Petroleum industry has many economic characteristics of its own, namely, capital intensity, increasing cost at the level of production of crude, significant economies of scale at 'down-stream' operations, limited price elasticity of demand, risk and uncertainty at the stage of production, joint products, competition from other sources of energy, storage of products, concentration and vertical integration and non-renewability of its raw materials.

Let us examine them in detail one by one with their implications.

Capital Intensity

One of the important features of the petroleum industry is its capital intensity. The proportion of fixed costs to total costs is very high in petroleum industry. There are four stages involved in the production of petroleum products, namely, production of crude, transport, refining and marketing. In each one of these stages there is heavy initial investment of capital.
(a) **Production of Crude**

This includes all the activities incidental to the exploration and location of petroleum lands, the drilling of wells, the extraction of crude petroleum from the earth.

(b) **Transport**

Closely related to production of petroleum is its transportation from the fields to the refineries. Transportation facilities take the form of pipe-lines through which the crude is pumped or tank steamer if the route is overseas. Transport enters the picture at two times in the oil industry. First, the crude oil i.e. the raw material has to be transported from the fields where it is available to the refinery where it is processed. Then the finished and semi-finished products have to be transported from the refinery to the consumers. Unlike in most other industry, where finished product is less in weight than the raw material of which it is composed, in petroleum industry, the volume to be transported in both cases is roughly the same. A modern refinery gets saleable products from 90 to 95 per cent of the crude oil.\(^1\) Oil requires a specialised

equipment and storage for transportation. Therefore, while other industries can rely on transport catering for a host of materials, the oil industry has to consider transport as being a major problem to be solved within its own orbit. The final purchase of oil is in extremely small amounts, while there is a great advantage in transporting large quantities. This conflict between demand in small quantities and transportation in large quantities has led to a series of storage facilities, so that large quantity movement can be carried as far towards the final consumer as possible.

(c) Refining

This stage includes all the activities involved in converting crude petroleum into a number of useful products which the industry produces. The liquid raw material petroleum consists of large number of molecular combinations of hydrocarbons and the refining process consists of separating these into marketable products ranging from solids to highly volatile liquids and gases. The refining processes are many and varied, but all of them employ heat, pressure, chemicals and catalysts.  

(d) Marketing

This includes the distribution of the products through whole-sale, intermediate and retail channels to the ultimate consumers. Its physical facilities include storage tanks, motor-trucks, tank cars, gasoline pipe-lines and service stations.

All these four stages of production involve huge expenditure in the beginning. And transport and refining have become highly automatic processes, characterised by low labour costs, huge investments and obsolescence. The only labour is that of repair and maintenance crews and supervisory work of reading gauges and manipulating valves. Capital costs are very high not only because of huge original investment but also because the equipment is short-lived. Depreciation charges are very heavy because equipment is continuously subjected to high temperature and high pressure operations.

This extreme relationship between fixed and variable costs gives rise to the problem of over production. Supply is not elastic to changes in price in the downward direction. In an industry where variable cost constitutes a larger proportion of the total cost, supply will come down when
price is reduced. But in an industry where variable cost constitutes a small fraction of the total cost, supply is not reduced if the price comes down, because any way fixed costs cannot be avoided in the short-run. Production continues even when the price is less than the average cost of production in the short-run, provided the price is above the variable cost. In order to make full use of fixed costs one produces more. Therefore, in industries without heavy fixed investments supply tends to adjust to changes in demand while industries with heavy fixed capital equipment like petroleum industry, supply does not adjust easily to changes in demand. Therefore, there is likely to be over production. When supply is not responsive to downward movement in price, a long period unprofitable price might ensue without leading to disappearance of surplus capacity. This may give rise to combinations for purposes of maintaining price.

Increasing Cost

The second feature of petroleum industry is that of increasing cost. The production of crude is subjected to increasing cost. There are 3 stages in the production of crude. They are exploration, development and extraction. All these activities together are referred to as production.
The production of crude at any given time is an increasing cost industry. We can find out the causes why it is so.

(a) **Exploration**

The first stage in the production of crude is exploration. This is a process of finding oil deposits and the more barrels found per rupee the lower is the unit cost of finding oil. At any given time, there are a number of places to look and better places are preferred. The oil company exploring oil arranges different places in a descending order according to their probability of yielding oil. Higher the output it wants to produce the costlier prospects are explored. Therefore at any given time with exploration plans, the more exploration, the more one must go into less and less promising areas.

