OLIGOPOLY

A market with a few sellers is called an oligopoly market. It is an important form of imperfect competition, which is characterised by standardised or differentiated products and high degree of interdependence.

The product produced and sold by the firms in an oligopolistic industry may be homogeneous or differentiated. If all firms produce and sell a homogeneous product it is known as pure oligopoly. On the other hand if the firms produce and sell a differentiated product, it is known as differentiated ~~products~~ oligopoly.

When the number of sellers is just two, the market form is called a duopoly and when it is more than two but limited to a few, it is called an oligopoly.

The price-quantity decisions in which the leader firm finalises its decisions in anticipation of those of the other firms or the other firms do the same in anticipation of the leader firm's decision or even on the basis of the leader firm's signals are all said to be independent.

When firms, instead of competing with each other, decide to consult each other in a friendly manner before making their moves, they are said to be colluding. They constitute a collusive oligopoly indulging in a cooperative game. As against this, when the oligopolistic firms are on the war path, whether in respect of price or quantity, the market form is termed as a non-collusive oligopoly indulging in a non-cooperative game.

There are two forms of an oligopoly

(1) Non-Collusive Oligopoly – Cournot Model/Stackelberg/Bertrand

(2) Collusive Oligopoly – cartel

* Equilibrium in an Oligopolistic Market :-

In the study of a market, we usually want to determine the price and quantity that will prevail in equilibrium. In case of perfectly competitive market, the equilibrium price equates the quantity supplied with quantity demanded. Then in case of monopoly, an equilibrium occurs when marginal revenue equals marginal cost. Finally in the discussion of monopolistic competition, long-run equilibrium occurs when the entry of new firms drives profit to zero.

In these markets, each firm could take price or market demand as given and largely ignore the its competitors. In an oligopolistic market, however, a firm sets price or output based partly on strategic considerations regarding the behaviour of its competitors. At the same time, competitors decisions depend on the first firm's decision. Then how we can get equilibrium price and output. For that purpose we need an underlying principle to describe an equilibrium when firms make decisions that explicitly take each other's behaviour into account.

A market is in equilibrium, when firms are doing the best they can and have no reason to change their price or output. Thus a Competitive market is in equilibrium when the quantity supplied equals the quantity demanded. Each firm is doing the best it can — it is selling all that it produces and is maximising its profit. Likewise, a monopolist is in equilibrium when marginal revenue equals marginal cost because it is doing the best it can and is maximising.

With some modification, we can apply this same principle to an oligopolistic market. Now each firm will want to do the best it can given what its Competitors are doing. It is natural to assume that these Competitors will do the best given what that firm is doing. Each firm, then takes its Competitors into account and assumes that its Competitors are doing likewise.

It gives us a basis for determining an equilibrium in an oligopolistic market. This Concept was first explained by John Nash in 1951, so we call the equilibrium it describes a Nash Equilibrium.

Nash Equilibrium :- Each firm is doing the best it can given what its Competitors are doing.

Here we will apply Nash Equilibrium to the analysis of oligopolistic markets. ~~Dua~~ Duopoly market is Considered in the present discussion, i.e, we will focus on the market in which two firms are Competiting with each other. Thus each firm has just one Competitor to take into account in making its decisions. Although we focus on ~~duopolist~~ duopolies, our basic results will also apply to markets with more than two firms.

COURNOT MODEL

This duopoly model was developed by French economist Augustin Cournot in 1838. It is the original version, as illustrated by Cournot himself through an example of two sellers of mineral water. The original version, though quite limited in its applicability due to its assumptions of identical products with zero production costs, can be extended to suit situations in which demands need not be identical nor costs identically zero.

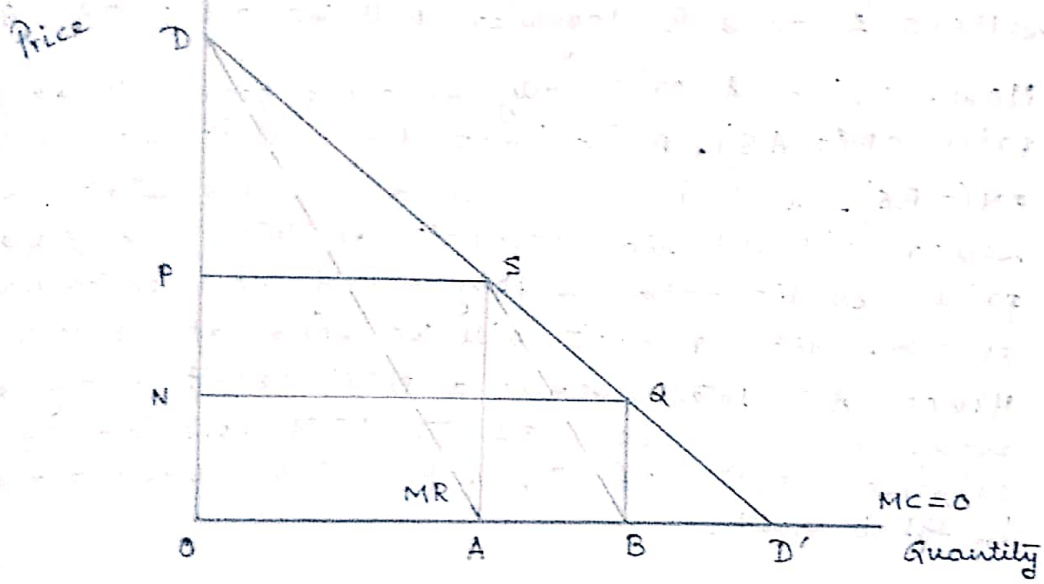
Cournot based his original version on the following assumptions.

