Towards Developing an Analytical Framework to Study Technological Change in the Small Units of the Developing Nations*

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Abstract: The existing literature on technological change enables one to study changes in the technology of an industrial unit that is either due to internal innovation or through the formal modes of transfer of technology. Both do not apply to small-scale industrial units in any developing nation such as India. Following an eclectic approach, this paper attempts to develop an analytical framework to study the firm-level technological change in small-scale industrial units. It draws on the relevant concepts from the evolutionary economics, economics of technological change, technological capabilities and organisation theories. The analytical framework developed in the paper is comprehensive both in terms of the coverage of the concept of technology and in taking into account all those factors that can possibly cause changes in the technology of small-scale units. In respect of technology, it goes beyond the usual definition to cover all three dimensions of technology, namely, transformation, organisation and information. Analysis of the study reveals that the product market, decision-maker's perception of market changes, technological capabilities, scale of operation, availability of information, finance, complementary skills and materials, relative factor prices and labour as the possible factors that can cause changes in the technology of an industrial unit.

Key Words: Technological change, technological capabilities and small-scale units

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1. Introduction

It is well accepted in the economics literature that technology plays a significant role both in macro (economic growth) and micro economic spheres (such as competitiveness of firms). Partly due to its fast changing nature, which result in shifts in the frontiers of technology and partly due to the increasingly integrated world economies that are necessitating further improvements in the competitiveness of the economic organisations technology *per se* has moved centre stage. Consequently, one finds voluminous literature on the economics of technology. The literature, however, suffers severe limitations both in terms of the scope of the concept of technology and in considering the factors influencing technological changes (discussed in Section 2). It does not provide a comprehensive framework to study the firm[1]-level technological changes especially in the small and household units that still contribute substantially to the developing economies. For instance, the small-scale industries (SSI) sector in India constitutes 95 per cent of the manufacturing units, 40 per cent of value addition in the manufacturing sector, nearly 80 per cent of the manufacturing employment and 35 per cent of the total exports of India.[2] This paper endeavours to make up the limitations of the existing literature on technology by developing a comprehensive framework through an *eclectic* approach. We draw on the evolutionary economics, economics of technological change, technological capabilities and organisation theories for the relevant concepts. Based on the selected concepts, an analytical framework has been developed in such a way that it enables one to study the firm-level technological changes by taking into account all the aspects of the technology and all the factors that can influence technology.

The paper is organised in six sections. Section 2 discusses the existing literature in the related areas, its limitations and some of the concepts from this that are used in the present study. To study the firm-level technologies, it is essential to know the internal structure of firms. Section 3 attempts drawing on the selected concepts to build the structure of a firm that enables one to describe the firm-level technological changes especially in the Indian small-scale units. Section 4 describes the process of firm-level technological change and analyses the factors that can

[1] 'Firm' refers to the ownership or decision-making unit in the production of goods and services. In the paper, we use firm, unit and enterprise synonymously. In the literature, theoretical works mostly refer industrial units as firms. Indian policy texts refer to them as units and the other literature refers these units as enterprises. Accordingly, we use the term depending on the context or the reference material.

[2] *Report of The Study Group on Development of Small Scale Enterprises,* Planning Commission, New Delhi, March 2001 (p. 1). SSI sector includes only modern small-scale industrial units that come under the purview of Small

possibly influence these changes. The small-scale sector is highly heterogeneous with a wide range of units, household to modern, varying in many respects such as technology. These variations make it difficult to have a common analytical framework for the entire small-scale sector. Hence, Section 5 tries to modify the analytical framework to suit the traditional/ household units. For the sake of completeness, the final section discusses some of the methodological approaches to collect the required data from the field.

2. Theoretical Base

The existing literature on the technological change, mostly, covers the changes in the physical processes of transformation of inputs into outputs including the product characteristics.[3] In addition, in the empirical works, technological changes are typically associated with the innovations[4] or the changes through the international technology transfers.[5] Both do not apply to the context of the Indian small-scale industries. As regards the factors influencing technological changes, literature has mostly focussed on two of the Schumpeterian variables, namely, scale of operation and market structure. Entrepreneurs, large and monopoly firms occupy a central position in Schumpeter's analysis.[6] Although one finds arguments both for and against large and monopoly firms in the literature,[7] empirical works, at large, indicate the positive association between the innovations on the one hand, and size and market concentration on the other.[8] Realising the methodological limitations in taking only two factors to explain innovations, later studies started considering various characteristics of firms such as their R&D capabilities, organisational and managerial attributes.[9] It seems that most of these variables are included in an *ad hoc* manner.

