THE NEOCLASSICAL AND EVOLUTIONARY THEORIES OF TECHNOLOGICAL CHANGE

Neoclassical theory of industrial development or how firms develop

Neoclassical theory assumes that firms face well-behaved production functions where all technological options or alternatives are known perfectly, and can be accessed at no cost; and the choice of any particular technology is the result of optimizing behavior of firms in the bid to allocate resources on the basis of capital/labour costs. Technical change in this framework is a shift of the production function resulting from some unexplained exogenous innovation, or from firms optimizing research and development (R&D) choices with predictable outcomes. Firms do not learn to use existing technology; they exhibit instantaneous and costless mastery over these technologies, and they operate is isolation from other firms. Free markets optimize resources allocation and there is no need for government intervention. In fact any intervention is likely to distort perfect markets (Dosi, 1997). "The correct set of policies then is always to allow free markets to work – the best government is the one that provides a stable macroeconomic climate, essential 'public goods' and stays out of the way of private enterprise" (Lall, 1995).

Dynamics of industrial development – Evolutionary perspective

A new firm starts by mastering the operational know-how of simpler technologies. At this stage the technology is usually embodied in equipment, and what is needed is a mastering of the skills to handle the equipment to produce efficiently. At a later stage more complex skills need to be learnt – "adaptation (of technology) and improvement; substitution of inputs; modification of products; learning product design and the principles behind the process and equipment; new product and process development; and finally, innovation in a more basic sense" (Lall, 1995). The movement is from a stage of know-how to one of know-why. Each step of the learning process has its own costs which rise with the complexity of the technology or the process involved. The movement to "more complex technologies leads to greater local value added, higher wages and a more dynamic pattern of export competitiveness" (Lall, 1995). At still later stage, formal R&D becomes critical as firm try to "create new products and processes, and absorb complex new technologies innovated elsewhere, keep track of changing technologies, and adapt them to specific uses (Lall, 1995).

Thus, policies for technological and industrial development may be regarded as the results of interplay between

a. Innovative opportunities
b. The incentives to exploit those opportunities
c. The capabilities of the agents to achieve success conditional on their perception of the both opportunities and incentives
d. The organizational arrangements and mechanisms through which technological advances are search for and implemented (Dosi, 1997).

Neoclassical theory of innovation

The neoclassical theory of innovation emphasizes the importance of demand in stimulating innovative activity and determining the timing and location of innovation (Griliches, 1997; Schmookler, 1962; Ruttan, 1997). A second theory emphasizes changes in relative factor prices as a spur to innovation – to economise the use of the factor which has become expensive (Hicks, 1932), or indeed to reduce total cost (Salter, 1960; Ahmad, 1966; Binswanger and Ruttan, 1978).

When it comes to incentives to innovate, neoclassical theory lays emphasis on how much resources are devoted to R&D, because it is hypothesized that R&D is the main determinant of technological change which, in turn, imparts growth to the economy. R&D is like any other economic activity subject to the dictates of profit maximization. The motivation and, therefore, the decision to undertake R&D and the resources allocated to this activity depend on the extent of appropriability of the rent streams coming from successful innovations.

The implications making R&D activities determined by market forces are that:

a. If the country or industry does not have a comparative advantage in R&D activities, i.e., if the country or industry is not already well off in R&D activities then no resource should be devoted to R&D, because it will not be profitable to do so.
b. Government promotion of R&D is likely to diminish welfare because the policy induces a waste of national resources during the period of technological catch up.

Evolutionary theory of innovation

This is in contrast to the neoclassical perspective which pictures innovative activity as arising from scientific advances triggered by firm – sponsored technological developments; from firm's own experience of design, development, production and marketing; from a wide variety of external sources at home and abroad – their customers, suppliers and contractors; from universities, government laboratories, consultants, licensors, etc (Freeman, 1994; Dosi, 1997); from a variety of learning processes – making use of the knowledge and problem – solving capabilities that firms embody in different degrees.