(1) There are two firms, each owning a mineral water spring.

(2) The production costs are zero for each

(3) The demand curve for the product is linear.

(4) Each firm acts on the assumption that its competitor will not change its output (quantity) and decides its own so as to maximise its profits.



Let there are two duopolist sellers A and B, whose demand curve for 'mineral spring water' in the market and respective price output policies have been shown in the above figure. Here, the market demand curve confronting these sellers is DD′ and the total output is OD′. This total output OD′ is equally attributable to the two producers, so that OA = AD′ and hence if the total output OD′ = OA + AD′ is placed in the market for sale, then the price is zero. Since the total cost of production has been assumed to be zero, the marginal cost has also been zero. So inorder to satisfy the profit maximising condition of MR = MC, where MC = 0, we should also see where MR = 0 which may occur, however, only when the elasticity of demand is equal to one. Such a situation has occurred with respect to the point S on the market demand or average revenue curve DD′ because the point S is the mid point of that curve. At the point S, the elasticity of demand $= \frac{SD'}{SD} = 1$ as $SD' = SD$ and accordingly at this stage, $MR = MC = 0$ at the corresponding level of output OA. Let A be the seller who decides to produce at the price AS(=OP) when the quantity sold by him is OA. His total cost is zero, A finds his total revenue = total profit = the area of □ OASP.

Now let the other duopolist B starts his production by assuming that A will keep his output unchanged at OA. B finds that A has considered DS segment as his demand curve. Therefore B considers the remaining SD' segment as his own demand curve. According, B finds that SG = GD' and hence with respect to the point G on the demand curve SD', the elasticity of demand = 1 and thus MR=MC if only AD' output is left for his production (as AD' = OD' − OA). So B decides to produce AB(= ½ AD') output when A has already produced OA output. If so the total quantity sold by sellers A and B together will be OB(= OA + AB)

Now, while A originally sold the product at the price OP(=AS), B decides to sell it at price ON(= BQ). But it has been assumed that each seller will sell the product at the ruling market price. So the total supply being now determined at OB, the product will be sold at price BQ. Hence A's total revenue = total profit may be measured by area of □ OATN instead of the original area of □ OASP which shows a reduction in total profit.

This action-reaction pattern continues, since firms have the naive behaviour of never learning from past patterns of reaction of their rivals. However, eventually an equilibrium will be reached in which each firm produces one-third of the total market. Together they cover two thirds of the total market. Each firm maximises its profit in each period but the industry profits are not maximised. That is, the firms would have higher joint profits if they recognised their interdependence, after their failure in forecasting the correction reaction of their rivals. Recognition of their interdependence would lead them to act as a monopolist, producing one half of the total market output, selling it at the profit maximising price P, and sharing the market equally, that is, each producing one-quater of the total market (instead of one third).

The equilibrium of the Cournot firms may be as follows.
The Product of firm A in successive periods is

Period 1 : $\frac{1}{2}$

Period 2 : $\frac{1}{2}\left(1-\frac{1}{4}\right)=\frac{3}{8}=\frac{1}{2}-\frac{1}{8}$

Period 3 : $\frac{1}{2}\left(1-\frac{5}{16}\right)=\frac{11}{32}=\frac{1}{2}-\frac{1}{8}-\frac{1}{32}$

Period 4 : $\frac{1}{2}\left(1-\frac{42}{128}\right)=\frac{43}{128}=\frac{1}{2}-\frac{1}{8}-\frac{1}{32}-\frac{1}{128}$

Product of A in equilibrium
$$= \frac{1}{2}-\frac{1}{8}-\frac{1}{32}-\frac{1}{128}$$
$$= \frac{1}{2}-\left[\frac{1}{8}+\frac{1}{8}\cdot\frac{1}{4}+\frac{1}{8}\cdot\left(\frac{1}{4}\right)^2+\cdots\right]$$
$$= \frac{1}{2}-\frac{1/8}{1-\frac{1}{4}}$$
$$= \frac{1}{3}$$