(b) **Development**

The second stage in the production of crude is development. It consists in finding out the horizontal and vertical limits of reservoirs in any given field by drilling wells and equipping them for production. As in the case of exploration the discoveries are evaluated. The higher the prices of oil the more it pays to drill the poorer discoveries and more oil is drawn from poorer discoveries.
(c) **Extraction**

The last stage in the production of crude is extraction. Extraction is drawing oil from an existing and fully developed field. Exploration and development costs are already sunk. The relatively small outlay for labour, fuel and power are practically independent of output. Therefore up to well capacity the more barrels produced, the lower the cost per unit. Over the remaining life time of the field marginal cost is a rising function of output. The basic fact about oil and gas production is the production decline curve. More oil can be produced either by locating new oil wells which work under natural drive or by extracting more crude from the existing wells by injecting either water or dry gas into reservoirs to increase crude flow. The former wells are called non-stripper wells and the latter stripper wells. In both cases marginal cost of producing additional oil increases. But in a large field much of oil can be produced at constant cost before the operators start approaching the thinner strata.

---

Therefore, the industry's cost function at any given time slopes upwards. Under any given conditions of knowledge, the more exploration is done, the higher will be the finding cost per unit. Similarly the more a given deposit is developed the higher will be the cost of additional development. Finally from the time the well begins to operate, the greater the output, the higher the cost of additional output.

When the industry's supply curve of crude slopes upwards, the optimal output that the industry can produce is that amount where marginal cost of the output is equal to the price. This price is also equal to the price of substitutes available for petroleum.

**Economies of Scale in "down-stream operations"**

The third characteristic of petroleum industry is that it has economies of scale in the down-stream operations. Transport of crude from the fields to the refineries, refining the crude and the marketing of the finished products - all these three activities are called "down-stream operations". There are economies of scale in each one of these stages.

In the short-run some of the total costs, such as fixed investment in capacity, investors return are fixed in amount.
They do not vary with output changes. We can see then average cost (AC) decreases over a range of output. Starting with a small output from the established plant, the company has a high average cost of production because the fixed costs are divided among only a few units. As the output increases the same or nearly the same total fixed cost is spread over more units of output and AC decreases. In the following diagram we can see that as the demand increases from $D_1$ to $D_2$ and $D_3$ the AC decreases until output is expanded beyond $OQ_3$.
Let us see how the economies of scale work in each of the down-stream operations.

(a) Transport

The unit cost of transport decreases with the increase in the amount of crude transported through pipe-line or by a tanker till capacity is reached. It is cheaper to transport crude in big tankers rather than in small ones. Because the cost of constructing a big tanker does not increase proportionately with the size. Similarly running costs do not increase proportionately with increase in size. So also in the case of pipe-line. The cost of construction of the pipe-line does not increase proportionately with the increase in the diameter of the pipe.

(b) Refining

In refining also it is said that by increasing the size of a refinery, costs of refining can be reduced until a throughput of 10 million tonnes a year is reached. But it is very rare for a refinery to start at this size.

---

4 See Duncan Burn, "Oil Industry" in Duncan Burn (Ed.) The Structure of British Industry, Cambridge University Press, 1958.
Increase in refinery output may increase the cost of obtaining crude oil and will increase the cost of distributing products.

(c) Marketing

Similarly the cost of marketing oil goes on falling as more and more oil is marketed because the fixed costs like cost of running a retail outlet are spread over larger units. Moreover there are economies of scale in the bulk transportation of finished products from the refinery to the market.

Economies of scale are common in all industries wherever there is large fixed investment of capital. When fixed capital is spread over larger and larger amounts of output the average fixed cost goes on declining up to a point. Then the rising average variable cost will lead to increasing average cost. But in petroleum industry the economies of scale are more significant in the sense that capital investment is not only fixed but indivisible to a certain extent. Therefore, the scale of operations in petroleum industry is much higher than in many other industries. There is a minimum scale of throughput below which it is not economic to build a refinery. That minimum throughput according to
Hartshorn is 7½ lakh tonnes a year. The capital investment is not perfectly divisible as in other industries. E.g. one can start manufacturing a commodity like textile at any scale. But in petroleum industry except at the production of crude the level of production will have to be very big. Therefore, when output is very small the indivisible costs are spread over smaller amounts of output, the average fixed cost per unit of output is very large. If output is expanded up to a certain point the same indivisible costs are spread over larger output and the average fixed cost goes on declining. This will have an impact on concentration of the industry by affecting entry.