Industries Development Organisation (SIDO). All the figures presented here refer to the modern small-scale sector as the data for traditional small-scale sector is scanty and scattered.

[3] Bos and Cole (1994: 232). This is despite the fact that the definition includes both physical processes and management methods. See Dahlman and Westphal (1982) for the definition of technology.

[4] Tietel and Westphal (1984: 2)

[5] At the level of imitation, which involves transfer of technology from the proprietor firm of technology to the other firms, literature is full of studies on the issue of international transfer of technology.

[6] While the entrepreneurs discover the untried ideas from the technology basket and introduce them into commercial reality, large and monopoly firms enable them to do so. Coombs *et al* (1987: 94)

[7] Some of the important reasons offered for a positive relation between size and innovative activity are, large firms have better access to capital markets, better appropriability and scale economies in R&D function. Some of the important counter arguments rely on propositions like loss of managerial control, lack of incentives for individual scientists with size [Cohen (1995: 184-5)]. Arguments in favour of the positive impact of market concentration on innovation highlight factors like the easier appropriability of innovation in concentrated markets. Some others argue that market concentration breeds bureaucratic inertia and discourages innovation (Cohen, *op. cit.*, p. 192).

[8] Cohen, *op. cit*. pp. 185-6, 192

[9] Cohen, *op. cit*. pp. 197-206

Apart from the studies in the Schumpeterian tradition, there are other works in the literature that have examined the determinants of innovations and have proposed a different set of factors. For instance, Schmookler (1962) emphasises the importance of market demand in the innovations.[10] The induced innovation theory forwarded by Hicks (1932) takes the changes in the relative factor prices to cause innovations. Rosenburg (1969), by looking at the historical processes of technological changes, concludes that the technological imbalances among the interrelated products and processes, skilled workers' non-compliance and strikes, shortage of materials due to wars are responsible for innovations. In addition, models of diffusion show that information availability, capital requirements for the change and profitability of the changes are important for a technology to be adopted by firms.[11]

In addition to the above-discussed literature on technological change, one finds a large number of studies on innovations in the framework of evolutionary economics. These studies focus primarily on how technologies evolve over time through the process of innovation[12] and try to bring out the salient features of innovations. The evolutionary approach considers innovations to a major extent as a deliberate action of the individual and/or organisations although the role of random factors is acknowledged. Further, they take the technological outcomes of the innovations as the result of the interaction between organisations and external environment. In this approach, technological choices are constrained by the past technological decisions and capabilities of firms that are in turn limited by bounded rationality and bias in human judgment.[13]

Interactions of organisations and environment are described under the 'selection mechanism', one of the basic principles of evolutionary economics.[14] The selection mechanism operates through the process of competition. Firms compete with each other by offering different products at different prices to the market. Firms producing more desirable products and more efficiently are

[10] "The fundamental conclusion of this paper is that technological progress is intimately dependent on economic phenomena … new goods and new techniques are unlikely to appear, and to enter the life of society without a pre-existing - albeit possibly only latent - demand." Schmookler (1962: 117)

[11] Karshenas and Stoneman (1995: 270-74). Diffusion being the process of spread of a new technology is relevant for the technological change in the small-scale units of the developing nations as they are imitators not innovators of technology.

[12] Innovation is taken as a process of search for, discovery, experiment ation, development and adaptation of new products, processes and organisational set up. Dosi (1988b: 222)

[13] Dosi, *op. cit.*, Garud *et al* (1997), and Saviotti (1996)

[14] It can be seen from Saviotti and Metcalfe (1991:10) that "Evolutionary explanation of economic change is driven by two distinct but related mechanisms. The first mechanism generates variety and the second selects between those varieties to change their importance over time. Selection also influences the generation of variety." Also see Dosi and Nelson (1994: 154).

selected in the sense that these units not only survive but also improve their positions in the market by growing at a faster rate. In order to be more competitive, firms focus their innovation activities on the promising lines of development where the degree of promise depends on their judgment. This judgment along with the firm's abilities to create or operate with superior technologies determine firms' competitiveness and hence survival. Thus, the selection mechanism operates at two levels. First, there occurs the *ex ante* selection of products or technologies for the development or adoption by the firms based on their cognitive structures, visions and competencies. Second, an *ex post* selection occurs in the market that selects the firms that chose well their products or technologies, and eliminates or forces reforms on the firms that could not come up with more desirable products or technologies. [15]

