CHAPTER II

CONCEPTUALIZING ISSUES OF TECHNOLOGICAL CHANGE WITH REFERENCE TO UNDERDEVELOPED ECONOMIES
2.0 INTRODUCTION

From the beginnings of the modern discipline, economists writing about economic growth have recognized technological advance as its key driving force [Smith, 1776; Marx, 1867; Schumpeter, 1911]. In the 1950s and 1960s, many studies tried to measure the contribution of technical change to economic growth in countries operating at the frontiers of technology [Solow, 1957; Denison, 1962]. The conclusion was that technological advance accounted for the lion's share of growth in worker productivity. Since that time, a vast empirical and theoretical literature has grown up on technological progress in the advanced industrial nations.

More recently, a number of economists have turned their attention to the mechanisms of technological advance in the development of economies that, initially at least, have been far behind the frontiers. Science, technology, and innovation have played a central role in the economic and industrial development of East Asian NIEs. The technological strengths within the region are considerable and rapidly growing [Dodgson, 2000]. The acquisition and progressive mastering of technologies that are new to them, if not to the world, obviously has been a central aspect of the newly industrializing countries [NIEs] that have grown so rapidly over the past thirty years [Pack and Westphal, 1986; Kim, 1997]. Since the early 1960s, countries such as Korea, Taiwan, Singapore, and Hong Kong have transformed themselves from technologically backward and poor to relatively modern and affluent economies. The success of the region and the policies pursued for technical development hold lessons for other areas of the world [Hobday, 1995], especially the underdeveloped economies [UDEs] where the non-application of and/or failure in applying technology has left them in varying degrees of stagnation [APCTT, 1986a:8].

The way the application of technology in developed nations has caused beneficial changes in their population, income, employment and the demand-pull effect of technology advancement [APCTT, 1986a:8], UDEs may also target to emulate the demand-pull technology development of developed economies [DEs]. But prior to that, UDEs should make a judgment of the background factors which are necessary to entertain a DE-kind of technology development. UDEs should look for areas of specialization to gain greater advantage and ultimately follow a by-passing way to technologization. A UDE must take its resource, time and marketing constraints into consideration, and thus, should go for choosing a strategy for technology development [APCTT, 1986a:27]. Therefore, instead of emulating the demand-pull technology development, today's developing nations need to avail of the technology push
toward technological transformation. In consideration of all the inherent factors in UDEs, this Chapter attempts to explore the present state of technology development in the UDEs with prior conceptualization of the term ‘technology’ and thus work on fixing the strategy and pattern of technological development in UDEs.

Due to conceptual ambiguity of ‘technology’ in a specific form, this Chapter commences her journey with characterizing technology and its progress as has been dealt with in different literature. Prior to this, the Chapter conducts a brief survey of literature to define the term ‘technology’ and, thus, identify the position of the UDEs in exploiting the ‘components’ for its growth [section 2.1]. Instead of searching for an accurate definition of technology, the Chapter attempts to characterize the process of ‘technological progress’ in relation to the UDEs [section 2.2]. In order to conceptualize the process of technical change in terms of the usage of factors of production, the Chapter then makes an analysis of the forms of technical progress and relates the discussion with some empirical examples to check the validity of the theoretical propositions in practice [section 2.3]. In continuation of this process, Chapter II makes an extensive study on the ‘Growth Theories’, both neoclassical and endogenous, and, thus, sorts out the factors causing technical progress [section 2.4]. Due to particular importance in this study, part 3 of section 2.4 makes a thorough study of ‘vintage models’ and points out the strengths of these models in explaining the ‘catching up’ and ‘technology gap’ issues of the UDEs. In order to explain the theoretical proposition of ‘dated labor’, the Chapter discusses the issue of ‘technical capability’ [TC] and the factors that influence the pattern of TC-development with reference to the UDEs [section 2.5]. Since UDEs mostly rely on imported technology, section 2.6 makes a discussion on the processes of technology transfer in relation to the UDEs. Section 2.7 presents an analysis of the processes of acquiring technology acquisition capability by a UDE. The Chapter ends with a discussion on the ‘optimal technological strategy’ for a UDE [section 2.8] followed by concluding comments [section 2.9]. For better understanding of the techno-economic issues and problems prevalent in the UDEs, relevant country-experiences, especially of the Asian NICs, are highlighted throughout the chapter.

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1 By definition, East Asia includes the ASEAN nations, China, Japan, Korea, and Taiwan [Dodgson, 2000].
2.1 CONCEPTUAL EVOLUTION OF 'TECHNOLOGY'

2.1.1 Defining 'Technology'

As technology can be embodied in various forms, such as machinery equipment, documents, process and skills, it conveys different meanings to various people under different context [Islam & Haque, 1994:7]. In order to avoid any ambiguity, technology is defined with respect to different contextual situation, eg, origin, purpose, characteristics, etc. Therefore, the definition of technology can vary from the very general to serving a very specific function [Virmani & Rao, 1999: 22].

Historically, 'technology' comes from two Greek morphs: 'Techne' and 'Logos'. 'Techne' means the skill or craft needed to make something; 'Logos' means discussion [or knowledge] of something. This knowledge can be visualized in figure 2.0 below.

Figure 2.0. Concept of Technology

![Diagram of Technology Concept]

Technology covers both the physical process for transforming inputs into outputs and the arrangements for organizing this transformation [Rao, 1997:31]. In more specific terms, technology can be defined as 'the combination of types of knowledge indispensable to carrying out the necessary operations for transforming the factors of production into products, the use of that knowledge or the provision of services' [Virmani, et. al, 1999]. One can also use the term 'technology' to refer to new and better ways of achieving economic ends that contribute to economic development and growth [Stewart, 1992].
However, there is no doubt that technology is man-made. It is a means to enhance the physical and mental capabilities of human beings. Some special features of technology are [Islam, et. al., 1994:7]: 1] it is produced in R&D institutes of both private and public sectors; 2] it has market value; 3] it is not given away free; 4] its price depends on bargaining strength; 5] it is a new form of currency; 6] it provides comparative advantage.

Today, a very broad definition of what constitutes technology has come into vogue as is evident in figure 2.1 below. In the figure, technology includes not only process technology [the narrow and traditional view of technology] but product technology as well as financial, marketing technologies and quality control.

Figure 2.1. Broader Concept of Technology

Technology can be understood as information or knowledge related to production. It exists in the form of tangible technology codified in blueprint and/or tacit knowledge embodied in plants, parts and components, human factors such as labor skills and firm-specific assets such as trade-secrets and organizational structure of the firm. In other words, technology in this sense encompasses various aspects of a firm's activities ranging from the production.

[Source: UNCTC, 1988]
know-how to operation technique and even to organizational structures of the firm [Suh, 1996]. Finally, in whatever way technology is defined, it is certain that ‘technology’ contributes to economic growth. Technology is a process of accumulating material wealth by transforming the natural world into a man-made world [Chopra, 1992]. This conversion is achieved through a series of transformation activities or through what may be called, the production system of a country [ESCAP, 1989:15]. If any transformation activity leading to the production of economic goods is examined, it becomes evident that it can be described in terms of four elements, namely: inputs, outputs, the technology used for transforming the inputs into outputs and the national climate influencing the performance of the transformation activity.

2.1.2 Technology Components

We begin by re-emphasizing that technology is a human-made resource which transforms the ‘natural world’ into a ‘man-made world’. The production system of a country is the key ‘actor’ in transforming natural resources into produced resources. Since technology is the transformer of natural resources into produced resources, a clear understanding of its elements and scope is essential. Many UDEs tend to treat technology as a “black box” [Rosenberg, 1982] without paying adequate attention to its characteristic features. This has led to a situation where important decisions pertaining to technology development are often made in a cursory manner [Sharif, 1995]. Therefore, to facilitate technology-based development, it is important to appreciate the various basic components of ‘technology’ so that it is not entirely considered a black box [Waluzzaman et al., 1993:10]. When one ventures into the so-called “black box” and thus looks into the complex process for the transformation of resources, it is possible to discern four basic components of technology. These are presented below:

2.1.2a Technoware: Object-embodied Technology or Physical Facilities

Technoware includes such things as: tools; equipment; machineries; vehicles, structures, etc. Technoware implies human powers and controls for transformation operations. In a business enterprise, technoware changes through a process of periodic substitution of old by new. In general, the degree of technoware sophistication corresponds to the increasing complexity of the physical facilities for transformation operations and other functions. Here, complexity may be due to scale of operations; the interrelationships among

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2 A relevant discussion has also been done while analyzing Technological Capability issues in section 2.5.
operations; scope of outputs; types of conversions; energy requirements; quality of outputs; the safety or environmental soundness of operations; etc. [for examples, see table 2.1].

2.1.2b Humanware: Person-embodied form of Technology or Human Abilities

Humanware includes human abilities such as: skills; craftsmanship; expertise; proficiency; dexterity; and creativity. Without relevant humanware, technoware is simply useless. Humanware changes through a process of the progressive learning of new things. Usually, the degree of humanware sophistication indicates the increasing level of competence of all individuals engaged by the enterprise. Here, competencies may be defined in terms of: skill level [derived from general education and specific training]; appropriateness of training; achievement orientation; extent of relevant experience; productivity orientation, creativity potential, and the motivation of the personnel; etc. [for examples, see table 2.1].

2.1.2c Inforware: Recorded Facts or Document-embodied Accumulated Knowledge

Inforware refers to: facts and formulae; design parameters; specifications; blueprints; manuals; theories; relations, etc. Inforware enables quicker learning and saving in terms of time and resources. Inforware changes through a process of the cumulative acquisition of knowledge. Conventionally, the degree of Inforware sophistication represents the increasingly increasing utility of an up-to-date knowledge base acquired for various enterprise functions. Here, utility depends on: nature and type of knowledge [relevance, timeliness and reliability of facts and figures]; ease of retrieval of stored knowledge, extent of networking for updating; etc. [for examples, see table 2.1].

2.1.2d Orgaware: Institution-embodied Technology or Organizational Frameworks

Orgaware is exemplified by: methods; techniques; organizational networks; management practices; linkages, etc. Orgaware is basically for the coordination of activities and for resources utilization towards achieving desired results. Orgaware changes through a process of evolving arrangements and practices. Generally, the degree of orgaware sophistication dictates the increase in value addition, and represents an increasing use of new management techniques, methods and relationships for the market competitiveness and self-reliance of the enterprise. Here, different schema relates to: job formulation; job facilitation; job conventions; task modifications; etc. [for examples, see table 2.1].
**Interaction of the Technology Components:**

In any resource transformation, all four components of technology are required simultaneously. No transformation can take place in the complete absence of any of these components. This simultaneity requirement can be summarized as follows:

Most sophisticated technoware often comes with built-in humanware and requires advanced Inforware. Labor intensive technoware requires higher skills and greater labor discipline. Knowledge resides best in well-written, illustrated and complete documents, which can be used by enterprises for competition. Knowledge which is not documented is not Inforware, but humanware. Knowledge is distinct from information in that it allows the owner to do something [know-how] or explain something [know-why]. The usefulness of Inforware depends upon the qualifications of the humanware. Orgaware frameworks which are not implemented are not orgaware, but merely Inforware [Sharif, 1984].

Therefore, the development of a generalized classification of the four components of technology in terms of increasing levels of sophistication would be of value in understanding and analyzing the behavior and characteristics of transformation facilities.

**Table 2.1 Sophistication Levels of Technology Components with Examples**

<table>
<thead>
<tr>
<th>Components</th>
<th>Level of Sophistication</th>
<th>Some Illustrative Examples</th>
</tr>
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<tbody>
<tr>
<td>Technoware</td>
<td>Manual Tool</td>
<td>Hand drill</td>
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<td></td>
<td>Powered Equipment</td>
<td>Power drill</td>
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<td></td>
<td>General Purpose Machines</td>
<td>Centre Lathe</td>
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<td></td>
<td>Special Purpose Machines</td>
<td>Air jet weaving loom</td>
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<td></td>
<td>Automatic Machines</td>
<td>Soft drink bottling plant</td>
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<td></td>
<td>Computerized Machines</td>
<td>Bar code sensing cash register</td>
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<td></td>
<td>Integrated Facilities</td>
<td>Computer chip manufacturing</td>
</tr>
<tr>
<td>Inforware</td>
<td>Familiarizing Facts</td>
<td>Brochure</td>
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<td></td>
<td>Describing Facts</td>
<td>Technical booklet</td>
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<td></td>
<td>Specifying Facts</td>
<td>Performance and usage specifications</td>
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<td></td>
<td>Utilizing Facts</td>
<td>Operating and maintenance manuals</td>
</tr>
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<td></td>
<td>Comprehending Facts</td>
<td>Design data and calculations</td>
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<td></td>
<td>Generalizing Facts</td>
<td>Comparative techno-economic performance date</td>
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<tr>
<td></td>
<td>Assessing Facts</td>
<td>Sate-of-the-art information</td>
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<tr>
<td>Humanware</td>
<td>Operating Ability</td>
<td>Semi-skilled operator</td>
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<td></td>
<td>Setting Ability</td>
<td>Skilled operator</td>
</tr>
<tr>
<td></td>
<td>Repairing Ability</td>
<td>Maintenance technician</td>
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<td></td>
<td>Reproducing Ability</td>
<td>Production engineer</td>
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<tr>
<td></td>
<td>Adapting Ability</td>
<td>Design engineer</td>
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<tr>
<td></td>
<td>Improving Ability</td>
<td>Improvement engineer</td>
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<tr>
<td></td>
<td>Innovating Ability</td>
<td>Development engineer</td>
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<tr>
<td>Orgaware*</td>
<td>Individual Linkages</td>
<td>Garage shop</td>
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<td></td>
<td>Collective Linkages</td>
<td>Cottage industry</td>
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<td></td>
<td>Departmental Linkages</td>
<td>Small-scale industry</td>
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<td></td>
<td>Enterprise Linkages</td>
<td>Medium-scale industry</td>
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<td></td>
<td>Industrial Linkages</td>
<td>Large-scale industry</td>
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<td></td>
<td>National Linkages</td>
<td>Multi-location industry</td>
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<td></td>
<td>Global Linkages</td>
<td>Transnational Corporations</td>
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</table>

*Source: 'Interim Report on Technology Atlas', UN Economic & Social Commission for Asia & the Pacific, 1986. Note: * In the case of Orgaware, the term 'linkage' is used to include both vertical and horizontal interactions.*
The level of sophistication of the technology-components can increase in a step-wise manner. But, in view of the desirability of rapid technological advancement of the UDEs, the above classification provides a useful means of examining the extent to which short circuiting [leapfrogging] is possible with respect to all four components.

