silence», it is better for player 2 to play «talk»; and, if player 1 plays «Talk», it is better for player 2 to play «talk» again. Then «talk» is a **dominant strategy** for player 2. In the same game, note that «Talk» is a dominant strategy for player 1, because he prefers it no matter what player 2 plays. In a game such as this, where both players have a dominant strategy, there is an **equilibrium in dominant strategies**, where each player plays his dominant strategy. An equilibrium in dominant strategies is necessarily a non-cooperative equilibrium. (Why? Make sure you understand that no player wants to unilaterally deviate from a dominant strategy equilibrium.)

- There are games with no equilibrium in dominant strategies. For example, in the simultaneous incumbent-entrant game, the entrant prefers to stay out if the incumbent plays «H». However, the entrant prefers to enter if the incumbent plays «L». Since the entrant would choose a different strategy depending on what the incumbent does, the entrant does not have a dominant strategy. (Similarly, check that the incumbent does not have a dominant strategy.) Therefore in the simultaneous incumbent-entrant game there is no equilibrium in dominant strategies.

Best Replies

- Player 1's **best reply** to strategy s_2 of player 2 is defined as the best strategy that player 1 can play against strategy s_2 of player 2.

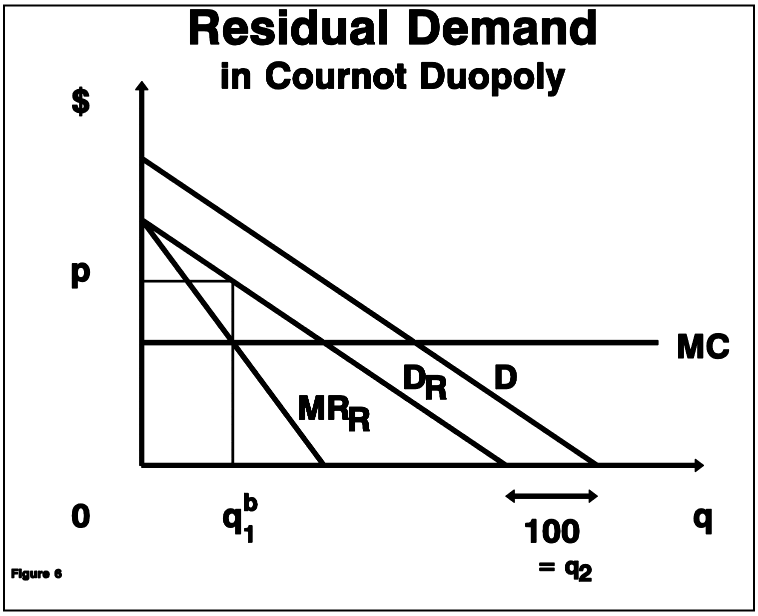
- For example, in the simultaneous incumbent-entrant game, the best reply of the entrant to the incumbent playing «High Q» is «Stay out». Similarly, the best reply of the entrant to the incumbent playing «Low Q» is «Enter». From the point of view of the incumbent, his best reply to the entrant's choice of «Enter» is «Low Q», and his best reply to the entrant's choice of «Stay out» is «High Q». Notice that at a non-cooperative equilibrium both players play their best replies to the strategy of the opponent. For example, at (Stay out, High Q), as we saw, «Stay out» is a best reply to «High Q», and «High Q» is a best reply to «Stay out». This is no coincidence. At the non-cooperative equilibrium no player has an incentive to deviate from the strategy he plays. This means that his strategy is the best among all the available ones, as a reply to the choice of the opponent. This is just another way of saying that the player chooses the best reply strategy. Therefore **at equilibrium each player plays a best reply strategy**. This suggests that we can find equilibria by finding first the first reply strategies. We do this in the oligopoly games that we discuss next.

Oligopoly
Cournot Duopoly

When few firms are interacting in a market, they have to take into account the effects of each one's actions on the others. We use **game theory** to analyze these **strategic** situations.

The simplest oligopoly model is due to Augustin Cournot (1838). There is one homogeneous good with demand function $p(Q)$. Two competing firms, $i = 1, 2$, produce q_i each. $Q = q_1 + q_2$. The profit function of firm 1 is

$$\Pi_1 = q_1 p(q_1 + q_2) - C_1(q_1).$$



Cournot assumed that each firm assumes that (at equilibrium) its actions have no influence on the actions of the opponent. In game theoretic terms, his equilibrium was the non-cooperative equilibrium of a game where each player uses quantity as his strategy. By assuming that firm 1 has no influence on the output of firm 2, Cournot assumed that the **residual demand** facing firm 1 is just a leftward shift by q_2 of the industry demand p(Q). Firm 1 is a monopolist on this residual demand.