Evolutionary theory says that:

a. Even though innovation offers profit to the innovating individual, firm or country, it is costly in terms of resources and time devoted to it; it is also uncertain in term of the actual returns on resources invested, and its ultimate economic and social acceptability.
b. It is known from empirical studies of innovation that uncertainty prevails at all stages of technological evolution, from initial design choices, through success or failure in the market place, to eventual environmental impacts and spin-off effects; that it is impossible to forecast technological change.
c. Technology keeps changing all the time. Change includes a continuous introduction of new varieties, or "species", and continuous subsequent improvements and modifications (Grubler, 1998).
d. Furthermore, technological changes build on previous experience and knowledge. Hence, technological knowledge and the stock of technologies in use grow continuously. As knowledge grows usually through "learning by doing" and "learning by using", unit costs of production decline. But they do not decline exponentially as portrayed by neoclassical economics, for that would mean that the cost reductions can be maintained indefinitely. In the real world, cost reductions become smaller relative to each increase in production volume, i.e., the experience required for each subsequent reduction in costs takes longer to accumulate and is more and more difficult to achieve. One might say that the potential for cost reductions becomes increasingly exhausted as the technology matures (Grubler, 1998).
e. There are reasons other than profit maximization or cost minimization which motive firms to undertake R&D:
    i. Countries and firms undertake R&D to catch up with technology leaders.
    ii. Countries and firms want to be first to develop new products and processes and thus be in a position to reap monopoly rents.
    iii. Countries and firms generally keep up with technical developments in order to be ready to exploit opportunities as they arise.

iv. R&D activities have to be created, promoted, and fostered; and governmental or public support is indispensable in this regard.
v. R&D is an activity that gives rise to more R&D; and conventional economics with its assumptions of constant returns to scale and diminishing returns to factors is not well equipped to deal with the R&D phenomenon.
vi. R&D in agriculture must necessarily be done in situ.

In the face of such unpredictability, such uncertainty, such unreliability of the market to give correct signals to resource allocation; in the face of the dynamic, cumulative, synergistic nature of technological change, making R&D be guided by market forces is not only naïve but shows the economic profession as readily willing to gloss over important economic and social issues if their tools cannot handle them.

Dosi (1997) makes the point that even though some expected differential profitability is a necessary condition for private actors to undertake expensive and uncertain search efforts, there is not much evidence that the intensity of search grow monotonically with the expected value of the rent streams. Rather, differences in opportunities and firm-specific capabilities account for firm's propensity to innovate.

Diffusion – Neoclassical theory

Neoclassical economics also has models of diffusion. The study of diffusion pertains to the manner in which follower economies share by imitation in the technological advances by leading-edge economies since imitation tends to be cheaper that innovation, the diffusion models predict a form of conditional convergence, i.e., that imitators will catch up with the originators – which is at variance with the facts.

Diffusion – evolutionary theory

Diffusion is the final, and sometimes painful, test of whether an innovation can create a niche of its own or successfully supplant existing practices and artifacts. Technology assumes significance only through its application (innovation) and subsequent widespread replication (diffusion). To be successful, innovations must be continuously experimented with, and continuously modified and improved. Suppliers and users must work together; information from the marketing department must be fed back to the research lab in order to suggest new promising avenues for both applied and basic research.

New knowledge is expensive to generate but cheap to imitate. Thus, benefits may not accrue to the innovator, and this risk is a disincentive for change. The risk can be reduced through effective patent system, for instance, a technology can have so much negative feedback that it does not diffuse, in which case all the resources and time put into it are lost.

Institutions, including governments, firms, and markets and social norms and attitudes, are especially important in determining how systems for producing and using artifacts emerge and function. They determine how particular artifacts and combinations of artifacts originate, which ones are rejected or which ones become successful, and, if successful, how quickly they are incorporated in the economy and the society (Grubler, 1998).