Nature and Pattern of Demand for Petroleum Products

Another distinctive feature of petroleum industry is the nature and pattern of demand for petroleum products. It has a limited price elasticity; and demand for petroleum products is both derived and direct. The exact boundary between these two areas of demand cannot always be sharply drawn. One can use car services in part for direct satisfaction of personal wants, in part as an aid to further productive effort.

The significance of this distinction between direct demand and derived demand appears in their respective elasticities. A derived demand for petroleum tends to be both elastic and inelastic. It will be elastic in so far as fuel substitutes are available. But once investment is made for a particular machinery using petroleum products, the demand becomes inelastic. Here the elasticity operates more in the area of prospective consumption and much less on existing use.

Direct demand for petroleum products tends to be inelastic. Direct consumption of petroleum products in India is kerosene for lighting in villages and towns and for cooking in towns. In the absence of alternative energy for lighting, kerosene is the only cheap method of lighting. As it is, it will take still lot of time to electrify all villages in India. Even when electricity is available all the people cannot switch on to electricity. It is observed that unless a person crosses certain income barrier he will not switch on to electricity for lighting. For a long time to come the demand for kerosene for lighting purposes will remain inelastic. But that part of the demand for kerosene

6 Dhar N.P., Petroleum Industry and the Third Plan, Institute of Economic Growth, New Delhi, p.10.
which is used for cooking is elastic, because there are substitutes available like charcoal, wood, and gas. If the price change is very small, probably it will not affect the demand. Over small changes in price, we can say, the demand is inelastic. Elasticity operates over big changes in price in this case. Similarly the demand for gasoline is inelastic. Because once a person has purchased a car which can be treated as fixed cost including licence fee and insurance, the variable cost i.e. consumption of petrol including lubricants and tyres is very small. A person cannot use the car sparingly simply because the price of gasoline has increased as this cost constitutes a very small fraction of the total cost of running a car. But this does not mean that the price of fuel has no influence whatsoever on the amount used. If the price change is too big it certainly matters. But small changes in price make little difference. Yet with all these reservations and exceptions the direct demand for petroleum products is likely to be inelastic. However this line of reasoning cannot be pushed too far. This factor has made petroleum an ideal commodity to tax.
Risk and Uncertainty at the Stage of Production

Petroleum industry is also characterised by risk and uncertainty at the stage of production. Oil exploration involves risk and uncertainty. The first step in the production of crude oil is petroleum prospecting. This may take the form of hit or miss efforts known in industry as "wild-casting" or more rational scientific efforts. During the first half century of the oil industry prospecting was almost wholly a matter of random drilling. It was guided by surface indications such as oil or gas seepages or by a hunch. Today prospecting proceeds along more rational lines. An extensive geological and geophysical survey of the area is undertaken. This requires a lot of investment and the returns are uncertain. Whenever the geological conditions are favourable for the existence of oil, drilling is undertaken. But these scientific aids offer no sure formula for finding oil. Nevertheless they have reduced risk involved in exploration. Crude oil exploration is exactly the reverse of coal mining. It is easy to locate coal but costly to bring the coal up to the surface. In the case of petroleum it is very expensive to locate crude but easy and cheap to bring the crude to the surface. Therefore, once the oil is found there is an inducement to get back
one's investment as quickly as possible because the fixed cost of every unit of oil produced goes on decreasing with increase in production. The wells that produce oil will have to cover the cost of dry wells also. Whenever a company undertakes drilling in a particular area, it undertakes the risk that the oil may not be found there. This risk factor has led to another peculiar characteristic of the industry namely vertical integration.