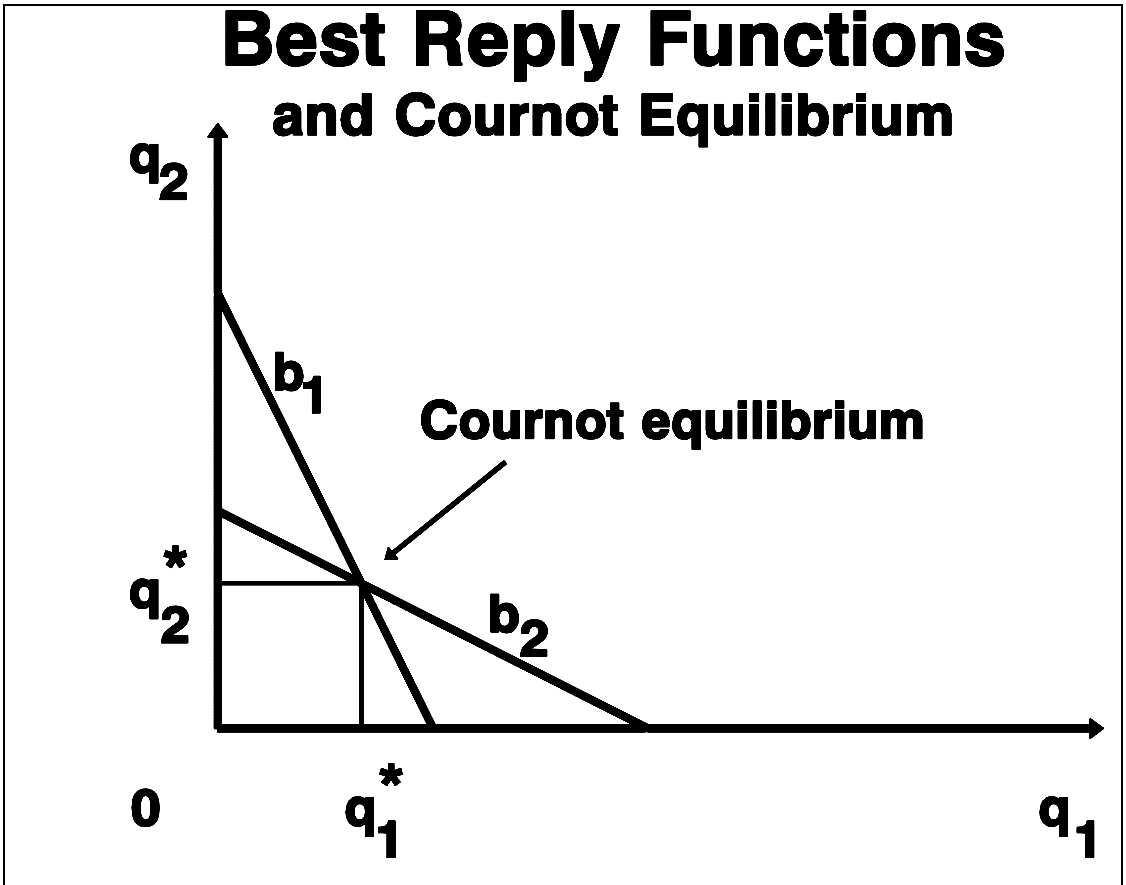
To find the non-cooperative equilibrium we first define the best reply functions. Maximizing Π_1 with respect to q_1 we get the best reply (or reaction function R_1) of player 1,

$$q = b_1(q_2).$$

Similarly, maximizing Π_2 with respect to q_2 we get the best reply (or reaction function) of player 2,

$$q = b_1(q_1).$$

The intersection of the two best reply functions is the non-cooperative equilibrium, (q_1^*, q_2^*).


Best Reply Functions
and Cournot Equilibrium
q2
b1
Cournot equilibrium
q2*
b2
0
q1*
q1
Figure 7

Cournot Oligopoly With n Firms

Let market demand be $p(Q)$, where $Q = q_1 + q_2 + ... + q_n$. Costs are $C_i(q_i)$. Then profits of firm i are

$$\Pi_i(q_1, q_2, ..., q_n) = q_i p(q_1 + q_2 + ... + q_n) - C_i(q_i).$$

At the non-cooperative equilibrium, marginal profits for all firms are zero, i.e., for i = 1, ..., n.

