**CHAPTER EIGHT:**

**INVENTION, INNOVATION AND DIFFUSION**

In this chapter we are going to discuss about the analysis of innovation and research and development (R&D) activities which are quite prevalent in manufacturing and other business circles. *Innovation is one of the several strategies through which a firm could change its situation in the market in pursuit of its objectives*. It is an instrument, which the firm uses to enhance its competitive power in the market. It provides a basis for greater degree of diversification and hence growth of the firm. The major elements of innovation or technological change, such as,

* New products,
* New methods of production,
* New markets and
* New forms of industrial organization etc,

These make the firms and industries to run efficiently over time. Recognizing such role, J.A. Schumpeter took innovation as "the fundamental impulse that sets and ­ keeps the capitalist engine in motion". He found innovation as the out­standing fact in the economic history of capitalistic society. Innovation is not confined to such a society only. It is a common feature in almost every economic system whether capitalistic or socialistic or something else. Science and technology become operative through innovation.

In the modern world,

An individual wants to be ***more creative***,

A firm or corporation strives for the ***progressiveness*** of its business and

A government works for the collective ***security and welfare*** of masses. Innovation is an important weapon for all these. In fact, survival of mankind depends to a great extent on innovation, particularly in the fields ofmaterial requisites oflife.

 ***What are the sources of innovation?***

Innovation in business is achieved in many ways, with much attention now given to formal (R&D) for "breakthrough innovations." But innovations may be developed by less formal on-the-job modifications of practice, through exchange and combination of professional experience and by many other routes. The more radical and revolutionary innovations tend to stem from R&D, while more incremental innovations may emerge from practice - but there are many exceptions to each of these trends. Another key source of innovation is user innovation, innovations developed by individuals when existing products do not meet their current needs.

**8.1 The process of innovation: Concepts and Relationships**

The terminology of innovation consists of a set of interrelated terms. The first and perhaps the most important one is the concept of *invention*.

 ***An invention is the creation of the new technology***. By 'techno­logy' we mean any tool or technique, any product or process, any physical equipment or method of doing or making, by which human capability is extended. It is an intellectual act which involves a perception of a new image, of a new connection between old conditions, or of a new area for action. All inventions, big or little, are made for some practical uses. ***The process of adopting an invention in a practical use is called innovation*.** It is the implementation of a new or significantly improved idea, good, service, process or practice that is intended to be useful.

 If the existing product line is changed by a firm, i.e. it introduces a new product with or without dis­placement of the old ones, and then it is defined as ***product-innovation.*** If a new method is initiated to produce existing products then it is ***process­ innovation.*** Both of these are the elements of ***'technological innovation'***. When a firm makes changes in its marketing strategy we define that as ***'market-innovation'***.

Similarly, there may have innovation in organizational practices, financing and any other aspect of business conduct. The concept of innovation is, thus, very broad. The entrepreneur or manager when performs the act of innovation is called '***innovator***'. He invests resources for the innovation and takes the risks involved in that. This is a very important role, indeed a pivotal one, for the growth of industries. ***Innovation occurs when the entrepreneur believes that it is worthwhile to commercialize the invention***. Schumpeter identifies five types of innovation, viz

1) The ***introduction of a new good*** —that is one with which consumers are not yet familiar—or of a new quality of a good.

2) The ***introduction of a new method of production***, which need a discovery scientifically new, and can also exist in a new way of handling a commodity commercially.

3) The ***opening of a*** ***new market*** that is a market into which the particular branch of manufacture of the country in question has not previously entered, whether or not this market has existed before.

 4) The ***conquest of a new source of supply of raw materials*** or half-manufactured goods, again irrespective of whether this source already exists or whether it has first to be created.

5) The ***carrying out of the new organization*** (the reorganization of methods of operation) of any industry, like the creation of a monopoly position or the breaking up of a monopoly position.

Another useful concept related to the innovation process is 'imitation'. It is a situation when an innovation is copied by others. That is, the inno­vation spreads across the market. In other words, we call it **'diffusion of the innovation'**. Such diffusion may be rapid or slower depending on the market situation, but it will be easier or safer than the act of innovation.

The three terms -invention, innovation and diffusion -are the succes­sive stages of the process of innovation or technological change. Diffusion is not possible without innovation which in turn is not possible without invention. The entire process of change, i.e. from invention to imitation, comes under research and development (R&D) activity of the firm.