### 2.1.3 Classification of World Technology

We find it analytically useful to classify technology into three usual types which are classified on the basis of five indicators: automation, science-relatedness, research-intensity, dominant innovative skills and leading sectors [Freeman, 1974]. Roughly speaking, the transition from the standard-modern to the highly modern era began in Western Europe and North America in the 1960s. In light of the transitional experiences during the last forty years, ‘technology’ can be categorized in *low-tech*, *intermediate- or medium-tech* and *high-tech*.

Some examples of the leading sectors that exemplify ‘medium tech’ capital goods and skills’ are steel, railways, electicals, automobiles, plastics, synthetic textiles and synthetic dyes. All these ‘old’ products have made the transition and are now available in their ‘high-tech’ avatars [Bhagavan, 1997:3]. Examples of these are information & communication technologies [digital and satellite-based telecommunications, informatics, computer software & services, e-commerce, web design and internet services], opto- & micro-electronics, computers, digital & multimedia activities, robotics, biotechnology [based on genetic engineering] & pharmaceuticals, aerospace, and even motor racing cars and equipment, as well as new materials [Keeble, 2001]. Finally, commodities which are produced by low- and semi- skilled labor using simple technology fall are treated *low tech* goods [such as, garments, textiles, etc.].

Most of the UDEs understood the importance of transitioning their economic status from being low-tech manufacturers to high-tech capital good producers in order to close the technology gap with the DEs, and catch-up the technology leaders. This realization followed by practical efforts of various dimensions have made the UDEs distinct from each other in three major categories: [1] strong South; [2] medium South; [3] weak South.

### 2.1.4 Category of UDEs in Terms of Technology Sophistication

Among the three categories of UDEs, the ‘strong South’ possess emerging S&T background and has made transition to medium-tech era, but has just embarked on the road to the high-tech destination. It is nearly self-reliant in meeting its domestic demand for medium-tech through domestic production, and also exports some of that technology to the world.
market. Prominent examples of the ‘strong South’ are Brazil, India, Mexico and China [Tech Monitor, 1987a; Bhagavan, 1997]. The ‘medium South’ is not self-reliant in ‘medium-tech’ like the ‘strong’ one, but is firmly on the road to it. At present, it imports not only all of its high-tech from the OECD, but a good deal of its medium-tech as well. Examples are Indonesia, Pakistan, Thailand, Turkey, South Africa, Argentina and Chile. The ‘weak South’ imports almost all of its technology from the OECD region including some from the ‘strong South’. Its technological dependence is as heavy today as it was before decolonization. This vast group of countries is exemplified by sub-Saharan Africa [except South Africa], parts of South and West Asia, the Caribbean, Central America & the northern areas of the Andes.

2.1.5 State of Technology Components in UDEs

It is possible to argue that the major differences between the DEs and UDEs is their relative strength with respect to technology in which sense UDEs are in fact technologically underdeveloped [Mansfield, 1968 & 1977]. Technological underdevelopment stems from the reality that the UDEs are, in general, weak and dependent on external sources for the major elements or building blocks which are essential for development, viz.,

- Quality of facilities for production [technoware];
- Technical abilities and skills of the people [humanware];
- Extent and utility of available knowledge [inforware];
- Effectiveness of existing organization and management [orgaware].

The inherited weaknesses and consequent external dependence in all the above four major elements appear to set in motion four vicious circles in these countries which result in overall vicious circle of technological underdevelopment. If the circle has to be broken, it is necessary to make appropriate interventions to remove constraints and exploit opportunities in all four building blocks in order to achieve overall technology induced progress [Islam and Haque, 1989:128].

Since all four components of technology are complementary and interdependent, development should ensure growth in all four components at the same time and its presence at least at certain minimum level. Since facilities need operators with certain abilities, abilities have to be strengthened gradually from operation to improvement and generation of facilities. Facts representing accumulated knowledge need to be upgraded regularly, while the frameworks have to continually evolve to meet changing requirements. As a whole, what the UDEs need is to take care of proper development of ability building of technology operators, ie, commonly known as technological capability [see section 2.5] in the Techno-Economic literature.
2.2 CHARACTERIZATION OF TECHNOLOGICAL PROGRESS

2.2.1 Survey of Literature

As is said, a central problem in examining technical progress, and one that makes it difficult even to define or characterize readily, is that it takes many different forms. For technical progress is not one thing; it is many things. Perhaps the most useful common denominator underlying its multitude of forms is that it constitutes certain kinds of knowledge that make it possible to produce,

1. a greater volume of output; or
2. a qualitatively superior output from a given amount of resources.

Technical progress is typically treated as the introduction of new processes that reduce the cost of producing an essentially unchanged product. At the same time, however, to ignore product innovation and qualitative improvements in products is to ignore what may very well have been the most important long-term contribution of technical progress to human welfare. In manufacturing generally, and especially in engineering, the increased precision and flexibility made possible by microprocessor technology has led to improved product quality [Warner, 1985]. In both engineering and electronics, hitherto impossible shapes, sizes and designs have been produced and commercialized. All these improvements have led western industrial societies today enjoy a higher level of material welfare. It is not merely because they consume larger per capita amounts of the goods available, rather, they have available entirely new forms of life-styles, and a bewildering array of entirely new goods which were undreamed of 150 or 200 years ago [Rosenberg, 1982].

Simon Kuznets [1972] has pointed out that whether any innovation concerns a product or a process depends very much upon whose perspective one is adopting. Process innovations typically involve new machinery or equipment in which they are embodied; this machinery or equipment constitutes a product innovation from the point of view of the firm that produces it. For example, computerization has made it possible a major reorganization in the financial institutions which now vie with each other in offering a complete range of financial services to the consumer [Rajan, 1984]. Previously each type of institution would offer a single service or at best a limited range of services. In these cases, ‘computer technology’ is a product innovation for its producer but a process innovation for those who are able offer their consumers a wider range of products or services than before. Furthermore, Kuznets had richly documented as long ago as 1930 [Kuznets, 1930] the central role of product innovation in long-term economic
Kuznets argued that all rapidly growing industries eventually experience a slowdown in growth as the cost-reducing impact of technical innovation diminishes. Also, because of the typically low long-term income and price elasticity of demand for old consumer goods, further cost-reducing innovations in these industries will have a relatively small aggregative impact. Therefore, continued rapid growth requires the development of new products and new industries.

Not only Kuznets, but also Joseph Schumpeter in his great work, 'Business Cycles' [1939], focused powerfully upon the historical role of technological innovation in accounting for the high degree of instability in capitalist economies. Schumpeter highlighted 'technical progress' as constituting major breaks, giant discontinuities with or disruptions of the past. The clustering of innovations was at the heart of Schumpeter's business cycle theory [1939]. His later book, Capitalism, Socialism, and Democracy [1942], is a virtual paean to the beneficent impact of what he called the "perennial gales of creative destruction". These "gales" were closely tied to product innovation that swept away old industries producing old products [Schumpeter, 1942:84]. The process of technological change involving discontinuous changes can be considered to have three stages — invention, innovation and diffusion — generally called the Schumpeterian trilogy4 [Stoneman, 1983]. In sharp contrast to Schumpeter's emphasis, Strassmann [1959a] points out that in the period 1850 to 1914, at least, the old and new technologies coexisted peacefully, often for several decades. Another school of thought has been more impressed with continuity in technological change. Many aspects of this perspective are traced back to Marx [1867] and to the work of Usher [1954].

Besides 'diffusion', some studies [eg, Islam and Haque, 1994] lay equal importance on 'substitution', through which technological change occurs over time. The substitution phenomenon is based on the fact that a new technology which exhibits a relative improvement

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4 Using Freeman's [1974] definition, invention is "an idea, a sketch or a model for a new improved device, product process or system"; or discovery of new knowledge or a new principle, such as electricity. When the invented new knowledge is brought into application with a new product, it is innovation, such as electric light bulb. The third part of the trilogy is diffusion, which occurs after the invention and innovation stages and refers to the process by which the innovation spreads across the market, thus having an impact on the economy, such as the use of the electric light bulb to create night shifts in factories. Obviously all inventions will not lead to innovations and not all innovations will be successfully diffused.
in performance or benefit over an established one will eventually replace the old technology whereas the 'diffusion' process refers to the acceptance over time of a new technology by individuals, groups or organizations. So, the notion of 'substitution' reverts to Strassmann's concept of 'coexistence of technologies with two dates' leading to Schumpeter's concept of 'creative destruction' which is explained through the trilogy.

In a broad sense, technological change in an economy, as viewed originally by Schumpeter [1961], may be manifested in any or all of the following [Beri, 1993: 15]:

[1] New process or new ways of using existing resources to produce existing products.

[2] New products implying the use of existing process to produce completely new or changed versions of existing goods/services.

[3] New source or type of raw materials, encompassing discoveries of new sources of supply or changes in the raw materials available.

[4] New markets, either in a geographic sense or in the sense of application of existing products to new products.

[5] New organizational methods - new means of controlling & organizing productive inputs

Of these five types of innovations much of the literature is on the first two types. These changes result in an increase in technological capability [TC] [see section 2.5] and are manifested in the improvement in competitiveness through productivity, efficiency and growth of the firms as well as of the economy [Simpson et al., 1987] in the following ways:

[1] those which lower labor costs; and

[2] those which lower capital costs;

[3] those which improve product quality;

[4] those which extend the range of products or services offered by the firm.

2.2.2 Technical Progress in World Economies

After gaining a conceptual idea of 'technology' and its progress, one needs to distinguish between consequences of technical change and its origin [Schumpeter, 1942]. Gilfillan [1935b] suggested that there are very few major inventions and innovations while mostly what takes place is an accretion of innumerable improvements and modifications. In a similar way, Freeman [1982a] divided the world technological progress in two major categories, viz., [1] the radical innovations in products and processes associated with increasing scale of

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5 For example, our need for long distance communication used to be fulfilled through direct visits; then through letters; then telegraphs and telephones; and now through radio links and satellites -- representing a series of
investment; and [2] the incremental improvements in products and processes which are associated with increasing reliance on learning [see section 2.7.1]. It can be generally held that the technological change of the former type reflects the historical observations of Kuznets and of Schumpeter, and is associated with the developed economies [DEs]. On the other hand, the UDEs mostly experience the latter type [incremental change] where the cumulative effect of these incremental changes can bring about major economic effects. Joseph [1997] mentions, in this connection, that two major forces work behind technological changes of the incremental type in UDEs. Since the resources needed for technology generation are unevenly distributed and new technologies emerge mostly in the DEs, the UDEs rely on imported technology from the DEs. To avoid the cost of 'reinventing the wheel', the technology acquired from the DEs need several types of adaptation for use in the UDEs which often lead to incremental-type technological changes leading, sometimes, to major innovations [Sharif, 1995].

Finally, in line with the historical observations of Strassmann [1959a], Usher [1954] and Marx [1867], it can be concluded that, in the UDEs, obsolete and best practice technologies may coexist. What a UDE has to do, in this regard, is – to develop the required technological ability to absorb and master latest imported technologies, and, thus, substitute the technology with indigenously innovated ones. Here, the meaning of the ‘required technical ability’ will be answered in the next sections of this chapter.

2.2.3 Steps of Technical Progress

The process of technical change can be explained with a simple example of ‘tracking mountain’ by two groups where the target is to reach the sky [meaning technical change is a never-ending process]. The mountain consists of several hills, each of which comprises of three vertical picks. In order to climb up the mountain, the first group applies the latest technologies whereas the second group applies the technologies which have been used earlier by the former one and, now, in a short span of time, became obsolete technologies. In reaching the target, the leader group climbs up the peaks of each hill in a smooth manner, even sometimes with revolutionary jumps, whereas the follower group lags behind the leader in each peak since it has to import the obsolete technology from the leader and, thus, absorb it. The leader group innovates and uses latest technologies so fast that the follower lags far behind as time passes. Now, if we consider that each hill is an ‘overall growth curve for technologies satisfying a sequential technological substitution processes.
particular human need', the highest peak of the hill proxies for 'the latest technology' whereas the lowest one represents the obsolete technology, we can understand the technical process in an S-curve pattern. The ‘Reference Manual’ of the APCTT [1986a] provides with an outline of this pattern which is highlighted in the following figure [2.2]:

Figure 2.2: Process of Technological Progress

Two implications for Developing countries
1. S-shaped growth pattern - Eventual Catch-up possible due to upper limits
2. Successive substitution process - Sometimes Leapfrogging possible through skipping intermediate stages

Overall growth curve for technologies satisfying a particular human need


Theoretically, the S-curve pattern indicates that technological growth has three phases: a slow initial growth [introduction]; a rapid growth after a certain take-off point [growth]; and a slowdown [maturity] from which two implications can be suggested for the UDEs:

[1] to follow the S-shaped growth pattern and enjoy eventual catch-up due to upper limit, or
[2] to follow successive substitution process where intermediate stages can be leapfrogged.

In Techno-Economics, leapfrogging refers to a situation where a late starter country is able to achieve short-cuts through judicious skipping of intermediate stages for technological development [Mahmud, 1993]. Examples of Japan in the forties and the fifties, and of South
Korea in the eighties can be cited in this context [Kumar, 1987]. These countries started technological leapfrogging with a background of a typical UDE with external dependence for transferring technical knowledge from a western nation. But, in this connection, a question well remains, 'how to leapfrog?' This question will be answered in the sections where 'growth theories' and 'technological capability (Tc)' will be discussed in details.