Joint-Products

Another peculiar feature of the petroleum industry is the joint products. Crude petroleum occurs in nature as a mixture of thousands of complex hydrocarbons and in order to be utilised for fuel, power, lubricants, its components must be separated. Before the introduction of cracking in 1913 fractional distillation constituted the principal refining process. This distilling operation takes advantage of the fact that the various constituents of crude have different boiling points. According to this process different products like gasoline, kerosene, residual fuel oil are produced in fixed proportions. When the different goods are produced in fixed proportions and when demand schedules of these products are inelastic, one main product will bear the entire burden of the cost of the joint processes and
other products command low price. The former product is then known as main product and the others known as "by products". Before the introduction of cracking in 1913 in petroleum industry kerosene was the main product and after the introduction of automobile gasoline became the main product. The cracking process changed production function from fixed to variable proportions. When the proportion in which various petroleum products are produced can be changed in this way it is no longer appropriate to consider any product as main or by-product. These are all joint-products. This condition means that it is impossible to apportion all costs among the various products in such a way that the firm can draw up marginal cost curve for each output independently of the other. Under such conditions of production the optimal product mix is that point along the iso-cost contour at which marginal rates of product substitution become equal to the prevailing price ratios. Corresponding to any given composition of output there will be an unique set of relative prices compatible with an equilibrium in which profits are maximized.
Similarly to each ratio of prices there is an unique equilibrium ratio of output. E.g. given a price ratio of $a_1 : a_1$ there is one possible composition of output $\tan \alpha$. And given a product mix equal to $\tan B$, the equilibrium price ratio must be equal to the slope $b_1 : b_1$. The problem of imbalances in the production and consumption of various petroleum products can be avoided by adjusting the output of various products to their demands. But this is possible in the long-run when the design of the refinery can be

---

changed. Once a refinery is designed the proportion in which different products are produced remains fairly fixed. So in the short-run there is not much flexibility in the production of different products.

**Competition from Other Sources of Energy**

The seventh characteristic of petroleum industry is that it faces competition from other sources of energy. Petroleum industry faces competition from coal, electricity and atomic power. Coal, electricity and atomic power can be substituted within limits for many petroleum products except in road transport and in agriculture where tractors are used. Similarly nuclear power when available commercially will add to the total energy pool, but like coal will not replace petroleum products in special uses.

By and large petroleum is used as a fuel in various types of transport and equipment used in agriculture, fisheries, power generation and industry. Important non-fuel uses of petroleum are lubrication, bitumen for road surfacing and in the form of light distillates as a raw material for the chemical industry. The major modes of transport are road, rail, water and air. Of these in road and air transport one or the other products of petroleum is the only fuel in use at present. Moreover, the dependence
of these modes of transport on petroleum is not likely to become less in the near future.

In rail transport in most of the countries coal burning steam locomotives have been replaced by either diesel or electric locomotives. Diesel and electric traction is considered to be more efficient. In India what type of traction should we adopt is a big question. Since we are short of petroleum resources in India, the only alternative seems to be electrification of railways on a large scale. In this connection a study made by NCAER will be of interest to us. This study has shown that electric traction is capital intensive compared to diesel traction. Therefore any decision to choose electric traction in preference to less capital intensive diesel traction would have to be made in relation to the quantum of traffic likely to arise over given sections of the railway. The study has shown that at traffic density of less than 13-18 Gross Tonne kilometres, diesel traction is more advantageous. Therefore, at present diesel traction is preferred to electric traction.

---

8 See NCAER: Economics of Diesel and Electric Traction, NCAER, New Delhi, 1970.
Similarly there is less scope for substitution of other fuels for petroleum in agriculture. Tractors are run exclusively on petroleum. Even in the operation of pump sets where electricity can be used a vertical stroke pumpset run on 'High Speed Diesel Oil' has an advantage over an electricity run pumpset.\textsuperscript{9}

Only in the generation of electricity coal has an advantage over furnace oil except in Southwest of India.\textsuperscript{10}

In conclusion we can say that in road, water and air transport petroleum has no substitute and its use would continue there. Tractors in agriculture and fishing crafts also fall in this category. In the case of rail transport use of petroleum fuel for traction would be to the overall advantage of the economy. Electrification of pumpsets is less advantageous than the use of oil engines.

When different sources of energy can be substituted, the cost of energy from all these sources in any use, where any one of these energies can be used, should be the same.

\textsuperscript{9} Singh J.P., "Petroleum or Coal", MARGIN, April, 1972. 
\textsuperscript{10} Ibid.
Similarly an economy which is investing in energy should invest in all these sources of energy in such a way that marginal cost of energy from all these sources is the same after making allowance for risk and uncertainty.

Therefore, a national policy for oil will have to take account of other sources of energies like coal, natural gas, hydro-electric power. The oil policy can be viable only as part of a comprehensive national policy dealing with all forms of energy.

The answer to the question which of these sources of energy is cheapest depends on the resources of a country. In a country where petroleum resources are abundant petroleum will be the cheapest source of energy. But in a country where petroleum resources are scarce other sources of energy will be cheaper compared to petroleum.