The Product of firm B in successive periods is

Period 2 : $\frac{1}{2}\left(1-\frac{1}{2}\right)=\frac{1}{4}$

Period 3 : $\frac{1}{2}\left(1-\frac{3}{8}\right)=\frac{5}{16}=\frac{1}{4}+\frac{1}{16}$

Period 4 : $\frac{1}{2}\left(1-\frac{11}{32}\right)=\frac{21}{64}=\frac{1}{4}+\frac{1}{16}+\frac{1}{64}$

Period 5 : $\frac{1}{2}\left(1-\frac{43}{128}\right)=\frac{85}{256}=\frac{1}{4}+\frac{1}{16}+\frac{1}{64}+\frac{1}{256}$

Product of B in equilibrium
$$= \frac{1}{4}+\frac{1}{4}\cdot\frac{1}{4}+\frac{1}{4}\cdot\left(\frac{1}{4}\right)^2+\cdots$$
$$= \frac{1/4}{1-1/4}=\frac{1}{3}$$

Thus the Cournot solution is stable. Each firm supplies $\frac{1}{3}$ of the market at a common price which is lower than the monopoly price but above the pure competitive ~~type~~ price.

The model suffers from the following drawbacks.

(1) The model does not say how long it will take to reach the equilibrium

(2) The assumption of Cost less production is unrealistic.

(3). Though the model can be generalised to any number of firms, it is a closed model as entry of new firms is not provided for. The number of firms remains unchanged through out the adjustment period.

(4) The firms seem never to learn from their past experiences as each continues to assume repeatitively that the other would not change its quantity in its next phase even when there exists evidence to the contrary.

* REACTION CURVE APPROACH TO COURNOT'S MODEL

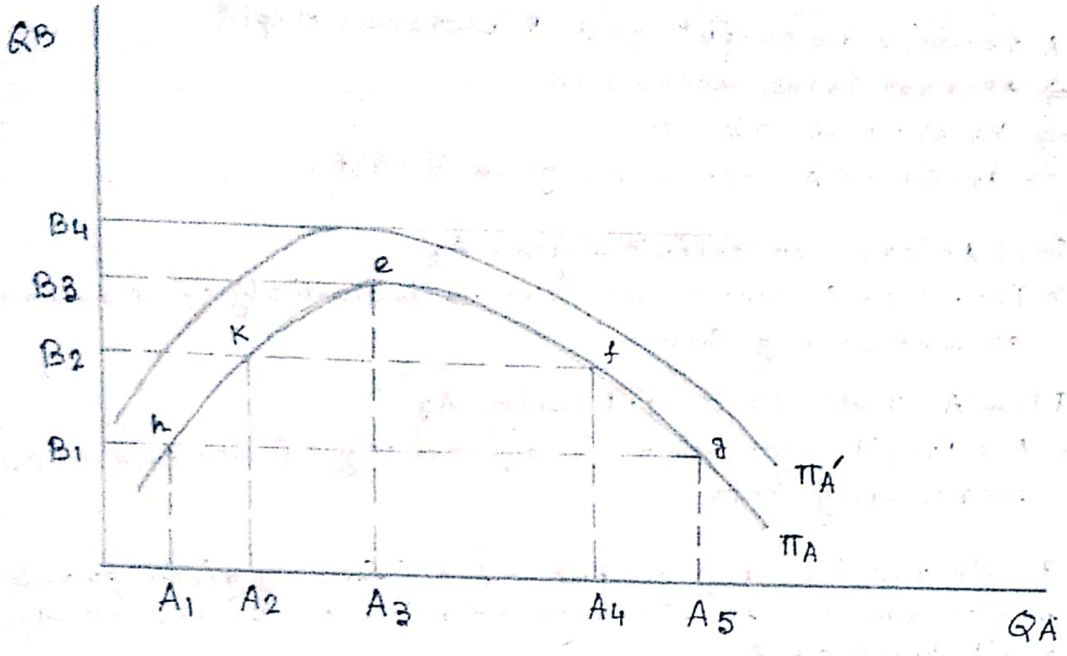
The reaction curve approach provides a more powerful treatment of Oligopolistic markets. This is so because it no longer requires the highly unrealistic assumptions of identical demand and cost conditions. This approach is based on Stackelberg's indifference curve analysis which introduces the concept of isoprofit curves of Competitors. We will first establish the shape of the isoprofit curves for substitute commodities, and from these curves we will subsequently derive the reaction curves of the Cournot's duopolists.

An isoprofit curve for firm A is the locus of points defined by different levels of output of A and his rival B, which yields to A the same level of profit.

Similarly, an isoprofit curve for firm B is the locus of points of different levels of the two Competitors which yield to B the same level of profit.