(1) $$\partial\Pi_i/\partial q_i = p(Q) + q_i p'(Q) - C_i'(q_i) = 0,$$

We define the **market share** of firm i as $s_i = q_i/Q$. Remembering that the **market elasticity of demand** is

$$\varepsilon = (dQ/Q)/(dp/p) = (dQ/dp)(p/Q),$$

we can rewrite (1) as

$$C_i'(q_i) = p[1 + (q_i/Q)(Q/p)(dp/dQ)], \text{ i.e.,}$$

$$C_i'(q_i) = p[1 + s_i/\varepsilon], \text{ i.e.,}$$

(2) $$(p - C_i'(q_i))/p = -s_i/\varepsilon = s_i/|\varepsilon|.$$

This says that **the relative price to marginal cost markup for firm i is proportional to the market share of firm i, and is also inversely proportional to the market elasticity of demand**.

Collusion

If firms were to collude, they would maximize total industry profits,

$$\Pi = \sum_i \Pi_i = \sum_i [q_i p(q_1 + q_2 + ... + q_n) - C_i(q_i)] =$$

$$= Qp(Q) - \sum_i C_i(q_i).$$

To maximize these, each firm would set

$$(2') \qquad \partial\Pi/\partial q_i = 0 \iff p(Q) + Qp'(Q) = C_i'(q_i),$$

i.e., market-wide marginal revenue equal to individual firm marginal cost.

At the collusive equilibrium there are incentives to cheat and produce more. To see that, consider the marginal profit of firm i if it produces an extra unit of output, starting at the collusive solution. It is

$$\partial\Pi_i/\partial q_i = p(Q) + q_i p'(Q) - C_i'(q_i) = -(Q - q_i)p'(Q) > 0,$$

by substituting from (2′), and noting that $p' < 0$. Thus, firm i has an incentive to violate the collusive arrangement. **The essential reason for this is that firm i's marginal revenue is higher than market-wide marginal revenue**, i.e., $p(Q) + q_i p'(Q) > p(Q) + Qp'(Q)$. Since firm i does not take into account the repercussions of its actions for the rest of the industry, starting from the collusive outcome, it has an incentive to increase output.

Cournot Oligopoly with Constant Marginal Costs

If marginal costs are constant, $C_i'(q_i) = c_i$, then the equilibrium profits of firm i can be written as

(3) $$\Pi_i^* = q_i(p(Q) - c_i) = (p(Q) - c_i)Qs_i = pQ(s_i)^2/|\varepsilon|.$$

Then the total industry profits are

(4) $$\Pi^* = \sum_i \Pi_i^* = pQ(\sum_i (s_i)^2)/|\varepsilon|.$$

We define the **Herfindahl-Hirschman index of concentration** as the sum of the squares of the market shares,

(5) $$H = \sum_i (s_i)^2.$$

Since market shares sum to one, $\sum_i s_i = 1$, the H index is smaller for more egalitarian distribution of shares, and always lies between 0 and 1. Monopoly results in H = 1, and n = 4 results in H = 0. For any fixed n, H decreases as the distribution of shares becomes more egalitarian.

For Cournot oligopoly with constant marginal costs, we have from (4) and (5) that

$$\Pi^* = HpQ/|\varepsilon|,$$

i.e., that **the industry equilibrium profits are proportional to the H index and to the total market sales, and inversely proportional to the market elasticity**.

For a symmetric equilibrium all firms have the same cost function (which do not necessarily have constant marginal costs), $C_i(q_i) = C(q_i)$. Then $q_i = Q/n$, so that $s_i = 1/n$. From (2) we have

(6) $$(p - C')/p = -1/(n\,\varepsilon) = 1/(n|\varepsilon|).$$

This says that **if firms have the same marginal costs, the relative price to marginal cost markup is inversely proportional to the market elasticity of demand and to the number of competitors** in Cournot oligopoly.

Cournot Oligopoly with Constant Marginal Costs and Linear Demand

For linear demand,

$$p = a - bQ$$

and constant marginal costs, $C'(q) = c$, optimization by firm i implies from (1),

$$a - bQ - bQ/n = c, \text{ i.e., } a - c = bQ(n+1)/n, \text{ i.e.,}$$

(7a) $$Q^* = [(a - c)/b][n/(n + 1)],$$

(7b) $$q^* = [(a - c)/b]/(n + 1).$$

The price to marginal cost margin is

(7c) $$p^* - c = a - c - bQ^* = (a - c)/(n + 1),$$

and the equilibrium profits are

(7d) $$\Pi_i^* = (p^* - c)q^* = [(a - c)^2/b]/(n + 1)^2.$$

Therefore price and individual firm's production is inversely proportional to $n + 1$, but profits are inversely proportional to $(n + 1)^2$. Also note that total (industry) production Q^* increases in n.