**Storage**

The eighth characteristic feature of petroleum industry is in respect of its storage. The petroleum products can be stored for a long period of time. Therefore, there are no problems of off-peak load as in case of electricity and transport. Production can go months in advance of demand. The problem of idle capacity as in electricity where capacity
should be able to meet peak-load demand does not arise in petroleum industry. The problem of storing the product arises at different stages of production. There is no problem of storing the crude because the best way of storing it is to leave it underground and go on producing only the required quantity. Next the problem of the storage arises at the time of transportation of finished products at the transport terminals. Finished products are also stored at retail outlet level. The purchase of these products is in small amounts but there are significant economies in the bulk transportation of these products. When they are transported in large quantities and sold in extremely small quantities, they will have to be stored. Seasonal demand also imposes a need for storage.

Concentration and Vertical Integration

The ninth characteristic of petroleum industry is concentration and vertical integration. The industry is highly concentrated and vertically integrated on an international scale. Extraction of crude, refining and distribution outside Russian sphere are largely in the hands of small number of large international firms of complex structure.
Large scale production at the level of production of crude reduces risk because the probability of getting oil is more when the number of wells is more.

Similarly by vertical integration the investment in each stage is made more secure. An enterprise involved in all phases of the industry has a greater prospect of economic survival than have those working on one or two levels only.

This high level of concentration and vertical integration has an important bearing on the pricing policies pursued by the oil companies. Osborne distinguishes two types of pricing behaviour in an oligopoly. One is Chamberlian behaviour and the other is Harrodian behaviour. In the first case the established firms ignore potential entry and set the price higher than the limit price. This attracts new entrants. In the second case established firms charge the limit price and exclude entry. Which of these two pricing behaviour is profitable depends upon the entry barriers to the industry. He suggests that in industries with very high barriers to entry firms will find their

---

greatest profits in Barrodian behavior. It should be noted that petroleum industry is best suited for this type of policy because the entry barriers in this industry are very high. Large capital requirement acts as a barrier in this industry. Therefore, petroleum industry satisfies all the four conditions which Osborne mentions in order to make the entry effectively impeded. They are:

(1) Technology must not be rapidly changing.
(2) Demand must not be rapidly growing.
(3) Minimum profitable output of entrants must be a significant portion of the industry's output. If not new firms can enter at a small scale changing market price little or not at all.
(4) Potential entrants must face significant non-scale economy disadvantages relative to established firms. This may appear in the form of the magnitude of capital requirements.

All these four conditions are present in petroleum industry. This is true of the international petroleum industry as well as the national petroleum industry where the industry is in the private sector. At the international level the industry is dominated by the seven big international companies. And in many countries where this
Non-renewability of Raw Materials

Another characteristic feature of the petroleum industry is the non-renewal nature of its raw material petroleum. In fact all minerals are non-renewable. But in case of petroleum and fuels like coal, recycling is also not possible. The fuel resources are destroyed when they are used. In case of metals however recycling is possible. In fact 20 per cent of the world's production of aluminium, 35 per cent of the world's steel production and 40 per cent of the world's production of copper are derived from recycled scrap.\textsuperscript{12} With improvement in technology this proportion can be increased. In case of fuels however recycling is not possible. Therefore, petroleum belongs to the category of non-renewable and non-recyclable resources.

In any country and the world as a whole certain amount of petroleum resources are available either in the form of known or unknown reserves. But, even though

theoretically reserves are fixed in amount, economically
they are variable. Because a certain proportion of
the known reserves is economically recoverable under
certain conditions. Some of these reserves may not be
recoverable at current prices and at current technology.
When prices change or technology improves these reserves
may become recoverable. Therefore, scarcity of any
resource is not the absolute scarcity in the Malthusian
sense but of a relative scarcity in the Ricardian sense.
The production of petroleum from tar sands and shale is
possible but it is costly and becomes economical only at
a higher price of oil. Therefore, the concept of reserves
tends to be elastic.

But if we take sufficiently long term point of view,
the increasing rate of consumption of petroleum might
exhaust all the reserves sometime in future. According
to Connelly and Perlman that time is far off and it may
not happen within next century. This may be postponed
by "feed back" mechanism which links scarcity to
consumption.

Implications of all these features for pricing of
petroleum form the subject matter of the next chapter.