Isoprofit Curves of a duopolist are Concave to the axis on which its output is measured. That is, isoprofit curves of duopolist A are concave to the x-axis, while those of duopolist B are concave to the Y-axis when output of A is measured on x-axis and that of B, on y-axis.

The shape of the isoprofit curve of A shows that it can react to any level of B's output by adjusting its own so as to maintain a given level of profit, π_A, for itself. The same can be said about the shape of the isoprofit curve of B, which enables it to react to any level of A's output by adjusting its own so as to maintain a given level of profit, π_B, itself. Now we will consider the isoprofit curve of A.



Action-reaction chain of the duopolists and its effect on Firm A's profit and its isoprofit curve:-

For a given output B_1 of B, Firm A retains same profit (Π_A) by supplying either A_1 or A_5. Price would be higher at h(A_1, B_1) than at g(A_5, B_1) because at h supply is lower than that at g. Due to the existence of economies, production cost of Firm A is lower at g than at h. A can retain therefore same profit (Π_A) by supplying either A_1 or A_5, given B's supply as B_1. If B increases its supply from B_1 to B_2. Firm A must decrease it from A_5 to A_4, if at g, so that the total supply may remain same and the fall in price caused by B's increase in supply may be offset by the rise in it caused by a suitable decrease in supply of A to make the same profit (Π_A); if at h. Firm A must increase it from A_1 to A_2 so that its production cost falls by the same proportion by which price has fallen in response to B's increase in supply. These adjustments of firm A form a part of its reaction to the moves of Firm B so that Firm A may maintain the same level of profit (Π_A) whether at h or K or f or g. If firm B increases its supply even beyond B_2, say to B_3. Firm A has to increase its own from A_2 to A_3 if at K or decrease it from A_4 to A_3 if at f on the same grounds. In case B increase supply above B_3, A's isoprofit curve will shift upwards to Π_A', indicating a decline in A's profits ($\Pi_A' < \Pi_A$).

The farther the isoprofit curves lie from the axes, the lower is the profit. And vice-versa, the closer to the quantity axis an isoprofit curve lies, the higher the profitability of the firm is.

If Firm B produces more than B_3, then A would not be able to retain its level of profit.

Suppose Firm B produces now B_4. Firm A can react in three ways: increase, decrease or retain its output constant.

(1) 'A' retains its output and B increases output
⇒ Market Price decreases
⇒ Revenue decreases
⇒ Profit of A decrease, given its Cost.

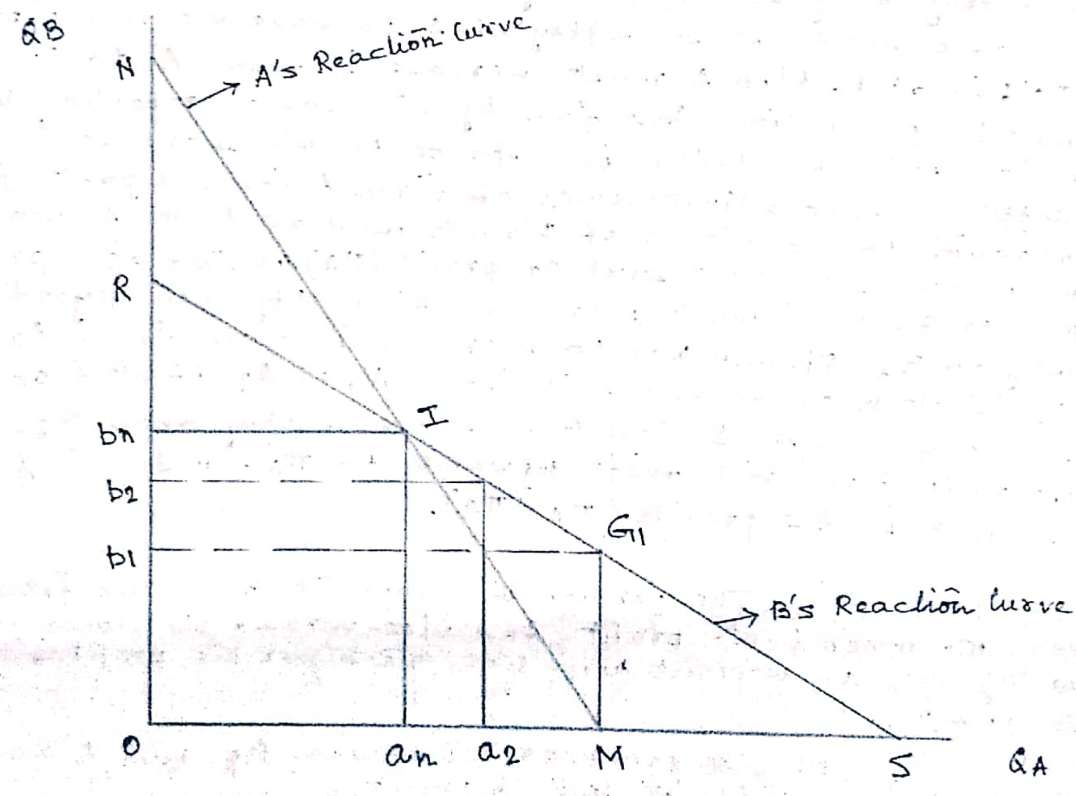
(2) Firm A increases output beyond A_3
⇒ Profit of A decreases due to inelasticity of demand and/or increasing Cost

(3) Firm A reduces output below A_3
⇒ A's Profit decreases due to elasticity of demand and/or increasing Costs.