Transfer of technology or international diffusion of technical knowledge

Neoclassical perspective: Technology is transferred in different ways – through technical cooperation programmes, the purchase of foreign know-how as in the form of licenses and patents, foreign investment, the purchase of capital equipment and capital, published material, foreign training, and conferences. It is admitted that the acquisition of more sophisticated technology requires the disciplines of management, and the organization of production and marketing of finished products in the recipient country or organization, but there is no inherent problem of access (Jones, 1971). The transfer of technology is fairly easy, smooth, and more or less costless.

Evolutionary perspective: they are of the mind that;

a. The proprietary nature of technology: firm that invests in technology development like to protect their results through patents and secrecy.
b. Even if technology could be seen as a book of blueprints and therefore easily transferable, a certain expertise is required to interpret and apply the engineering principles to a real-life situation. Firms or countries often lack this capacity
c. Only a portion of technological knowledge is codified in the form of basic principles; a good proportion is tacit or unwritten. Thus, some skills take considerable time to learn.
d. Even if engineering and scientific principles are well established and can be learned, applying them requires heavy capital investment in order to develop effective prototypes and a long period of learning to get the technology right (Irfan ul Haque, 1995).

Since learning costs differ between activities, interventions to ensure effiecient resource allocation have to be selective rather than uniform. Little protection is needed for simpler activities. In complex activities, with large scales, advanced information and skill needs, wide linkages and intricate organizations, the learning process could spread over a longer period. These activities may never be undertaken unless protection is given.

The second kind of allocation, affecting the deepening of capabilities within activities, can also suffer market failure. Arrow (1962) noted that a free market may fail to ensure optimal innovative activity because of imperfect appropriability of information and skills. It is also generally easier to import foreign technologies fully "packaged" where the process is commercially proven, and the supplier provides the hard and software, does the start-up, training and adaptation, and manages the operation and marketing. This is the definition of foreign direct investment (FDI); unfortunately, it leads to little capability acquisition in the developing country apart from production skills. The move from production to innovative activity involves a distinct strategic decision which foreign investors tend to be unwilling to take in LDCs. There is generally less investment in design, development and innovation, and the externalities generated by the technological activity that does take place tend to be captured by the investor rather that the host economy.

Deepening can also be used in the sense of increasing local integration: the development of local suppliers and subcontractors. There could be market failures here. For, apart from the production benefits these linkages speed the diffusion of technology, increase specialization and raise industrial flexibility. In particular, the development of local equipment suppliers can raise the generation and diffusion of technology. Because of these externalities, there may be a valid case for promoting entire sets of related activities, which would not otherwise be able to coordinate their investments. There may also be a case for selecting those sets of activities that offer higher learning potential, because of the advanced technologies involved.

One would have no objection if neoclassical economists accepted evolutionary economic theory and institutional economics as complementary theories capable of dealing with socio-economic issues not easily handled by conventional economics. On the contrary, there is a certain resistance to introducing the evolutionary method into economic theorizing not because it could be complex and difficult to understand but because the equilibrium concept is regarded as aesthetic; and general equilibrium theories are seen as elegant. Thus any theories that depart from these are regarded as ad hoc (Nelson, 1995). Indeed, some of the best brains in economics are currently engaged in research into the sources, direction and rate of technological change in endogenous growth models using mechanistic optimization and the dynamic equilibrium method.

University-Industry Interactions

1. **The Sabato's Triangle:** Some forty years ago, a hypothesis was proposed by an Agentian physicist, **Jorge Sabato,** who was also an academic and an R & D manager. Looking at the Agentian reality in particular and Latin America is general, Sabato suggested a **strategy to use science and technology** to overcome Latin America's state of under development. He elaborated a triadic schema (later called Sabato's triange) as an instrument of diagnoses and strategy formulation for science and technology policy. [(These ideals were presented in a paper delivered at "The World Order Models Conference" in Italy in 1968, and published two months later (Sabato and Botano, 1968)].