2.3 FORMS OF 'TECHNICAL PROGRESS'

Apart from the historical distinctions of 'technological progress' in the above ways, it can be presented in some other ways which are related to its nature of occurrence, viz., disembodied and embodied, endogenous and exogenous, neutral and non-neutral, etc. The 'embodied' or 'hardware' form of technology consists of tools, machinery, equipment and vehicles, which together make up the category of capital goods [Bhagavan, 1997:2]. The 'disembodied' or 'software' form of technology encompasses the knowledge and skills required for the use, maintenance, repair, production, adaptation and innovation of capital goods, often also labelled in the literature as the know-how and know-why of processes and products [Bhagavan, 1997:2]. We start with disembodied technical progress which applies equally and alike to all resources of labor and capital in current use. To use a well-known simile, such technical change represents technical know-how falling like manna from heaven.

Technical change can be looked at in terms of the efficiency of technology which shifts the production function in such a way to leave undisturbed over time the balance between capital and labor in current production. For this purpose, growth literature specify neutral technical progress which represents technical change with no bias in the direction of either capital-saving or labor-saving which occurs in non-neutral progress. Other than the efficiency of technology, neutrality contains another component: technologically determined returns to scale -- for a proportionate increase in inputs, the outputs may increase in the same proportion or less than or more than proportionately and accordingly there will be constant returns to scale, diseconomies- as well as economies- of scale respectively. Obviously if the scale parameter increases, the rate of output will increase. A neutral shift can be shown in several ways in which disembodied technical progress is incorporated in a smooth production function such as:

\[ Y = F(K, L, t) \]  

where Y, K, and L are continuous variables over time, where \( F \) is a given continuous and differentiable function, and where the variable t is introduced explicitly to allow the whole
production function to shift over time.

2.3.1 Harrod-Neutral Technical Progress

In specifying neutral shifts, Harrod-neutral technical progress appears as the first case to formulate. It obtains when the production function shifts over time according to the form:

\[ Y = F(K, \alpha L) \]  

where \( \alpha = \alpha(t) \) subject to \( \alpha(t) = 1 \) at \( t=0 \) and \( \alpha(t) > 1; \alpha'(t) > 1 \) for \( t > 0 \)

This definition follows Joan Robinson’s concept of an ‘all-round increase in the efficiency of labor’ [Robinson, 1938], rather than Harrod’s original definition, which can be written as:

\[ Y = F(K, L) \text{ where, } L = \alpha(t)L \]  

Technical progress of this form is labor-augmenting in the sense that a given output can be obtained from a given capital input and the same labor input \( L (=\alpha L) \) over time but measured in efficiency units. As time goes on, a given labor force \( L \) in men represents an increasing number of efficiency units because of technical progress \( (L=\alpha L) \); so the same input in efficiency units represents a decreasing number of men.⁶

The reduction of labor costs per unit of output is perhaps the most common efficiency outcome of the introduction of new technology in labor-augmenting form [Simpson et al., 1987]. This may raise the factor saving proposition of Harrodian technical change and cause substitution of capital for labor. But empirically, in many industries – banking, insurance and finance are perhaps the most prominent examples [Rajan, 1984] – new technology has permitted a faster growth of output, which has meant that lower unit labor costs have been combined with no redundancies. In other industries, direct labor-shedding has so far been sufficiently small that it could be accommodated by ‘natural wastage’ [Simpson et al., 1986]. On the other hand, in some industries, such as mechanical engineering, the introduction of new technology has apparently been accompanied by massive labor-shedding, especially during the recession years 1980-82 [Simpson et al., 1987:16], but closer inspection shows that the introduction of new technology often followed a cost-reducing reorganization of production.

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⁶ A Harrodian labor augmenting technical progress augments the productive power of the labor force so that the amount of labor required to produce a unit of output continually declines while the capital coefficient remains undisturbed and productive equipment must have an unchanging capital-output ratio at a constant rate of interest [Burmeister et al., 1969; Stoneman, 1983:6; Rampa et al., 1998].
rather than accompanied it [Chowdhury, 2003]. Therefore, the theoretical proposition of adopting labor saving approach which is assumed to happen due to ‘labor-augmenting technical progress’ does not remain valid.

2.3.2 Solow-Neutral Technical Progress

Solow-neutral technical progress is of the same form, except that it is capital-augmenting instead of labor-augmenting. The shifting production here is:

\[ Y = F(\alpha K, L) \]  

which is alternatively,

\[ Y = F(\mathcal{R}, L) \text{ where, } \mathcal{R} = \alpha(t)K \]

in terms of a fixed production function but with capital measured in efficiency units which vary over time. The properties of technical progress in this form are similar to those of the Harrod-neutral type with K and L interchanged. It follows, however, that it is not an appropriate form of technical progress for growth models in which the output-capital ratio is constant, at least as long as the technical change is of the disembodied kind now considered [this condition apply equally to Hicks-neutral technical progress, as discussed next]. It becomes more relevant [and in fact so considered by Solow too] to models of the vintage type in which technical change is embodied in successive vintages of machines that become more efficient as time goes on [see section 2.4.3].

The capital-augmenting technical progress may raise the factor saving proposition of Solow towards ‘capital’. But empirical experiences have proved this proposition wrong in many cases throughout the century. This issue can be explained through the experience of the IT revolution in OECD countries in the 1980s and 1990s as presented elaborately in Rampa, Stella & Thirwall [1998]. According to their observation, the power of IT equipment advances both because of capital-augmenting technical progress due to the increasing cheapness of the new plant which incorporates it and because its growing cheapness pushes its development into a capital-using, rather than capital-saving direction. Also, as Heertji [1973] argues, at a given propensity to save, the capital-augmenting character of technical change ensures that the under-utilization’ of labor disappears more quickly than in Harrodian technical change [p.184]. So, the theoretical proposition of adopting capital saving approach which is assumed to happen due to ‘capital-augmenting technical progress’ does not remain valid.

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*In the growth models that incorporate technical development a full-employment labor market is usually assumed and then only the main aim of the analysis is fixed whether an equilibrium growth of production and the factors of production is possible to find out [Heertji, 1973:183].*
2.3.3 Hicks-Neutral Technical Progress

Hicks-neutral technical progress is the form of disembodied technical progress that appears to conform most naturally to the idea of neutrality, and it was the first type to be proposed by Hicks [1932/1963]. It obtains when production function shifts over time by a uniform upward displacement of the whole function:

\[ Y = \alpha F(K, L) \quad [4] \]

where the linear and homogenous property is,

\[ F(\alpha K, \alpha L) = \alpha F(K, L) \quad \text{for any } \alpha > 0 \quad [4a] \]

Hence the shifting production function in the Hicks-neutral, constant return case is:

\[ Y = F(\mathcal{R}, \mathcal{L}) \quad \text{where, } \mathcal{R} = \alpha K \text{ and } \mathcal{L} = \alpha L \quad [4b] \]

where \( \alpha = \alpha(t) \) subject to the same conditions as before [in Harrodian- & Solowian- neutralities]. If the inputs \( K \) and \( L \), in their natural units, remain unchanged, then a product is obtained that increases over time at the proportional rate \( \frac{d\alpha}{dt} \). In the most obvious sense, this is manna from heaven which is assumed to be a “free good” [every country has access to new technologies] in neoclassical model of growth [see section 2.4.1].

In all the cases above, it has been obvious that, in whatever way technical progress is expected -- whether embodied or disembodied -- investment in ‘labor’ is always necessitated. It is because, it is labor which operates the technoware/hardware for which sufficient knowledge and skills are required. Investment in labor does not have any alternative since it is labor that functions as software/operator of the hardware and leads to innovation. It cannot be ignored also that ‘the efficiency level of the labor’ would depend on some associated factors which are conducive to imitation and innovation. These factors can be identified in the study of growth theories, TC and technology transfer in this chapter.

2.4 Technology Actors in Growth Theories

The desire to analyze the problems and policies for economic development of many war-ravaged countries in the world after the Second World War as well as the necessity to stimulate growth in many poor countries in Asia, Africa and Latin America [Ghatak, 1995: 49] have led the development of the theories of growth, or what Marshall regarded as long-run equilibrium analysis, in the last forty years. Indeed, the analyses on the origin and evolution of
economic growth in these theories have repeatedly highlighted 'technological progress' as the major source of growth [Cameron, 2003:2].

Much of the recent work on economic growth can be viewed as refining the basic economic insights of classical economists. The great classical economists were quite aware of the industrial revolution going on around them and technical advance, at least in manufacturing, played an important role in their analysis. The first part of Adam Smith's *Wealth of Nations* is mostly about what now-a-days would be called technical change and economic growth. The emergence of theories by Solow [1956], Swan [1956] and Cass [1965] revived the classical concept and expanded the work of J. S. Mill [1848] and developed the neoclassical growth models. The neoclassical theories assumed technical progress as exogenously determined without making any further analysis on it. The study of economic growth, then, languished for nearly two decades because economists had few new things to say. Since the mid-1980s, research on economic growth has experienced a new boom, beginning with the work of Romer [1986] and Lucas [1988]. Being dissatisfied with exogenously driven explanations of long-run economic growth, they were motivated to construct a class of growth models in which the key determinants of growth were endogenous to the model; hence, the designation 'endogenous growth models.' Now, with an aim of examining the 'technological factors' in the process of growth, a detailed discussion on the 'theories of growth' is done below:

### 2.4.1 Neoclassical Growth Models

The basic neoclassical tool for the study of technology and of technical change is the notion of a production function [Elster, 1983:96]. And interestingly, the key aspect of the Solow-Swan model is none but the standard neoclassical form of production, a specification that assumes constant returns to scale, diminishing returns to each input, and some positive and smooth elasticity of substitution between the inputs. This model takes rates of saving, population growth and technological progress as exogenous for which the model is also considered as an 'exogenous model.' In a neoclassical way, technology can be postulated through a Cobb-Douglas production function where production at time $t$ is given by,

$$Y = AK^aL^{1-a} \quad 0 < a < 1$$

where $Y$ stands for total output, $K$ and $L$ for capital and labor inputs respectively, and $A$ for autonomous/exogenous technological change. The sustainable growth path (for very long
periods] is determined by the steady rate of technical change in the economy. As found by Schultz [1963], Goode [1959], Kendrick [1961], Denison [1962], Suk & Kyung [1985], among others, an increase in capital and labor account for half or less of the growth of output typically. In an empirical work by Solow [1957], the estimation of such a 'technical change' highlights that almost 90% of the growth in the US economy could be attributed to the technical factor.

Denison [1962], in a study resemblant to Solow's, estimates that 48% of the rise in output per worker in the USA between 1930 and 1960 could be attributable to the advance of scientific and technological knowledge, 23% to improved work force education, and only 12% to increased capital intensity. Although the contribution of 'technical change' [ie, 48%] in growth is found lesser as compared to Solow's study, Denison's estimation still highlights the importance of 'technical change' in the process of growth.

In light of the empirical observations, it is argued that the neo-classical theory can explain half of what it purports to explain. The rest, the residual [the so-called Solow residual] defines total factor productivity [TFP] which is determined by 'technical change' in the neo-classical models [Cameron, 2003]. It is a surrogate for technical and organizational change [Jorgenson et al., 1989:488]. TFP can be expressed in the following mathematical form,

$$G_T = G_Q - s_K G_K - s_L G_L$$  \[5a\]

where $G_T$ = the rate of productivity growth [$\Delta Y / Y$]; $G_Q$ = the growth rate of output [$\Delta Y / Y$]; $G_K$ = the growth rate of capital input [$\Delta K / K$]; $G_L$ = the growth rate of labor input [$\Delta L / L$]; $s_K =$ the share of capital [$\alpha$]; and $s_L =$ the share of labor [1-$\alpha$]. The above growth accounting approach was the dominant methodology for empirical studies of productivity until the early 1970s [Cameron, 2003]. In practice, TFP estimates face serious methodological and interpretation problems [Kim et al., 2000] [the rest of this methodological issue is discussed in chapter III]. But it is important to note that, however, that introduction of new factors in the production function as proxy of technical progress in the recent growth literature has minimized the importance of estimating technical progress through 'residual' as TFP. The following section makes a broad discussion in order to identify these new technological factors.

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8 Denison [1967] concludes the same in a comparative analysis of the growth performances after the 2nd world war of the US and eight European countries.
2.4.2 Endogenous Growth Models

The most exciting aspect of the new growth theory is the combination of both economic theory and empirical work [Ahmed, 2001:151]. None of the new growth theorists appeared to be aware that Nicholas Kaldor [1957] had, some 30 years earlier, developed a growth model that endogenized technological change using a 'technical progress function'. Thereafter, the development of endogenous growth models has passed through four stages. The first stage involved an attempt by Romer [1986], Lucas [1988], and Rebelo [1991] to introduce technological change in the form of learning-by-doing as an unintended consequence of investment. Yet this was not really a theory of technological change. In the second stage, Romer [1986], Lucas [1988] and others have formalized the earlier ideas in the new growth theory which originated in the learning-by-doing models and inspired by Uzawa's [1965] model of investment in human capital. The third stage of the development began in the late 1980s and early 1990s with the introduction of theories of R&D and of imperfect competition by Romer [1987, 1990], Aghion & Howitt [1992], and Grossman & Helpman [1991]. In these models, technological change is the outcome of deliberate investment in R&D to achieve monopoly profits. The outcome of R&D investment is positive longrun growth, but only for as long as this investment continues. Finally, in the fourth stage, another group of models, namely, endogenous innovation models, integrated more explicitly on innovation and the problem of transfer and diffusion of technologies. These models by Abramovitz [1986], Benhabib and Spiegel [1994], Pavitt and Patel [1995], Cohen and Levinthal [1989] highlight the idea that national technological capability strongly determines the ability to imitate foreign ideas and to find new ones [innovation]. Although the first three groups of models are discussed here, the fourth one is discussed in chap. III where 'assessment of national technical climate' is done for Bangladesh.