The Profit maximising output of A (for any given quantity of B) is established at the highest point on the lowest attainable isoprofit curve of A.

For firm A, the highest points of successive isoprofit Curves lie to the left of each other. If we join the highest points of the isoprofit curves we obtain firm A's reaction curve.

Thus, the reaction curve of Firm A is the locus of points of highest profits that Firm A can attain given the level of output of rival B. It is called 'reaction curve' because it shows how Firm A will determine its output as a reaction to B's decision to produce a certain level of output.



Cournot's equilibrium is determined by the intersection of the two reaction curves. It is a stable equilibrium, provided that A's reaction curve is steeper than B's reaction curve. (This condition is satisfied by the assumption we made that the highest points of successive isoprofit curves of A lie to the left of one another, while the highest points of B's isoprofit curves lie to the right of each other.

In Period 1 — A's output is OM and B assumes that A will continue to produce OM.
Hence B plans to produce ob_1 units of output as is observed from the point G_1 on B's reaction curve RS. The combination of output as planned to be produced by A and B is thus OM and ob_1 respectively.

In Period-2, B's output remain unchange to ob_1; A's output will be oa_2

In Period-3, B will produce ob_2 assuming that A will continue to produce oa_2.

It is clear that these adjustments of output by sellers A and B will continue until A and B produce oa_n and ob_n respectively as indicated by the point 'I', i.e. the point of intersection of their two reaction curve, MN and RS.

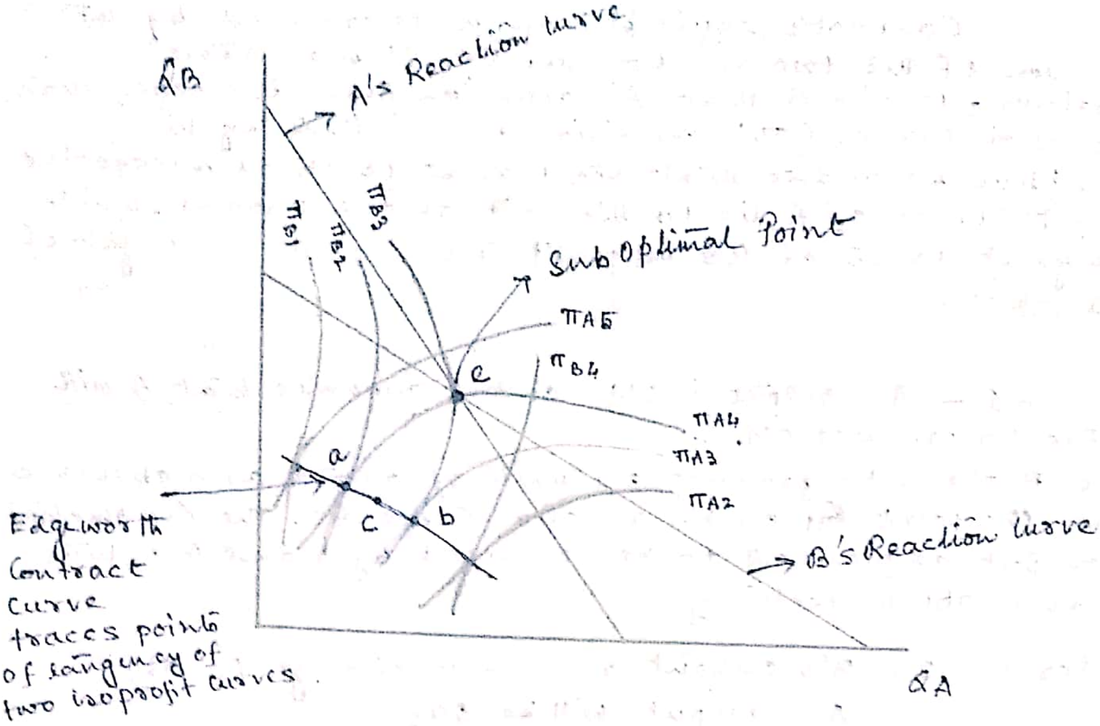
Now, the Cournot Model is analytically attractive with respect to the point of intersection (I) of these two reaction curves of two duopolists because it yields a unique and stable equilibrium solution for each duopolist. The nature of this equilibrium is largely determined by the assumption that each duopolist assumes that irrespective of the output plan that he implements in any period (t+1), his rival will maintain his output as the same level as in period t.