   Sabato's triangle was a proactive strategy aimed to both force and enable the participation of Latin America in science and technology with the view of successfully achieving this objective by the year 2000. **The issue was how to insert S and T** into the development process and "how to innovate". Innovation, as understood by Sabato, meant the **"incorporation of knowledge** – one's own or alien – directed toward generating or changing productive process". For this reason, the insertion of s and t into the development project itself assumed the ability to know where and how to innovate and to have the political means at hand to direct the process.

   According to Sabato, in order for development to take place, it was necessary to construct a regions **s and t** infrastructure linked to the productive structure of the society. **This process involved the multiple and coordinate actions** of three vertices of society: **government (g); the productive structure (e); including** private and government-owned companies and the **science-tech infrastructure (z),** including universities, public and private research and development centres. Saboto posted a set of three types of relationship among the elements of the triangle: **intra-relations** (within the vertices) and **extra-relations** (with the government directing the two other vertices). This concept for science-based development was premised upon the **government triggering** a process of strong inter-relations among the three players.

   The **cornerstone** of the science and technology revolution in the 2nd half of the (20th was perceived by Sabato as resulting from a **purposeful process of interrelations.** In his terms, it occurred through commands circulating down from the top vertex g, to the vertices at the base of the triangle, "e and z"; and horizontally between the last two vertices. Those horizontal interrelations are different to established especially when the different fixings are performed in specialized institutions, as in the case of a company that does not earn, out research and institutions devoted to research. Lack of capacity to internally translate from one institutional sphere to another was characteristic of organizational underdevelopment, the Latin America gap that Sabato was determined to fill by direct government action.

   Sabato suggested the mobilization of R and D resources by the US during the WWII as a historical instance of a triangle of relations in full functioning force. According to Sabato, the US put all its scientific pontential to use through the government acting upon the other two vertices, formulating policies and mobilizing resources.

   The use of a triangle schema to express a s and t policy was not an "invention" of Sabato. He acknowledge that he was introduced to the concept of triangle in a paper written in 1967 by H.W. Julius (Director of the Netherlands Central Organization for Applied Scientific

Research) and titled "Government, Industry and Partnership" in scientific application with special reference to the Netherlands.

In this paper, Julius held that "all those responsible in one way or another for the all-important economic development of their countries rack their brains to find the balance within the any complicated relationships in the modern external triangle of government, industry and science. (Ciaqpuscio, 1994 : 17).

2. **The Triple Helix Model of Innovation:** The organizational principle of the triple helix is the expectation that the university will play a operates role in society, the so-called "Third Mission". The Triple Helix Thesis is that the University-Industry-government interaction is the key to improving the conditions for innovation in a knowledge-based society. Industry is member of the triple helix as the locus of production; the government as the source of contractual relations that guarantees stable interactions and exchange. The university as a source of new knowledge and technology, the generative principle of knowledge-based economies. The entrepreneurial university of social reproduction and extension of certified knowledge, but places them in a broader context as part innovation (Etzkowits, 2003).

   The triple helix model was developed as an exposed concept, reflecting the reality of the developed countries where innovation has been associated with science-based industries and R & D activities. As the role of codified knowledge in innovation has increased, research universities have played a more important part in this endeavour. Moreover, university industry cooperation has been facilitated by explicit science and technology government policies.

   The triple helix explains the formation and consolidation of learning societies, deeply routed in knowledge production and dissemination and a well-articulated relationship between university industry and government. It must be admitted that in several NICs with very interesting experiments, these countries lack of well articulated university-industry-government relationship that would qualify as a time triple helix.

   Never the less, the triple helix model can be used as an ex-ante concept, a strategic tool to open up roads for a catch-up process, with an ultimate goal of creating a learning society.