2.4.2a Lucas' Growth Model

In an influential paper published in 1992, Mankiw, Romer and Weil augmented the Solow model by including accumulation of human capital in the model and concluded that it performed very well. Their study provides an excellent description of the international variation in income per capita that includes accumulation of human capital and different skills [by foregoing consumption]. Extending the Solow model to include human capital or skilled labor is relatively straightforward which can be done following Lucas [1988] which assumed
that individuals spend time accumulating skills, much like a student going to school [Jones, 1971]. The consideration of human capital as a new factor of production [Lucas, 1988] has made technical progress endogenous and the model different from the exogenous neo-classical models. Also, Lucas production function turned the neoclassical model to a situation where technical progress does not drop like manna from heaven, rather occurs in embodied form. The Lucas function can be shown in the following equation form:

\[ Y = K^\alpha [AH]^1 \]  

[6]

where, \( A \) represents labor-augmenting technology that grows in an exogenous manner similar to Harrodian technical progress. But this exogenous nature of technical progress becomes endogenous when the dual role of ‘human capital’- internal and external - is introduced in the Lucas model [1988]. The theory focuses on the fact that the way an individual allocates his time over various activities in the current period affects his productivity in future periods. Introducing human capital into the model, then, involves spelling out both the way human capital levels affect current production and the way the current time allocation affects the accumulation of human capital. These are the two aspects of the so-called endogenous “technology”. Following the way of Uzawa-Rosen, both these aspects can be formulated as,

\[ h^*(t) = h(t) \delta [1 - u(t)] \]  

[6a]

where star marked \( h \) is the growth of human capital when \( 1-u(t) \) of the non-leisure time is devoted to human capital accumulation, ie, time devoted to education. \( \delta \) determines the rate at which human capital grows. More clearly, \( \delta \) denotes the positive coefficient representing workers’ skill formation or learning by doing in a particular sector.

The external role of human capital pertains to the productivity of all factors of production. Therefore, one consequence of Lucas model is due to the “external effect”, \( h_0(t) \) in the production function for which the accumulation of human capital is likely to be below socially optimal level. Accordingly, there will be an equilibrium growth path under an optimal situation, unless there is market intervention [e.g. subsidy to education]. In empirical studies, the external effect of human capital appears difficult to estimate.\(^9\)

\(^9\) For empirical convenience, Lucas [1988, pp 37] suggests to incorporate only the internal effect ie, \( h(t) \) to the growth model while treating \( h_0(t) \) as exogenously determined.
2.4.2b Romer's Linear Model

Paul Romer [and his colleagues] believed that "technological progress" is crucial for understanding growth. Therefore, he first revived the theory of growth by adding an **endogenous** factor, i.e., "knowledge" [e.g., about how to make things] to the neo-classical production function leading to the production of new knowledge. He considers 'knowledge' as a public good [i.e., termed 'general knowledge' by Becker, 1962; and Oi, 1962] and argues that the private investment in capital increases the level of technology available to entrepreneurs. Romer's view can be expressed in the following simple equation:

\[ Y = F (R, K, H) \]  

where, \( R = \text{Research} \), \( K = \text{Physical capital} \) and \( H = \text{Human capital} \). In equation, the representation of research and human capital, i.e., the consideration of a broader concept of capital encompassing physical and human components, depicts the absence of diminishing returns to capital. The emergence of knowledge in the theoretical production function [i.e., neo-classical] has made it much more plausible in a variety of ways.

In Romer's theory [1986], knowledge is a factor of production which, like capital, has to be paid for by forgoing current consumption, which helps the economy be more productive in the future. Thus, the output produced by a firm \( i \) depends on [1] a vector, \( x_i \), of standard inputs such as labor and physical capital; [2] the amount of firm-specific knowledge, \( r_i \); and [3] the total amount of knowledge in society, \( R \). If there are \( N \) firms, then,

\[ R = r_1 + r_2 + \ldots + r_n \]  

The introduction of \( R \) in each firm's production function is meant to capture the idea that the generation of knowledge has externalities because other firms can never be totally prevented from learning and emulating [Basu, 1998]. As a whole, societal knowledge, \( R \), can be shared in a non-rival manner for advances in knowledge, i.e., for new ideas [following Romer, 1990; models of this type were pioneered by Aghion and Howitt, 1992] whereas firm-specific knowledge [\( r_i \) ] is partially excludable. Therefore, the level of technology can be advanced by purposeful activity, such as R&D expenditures, as a result of which each firm's production function would exhibit increasing returns to scale.

In all cases of the endogenous growth models, as discussed above, per capita income can grow endlessly and growth rates need not converge across countries [Basu, 1998:54]. The
equilibrium growth path that occurs happens to be socially suboptimal due to the "external effect" of human capital in the production function [Lucas model] and the R&D investment [Romar's model] resulting in monopoly profits. In particular, left to the market, consumption tends to be too high and investment in knowledge too low; or, in terms of Lucas's model [1988], the market underproduces human capital. Therefore, to achieve optimality, government intervention [eg, taxes, subsidy to education] becomes essential [Snooks, 1998] in an UDE where the process of human capital accumulation always suffers from distortions by 'invisible hands'.

Finally, it is clear that the neo-classical position becomes weakened when investments are made on human capital and R&D, resulting in sustained growth through either spill over effects or virtuous circles for the investing firms [Erixon, 1998:3]. The theories of endogenous growth, in this connection, have naturally shifted attention to the importance of education, learning, research activities, and more generally the spread of ideas as the causal factors of technical progress in an economy. These theories, in this way, have also been able to venture into the 'residual' and break down TFP in technical factors. But these have certainly failed to deal with the 'technology gap' issue between the UDEs and the DEs although one of the aims of these models has been to work on such differences. The way Paul Romer [1990] criticized the Solowian theory, both theoretically & empirically, justifies this aim of endogenous models –

"differences in growth rates between countries must be explained by differences in 'technology' and a theory, in contrast to Solow's original one, must be formulated to explain such differences".

Although the growth theorists since Adam Smith till Abramovitz have highlighted the importance of investing in labor [ie, in human capital, research and learning], all their propositions have surely failed to highlight the fact that "for faster learning and absorption for the sake of catching up and closing technology gap by the UDEs with the DEs, a most recently trained labor force is required to man a latest technology". This idea is only highlighted in one of the most neglected models of embodied technical progress which is known as "vintage model".

2.4.3 Vintage Models

The assumption which 'vintage models' suggest is that technical progress is embodied in the current vintage of machines being installed [as opposed to existing machines] and in the currently trained men of the labor force [in contrast to those trained at earlier times]. Broadly speaking, we can say that it is the age of men and machines which we have to distinguish. For simplicity, we confine our exposition to the case of technical progress embodied in vintage
capital. But when vintage labor is linked directly to vintage equipment, the following analysis applies to at once to the combination of vintage capital and labor.

The assumption of a homogenous capital stock [as in disembodied technical change] is relaxed by taking the stock as made up of machines of different vintages. Each vintage consists of a homogenous set of machines produced for installation at one time; successive vintages relate to a sequence of times. We need two time variables, one (t) for time in the usual sense and the other (τ) for the dating of vintages of machines in use at time t. In a discrete analysis, with equal spacing of vintages [say, each year], the machines in use at time t are of vintages $τ = t$ [new], $t - 1$ [one year old], $t - 2$ [two years old], etc. In a continuous analysis, as adopted here, there are machines of all vintages $τ ≤ t$ in use at any time t.

When we take machines and labor as substitutable, we assume a smooth production function that incorporates technical progress up to the time the machines are being installed but not beyond. The question now is, what form to take for the function? As we know, to ensure steady-state growth, technical progress should be of the labor-augmenting [Harrod-neutral] type. On the other hand, it would be convenient [to say at least] if technical progress were of the capital-augmenting [Solow-neutral] type, so that successive vintages of machines of increasing efficiency can be allowed. We look, therefore, for a production function that is both Harrod-neutral and Solow-neutral, in order to have both ways and secure the advantages of both types. There is one and only one function which is both Harrod- & Solow-neutral, the Cobb-Douglas form with constant returns & two parameters:

$$Y_t = e^{λt} (K_t^α L_t^{1-α})$$

where $λ > 0$ and $0 < α < 1$  \[8\]

It is written here for machines that are new [substitutable with labor] at time t, ie, of vintage $τ = t$ which produces $Y_t$ amount of output by use of a labor input of the same vintage [$τ = 1$] at the time of its installation. As a proxy of technical progress, $λ$ can be interpreted in terms of Harrod- and Solow-neutrality which is not a major concern of discussion here.

Two cases are explored to examine whether machines and labor are substitutable once they are installed at time t. One of these is 'putty-putty' and the other is 'putty-clay'. The putty-putty case has smooth substitution both when the machines are new and after installation and according to the same [Cobb-Douglas] production function. Both King [1972] and Koizumi [1969] have investigated investment in a putty-clay vintage model. According to Koizumi, in the putty-clay case, expected future output is known; that there is ex ante, substitution possibilities.
but *ex post* no substitution [ie, once installed, a machine is operated by a fixed labor crew]. The
capital good has an infinite physical life but an *expected* economic life which is determined by
*quasi-rent*. Johansen [1959] and Phelps [1963] analyze that the quasi-rents of old machines
decline and eventually become *zero* [ie, old machines just covering its operating costs – labor plus
materials, etc.] as the wage rate rises. Thus, the economic decision is taken to scrap the machines
as *obsolete* despite their continuing physical durability.10

Due to the assumption of perfect substitutability between factors, the putty-putty case
turns out to be consistent with steady-growth almost precisely as in a neoclassical model of
disembodied technical progress. But when the question of constructing a more ‘realistic’ form
of vintage capital arises, the *putty-clay case* emerges as the most suitable one where a machine,
onece brought into production, continues to employ a fixed labor crew until it is scrapped. Also,
empirically, the putty-clay case appears to be more appropriate over putty-putty when one
considers the negative aspects of import of the latest technologies on employment growth and
overall level of unemployment in the UDEs. Introduction of computerization and automation
displaces less skilled labor in large numbers and creates a few skilled jobs. This has also been
argued by Ernst [1986] in the context of the spread of micro-electronics in the South Asian
countries. Thus, by expanding the number of lines of production, the overall level of
employment is maintained. But, at the same time, requirement of a major program of retraining
labor cannot be ignored which are already of older vintage [eg, \( \tau = \ell - 1 \) or more] in comparison
to the machines installed [of vintage \( \tau = \ell \)].

The great *strength* of the vintage model is that it illustrates that it is perfectly rational for
entrepreneurs to use old technology even when new best-practice techniques exist. Essentially,
old machines can still yield a contribution to *profits* if price covers operating costs, and they
are, therefore, worth using while this condition holds. They are replaced only when the
appearance of new machines drives price below operating costs. Thus, the vintage models do
not support Schumpeter's emphasis upon the centrality of creative destruction as the source of
technical progress. Rather, the models reflect the views of Strassmann [1959a], Marx [1867] and
Usher [1954; first ed. in 1929] which point out that, in the process of technical change, the old
and new technologies may coexist peacefully. To note that the latter views mostly reflect the

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10 Borrowing the terminologies from Hahn and Matthews [1964], it can be said that, in the putty-clay model,
decisions are taken at two margins – *intensive margin* where the decision to invest in new machines is taken and
*extensive margin* where the decision to scrap machines because of obsolescence.
growth experiences of the UDEs, in which sense, the vintage models can be suitably applied in analyzing the technological issues in the UDEs.

Although the vintage models are an improvement on the models of disembodied change, they are, in some cases, not satisfactory. First, the models argue that all investment is in machines of the latest type. This has been found to be empirically suspect [Gomulka, 1976] especially in the case of UDEs. Second, the models are firm oriented and say nothing of the number of firms. This limitation can be ignored in case of macroeconomic studies. Third, they consider the level of output to be exogenous rather than endogenous. In order to face these two later limitations, we can consider Salter’s more valid approach to investment in vintage models where he argues that

... each period brings forth a new set of best practice unit requirements for labor, investment and materials ... If the prices ... do not change, the improvement in best practice techniques allows the possibility of supernormal profits. These will induce entrepreneurs to build such plants ... until output is expanded sufficiently in relation to demand conditions [so that] supernormal profits are eliminated [Salter, 1966].

This approach makes both the number of firms and output endogenous. It is not known, however, of any literature that has used this approach to generate a vintage model-based investment function. Therefore, further research is required to formalize this approach.

Now, with a possibility that the overall level of employment can be maintained even after the introduction of machines of new vintages in UDEs, the discussion can be extended to a larger mode of analysis taking ‘type of technology used’ [see section 2.1.3] and ‘diversity among the UDEs’ [see section 2.1.4] into consideration. We assume that an UDE imports machines of vintage \( \tau = t \) [latest in UDE context, but low-tech in world perspective]. If the labor force to man the new machines are of vintage \( \tau = t - 1 \) or older, then it can be certainly guessed without any formal calculation that the economy lags far behind the technology leaders [which produce high-techs at the moment]. The situation gets worse when the diversity among UDEs is taken into consideration in three major categories suggested by Bhagavan [1997:4] – the ‘strong South’; the ‘medium South’ and the ‘weak South’ [see section 2.1.4].

With the assumption that an UDE imports low-tech machines of vintage \( \tau = t \) [in the UDE context], we add one more assumption that the UDE belongs to the ‘weak South’. If the labor force to help man the new machines are of vintage \( \tau = t - 1 \) or older, then it is very easy to imagine that the dated labor of the economy is of very old vintage even to catch up its South counterparts. Hence, the weak South UDEs need to develop their existing labor in such a
standard that it not only overcomes the technological dependence but also jumps up to the level of a high technology creating country skipping intermediate stages of technology creation.