**8.2. Stages of Technological Change**

**The first stage (*Invention*)** is carried on by indivi­duals or corporate bodies like research institutes, universities, government bureaus and companies- the source of invention. It is just like any other corporate activity such as sales or production where certain inputs are used to get some output in a broad sense; we may call invention as output of the research industry. If so, an invention will be a goal-oriented activity. A government or corporation will be making invention for solving some social problem or for the sake of extra profits or money. To achieve the goal of invention a series of steps will be taken beginning from the definition of the problem, the alternative routes to its solution and finally the output in the form of the invention. It is an orderly sequence, a matter of applying conscious intelligence to the solution of the problems. The ‘output’ of the process may not come during the stipulated time. There may be frustration, delay, failures, etc., but the process of invention goes on. In general invention can be taken as an orderly, intellectual, goal oriented process, a fundamental one, for the innovation or technological change in a society. It does not usually move in a straight line according to the plan, but takes unexpected twists and turns to reach the destination.

**The Second stage *(innovation)*** is a logical extension of invention. When an invention is made, its fruits are made available to the society through innovation. An entrepreneur or corporation comes forward, makes the required investments for the innovation. As mentioned earlier, innova­tion may be in product or process of manufacturing or any other activity of the corporation. It involves risks and uncertainties. An innovator bears them and it is precisely on this ground that economists justify existence of excess profits for him. *Process-innovation* and *product-innovation* are two important types of innovation.

***Process innovation*** arises when relative prices of factors of production change. If labour becomes costly, the firm may think of cost saving by adopting capital intensive technique and vice-versa. In the familiar isoquant framework, it implies a movement along the isoquant when the input prices change. There will not be any R&D expenditure involved in this, as technology will not change. Only the equili­brium situation for the least cost combination of inputs changes. Further, if technology changes this means a new production function causing a shift of the isoquants. In this situation, the need for process innovation is obvious. The input proportions to produce a given level of output will change if there is technological change giving rise to the process innovation.

***Product innovation*** is necessitated because of a variety of reasons. Primarily, a product change may be stimulated either by a new technology or by a change in relative prices of existing products. Changes in consumer preferences and cost of production- are the sources of change in relative prices of the products. If a product is costly for the firm and at the same time its price declines in the market because of unfavorable circumstances, it will be less profitable and, hence, is likely to be replaced by a new one.

The process of innovation has a well defined goal and the adaptation of the new technology or product to achieve the goal is an orderly management function of the firm.

**The third stage (*Diffusion*)** is the imitation of innovation. The innovation, initiated by an innovator, spreads in the market. The rate of diffusion depends on market structure. If there are rigid patent practices and the government assistance in technological progress is negligible, then we expect a low rate of diffusion of the inno­vation. On the other hand, if technology is freely available, there are no rigid patent practices and investment requirements for the new technology are not alarming, then the rate of diffusion will be fairly high. From social point of view diffusion or spread of the innovation is desirable but from an individual firm & point of view it is not, as the firm would not be able to maintain its gains through innovation when it is imitated by its rivals.

**8.3 Measurement of Innovation Activities**

We need precise measurement of inno­vation like any other economic activity. There is no unique method for this. Researchers in the field tackled the problem by measuring either the ***inputs*** (i.e. total cost or some component of it in money or physical terms) put in the process of R&D or the ***output*** of this activity. The most simple and widely used method is to take the ***statistics of R&D expenditure***, absolute or a proportion of total annual budget of the firm, as a measure of innovation activity. The assumption for this method is that larger the volume of R&D expenditure more will be the activities in innovation. This method is useful if all R&D activities are in organized form. There may be significant contribution by the individuals or departments of the firm which do not come under R&D unit. How to measure their contribution is a problem. At present it is generally ignored and available statistics on R&D is used simply to measure the innovational activities.

There is another method in which the number of scientists and engineers in the R&D department is taken as a measurement of innovational activities. The assumption in this case is that the greater the number of such personnel the more will be the R&D activities of the firm or research organization. This measure has limitations similar to the R&D expendi­ture. Contributions made by non-scientists or non-engineers are not captured by this index.

From the output side one may use either the number of patents issued or sale of new product as appropriate measurements of innovation or R&D activities. Taking number of patents as a measure of innovation has some draw backs. Patenting generally refers to invention stage. It does not reflect innovation and diffusion stages properly. Further, all in­ventions are not patentable equally. Large firms doing research may avoid patenting of their inventions in order to escape from monopoly regulation practices. They may keep their inventions secret for long time, as we observe in drug industry, by not registering the patents since a patent can be bought or copied by rivals. Further, patenting is more appropriate for product innovation. In the case of process innovation it does not fit properly. Patent system does not reflect the quality of innovation also. On the whole, taking number of patents as a measure of R&D activities is a partial index. In spite of its drawbacks the index is popular for empirical studies.

The index of *sales of new product* is another measurement of R&D output. But this is again a partial index reflecting the side of product inno­vation. It does not take into account changes in the process of manufac­turing and saving of costs arising as a result of innovation.