When each seller assumes that the change in the output level of his rival seller depends on change in his own output level. In this case, it is said that the two sellers behave conjecturally.

Conjectural behaviour — $\frac{\partial q_j}{\partial q_i}$

In the Cournot model it is assumed that the conjectural variation is zero, i.e. $\frac{\partial q_2}{\partial q_1} = \frac{\partial q_1}{\partial q_2} = 0$

If each seller behaves conjecturally then the reaction functions can be drawn and their intersection point may denote a stable equilibrium position.



At b ⇒ B's profit remains same and A would move to higher profit

At a ⇒ A's profit remains same and B would move to higher profit

At c, a point between 'a' and 'b'
⇒ Both firms would realise higher profit

The question arises of why the firms choose the suboptimal point.

Because the Cournot pattern of behaviour implies that the firms do not learn from past experience, each expecting the other to remain at a given position. Eal firm acts independently, in that it does not know that the other behaves on the same assumption (behaviourial Pattern)

In the subsequent section Stackelber modified the model, by assuming that one or both of the duopolists may be sufficiently alert to recognise that his rival will make the Cournot assumption abo his behaviour.

In Cournot's duopoly model firms choose quantities rather than prices. Given the quantity choices q_1 and q_2, the price adjusts to the level $P(q_1+q_2)$ that clears the market; $P(q_1+q_2)$ is the inverse demand function. We assume that $P'(Q)$ [that is, $\frac{dP}{dQ}$] < 0 at all $Q \geq 0$.

The Cournot-Nash equilibrium for this model consists of a pair of quantity choices (q_1^*, q_2^*) such that

$$\pi_i(q_i^*, q_j^*) \geq \pi_i(q_i, q_j^*), \quad i \neq j, \quad i,j = 1,2.$$

We can solve for the equilibrium quantities by looking at the best response functions or the 'reaction function' of the two firms. Firm 1's reaction function shows the quantities that Firm 1 should produce to maximise its profit, for any level of output produced by Firm 2. It can be obtained from the equation $\frac{\partial \pi_1}{\partial q_1} = 0$, which yields the best output of Firm 1 as a function of firm 2's output: $q_1 = R_1(q_2)$. Similarly, we can use the equation $\partial \pi_2 / \partial q_2$ to get the reaction function for firm 2 $q_2 = R_2(q_1)$.

It will be instructive to analyse the Cournot-Nash equilibrium for the case where both demand and cost functions are linear.

Suppose that the inverse demand function is

$P = a - Q$

where $Q = q_1 + q_2$

$P(Q) = a - Q$ when $a > Q$

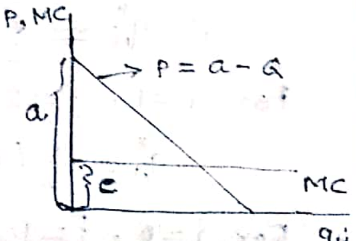
$P(Q) = 0$ when $a < Q$

Neither firm will produce a quantity $q_i \geq a$

We assume that the total cost to firm i of producing quantity q_i is

$$C_i(q_i) = c\,q_i$$

$\Rightarrow$ there is no fixed cost where $a > c$



$\Rightarrow c < a$

We now want to find the Nash equilibrium of the Cournot game.

The pay-off $u_i(s_i, s_j)$ in a general two player game in the normal form can be written here as

$$\pi_i(q_i, q_j) = q_i\left[P(q_i+q_j) - c\right]$$
$$= q_i\left[a - (q_i+q_j) - c\right]$$

Each firm's strategy space in the Cournot game is given by $S_i = [0, \infty]$ in which a typical strategy s_i is a quantity choice $q_i \geq 0$. One could argue that extremely large quantities are not feasible and should not be included in firm's strategy space.

In a two-player game, the strategy pair (s_i^*, s_j^*) is a Nash equilibrium if for each player i,

$u_i(s_i^*, s_j^*) \geq u_i(s_i, s_j^*)$ for every feasible strategy s_i in S_i.