In fact, studies highlight that governments of the weak South countries have been either unwilling or unable to invest adequate resources [domestic or foreign] in higher education and research in the natural and engineering sciences, which are the foundations for technological advance [Bhagavan, 1997:5]. Basically, it is education and research which help to generate dated labor with enough absorption power and capability of handling the latest vintage machines. It is important to note that, in the entire South, in general, less than 10% of scientists and engineers are directly involved in activities related to technical change [Bhagavan, 1997]. The great majority work with existing technology in various sectors of the economy and society. Issues related to the systematic upgrading of the skills of this huge corps of S&T workers into a 'dated' one [ie, men of vintage \( \tau = \delta \)] have been neglected by Southern governments.

2.5 TECHNOLOGICAL CAPABILITY

It is evident that the UDEs use imported technologies rather than being initial innovators. Taking into account the peculiarities of their technological development, the concept of TCs has been used in the development literature to analyze both how such imported technologies are used at different levels of technological assimilation, adaptation and improvement, and whether these stages progress into a more independent TC [Gonsen, 1998:1]. One of the important factors of TC is 'technical manpower' in which technology is embodied. A large portion of technological knowledge eventually accrues to 'human capital' rather than to facilities [Kim, 1995]. The 'quantity and quality of labor' at various levels are important factors determining the capability of industry. So, it is the ability of labor force to make effective use of technological knowledge [Kim, 1993] and it is nothing but the 'dated labor' which 'vintage models' prescribe in a similar way. Thus, realizing the importance of 'acquisition of TC' in developing 'vintage labor', this section discusses the issue of TC in details:

2.5.1 Forms of Technological Capability

For a country to develop competitively, new TCs need to be accumulated progressively. Although a conceptual differentiation of forms of TC may be difficult to apply in practice, any classification of forms of TC should allow a clear identification of the kind of skills, amount of effort, and other implications for each identified form. In this connection, on the basis of the approaches of Fransman [1984], Lall [1987], James [1988] and Sharif [1995], the
forms of TC [at the firm level] can be divided in the following five categories:

2.5.1a Acquisition Capability [ie, acquisition of technology- & other resources]

The first elements of TC refers to the capability to search for, assess, negotiate, procure and transfer technology [available locally or abroad]. It is also known as investment capability [Lall, 1987] or acquisitive capacity [Dahlman, 1990]. In the UDEs, this element may be quite difficult given the imperfections of technology markets and poor information flows.

Bringing in new technology is becoming even more important because of the acceleration of technical change over the last decade [Dahlman, 1990]. Local public or private R&D centers may be an alternative source of new technologies, but this is very much undermined in UDEs because of weak linkages between local research institutions and industrial firms. As has been pointed out by several authors [Cooper, 1973; Sagasti, 1979; Wionczek et al., 1988; and White, 1989; among others] the private sector has centered its technological activities on copying or importing technology from abroad and on minor innovations without considering the national universities as a source of technology.

At the national level, getting access to relevant foreign technology also involves an adequate policy framework for FDI, technology transfer, capital goods imports, and intellectual property protection [Dahlman 1990; Gonsen 1998: 10-3].

2.5.1b Design and Project Implementation Capability

[ie, actual utilization of product development technologies]

Sercovich [1987] stresses the importance of basic engineering design because it determines the conditions in which the learning process during plant operation can occur, ie, the amount of technological effort and the results it can derive during plant operation will be highly dependent on the starting point defined by participation of the producing firm in their basic design. The actual setting up of the project is referred to as project implementation capacity. This involves a variety of engineering, mechanical, construction and organizational capabilities, the main functions being: detail engineering design, equipment specification, procurement and testing; civil construction; mechanical erection; ancillary services; overall project coordination and supervision; commissioning and, usually training of operatives [Lall, 1987].

UDE-firms participate to a lesser extent in the definition and analysis of initial design conditions than on the implementation of the project as a consequence of ignorance or lack of concern, and of difficulties regarding access to information [Sercovich, 1987].
2.5.1c Assimilative / Transforming Capability

[ie, utilization of available technologies for the transformation process]

Capacity to assimilate technology, also described as technological mastery or operational capability, refers to the successful use of technology in transforming inputs into outputs. It implies operation and maintenance of the plant. It includes development of labor skills to meet standard specifications and training to upgrade technical competence. The capacity for technology assimilation or absorption can be described as the necessary capacity to better understand the principles of the technology that enterprises are using, to master its application and to achieve the same level of productivity as in the country of origin [see Sagasti, 1979; Fransman, 1984; and Dahlman, 1990].

The task of learning to make effective use of existing knowledge requires technological effort [Dahlman & Westphal, 1982]. Thus, technological mastery of a foreign technology, or the process of assimilating it, is itself a difficult, long and uncertain process. In a UDE environment, this technological effort is greater, and even more so, when the technology itself is new to the country and complex in its characteristics [Lall, 1987]. The rate of technological absorption may be slowed down when reliance on foreign consultants is maintained and no explicit actions are taken to transfer technological knowledge and experience from foreign to local engineers [Gonsen, 1998].

2.5.1d Modifying, or Improvising and Improving Capability

[ie, continuous improvement of all activities and technology components]

Capacity to modify refers to the ability to carry out modifications to existing technology. It involves the acquisition of additional knowledge [by reading journals, scientific research articles, etc.] to make minor product and process modifications [local minor innovations]. It is because, as stressed in the literature, imported technology is often best suited to the factor endowments of developed countries and adaptation is required to match transferred technology to the conditions prevailing in the UDEs.

The availability of different kinds of skilled labor, the supply and quality of local resources, the size and characteristics of local markets, the degree of competition in protected markets, foreign exchange shortages, and so on are factors that affect the degree and direction

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11 The view of technical progress as consisting of a steady accretion of innumerable minor improvements, modifications and adaptations, with only very infrequent major innovations, was nicely embodied by S.C. Gilfillan
of adaptive activity. For example, Korea is a country that has acquired the capacity to search and select the technologies to be imported. It has effectively assimilated various elements of foreign technology and it has implemented minor innovations that have been significant in increasing production efficiency, changing product designs, upgrading quality, and improving management practices [Westphal et al., 1984b]. The creation of a technological infrastructure, built into an institutional framework, has supported such development. There is also a strong base of technical human capital and a high educational level of the population, as well as high expenditures on R&D [compared to other NICs] [see, for example, Lall, 1990; Enos & Park, 1988; and Westphal et al., 1984b].

2.5.1e Generating/Innovative Capability [ie, utilization of process dev't technologies]

The literature that analyses the technological behavior of manufacturing firms in Under developed economies [UDEs] sometimes refers to innovation as activities to improve existing technologies, either through incremental and minor modifications, or major changes rather than Schumpeterian or revolutionary as occurred in developed countries [Freeman, 1982a].

The capability to create technology is composed of a predetermined quantity and quality of scientific and technological manpower with which to conduct pure and applied R&D activities, physical facilities [including laboratories and equipment], and other support facilities and services [such as educational institutions, libraries, consulting and engineering services, and technological information services]. In other words, what is required is a good technological infrastructure, which is especially important in the formative stage of science & technology [S&T] capabilities. The ability to create technology also demands cooperation between government and industries, links between the educational and productive sectors, a sound financial base, and development of local human resources.

The four components of technology and the types of TCs mentioned above are interrelated in a systematic way. Productivity [resulting in better business performance] can be improved by: upgrading the sophistication of technological resources [ie, better physical facilities; improved human abilities; updated documented facts; and re-engineered organizational frameworks]; and increasing core competencies through capability accumulation [ie, maximum transforming capability; better acquiring capability; enhanced modifying capability; effective vending capability; creative designing capability; and state-of-the-art (see Stoneman, 1983:15) generating capability].
Therefore, for the competitive development of an economy through 'vintage labor', it is necessary to achieve increased **sophistication in terms of the technology components** [related to the production process and the product aspects] as well as cumulative advancement in terms of TCs.

### 2.5.2 State of TC Activities in UDEs

From the above analysis of the forms of TC, the composition of dated labor in terms of TC can be made with two broad categories in line with the proposition of Alagh *et al.* [1993] --

1. **Production/manufacturing capability** - capability to manufacture goods and provide services to given design and specifications, which Dodgson [2000:233] named “technology diffusion capability”. This capability enables firms efficiently to accumulate, assimilate, and adapt appropriate extant technology. It requires substantial level of capability on the part of the firm in selecting, using, and developing technology.

   Technology diffusion capability depends on the government's selection and support of **munificent technologies and provision of good technological infrastructure** [Kim *et al.*, 2000:234].

2. **Innovation/design capability** - the capability to design changes in given products/processes or to design entirely new products/processes in response to changing factor and product market conditions. In a broader sense, it is named “technology creating capability” [Dodgson, 2000:233]. It is the capacity to create new technologies based on R&D and directed at creating first-mover advantages in the market, intellectual property, and licensing income. In an underdeveloped economy context, “technology creating capability” is needed to come through a combined process of, *technology import* from developed countries and internal development through R&D activities [Fransman, 1985].

   Technology creating capability depends on good scientific training, opportunities for linking with scientific expertise in universities and research labs, and effective intellectual property rights [IPR] protection [Kim and Nelson, 2000:234]. Again, a provision of good technological infrastructure can ensure all these factors for technology creation.

   Generally, a firm/industry in an underdeveloped economy [UDE] can improve its TC by moving along a technology “dependence-independence” continuum, ie, importation of technology from abroad for local adaptation, improvements and innovations, and even export of technology. In this connection, Kim [1985] prescribes three stages of TC-building: [1] assembly, [2] assimilation and [3] imitation/improvement. These three areas of TC are

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book 'Steamboats on the Western Rivers' [1949].
achieved in a stepwise process from production capability to innovation capability, which, as a whole, constitute *dated labor force*. An economy, that has insufficient production capabilities, eg, inefficient control of raw materials, production scheduling, and quality, is said to remain in the assembly stage. This is the stage where most UDEs are found to run their production.

Finally, in contrast to the DEs, the efforts of the UDEs to develop *indigenous* S&T capability are often impeded due to problems emanating from various angles such as:

> "the existing conditions of different components of technology; the national climate in which technology is to grow and operate; and the dependence on external assistance" [APCIT Reference Manual, 1986].

Therefore, the policy planners and decision makers must have a clear understanding of all these constraints and problems so that intervention can be made judiciously at the right spot in the efforts to build the national S&T capability.

### 2.6 TECHNOLOGY TRANSFER

The issue of technology transfer (TT) is one of the most important factors in modern day development [Donovan, 1999:20]. Historically, the pattern of international technology transfer characterized some common features of technology flow among countries which can be penetrated in the following ways:

1. Import of mature technologies by the UDEs from developed economies (DEs);
2. Export of low-technology products by the UDEs;
3. Trading of generally low technologies among UDEs and high technologies among DEs; and
4. Exchange of technologies with equal value.

The above features of technology flow indicates that technology transfer among countries follow a particular pattern and outlines some north-north, north-south kinds of relationships among the technology traders. In this connection, the main purpose of this section is to deal with some questions regarding the pattern of TT among countries, such as,

> *Why do some specific patterns of TT dominate in north-south, and north-north relationships of international technology markets?*

and in this situation,

> *Which pattern would be optimal for underdeveloped economies (UDEs)?*

Prior to dealing with these queries, we start with a discussion of a TT model which provides with a systematic explanation of the stages of absorbing foreign technology successfully.

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12 APCIT in its ‘Reference Manual’ on ‘Technology Policy Formulation and Planning’ highlighted a very similar pattern of technology flow fifteen years back [1986: 21] and the pattern still shows the same features.
2.6.1 Technology Transfer in UDEs

Several models of framework were developed by economists and specialists in the area of technology transfer. Most literature on ‘Management of Technology [MOT]’ intends to emphasize on two models for discussion purpose. The first model is called ‘Technology Transfer Process Stage’ or Souder’s model [1990] whereas the second one is known as ‘Technology Acquisition Model [TAM]’ or Adikibi’s model [1984]. The former model analyzes the process of technology transfer in the context of a typical DE. On the other hand, Adikibi’s model is known to be a very simple, practical and realistic one due to its systematic explanation and analysis of the process of foreign technology acquisition by a UDE. Due to its relevance, this section only analyzes TAM which prescribes four stages of technology acquisition:

2.6.1a Physical Transfer Stage:

The first stage comprises of the actual movement of technology elements such as plants, machinery, equipment, patents, personnel from the home to the host country. This stage is completed when the structure of production is set up to commence operations. As pointed out by Adikibi [1984], the duration of this stage depends largely upon the level of development of both countries, home and host. But in general, this stage takes a duration of 3-8 years for its completion.

2.6.1b Anchorage Stage:

As is described by Adikibi [1984], this stage is critical in the acquisition of foreign technology, without which the know-how remains alien to the host country. In phase I of this stage, low level of technology anchorage, and the dominance of foreign input is noticed, especially in the case of a 100% wholly owned subsidiary. The preparation of detailed training programs and the provision of the training facilities take place in this phase of anchorage.

Phase II, as described by Adikibi [1984], is the transitory phase from I [foreign input dominance] to phase II, which is characterized by domestic factor dominance. The major characterization of this stage is training of the local employees. It includes in-plant, out-plant and overseas programs geared towards implanting the technology and developing indigenous personnel capabilities. Phase II is the longest in duration and the most difficult to accomplish.

In phase III, all the expected evidence of complete anchorage of technology appears, such as effective control in the areas of management, production, technical and financial functions; substantial decrease in the import of factor-inputs; production under the
management by local personnel. Phase III, as described, is shorter in duration than phase I & II, and it represents the stage where the technology is ripe for diffusion into the industry.