The importance of the past technological decisions and capabilities stems from the fact that much of the innovation activities originate from learning-by-doing/ using, by solving a production problem, meeting specific customer requirements, etc. Also, firms seek to improve or diversify their technologies searching in the neighbourhood zones of the existing technology. Successive investments along these lines result in an increasing momentum in a particular direction leading to 'path dependency' wherein what a firm can do technologically in future is constrained by what it has been doing so far.[16]

Discussion in the preceding paragraphs makes it clear that both the literature on technological change and evolutionary economics is confined to innovations, which may seen as an exception rather than a rule in the small-scale industrial units of any developing nation like India. In addition, both sets of literature suffer from methodological limitations.[17] It necessitates the development of an analytical framework that enables one to study the firm-level technological changes especially in the small-scale industries in a developing nation like India. To develop such an analytical framework, we make use of the concepts of selection mechanism and the process of innovation from evolutionary economics, the definition of technology and the possible determinants of technologies from the technological change literature.

[15] Nelson and Winter (1977: 58); and Dosi and Orsenigo (1988: 13)
[16] Dosi (1988 a, b) and Garud *et al* (1997)
[17] Refer to Cohen (1995: 197-206) for the technological change literature and Saviotti and Metcalfe (1991: 18); and Dosi and Nelson (1994: 156) for the evolutionary economics.

In addition, we make use of the concept of technological capabilities since it is considered as a pre-requisite for any changes in technology.[18] Hence, we briefly discuss this concept in the subsequent paragraphs.

Technological capabilities in the literature are broadly taken as the "capabilities needed to identify, acquire, assimilate, use, change or create a technology,"[19] where "capabilities include all kinds of information and skills such as technical, managerial and institutional."[20] Literature distinguishes four kinds of technological capabilities at the firm level, namely, production capabilities, linkage capabilities, investment capabilities and innovation capabilities.[21]

Production capabilities range from the basic skills such as operation and maintenance, quality control to more advanced skills required for adaptation and improvement. They cover both process technologies as well as monitoring and control functions. These capabilities determine how well a given technology is operated and improved.

Linkage capabilities are the skills needed to transmit information, skills and technology, to and from component or raw material suppliers, subcontractors, consultants, service firms and technology institutions.

Investment capabilities refer to the skills required to identify, design or obtain technology, construct and commission a production facility and/or to expand any existing facility.

Innovation capabilities are those capabilities that can create and carry out new technological possibilities to economic use.

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[18] Its importance is well articulated in the literature. See for instance, Dahlman *et al* (1987: 759) that "inventing products and processes is not at the centre of the technological development needed for successful industrialisation. It is at the fringe. What is at the centre is acquiring the capabilities needed for efficient production and investment." At a specific level, Bell and Pavitt (1992: 261) argue " to generate continuing incremental changes in the existing facilities, the user of the technology must play an active role and must therefore have the relevant technological capabilities."

[19] Dahlman, *et al*., *op cit* ., p. 762

[20] Biggs *et al* (1995: 16)

[21] One finds innovation capabilities in Dahlman, *et al.*, *op cit.*, and linkage capabilities in Lall (1992). The remaining two namely, production capabilities and investment capabilities are considered by both the works. Definitions of the individual capabilities are mainly drawn from these two sources.

At the national level, technological capabilities are taken to include physical investment, human capital and technological efforts. Technological capabilities are determined by attitudes, motivations, education and experience at an individual level, and by the technological infrastructure, policies and the incentives they create at the national level.[22]

Technologies do not directly compete with each other in the markets for their own sake. Firms are the 'carriers of technology' and the technology that they use affects their survival.[23] Hence, it is the firm that changes technologies. Accordingly, it is essential to know the internal structure of a firm in order to study the changes in technologies. In this respect, we review the organisation literature for the structure of economic organisations. We draw mainly on Mintzberg (1979) for a synthesis of the existing literature on organisations to develop the structure of organisations in relation to their functioning.