Equivalently, for each player i, s_i^* must solve the optimisation problem.

$$\max_{s_i \in S_i} u_i(s_i, s_j^*)$$

In the Cournot duopoly model, the analogous statement is that the quantity pair (q_i^*, q_j^*) is a Nash equilibrium, if, for each firm i, q_i^* solves

$$\max_{0 \leq q_i < \infty} \pi_i(q_i, q_j^*) = \max_{0 \leq q_i < \infty} q_i \left[a - (q_i + q_j^*) - c\right]$$

Here, $\pi_i(q_i, q_j^*) = q_i\left[a - (q_i + q_j^*) - c\right]$

$$\therefore \pi_i = aq_i - q_i^2 - q_i q_j^* - cq_i$$

$$\frac{\partial \pi_i}{\partial q_i} = a - 2q_i - q_j^* - q_i \frac{\partial q_j^*}{\partial q_i} - c = 0$$

$\because \frac{\partial q_j^*}{\partial q_i} = 0$ i.e. the Cournot model is based on zero conjectural variation.

$$\therefore a - 2q_i - q_j^* - c = 0$$

$$\therefore q_i^* = \frac{1}{2}(a - q_j^* - c)$$

For $i = 1$, $j = 2$

$$q_1^* = \frac{1}{2}(a - q_2^* - c) \quad \cdots\cdots\cdots \text{(i)}$$

For $i = 2$, $j = 1$

$$q_2^* = \frac{1}{2}(a - q_1^* - c) \quad \cdots\cdots\cdots \text{(ii)}$$

(i) and (ii) $\Rightarrow$ One firm's best response corresponding to a strategy chosen by the other firm.

Thus (i) $\Rightarrow$ best response of firm 1 corresponding to the strategy chosen by firm 2, i.e. the reaction function of firm 1 or $R_1(q_2)$

$$\therefore R_1(q_2) = q_1^* = \frac{1}{2}(a - q_2 - c)$$

Similarly, (ii) $\Rightarrow$ Reaction function of firm 2

i.e. $R_2(q_1) = \frac{1}{2}(a - q_1 - c)$

Solving equations (i) and (ii) we get

$$q_1^* = q_2^* = \frac{a-c}{3} \quad \ldots\ldots \quad (iii)$$

In (iii) as $c < a$ which indicates $(a-c) > 0$

we have $q_1^* > 0$

$q_2^* > 0$

Aggregate Output is $Q = q_1 + q_2$

$$= \frac{2}{3}(a-c)$$

The market clearing price is $p^* = a - (q_1^* + q_2^*)$

$$= a - \frac{2}{3}(a-c)$$

$$= \frac{a+2c}{3}$$

Firm 1 earns profit $\pi_1 = q_1 (a - (q_1+q_2) - c)$

$$= \left(\frac{a-c}{3}\right)\left[(a-c) - \frac{2}{3}(a-c)\right]$$

$$= \frac{(a-c)}{3} \cdot \frac{(a-c)}{3}$$

$$= \frac{(a-c)^2}{9}$$

Similarly, $\pi_2 = \frac{(a-c)^2}{9}$

Maximised duopoly Profit (aggregate) $= \pi_1 + \pi_2$

$$\pi_{max}^{DUO} = \frac{(a-c)^2}{9} + \frac{(a-c)^2}{9} = \frac{2(a-c)^2}{9}$$

$$= 0.22\,(a-c)^2$$

* <u>Intuition behind the equilibrium</u>

Each firm would like to be a monopolist in the market, in which case it would choose q_i (setting $q_j = 0$) to maximise $\pi_i(q_i, 0) \Rightarrow$ it would produce monopoly quantity.

From (i) we have $q_i^* = \frac{1}{2}(a - q_j^* - c)$

Monopoly $\Rightarrow q_j^* = 0$

$$\therefore q_i^* = \frac{a-c}{2}$$

Monopoly Profit is $\max\limits_{0 \leq q_i < \infty} \pi_i(q_i, 0) = \max\limits_{0 \leq q_i < \infty} q_i[a - q_i - c]$

$$\pi_i = a q_i - q_i^2 - c q_i$$

$$\frac{d\pi_i}{dq_i} = a - 2q_i - c = 0 \Rightarrow q_i = \frac{a-c}{2}$$

Maximised monopoly Profit

$$\pi_{max}^{Mon} = \left(\frac{a-c}{2}\right)\left[a - \frac{a-c}{2} - c\right]$$

$$= \left(\frac{a-c}{2}\right)\left(\frac{a-c}{2}\right)$$

$$= \left(\frac{a-c}{2}\right)^2 = 0.25\,(a-c)^2$$

Thus, $\boxed{\Pi^{DUO}_{Max} < \Pi^{Mon}_{max}}$

Aggregate output under Duopoly, $Q^{DUO} = \frac{2}{3}(a-c)$

A. Monopoly output, $Q^{Mon} = \frac{a-c}{2}$

As $\frac{2}{3}(a-c) > \frac{1}{2}(a-c)$

$\Rightarrow \boxed{Q^{DUO} > Q^{MON}}$

Price under monopoly $P = a - Q$

$= a - \frac{a-c}{2}$

$P^{MON} = \frac{a+c}{2}$

And $P^{DUO} = \frac{a+2c}{3}$

It is to be noted that $\boxed{P^{DUO} < P^{MON}}$

This is because $\frac{a+2c}{3} < \frac{a+c}{2}$

$\Rightarrow 2a + 4c < 3a + 3c$

$\Rightarrow c < a$

Which is true in the context of our model.