2.6.1c Diffusion Stage:

The diffusion stage, has two main features, the first of these is the emergence of 'imitator' indigenous firms within the industry which copy the basic and standardized designs and techniques of production in the industry. The second phase of the Diffusion Stage manifests in three ways. 'Imitative Production' involves production of goods similar to those of the technology transferee. The other comprises the development of indigenous enterprises in the industry which compete with the transferee enterprise, the third feature is the increased number of host country nationals knowledgeable in the technology compared with number in the Anchorage stage. At this stage, licensing of advanced technology for production becomes a beneficial and efficient method of cooperation with foreign counterparts, because the basic know-how of the industry has now been diffused in the system. Unlike the Anchorage Stage, explained Adikibi, the completion time of the Diffusion Stage is expected to be much shorter. Adikibi concludes that the start and completion times of the Diffusion Stage depend more on factors in the host national than foreign environment.

2.6.1d Assimilation Stage:

The main features of this system, as described by Adikibi, are high degree of concentration on R&D and deeper understanding of the process technology in order to determine whether to adapt or modify the technology to suit local needs. This stage, as Adikibi argues, has no completion time, because, as he states, the adoption and modification of any know-how is a continuous process.

The Question of Time in Technology Acquisition:

Adikibi's model [1984] very clearly highlights the tracks that an UDE may follow to make a successful acquisition of technology. The estimated time frame suggested by Adikibi indicates that a UDE has to spend a lot of time to gain required capability to adopt and modify the imported technology. When a UDE aims to catch up the technology leaders and close the technology gap in shortest possible time, step-by-step movement ahead with different stages raises the issue of shortening the time span of each stage, and thus the entire acquisition process. Adikibi argues that, depending on the nature of technology and determinants of host country, some technology may be so desirable that the user or the transferee firms adopts them
during the physical transfer stage of technology, thus by-passing the subsequent stages. In addition, some of the stages may be carried out in parallel, depending on the government policy, effective information network, level of co-operation and collaboration between the firms, universities, R&D departments in the host country – strong technology infrastructure, as a whole. Adikibi's view is that the 'overlapping activities between the stages' [i.e., leapfrogging] contribute principally to the objectives of the stages, to which they belong.

The purpose of this model, as well declared by its developer, is to analyze and assess the process of technology transfer to and within the industries in an underdeveloped economy [UDE]. In addition to fulfilling its purpose, this model also shows the significance of facilitating 'technologically capable human resource' to fasten the technology acquisition process.

2.6.2 Processes of Technology Transfer

2.6.2a Classification of TT Processes

The process of TT involves two basic models: the direct and indirect transfer models [UNCTAD, 1991]. Others have referred to these as 'unbundled' and 'bundled' methods, respectively. Following Dahlman and Westphal [1982], this study divide the patterns/modes of technology transfer on the basis of two primary distinctions [Figure 2.3]. Though all these modes of technology transfer are possible their relative role in bringing about technological change will vary across industries and countries, depending on the policy framework [Joseph, 1997:128]. Moreover, the patterns of TT are determined by the characteristics of the technology and the bargaining power between importer and exporter [Kim, 1996: 26].

Continued ...
Figure 2.3: Different Modes of Technology Transfer

<table>
<thead>
<tr>
<th>Active role for foreigners</th>
<th>Passive role for foreigners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type I</td>
<td>Type II</td>
</tr>
<tr>
<td>Direct foreign investment; joint ventures; turnkey projects(^{14}); licensing</td>
<td>Purchase of capital goods</td>
</tr>
<tr>
<td>Type III</td>
<td>Type IV</td>
</tr>
<tr>
<td>Learning by exporting</td>
<td>Imitation; trade journals; scientific exchange</td>
</tr>
</tbody>
</table>


The classification is arbitrary since it is common in practice to find a single contractual agreement covering more than one of the categories. For instance, license agreements generally incorporate technical service contracts. A ‘turnkey’ agreement, on the other hand, may include license, technical service as well as engineering and construction contracts. The choice of any one device depends upon the requirement of the receiving enterprise [Shamsavari et al., 2002:21].

It is obvious, whatever may be the mode of transfer adopted, that there is a cost associated with technology transfer [Kumar, 1987] and it would vary from one mode to another. Let us take the Type I mode of technology transfer which is market mediated and in which there is an active role for foreigners. As in the case of any other goods, the seller will seek to sell the technology at the highest possible price and will attempt to establish a monopoly position to the extent possible through such practices as ‘packaging’\(^{15}\). The buyers, on the other hand, will seek to buy at the lowest possible price and in an ‘unpackaged’ form. The ultimate terms and conditions of technology transfer, as manifested in the extent of ‘unbundelling’, price, non-price tags like restrictions on export and so on, depends on a number of factors like

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\(^{13}\) The formal types of TT are considered the typical patterns of TT in a commercial base [Kim, 1997].

\(^{14}\) Turnkey projects involve the design and construction of a facility by an MNC in return for a fee in a host country. The other party may be a domestic company in the host country or a national government. Car assembly plants, suspension bridges, telecommunication systems and power stations are some examples of turnkey projects. Thus a turnkey project is a one-off transaction [Shamsavari et al., 2002:26].

\(^{15}\) The technology ‘package’ has many components such as drawings and designs, operation process parameters, material specifications and others. The ‘package’ provides, among others, plant and equipment, engineering and technical know-how, technical service and assistance, process technology, patents, trademarks and, most importantly, management skills and know-how. The payment [technology price] would be related to the package that is being acquired [Daussage, 1992; Kumar & Bhat, 1999: 20].
the bargaining power\textsuperscript{16} of the buyer and the nature of technology.

\textbf{2.6.2b Modes of TT: A Historical Flashback}

It is widely believed that most traditional technological transfer models are based on a closed-economy assumption which have been suitable in 19\textsuperscript{th} and early 20\textsuperscript{th} century. However, the post-World War II period has experienced greater globalization in world economy, thus, outdating the traditional TT models. These models are based on a narrow definition of technology [ie, process technology] and, as mentioned above, closed economy assumption. If these definitions and assumptions are relax, and open economies are assumed -- a broader definition of technology -- the traditional models fail to explain technology transfer. The broader definition of technology implies that in the new millennium, transfer of knowledge is the key issue. Thus a UDE may not be able to transfer [process] technology completely, but may be able to excel in other aspects of technology/ knowledge transfer [Shamsavari et al., 2002].

As understood, the TT models viewed so far are based on closed economy assumption and are fair descriptions of technology transfer in the 19\textsuperscript{th} century and early 20\textsuperscript{th} century. For instance, USA, Germany, Russia and Japan began industrialization in the second half of the 19\textsuperscript{th} century. They all relied on import substitution [ISI] strategy using tariffs as protective measures. The main argument was ‘infant industry’ [Alexander Hamilton in the USA and Fredrick List in Germany]. In the 20\textsuperscript{th} century, the prime examples of ISI have been the former Soviet Union, Brazil, India, Iran and Nigeria. The former Soviet Union used the \textit{licensing method} to transfer technology. It is clear from the ideological perspective of the Soviet Union that technology should be transferred with a view to economic independence from the imperialist west. For Japan, a similar perspective existed as Japan since the Maiji Restoration in the 1870’s was desperate to stay independent and avoid colonization by the west. China’s attempt at economic independence in the 1950’s shadowed the Soviet experience.

To a lesser extent, Japan also used \textit{licensing} [Stewart, 1978]. This method of TT is suitable in a number of sectors of the economy where brand names, trademarks and ultimately quality control are not essential. These sectors include engineering industries [and in general capital goods sector] and those consumer goods industries that at early stage of development of a country where the object is to meet ‘basic needs’, do not depend on brand loyalty, product

\textsuperscript{16} It has been shown that \textit{government policy intervention} in India to some measure has helped Indian firms strengthen their bargaining power and acquire technology in less packaged form and at lower cost [Subrahmanian 1984]. Also, it is important to point out that good TC generates strong bargaining power for the firms [Alagh et al. 1993].
differentiation, etc., eg, textiles, hygiene goods such as soaps. Thus technology could be transferred in the 2nd half of the 19th century and the 1st half of the 20th century through licensing.

The post-war period presents a different picture altogether. In this period, both in the North and South rising per-capita incomes, consumerism and rising expectations as well as changing lifestyles associated with the rise of sub-cultures as well as social movements are witnessed [civil rights, Women's Liberation]. Consumer products, product differentiation, quality, etc. in the context of rising per-capita incomes and increasing competition [Auerbach, 1988] made licensing a less attractive route for technology transfer. Thus licensing that essentially led to some kind of technological independence [through complete transfer of technologies] became less relevant as the emerging industries in the South had to cater to more sophisticated customers in an increasingly competitive world economy. Under these circumstances, in the post-war period, we witness an increased role in technology transfer for:

- Foreign Direct Investment [FDI],
- Joint ventures,
- Franchising, Management contracts and
- Turnkey projects.

Thus compared with the late 19th century and early 20th century methods of technology transfer [TT], Techno-Economics and MOT literatures are faced today with a multitude of methods. These methods are based on factors ranging from consumer loyalty to brands to the complexity of technical know-how. A recent study of technology transfer in car industry in Egypt [Taha, 2002] shows how this industry from the end of World War II to the present has moved from a strategy of complete [process] technology transfer [ISI] to a more market and export oriented strategy that does not require complete process technology transfer.

2.6.2c Equilibrium Choice of Transfer Processes:

The idea of choice presupposes the availability of alternatives. The choice of channel of technology transfer [TT] is made basically between two alternatives either [UNC/T, 1988]:

1) To transfer technology by FDI or joint venture [the indirect/internalized method],
2) To transfer through contractual arrangements, eg, licensing agreements/turnkey contracts [the direct method17 or externalized route].

However, based on the expectation of how long its monopolistic power can last in the recipient market, the importer chooses a pattern under the constraint of its TC, while the exporter decides either investment or sale of its own technology [Kim, 1996].

First, suppose that TC of the recipient is not competitive: The importer prefers FDI or turnkey projects because he may not have enough ability to utilize and operate the technology imported without detailed background know-how. The exporter, however, will choose licensing\textsuperscript{18} or turnkey projects only if his monopolistic power lasts for a short period & will prefer FDI to maintain monopolistic power for a long period [see figure 2.4 below].

**Figure 2.4: Choosing Suitable Mode of TT when Importer is less TC-Competitive**

<table>
<thead>
<tr>
<th>TT Pattern</th>
<th>Long</th>
<th>Short</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct foreign investment</td>
<td>M-X</td>
<td>M</td>
</tr>
<tr>
<td>[FDI]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Licensing</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Turnkey projects</td>
<td>M</td>
<td>M-X</td>
</tr>
<tr>
<td>Capital goods transfer</td>
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</tr>
</tbody>
</table>

Note: M and X denote importer's- and exporter's possible choices respectively

However, the turnkey project is not likely to occur under the exporter's expectation that monopolistic power will last for a long period. Therefore, for the importer who has low level of TC, advanced technologies are transferred in the form of foreign direct investment, and obsolete technologies in the form of turnkey projects.

Second, when the importer has a competitive level of TC: In this case, the importer prefers patterns of licensing or capital transfer, while the exporter chooses FDI or licensing under the expectation of long lasting monopolistic power and licensing or turnkey projects under the short lasting monopolistic power. Therefore, in this case the equilibrium pattern of TT is licensing [see figure 2.5 below].

\textsuperscript{18} Licensing is a process in which one company [the licensor] which possesses intellectual property rights, eg, technology, brand name, etc. allows another company [the licensee] to use or sell these rights in return for a financial reward [royalties]. Licensing agreements are not new in the business world. The former Soviet Union and Japan used licensing to acquire technology from the West [Shamsavari \textit{et al.} 2002:21].
Figure 2.5: Choosing Suitable Mode of TT when Importer's TC is Competitive

<table>
<thead>
<tr>
<th>TT Pattern</th>
<th>Monopolistic Power</th>
<th>Long</th>
<th>Short</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct foreign investment [FDI]</td>
<td>X</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Licensing</td>
<td>M-X</td>
<td>M-X</td>
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</tr>
<tr>
<td>Turnkey projects</td>
<td>---</td>
<td>X</td>
<td>M</td>
</tr>
<tr>
<td>Capital goods transfer</td>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
</tbody>
</table>

Note: M and X denote importer's- and exporter's possible choices respectively

From the discussion of the relationship between a technology importer's TC and the pattern of TT, the major finding that emerges is: the equilibrium pattern of TT –

- between north-south is FDI or turnkey projects, while that
- between north-north is licensing.

2.6.2d Complementarity of R&D With TT

It is observed in the above analysis that the most common source of TT to UDEs includes the modes given in the north-west rectangle [Type 1] which naturally has been subjected to substantial inquiry [Joseph, 1997: 128]. Among all the available modes of TT to UDEs, the discussion above finds substantial biases of the UDEs to FDI for the purpose of transferring advanced technologies [ATs] – advanced in context of their economies. Empirical evidences also show that in the Asian and Latin American countries, over half of capital flows have been in the form of FDI. The liberalization of trade and investment regimes in many UDEs and also the growth in intra-regional trade have influenced the surge in FDI flows to UDEs since the late 1980s [Kirkpatrick, 1995] In a number of UDEs, accelerating privatization programs have also attracted FDI inflows [Cook and Kirkpatrick, 1995]. In this connection, it is worth mentioning that UDEs should be well aware of the possibility of technology dependence by higher frequency of FDI [Kim, 1996:27]. In this connection, a question well remains,

'How to overcome or reduce the dependence? – Is it by developing local technological capability of the technology importing countries through R&D effort?'

As Nelson and Winter [1977] and others pointed out, technological knowledge, because of its complexity, cannot be transferred in its entirety, for instance, in blueprint. Technology which cannot be transferred in blueprint is called tacit knowledge. In this context, from the viewpoint of the receiver of technology, the most critical issue is,
"how to absorb this kind of tacit knowledge where the purchaser of technology always receives a less complete information set than what is possessed by the seller?"

Moreover, the technology transferred by the developed countries is generated in specific developed economy context; the effective use of technology transferred will call for adaptations to suit the local conditions of both factor and product markets. To elaborate, given the lower levels of income and consequent smaller market, there will be the need for scaling down [Desai, 1980]. Also, given the differences in factor prices the imported technology will have to be adapted to suit the local factor endowments [Joseph, 1997: 129]. In this connection, the question which becomes important to be answered is,

'Should adaptation of imported product and process technologies to local conditions be done through R&D?'