**8.4 The Theory of Technological Innovation**

Attempts are being made by economists to identify the conditions (or determinants) which encourage initiation and adaptation of a new technology. To begin with the identification of such conditions, we may pose a simple but basic question related to the technological innovation.

Why do scientists or engineers or anybody else make invention?

 In a different way, we may ask this question as:

 Why is a huge amount of money being spent on R&D activities all over the world? The answer to this question is straight forward, that is, inventions are made because there is a need for them. Fast moving modes of transportation came into existence because there was need for them. Radio, television and hundreds of other inventions were made with some purpose. Through inventions and their commercial exploitation man controls his environment. An invention without commercial exploitation for personal or social uses cannot be viable. Given this basic proposition of need which backs up inventions, that, makes them goal oriented, we have to identify the conditions which are conducive or which accelerate the pace of invention and innovation or broadly the technological change in economy. Since we are concerned with the study of the economic behavior of firms, and industries in this course, we will therefore examine the determinants of R&D intensity in this context.

The first and most intensively debated determinant of R&D is the *market structure* of the industry. Particularly, the elements of market structure such as the degree of market power and absolute size of firms were used in theory and empirical work on R&D behaviors of the firms and indus­tries. Perfect competition and monopoly were taken as two extreme contrasting situations to analyze the link between innovational motivation and market power. To test this link, the major hypothesis was put forward by Schumpeter who argued that a monopoly firm has a greater demand for innovations because its market power increases its opportunity to gain from them. This assertion has not been accepted by the economists unanimously. At present they are divided into two opposite schools, such as

* ***Competi­tive pressure school*** and
* ***Monopoly profit school***.

The *competi­tive pressure school* argues that in an atomistically competitive situation, with its strong tendency for a uniform normal rate of profit, there will be great pressure and hence inducement for making cost-saving innovations. Such pressure diminishes as market power of the firm increases and so the rate of innovation will be inversely related to the degree of market power.

The *monopoly profit school* does not agree with such contention. It argues that since innovation is risky, it will not be undertaken in atomistically competitive markets where the gaps from innovation will be momentary. According to this school, the conditions for sustained R&D activities are best provided by the monopoly or concentrated markets. Through R&D activities a firm gains and acquires monopoly power over its rivals. The firm would like to perpetuate its monopoly power by undertaking new innovational activities. There is thus a positive relationship between the rate of innovation and the degree of monopoly power as conceived by the monopoly profit school. Normally, large firms in industries will be having considerable monopoly power. They will be capable of providing adequate resources for R&D and taking the associated risks. The monopoly power and large absolute size are thus complementary attributes which are relevant determinants for R&D activities. Taking this view in mind we may summarize the stand of the monopoly profit school as “… the greater the profits and the degree of market power or firm size, the greater should be the efforts to innovate.”

Another important factor that affects the rate of innovation is the nature of the elasticity of demand for the product or products of an indus­try. Rapid technological changes are seen in the industries' having elastic demand. Most of the luxury goods industries fall in this category.

 We know the link MR = P [1-1/ed]

Where;

 MR is marginal revenue,

 Pis price and

edis price elasticity of demand.

This equation shows positive marginal revenue when elasticity of demand is greater than unity and negative marginal revenue when edis less than unity. MR will be zero when ed= 1.

Suppose there is process innovation such that cost of production reduces. By a reduction in cost of production the firm position to reduce product price in order to get more revenue (i.e. positive MR) if elasticity of demand is more than one. The firm will do so. It is beneficial to the firm as well as to the consumers of the firm since they pay less price for the product now and the firm gets more revenue. Thus, there will be more inducement for innovation when price elasticity of demand for the products of the firm or industry is elastic.

R&D intensity also depends on diversification. The basis for this relationship is that a more diversified firm will be in a better position to exploit unexpected research outputs than the one having a narrow base of operations.R&D activities also show strong positive association with growth of output of a number of industries. R&D activities are committed intensively where the growth prospects are good and profits are likely to be high. However, there may be an upper limit for such positive relationship. A stage will come when a product reaches ‘maturity’ stage of its life cycle with no more growth prospects. At this stage, the firm has to go through intensive R&D activities in search of a new product or products to replace the old one. The relationship therefore may not hold true or it may be negative after such stage is reached. Yet another factor that we may mention here as a determinant of R&D behaviour of the firm. We have discussed the general factors that determine the R&D behaviour of a firm or industry.In brief, we may say that R&D activities of a firm depend on

1. market structure,
2. size of the firm,
3. technological opportunities,
4. nature of elasticity of demand for the products of the firm,
5. the degree of diversification,
6. growth of market, and
7. Expec­ted return on R&D investment.

 The list of determinants is not exhaustive. There may be more depending on specific situations. The material presented above gives us a fairly good description of the theoretical determinants of R&D activities of the firms. There are many analytical models suggested by the economists for determinants of R&D. Let us review one of them.