Organisation literature considers the groups of people performing distinct tasks as the basic components of an organisation. Five groups are taken as fundamental and cover all types of contemporary organisations. They are operating core, strategic apex, middle management, technostructure and supporting staff. *Operating core* consists of all operators involved in the basic work of production such as procurement of inputs, transformation of inputs into outputs, distribution of outputs and other supporting activities like maintenance of machines. *Strategic apex* includes the persons who are charged with the overall responsibility for the organisations such as chief executive officers. To ensure that the organisation serves its mission in an effective way, the strategic apex is entrusted with three sets of duties. One is direct supervision including the assignment of people and resources to different tasks, issuing of work orders, monitoring and control of the works. Second, management of the organisation's relationship with its environment that involves the role of spokesman, negotiator in the case of any agreements with outside parties and to develop and tap the external contacts. The third set of duties relate to the development of strategies that are required to deal with the changes in the environment. The strategic apex is joined to the operating core by the chain of *middle management* that includes floor supervisors to senior managers. *Technostructure* covers those persons who are not part of the operating core but affect their work either by designing or planning the work systems or by training them. *Supporting staff* includes those that support the organisation from outside the operating workflow

[22] Dahlman, *et al (*1987) and Lall (1992)
[23] Dosi and Nelson, 1994: 156

such as accountants and legal counsel. Every organisation always has an operating core and a strategic apex. As organisations grow, they extend typically to include middle management, supporting staff and technostructure. All the basic parts of organisation are joined together by different flows, i.e., flow of authority, of work materials, and of information. These flows facilitate the two basic processes of organisation, namely, decision-making and production of goods and services.

Decisions are categorised as operative, administrative and strategic. *Operative decisions* are taken routinely and executed quickly. For example, a lathe operator makes an operating decision when he starts or stops his/ her machine. *Administrative decisions* are taken to guide and coordinate operating decisions such as production scheduling. *Strategic decisions* are the least routine and taken by the strategic apex. Strategic decisions may be evoked by a change in the environment like policy reforms or by an individual initiative of the managers. The extent to which decision-making power is given to the relevant individuals depends on the design of the organisation. In a centralised organisation, a single individual, usually the chief executive officer is given all the power for decision-making. In the decentralised organisation, the power to make decisions is dispersed among many individuals.

There are five fundamental ways in which organisations coordinate their work, namely, mutual adjustment, direct supervision, standardisation of work processes, standardisation of work outputs and standardisation of worker skills. Mutual adjustment coordinates work through the process of informal communication. Direct supervision ensures coordination by entrusting one individual with the responsibility for the work of others. The selected individual issues instructions to the work force and monitors their actions. In the standardisation of work processes, the contents of work are specified. In the case of standardisation of outputs, the results of the work, i.e., the dimensions of products or performance are specified. Skills are standardised through the specifications of the contents of the training required to perform work. As the organisation becomes more and more complex, the coordination mechanism shifts from mutual adjustment to direct supervision to standardisation.

Based on the kind of decision-making, coordination mechanism, and flows of work, information and others, five structural configurations of the organisation are developed in the literature that can suit all the existing organisations. They are: simple structure, machine bureaucracy,

professional bureaucracy, divisionalised form and adhocracy. In a simple structure, the strategic apex is the key part with full control over decision-making through centralisation and it coordinates the activities of the other persons by direct supervision. Technostructure with limited horizontal decentralisation is the critical part in a machine bureaucracy where the standardisation of work processes is the main coordination mechanism. In professional bureaucracy, the horizontal and vertical decentralisation makes the operating core as the dominant component and the activities are coordinated through standardisation of skills. There is limited vertical decentralisation in the divisionalised form giving power to middle management and coordination is achieved through the standardisation of outputs. In adhocracy, supporting staff is involved in decision-making owing to its expertise. Power is decentralised selectively and persons involved in decision-making are free to coordinate through mutual adjustment.

Since many small organisations remain as simple structures,[24] we elaborate a little on the simple structure. The simple structure often consists of little more than a one-man strategic apex, operating core and few supporting staff. It does not have middle management and technostructure. It has a loose division of labour with little formalisation of behaviour. It makes minimal use of planning, training and liaison devices. Coordination is largely attained through direct supervision. Power to make important decisions tend to be centralised in the hands of the chief executive officer and he takes sole responsibility for the strategy formulation. Hence, strategies reflect chief executive's implicit vision of the place of the organisation in its environment. In other words, strategies can be taken as direct extrapolation of the chief executive's personal beliefs and an extension of his/ her own personality.[25] As we are dealing with the small-scale industrial units, our study confines to the simple structure of the firm and develops the analytical framework within this structure.