The issue of R&D is taken up for analytical discussion in section 2.7.3.

2.7 PROCESS OF ACQUIRING TECHNOLOGY ACQUISITION CAPABILITIES

2.7.1 Technological Learning

It is evident from the above analysis that TC plays an important role in attracting foreign technologies through superior mode of TT. TC also helps to shorten the technology acquisition period and, thus, fastening catching up with technology leaders. Note that capability is not an "item" that is traded in the market. TCs are activity specific, a function of how the activity is accomplished with the technology available for that activity. The process of TC acquisition is related to a process of technological learning19 and it is interesting to note that 'a learning process in the generation of new technologies' is nothing but what we call 'R&D' today. R&D include various forms of learning which are found relevant to the innovation process. At the basic research end of the R&D spectrum, the learning process involves the acquisition of knowledge [concerning the laws of nature] some of which turns out to have useful applications to productive activity. At the development end, the learning process consists of searching out and discovering the optimal design characteristics of a product, and then inventing the commercial dimension of this innovation process, as well as incorporating the knowledge in final product [Rosenberg, 1993] [a detailed discussion is done in section 2.7.3].

19 Capabilities are acquired through experience and learning, which is referred to as 'the acquisition of additional technical skill and knowledge by individuals and, through them, by organisations' [Bell 1984: 188], ie, expanding the ability to produce the desired results.
Car assemblers of capital goods in Korea show a distinctive pattern of 'technological learning'. For instance, Hyundai Motors, the largest car assembler in Korea and an affiliate of Hyundai Group, made large investments in training engineers abroad in order to begin technological learning for capital goods technology, much of it involving on-the-job experience. As a result of this effective means of learning, Hyundai Motors shortened learning time [Westphal, Rhee et al., 1985], rapidly adopting and utilizing foreign technologies to suit its internal requirements better. Now, for better conceptual clarity, the 'learning' issue is analyzed with respect to the issue of 'technological capabilities' [see, section 2.5] in two points of view --

- learning by doing\(^{20}\) [using available technologies], and
- learning by changing [introducing technological innovations].

Interestingly, these are the two kinds of learning that we have looked at through the R&D spectrum analysis above and experience of both these kinds of learning gives rise to real technological capability. Unit cost of production declines with experience because - learning through specializing, and learning through cumulative volume of production helps to reduce unit total costs. Generally, group learning involves error detection and correction; modification of standards; and improving the learning process. It has been suggested that the most important competitive advantage to acquire is the ability to "learn how to learn", and to learn faster than the competitors [Shanf, 1995].

2.7.1a Learning by Doing

In recent years, the aspects of learning commanding most attention deal with learning by doing - introduced first by Arrow [1962] and Shesinski [1967]. This form of learning is characterized by three properties: it arises passively, it is virtually automatic and it is costless. The kind of addition to skill formation in the doing-based learning process comes through the acquisition of greater understanding of the particular form of technology, the acquisition of greater knowledge of the principles involved and the acquisition of increased confidence in manipulating the technology. Simple learning-by-doing is an indispensable, but relatively minor, element in the acquisition of skills. It constitutes one mechanism for augmenting labor but at a certain point explicit effort and investment becomes a necessary condition for any other progress [Bell, 1984].

\(^{20}\) The aspects of learning commanding most attention in recent years deal with learning by doing [Arrow, 1962]. This is a form of learning that takes place at the manufacturing stage after the product has been designed, that is, after the learning in the R&D stages referred to above has been completed.
Learning-by-doing takes place at the manufacturing stage and learning at this stage consists of developing increasing skill in production and leads inventions and innovations [Arrow, 1962]. Therefore, the total mass of output has been suggested as a measure of learning and of technical progress. But this hypothesis would condemn any late starter to permanent backwardness since output may be increased simply by repetitive application of the same technology. All past investments as an alternative measure may also run into objections similar to the ones raised against the output measure [Kumar, 1987]. However, whatever may be the best measure to explain self-reliant growth, what a UDE has to keep in mind as a late starter is that it has to postulate quantum jump in technology for accelerated growth.

In the process of learning-by-doing, a cause-consequence effect can be noticed, because various kinds of 'doing' lead to augmented technological skills, but at the same time, the extent of learning that can be achieved is a function of the prior existence of capacities to undertake such 'doing' and to acquire knowledge during this process. In most cases, the nature and quality of science determines the strength of this prior know-why capacities in a country. This is the reason why a technology importer tries to maximize the 'learning and diffusion effects' of imported technology on the basis of technological knowledge already attained [Kim 1996] – it is an interdependent process which the UDEs have failed to recognize.

2.7.1b Learning by Using

Rosenberg [1982: 122] called attention to a separate category of learning, ie, learning by using, that begins only after certain new products are used subsequently. Learning by using is complementary to doing-based learning, but in course of time, the former beings where the latter ends. Systems characterized by a high degree of complexity cannot be understood by the available theories so that complete conceptualization is not possible and one learns in the process of use of the products of the technology. Today, this is true for most of the advanced technologies, like aerospace, computer software, etc. [Kumar, 1987:3].

Learning by using in aircraft generates highly specialized knowledge concerning the optimal design of aircraft components. This knowledge flows into a growing pool at the product development stage that is fed by other sources, such as metallurgical improvements, further progress in the miniaturization of electronic components [avionics], and so on. Out of this confluence comes a steady flow of small improvements that can he embodied in new hardware. Learning by using, thus, appears as an embodied knowledge. The knowledge, in this case,
generated leads to certain alterations in use that require no [or only trivial] modifications in hardware design and, in turn, leads to new practices that increase the productivity of the hardware. Therefore, Rosenberg (1993) describes that learning by using, in its purest form, is only disembodied knowledge. However, whatever is the type of embodiment, this raises the question of the prior existence of required science knowledge in a UDE.

While measuring 'learning by using', the total output is often thought of as a possibility. But, as Kumar (1987) observes, this measure would be inadequate as the entire output of a nation is not involved in the use of technologies which consist of a high degree of certain complexity. Also, he argues, as the country advances technologically, the percentage of output coming from high technology would increase and, thus, output would not even remain a good proxy for the required measure. Now, if dependence on the rate of investment is postulated as a variable to capture technical progress, it may pose some problems. However, a small sized investment in a small country may represent the same in a large economy in percentage and yet no research in high technology may be feasible. Therefore, one needs to also consider the size of the investment program of the country.

Finally, if the rate and scale of investment come as an alternative measure, it may again pose problems. As in the UDEs, investment may entirely be based on imported technology and personnel resulting in no indigenous development. Hence, it is the scale and the rate of direct investment in S&T that are crucial for measuring technical progress in a country. This is a straight result of the growing trend of specialization between production and R&D.

2.7.1c Learning-Diffusion Effects and the Pattern of TT

The categories of learning mentioned so far deal with producing new scientific knowledge, incorporating new knowledge in the design of a new product, learning new productive activities when a novel product is put into production, and learning ways to improve the productive process itself that grow out of experience with that process as well as learning to determine the optimal performance characteristics of a durable capital good. But what is left so far in the present discussion is,

What should be the level of learning effects in most of the UDEs where TT remains the main source of the so-called technological progress with heavy dependence on FDI due to their lack of investment and TC?

In the UDEs, TC linked with learning ability and diffusion effects remain one of the main factors affecting the pattern of importing technology through the bargaining mechanism
between the importer and exporter of technology. In this process, we have seen that less competitive TC and lack of physical investment lead UDEs to depend mostly on FDI as the source of TT. But, as observed in the study of Kim [1996], FDI allows greater and faster learning-diffusion effects only in the beginning stage which lasts for a short time.

On the other hand, ‘Licensing’ which has been seen to be a good source of advanced technologies, explores a gradual and steady effects for a long time. But as it has been also observed [for detail, see section 2.6], ‘licensing’ pattern of technology transfer [TT] requires higher degree of technical capability [TC] in an economy which underdeveloped economies do not possess. So, it highlights a vicious circle of technological indolence where the UDEs will keep on lagging behind in acquiring competitive TC, accumulating investment, and thus welcoming FDI for TT, allowing low technology or even obsolete technology to enter, finally resulting in poor incompatible learning and diffusion effects in the industrial sector.

In order to facilitate compatible learning and diffusion effects, the presence of dated labor must be ensured. Only labor with modern ‘know-why’ and ‘technical capability’ ranging from production to innovation can ensure transfer of technology [TT] in a better mode such as licensing, the way Japan, Korea, China did in their initial stage of technology development. But as previous discussions emphasized, effective learning requires prior capacities which depend on modern science [know-why] learning mainly through ‘education and training’.

### 2.7.2 Human Capital

Among various economic forces, education and training function as determinants of building up TCs and convey knowledge in the industrial sector. Education & training [including in-firm training] are essential to the provision of skills required in all forms of TC, from the most basic engineering activities to the most advanced R&D. It has been convincingly argued that a primary effect of education is to facilitate the ability to deal with rapid change [Nelson and Phelps, 1966; Schultz, 1975]. It, therefore, determines the capacity of individuals and labor markets as a whole to respond to changing circumstances, over the longer term [see Ergas, 1986; OECD, 1987; Lall, 1990; and Enos, 1991; among others]. The adequacy of national education and training system, thus, appears to be crucial factor in determining how effective a country’s firms are in applying technological skills across the full range of their activities.

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21 The education and training of workers is called human capital. But now-a-days better health & medical facilities, housing, etc., are also coming in consideration while defining human capital [Sharif, 1999].
Developed countries have reached their present stage of prosperity precisely because they, realizing that manpower represented their greatest resource, proceeded to improve the quality of their human resources through education and training. Curriculum development has been a continuing exercise with these countries to meet the rapidly changing world technological situation. The history of higher education in OECD [developed] countries since the early 1960s have been traced in a publication of OECD [1984]. It states:

"During the 1960s there was a massive expansion in higher education throughout the OECD area. Governments were obliged to take steps to deal with this unprecedented increase in demand for higher education by opening new universities and by recognizing and expanding the ones existing. Besides supporting the universities and other institutes of higher learning, the governments have also established a network of full-time or part-time courses for technician training and a similar network for vocational training. The Polytechnics house brings all these courses under one roof. The Open University System makes it possible through TV for employed persons to obtain a degree by part-time study: industry, whether in the public or private sector, has training programs to upgrade the skills of employees. Personnel whose skills have been rendered obsolescent by technological development have to be quite frequently retrained to impart new skills for which there is a present demand" [APCTT, 1986: 235-7].

It is generally accepted that the successful industrialization of the East Asian NICs was possible because of the availability of a sufficient number of educated and literate people. This favorable human environment has been largely the result of an early priority given to the development and upgrading of human resources. Important efforts were made not only to expand and improve secondary and higher education but also, and probably more importantly, to organize an efficient country-wide vocational training system. This quality of this training is considered to be the decisive factor in coping with technical change and in applying new technologies [UNIDO, 1989 and Frishwick ed., 1988]. For instance, Korea, the most successful of the Asian NICs, showed high values of human capital indicators. In 1989, 108% in relevant age group were enrolled in primary school, 86% in secondary school and 38% in tertiary institutions. The last indicator is, after Argentina, the highest level of enrolment in a group of 13 NICs [UNESCO Statistical Yearbook, 1990]. In vocational training, Korea and Taiwan were ahead with 2% of the total population in 1984, and as a proportion of the industrial labor force, Korea [39%] led together with Mexico [44%] [see Lall, 1990].

All the country-experiences [eg, of Japan, Asian Dragons, USA, etc.] highlight that as quality of people upgrades, the contribution of the people to further development of the economy increases as well. The reason is simply that a well educated population is able to produce more qualified outputs and adapt quicker to new technology than a poorly educated population. Another aspect of labor upgrading is that human beings are the source of new
ideas and of innovation. As a consequence, government decisions to invest in human
development, and science & technology [S&T] may therefore be a result in a growing economy
as well as an important instrument in fostering growth [Stockey, 1991].

The rate of progress in new technologies today is so fast that gaps rapidly widen,
rendering it almost impossible in future to catch up in key areas. If the country is unprepared
with respect to its human resource then it will be unable to make use of key new technologies
in future. Moreover, the latter can no longer be termed today as "glamour technologies" because they are going to be the basic technologies of tomorrow. The time lag between global
launch and introduction in a growing market is shrinking; Pentium chips, Windows 95 were
introduced in Singapore within weeks of their launch in USA whereas it took 100 years for the
steam engine technology to travel from England to Japan [Rao, 1997:30]. This implies that
unless correct strategies are adopted now for relevant education and ‘training’, the labor is
destined to face enormous difficulties in future in absorbing and adjusting to advanced
technologies [ATs] in manufacturing processes.

Of equal importance is the urgent need to create a management culture in UDEs’
industry sector so that the attitudinal constraints towards adoption of AT do not take
precedence over the need to be forward looking and supportive to new technologies. This is
particularly true for the export-oriented technology-based industries in which the UDEs like
Bangladesh have started to make a beginning. Finally, it is imperative that serious attention be
given in the UDEs towards planning appropriate institutions, facilities and modalities to convert
the manpower base into a dated one -- dated enough to deal with the new and emerging
technologies without any difficulty.

2.7.3 Research and Development [R&D]

As a potential answer to the above raised questions in section 2.6.2d, let us now turn to
identify the characteristics of the other major force, namely, R&D, that shapes technological
change in the Third World where the need for domestic R&D is obvious. In UDEs, R&D play
a crucial role in any technology transfer, absorption, assimilation and upgradation. Aggressive
R&D activities are in the forefront in developing leadership in the competitive market, and in
the long run pays a return on investment. R&D can be of two types [Virmani and Rao, 1999:42]:

[1] Basic R&D where the emphasis is on development of technology or processes for
production increase and design of new products; and [2] R&D for development of
capabilities to absorb, assimilate and upgrade technology brought in from other countries.
The above two categories of R&D highlight two major streams of world economies. The former category of R&D is mostly conducted in the DEs whereas the latter category is related with TT activities in the UDEs [specially in strong South]. The main emphasis of this section remains on the latter kind of R&D activities which rely on TNC-based FDIs. Since the 1980s, the TNCs have started internationalizing their corporate R&D into some UDEs. This move by TNCs is facilitated by the availability of a well-structured technology infrastructure with a large pool of scientifically trained researchers and good universities/research institutes, and an adequate industrial base in some of the DCs/UDEs [Brundenius et al., 1993:78].