**Dasgupta and Stiglitz Models**

Dasgupta and Stiglitz jointly produced exhaustive theoretical material related to the relationship between industrial structure and the nature of innovating activities. The basic stand taken by them in their analytical frame­work is Neo-Schumpeterian in nature where, except in the short run, both market structure and the nature of inventive activity are endogenous. They are determined by some more basic factors, such as the technology of research, demand conditions, the nature of capital market, i.e. market rates of interest and the ability of firms to borrow to finance R&D outlays, and the legal structure related to patent rights. To analyze the R&D behaviour, the authors postulated market situations such as the socially managed market, the pure monopoly, the imperfectly competitive markets like oligopoly with free entry, oligopoly with barriers to entry, and duopoly. Both, certainty and uncertainty situations were considered by them sepa­rately in developing the R&D behavioral models. The equilibrium conditions derived by them for different market situations are based on maximization of gains from R&D activities. The major conclusions established by them are:

1. Even when, market structure is endogenous, if the degree of concen­tration in industries is small, industry-wide R&D effort is positively correlated with concentration. When the degree of concentration in industries with free entry is small, R&D effort per firm, and therefore cost reduction, is often positively correlated with concen­tration.

2. High degrees of concentration are by themselves not an evidence of lack of effective competition.

3. Both optimal R&D expenditure and R&D expenditure per firm in a market economy increase with size of market. They decrease with increasing cost associated with R&D technology if demand is elastic and increase with increasing cost if demand is inelastic.

4. If there are barriers to entry, an increase in the number of firms would result in a decrease in R&D expenditure per firm in a market economy, although industry output/would increase, and therefore, the degree of monopoly would decrease.

5. There is some presumption that cost-reducing in an industry in a market economy, even when there is free entry, is less than the socially optimal level.

6. If demand is highly inelastic, total R&D expenditure in an industry with free entry exceeds the socially optimal level.

7. There may be excessive duplication of research effort in a market economy in the sense that industry wide R&D exceeds the socially optimal level even though cost-reduction is lower.

8. In the case of process innovation, a good case can be made for encouraging investment in risky research projects, even if society is risk-averse.

9. A pure monopolist appears to have insufficient incentive (a) to undertake R&D expenditure, and (b) to engage risky research ventures.

10. Since the mark6t power of a firm increases as its cost advantage over its rivals increases, there is a presumption that competitive markets encourage firms to engage in overly risky research projects.

11. Pressure of competition may result in excessive speed in research and, in general, there is no presumption that a market economy has a tendency to generate inefficient information.

As one may infer from these conclusions, the extreme ends of market structure, e.g. pure monopoly and perfect competition, may not provide significant incentives for R&D activities. The type of market structure between these two extreme forms such as duopoly, oligopoly and mono­polistic competition are likely to provide the incentives as well as competi­tion for R&D activities of the firms.

**8.5. Innovation and Employment**

Although innovation leads to benefits for society, it does not necessarily follow that every member of society gains. Since welfare has increased overall, in principle the gainers could compensate the losers. However, while the benefits are generally spread thinly over consumers as a whole, the losses may be concentrated on just a few. The latter may well resist such a change. Analysis of the effects of innovation on the employment of factors of production will identify groups likely to suffer a loss of welfare as a result of change.



**Figure 8.1The impact of a process innovation on factor employment in a perfectly competitive industry**

Figure 8.1 shows the impact of a process innovation in a perfectly competitive industry. Demand and supply curves for the product are shown in the upper part of the diagram. Initially the market price and output are OPl and OQl respectively. The corresponding derived demand curve for labour (Nl) is shown below the horizontal axis. (It might equally well have shown the derived demand for capital). Before the process innovation, OLl units of labour are required to produce quantity OQl.The process innovation, by reducing marginal cost, shifts both the demand for labour schedule and the market supply curve to N2 and S2 respectively. If the effect of the new production method leaves the capital-labour ratio unchanged then the demand for both factors of production increases. In this example, labour demand will increase from OLl to OL2,with a similar increase in the demand for capital. Alternatively, if the change results in a higher capital-labour ratio, then the demand for labour will fall. This is shown by the post-innovation demand for labour curve N3 in Figure 8.1, with employment falling toOL3.

Assuming perfect knowledge and homogeneous factors of production the reduction in welfare suffered by displaced factors will be transitory as they will be rapidly re-absorbed into the economy. With imperfect knowledge, it may take time for displaced factors to find alter­native employment. Also, the expanding industries may require different labour skills. Technological unemployment can arise if the growing sec­tor requires skills highly specific to the new technology but displaced labour is skilled in more traditional trades. When skills become redundant, the value of human capital is reduced. Social problems may also arise, particularly if the industries adopting labour-saving innovations are regionally concentrated.