   The triple helix model, which involves interaction links between government agencies, universities and business and industry, is increasingly being used as a policy framework in both developed policy framework in both developed and developing countries to strengthen their national and regional economies through learning and innovation. The model is underpinned by strong interactions between key actors in the form of government institutes, business organizations and teaching and research institutions. It is influenced by the formation of these networks, collaboration and alliances leading to greater integration within and between each of these institutions. It is therefore based on the idea of rapid learning and innovation through proximity and collaboration between these key actors and institutions (Leydesdorff and Etzkowits, 1998).

   The triple helix model involves a **wholistic approach** to innovation base on the networking of diverse organizations and discipline. As a networking exercise, it seeks to promote rapid learning through proximity and collaboration between the main actors. Each actor in the system would scrutinize the innovation process according to its own interest. (In terms of disciplinary network, economists would, for instance, view innovation as a vital factor in fostering economic growth. For psychologists and specialists in organizational behavior, innovation is mostly perceived as a team effort and the aim is to understand changes in human behavior. Sociologists and organization theorists also focus on human behavior but only to the extent that it enhances interactions among people in a group or organization. This objective is to investigate the role of organizational structure political scientists focus on the formation of groups and the way they pursue their interest. They investigate issues including the impact of the government decisions, decision-making methods and the politics of implementation. For engineers and technologists, the primary concern is the design of products and its production process. They focus on the efficiency of the various means for achieving production. These disciplines when brought together in a network system explain the synergy underlying the innovation process. The same applies to organizational actors interacting in a network system.

The key features of the triple helix model derived from theories of innovation starting from Schumpeter contribution to the analysis of the role of innovation in the process of economic change and including inter alia, the more recent works of neo-Schumpeterian for whom innovation is an evolution, interaction, cumulative, institutional and is equilibrating process.

The triple helix model is a further development of the technology economic paradigm introduced by Freeman and Perez (1988). This paradigm is based upon the feedback deriving from the interaction between the economic, social, political and institutional spheres which influence the development and diffusion of innovation.

For the **triple helix model, innovation is caused by the interaction of key players or actors** in the model on their own, individual players are ineffective. This multi-factor approach network system to innovation indicates that, most of the major innovations take place as a result of the interaction between technology, science and the market.

Factors Inhibiting Implementation of the Helix Model

Most barriers to the successful implementation of the triple helix model arise mainly from **inadequate technology and learning policies, insufficient commitment and internal preparedness by the participating organization** or institutions. Some of these barriers include:

(1) **Prevalence of strong culture of centralizes economy and bureaucracies.**
(2) **Reliance is state-funding of innovative activities**
(3) **Absence of policies to provide for the development national and regional innovative system.**
(4) **Lack of a close relationship between business and universities.**
(5) Short term approaches to businesses
(6) Lack of commitment to the concepts of partnership, learning and innovation
(7) Lack of strategic leadership
(8) Inappropriate organizational structure
(9) Lack of common purpose and transparent and mutually beneficial goals
(10) Resistance to the sharing of information procedures and processes.
(11) Inappropriate distribution of risks
(12) Inappropriate learning of approaches
(13) Inappropriate distribution and exercise of power, deriving from hierarchical organizational structure.

Crucial for the innovation process particularly in developing countries is the development of a social, economic and technological culture that would facilitate rather than inhibit innovation learning and partnership, initiatives. The successful implementation of the T.H.M. in typical developing countries would call, interalia, for the following conditions.

(i) common purpose and commitment leading to win-win solutions

(ii) **effective leadership within each of the organizational and institutional spheres**

(iii) **preparedness and commitment of all the organizations and institutions to the culture of alliance and partnership.**

(iv) Championing this culture at all levels and stages of network and partnership

(v) Effective governance which is more particularly relevant to the context of developing countries.

(vi) Selecting the most appropriate partners and firms of alliance

(vii) Organizational structures and procedures which facilitate communication, interaction and sharing (SAAD 2000)