In the few cases where some R&D was performed in UDEs, it was, as confirmed by studies in the late 1970s and 1980s [Craemer, 1976; Ronstadt, 1977; Behrman and Fischer, 1980; Hirschey and Caves, 1981; Brundenius and Goransson, 1993; Reddy, 1993], limited to adaptation, local technical services or at the most to product development for the local market. But there is evidence [Parthasarathi, 1987] which suggests that the UDEs also perform R&D activities oriented towards [a] search for new products and processes, [b] developing new products and processes [new from the point of view of the Third World], eg, Hindustan-Lever Ltd. in India [Ronstadt, 1984] and [c] basic research, eg, Weizmann Institute in Israel for genetic engineering research in collaboration with Kabi-Vitrum, Sweden [Hakansson, 1989].

Dorrenbacher and Wortmann [1991] analyzed the motives for internationalization of R&D at two different levels. First, if the R&D is done at the location which is most efficient within the framework of the corporate R&D system, then it is considered as “R&D related motive”. Second, if the R&D serve purposes not related to an improvement of the company’s R&D system, then it is considered as “R&D unrelated motive”. There are two kinds of “R&D related motives” for R&D abroad. The first is to support the local production through adaptation to local requirements. The second is aimed at the generation of new technologies that will be used throughout the whole company. The innovative potential in the foreign country does not necessarily have to be more advanced than the potential in the home country. Technological expertise can be complementary. “R&D unrelated motives” include the inducements & pressures from the national governments [Behrman & Fischer, 1980a], improving the image of the company, attracting qualified personnel to work for the company, etc.

Ronstadt [1984] and Behrmann and Fischer [1980a] in their studies found that most of the R&D units abroad were established for R&D related reasons. Non-R&D goals – monitoring foreign R&D activities and using cheap R&D labor – played no role in the majority
of the cases. At the time of their studies, R&D was established abroad to provide local technical services. So, such R&D units were, probably, considered as additional costs of transfer of technology rather than as sources of new ideas. Therefore, in the past, reduction of R&D costs might not have been a motive for R&D abroad.

In the context of UDEs, the criteria used by TNCs for the selection of R&D location can be explained in terms of the following typology of countries [Brundenius et al., 1993:97-8].

1] Advanced Developing Countries [ADCs] or Strong South Economies – countries with strong science and technology base, eg, Brazil, China, India, etc.;
2] Newly Industrialized Economies [NIEs] – countries with strong and sophisticated industrial base, eg, designing of semi-conductors, etc.;
3] East Europe – countries similar to ADCs;
4] Other Developing Countries [ODCs] – UDEs like Bangladesh, Nepal, Fiji, etc.

It is interesting to note that technologies oriented towards product development and direct industrial application seem to prefer R&D in countries like South Korea, Taiwan and Singapore [ie, Asian NIEs]. The companies from these countries have already been playing a vital role in the international markets. On the other hand, ADCs like Brazil and India, which have well known research institutes in pure science, seem to be attracting R&D investments in mission oriented basic research [biotechnology] and disembodied software design and development. The latter group of countries, although have an adequate industrial base, do not have an internationally competitive industrial base in the new technologies. The countries could be put into the following typologies:

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<th>Industrial Base</th>
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<tr>
<td><strong>B A S E</strong></td>
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<tr>
<td>Strong</td>
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<td>Strong</td>
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<td>Industrialized</td>
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<td>Countries</td>
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<td>Weak</td>
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Part of the explanation for such differences is found in the type of of policies followed by these countries. ADCs for a long time followed import substitution policies and built up capabilities for the total system design and development, which probably is more suitable for
R&D into basic science. On the other hand, the NIEs followed export-led strategy and built up specialized capabilities in a few components of the system and this expertise seem to be more suitable for direct product development and industrial application [Brundenius et al., 1993:98].

Moreover, it is also observed that mostly the firms dealing with new technologies [biotechnology or microelectronics or new materials] are involved in global R&D activities. New technologies seem to have universal applicability, whereas conventional technologies [like engineering, automobile and chemical] need to be adapted to the local market requirements. Hence, in conventional technologies, R&D abroad by TNCs had only the local market orientation, whereas R&D in new technologies has global or at least regional orientation. Moreover, since the new technologies still are in the emerging stages, everybody is in the learning stage. So, Perez and Soete [1988] feel that developing countries [DCs] hold promising opportunities of joining the main stream by concentrating on new technologies. According to them, the DCs have the necessary requirements for entry into the initial stages of development of new technologies. The TNCs, realizing this and therefore, started performing some of their global R&D in DCs.

In light of the above discussion, it is clear that governments in the UDEs must endeavor to establish and refine their domestic technology infrastructure and adopt measures to support the technological- as well as R&D capability building activities in order to reduce dependence on technology import [Zhaojun, 1996: 36-7]. Besides R&D, TC-building activities also require development of learning ability and human capital [Lee, 1990] to strengthen bargaining power of technology importer and thus reduce magnitude of technology import.

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22 However, as Marie-Jose Smits [1990] warned, the DCs/UDEs need to be aware of their vulnerability in the international division of labor to become experimental sites to potentially hazardous activities. Such dangers exist only in a few cases of R&D in biotechnology. The international R&D centers, instead of diffusing the benefits throughout the economy, may remain isolated islands of high-tech benefiting only the researchers. But in the long run, some spin-off benefits could be safely expected.

23 Such as the construction of public digital information networks [eg, CHINANET] in China, setting up of 'system of hierarchy' in Japan, framing of aggressive export-promotion policy in Korea, etc. [Zhaojun, 1996: 36-7].
2.8 OPTIMUM TECHNOLOGICAL STRATEGY FOR UDEs

As a very late-starter, it can be expected, the UDEs like Bangladesh, can utilize the advantage of being late and arrange to accomplish some steps in targeting a high level technological attainment compatible with the technology leaders. The following discussion may penetrate an outline of the possible technological strategy that a UDE may pursue for:

Several useful technologies are available for a price and, therefore, late starters should consider the various aspects of technology importation. Mature technologies take less cost and risk to purchase and adopt but are not suitable for catching-up technology leaders. The imported technologies should be 'new' [of current vintage] and mastered through R&D efforts since mere import of machinery and plants, and manufacture with given formulae might not lead to technology transfer [TT] or capability [TC] building. The experience of successful UDEs proves that effective R&D systems are the core of a national capability development process which strengthen the ongoing human capital accumulation and learning activities [Cooper, 1973; Sagasti, 1979; Gonsen, 1998]. Therefore, Benhabib & Spiegel [1994]; Quah [1996]; and Barro and Sala-i-Martin [1997], in their endogenous growth models, highlighted the importance of imitation and research in countries' growth. As a whole, technological mastery can be resulted from adaptation [digestion] and upgradation of technoware and from indigenous efforts [generation]. The mastery gained in assimilating technoware would help the UDEs in a number of ways:

[1] enable greater indigenous participation in subsequent transfer of related technoware, thereby increasing the effectiveness with which they are assimilated; [2] reduce the need for reinventing the wheel; [3] help in leapfrogging certain generation to jump to a higher level.

In consideration of the fact that UDEs lag far behind the technology leaders and they have to catch-up the leaders so that 'technology gap' is narrowed down to zero or so, 'leapfrogging' appears to be the best available strategy for them. It is possible to skip intermediate steps in technology development provided the preconditions, such as technically equipped human capital with high learning ability, presence of R&D culture in the country with continuous investment and incentives by the government, etc., have been met. The strategy, in specific, is to generate competent technology and not just live with an imported mature technology. Thus, overall considerations of the choices available to late starters [such as Bangladesh] in technology development reveal two basic strategic considerations in arriving at a development policy [for relevant idea, see Waluzzaman et al., 1993]:
1. It is necessary to select and import some mature technologies and successfully digest these in the socio-economic milieu through an evolutionary learning absorption process in which local R&D institutions and industry work hand in hand.

2. It is essential to attain some strong capability [of latest vintage] to develop a few carefully selected technologies [of some specialized areas] in the local technology generation facilities [RDI] which will give the country some competitive edge in the international market.

2.9 CONCLUDING REMARKS

This chapter has discussed all technology-oriented issues keeping in mind that ‘technology’ is a black box. Since any particular concept of technology is non-existent, this Chapter has therefore initiated the present discussion by presenting some commonly used definitions of technology in the literature. For an in-depth idea, the chapter has gone through the historical perspective of the evolution of technology and its progress and has found, till today, the so-called Schumpeterian trilogy is equally valued while defining technological progress in the literature of Techno-Economics and Management of Technology [MOT]. An analysis on the components of technology has led to the conceptualization of technology in the following way,

”Technology means resource transformational activities, ranging from production, operation to organizational structures of industrial activities, resulting in higher efficiency and competitiveness of firms leading to economic growth”.

Finally, in whatever way technology is defined, it is understood that ‘technology’ is a process of accumulating material wealth by transforming the natural world into a man-made world what is called the production system of a country theoretically. When the transformation activity leading to the production of economic goods is examined, it becomes evident that, it can be described in terms of four elements, namely: inputs, outputs, the technology used for transforming the inputs into outputs and the national climate influencing the performance of the transformation activity [this issue is widely discussed in Chapter III].

From the technology characterization process, the Chapter finds incremental type of technological change to occur often in the underdeveloped economies [UDEs] due to their dependence on ‘foreign technology [matured]’, and weak internal R&D efforts. It is understood, due to less competitive TC-characteristics in the UDEs, most of them have to rely mostly on FDI for technology import/transfer although licensing mode of TT serves better results provided the UDE has strong TC. It means that UDEs need to strengthen their TC-building.

24 The possibility has been discussed in many occasions in this chapter such as in ‘technology sophistication levels’
activities to reduce dependence on FDI for TTs. Also, since foreign [tacit] technology is not transferred in complete form, UDEs need to adapt this in its local R&D centers.

In consideration of the fact that there is always some risks associated with R&D funding, very few private enterprises are willing to take the risks. Therefore, in the UDEs, the responsibility of carrying out most of the R&D activities falls on the shoulder of the public sector. However, R&D in the public sector, though appropriate in some cases, has one major disadvantage in that it usually results in less cross-fertilization of ideas than would be the case if the same activity were carried out in the industry. Since most UDE-innovations are incremental rather than Schumpeterian revolutionary, as an investment for the future, it would be unwise for the UDEs to rely solely on their public sector centers of excellence to provide the feedstock of technical ideas. It is, in this context, that mobilization of the private sector for technological development assumes importance with active government support and supervision. This issue is discussed in terms of 'the motives of R&D internationalization' where it is found that UDEs can be successful in promoting R&D through TNCs only if it is facilitated by proper technology structure. Throughout the chapter, a growing role of government in the UDEs is observed necessary for the proper nourishment of R&D culture as complementary process to TT.

An analyses on the neoclassical- and endogenous- growth theories have highlighted the importance of investments mainly in R&D [for accumulation and commercialization of knowledge], human capitalization for effective utilization of imported technology and innovation of new technology, as well as development of protected information and compatible organization. When human resource with greater learning ability is well-developed in any particular technological area, buying technology becomes a lucky option. In UDEs, ‘learning’ consists of a joint process of advance of technology [know-how] and of science [know-why] which, at present, are considered separate in the case of modern technologies. But, since the labor force in UDEs lack readiness to absorb foreign technology, learning consists of a blend of both learnings of -science and -technology while using ‘technology’. Although endogenous growth models successfully established the importance of investing in human capital, research and learning activities, all their propositions have failed to highlight the fact that a latest imported technology requires a most recently trained labor force in the host country for faster learning and absorption. Among none, one of the most neglected models of embodied technical progress, namely, vintage models, have explained this issue.
Vintage models, as the theoretical base of this study, have helped to deal with the 'catching-up' and 'technology gap' issues in the UDEs. It is understood, simply manufacturing or assembling on the basis of a given design or an imported mature technology does not create any scope of catching-up for a technology follower. In order to close the 'technology gap', these models suggest that a follower has to invest in latest machines which have to be crewed by men with advanced know-why. Since a UDE has to skip intermediate stages of technology creation to catch-up the leaders, it has to produce 'skilled labor' [currently trained men] which is capable enough to imitate new technology and innovate further on the existing technology. Simply welcoming low technologies through FDI and assembling on given formulae without applying creative ideas will not create any opportunity of catching up leading to closing technology gap. Meaningful 'catching-up' and 'narrowing technology gap' are only possible when a UDE can successfully combine imported technologies with cheap but dated labor and fully exploit the human factors to indigenously generate new technologies and even export some of them to developed countries. This is exactly what China did in their growth process and, as a consequence, now exports to countries like UK, USA, Sweden, Luxembourg, etc.

Therefore, in order to diffuse knowledge and facilitate technological leapfrogging, the learning process must be strengthened by heavy investment in human capital, knowledge accumulation and R&D – i.e., development of technological infrastructure as a whole to promote technology –diffusion and –creating capabilities. While defining 'technology' as a transformational process in this chapter, the importance of developing 'technology infrastructure' has, in fact, been highlighted as 'technology climate'. Again, the same has been emphasized strongly as 'national technological capability' and 'national technology climate' by endogenous innovation models and APCIT [1986] respectively. Due to the immense importance of 'national technology infrastructure/climate' while fixing and pursuing with aggressive technological strategy, the next chapter takes up this issue in detail and makes an assessment of 'national technical capability of Bangladesh' as a case of this study.