If we consider the fact that each firm thinks themselves to be a monopolist then aggregate profit for the duopolist would be maximised by setting the aggregate quantity $q_1 + q_2 = q_m$. It implies maximum joint profit.

This would occur if $q_i = \frac{q_m}{2}$ $\forall i = 1, 2$

$q_m = \frac{a-c}{2} \Rightarrow q_i = \frac{a-c}{4}$

In this case $\Pi^{Mon}_{max} = \frac{(a-c)^2}{4}$

Whereas $\Pi^{DUO}_{max} = \frac{(a-c)^2}{9}$

As $\Pi^{mon}_{max} > \Pi^{DUO}_{max}$

and $Q^{DUO} > Q^{MON}$

We also have $P^{MON} > P^{DUO}$.

In monopoly each firm has an incentive to deviate because the monopoly quantity is low, the associated price is high and at this price each firm would like to increase its quantity inspite of the fact that such an increase in production drives down the market clearing price.

In Cournot, the aggregate quantity is higher, so the associated price is lower. Hence the temptation to increase output is reduced.

Nash equilibrium in the Cournot game can be graphically demonstrated in the following manner.

$$q_2^* = \frac{1}{2}(a - q_1 - c)$$

$$\Rightarrow q_2^* = R_2(q_1) = \frac{1}{2}(a - q_1 - c) \quad \text{if } q_1 < a - c$$

$R_2(q_1) \Rightarrow$ Firm's 2's best response

i.e. Firm 2's reaction function

slope of $R_2(q_1)$ is $\frac{dq_2}{dq_1} = -\frac{1}{2}$

Likewise

if $q_2 < a - c$

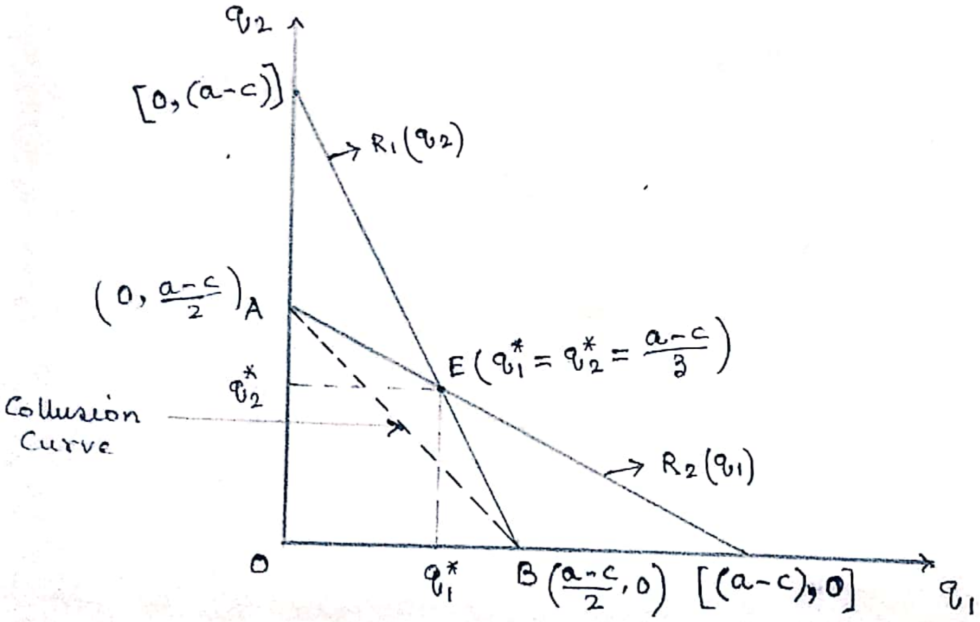
$$q_1^* = \frac{1}{2}(a - q_2 - c)$$

$$\Rightarrow q_1^* = R_1(q_2) = \frac{1}{2}(a - q_2 - c)$$

$R_1(q_2) \Rightarrow$ Firm 1's best response

i.e. firm 1's reaction function

slope of $R_1(q_2)$ is $\frac{dq_1}{dq_2} = -\frac{1}{2} \Rightarrow \frac{dq_2}{dq_1} = -2$



If the two firms collude to maximise the joint profit, then they will be acting like a monopoly. We have seen that a monopolist will produce $Q = (a-c)/2$. That is, in a collusive outcome $q_1 + q_2 = \frac{(a-c)}{2}$. This is the equation of the line joining the points A and B in the above figure. If the two firms agree to produce equal amounts and share profits equally, each will produce $q = (a-c)/4$ and the collusive outcome will be the mid-point of the line.

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