3 Business Environment and the Firm

In this section, we, first, place the firm or an industrial unit in its environment in the broad conceptual frame of the selection mechanism of the evolutionary economics. Later, the section focuses on those elements of the firm that are essential for the changes in its technology. In order

[24] Mintzberg (1979: 310); and Douma and Schreuder (1998: 148)

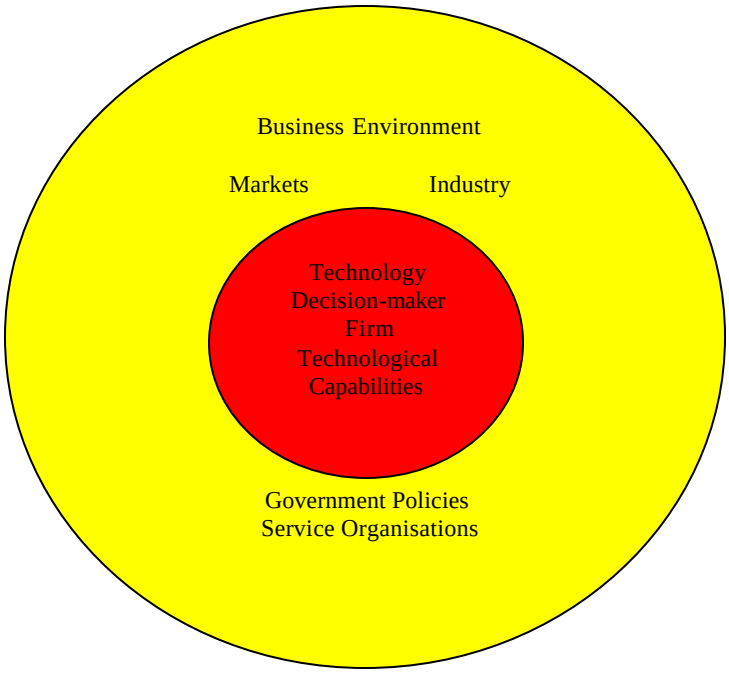
[25] Empirical studies on Indian industrial houses show that even in large-scale units "management decisions are based on personal experiences, aims and visions of one person. Usually, it is the head of business or chairman of a company." Piramal (1996: x)

to locate these components within the firm, we take small industrial units to have simple organisational structures.

We take *firm* as an economic organisation that produces a given set of goods and services for a specified market. Firm competes with many other firms that are producing similar or substitutable products in the market. Markets (product as well as factor markets), industry (competing firms) and other institutions such as service organisations and government policies form the *business environment* of the firm. The business environment of the firm changes continuously as all its elements keep changing. For instance, the product market change as incomes, tastes and preferences change causing shifts in the demand for the specified products. The number and structure of the firms in the industry change and affect the supply of the given products. Government policies change over time shifting the demand and supply structures of the products further. The demand and supply structures affect the price of the products and thereby profitability and commercial viability of the firms producing them. The variations in the business environment thus change the parameters of selection for successful firms in terms of the importance of different characteristics of the firms such as the type of product the firm produces and its method of production, i.e., technology. Firms strive continuously to get selected, i.e. to maintain and to improve commercial viability through different strategies (taken in terms of the changes in one or more of its characteristics) in the face of the changing environment. For example, it was the strategy of 'diversification' that fetched profits for Indian firms especially larger ones during the regime of regulation with the closed market. It is, however, to the strategy of 'focus on core competencies' that these firms are turning in order to improve their competitive strength in the regime of liberalisation and open markets of the nineties. We treat the changes in technology as one such strategy of firms to operate effectively in the changing environment.

The term 'firm' is too abstract to formulate any strategy. Somebody within the firm does the job of formulating and implementing strategies. We refer them as 'decision makers'. Change of technology requires abilities to understand and manage technology, i.e., technological capabilities. Accordingly, we focus on the three basic elements of a firm to study the unit-level technological change. They are: *technology* (that undergoes change), *decision-maker* (who undertakes changes) and *technological capabilities* (pre-requisite for change). We elaborate on these elements in the subsequent paragraphs. The structure of a firm in relation to its business environment is given in Diagram 1.

Diagram 1



For the purpose of the study, *technology is taken to include the physical processes of transformation of inputs into output, organisational methods that structure these processes and information flows required to carry out these processes*. Thus, the study considers three dimensions of technology, namely, transformation, organisation and information.[26]

We take the *transformation aspect* of technology to include plant and machinery, tools, components, accessories, materials and products. The *organisation aspect* is considered at two levels: structure and operation. At the structural level, it refers to the way a firm is organised as a business concern (such as proprietary concern) and how it is been managed (like owner-managed or professional-managed). At the operational level, it refers to the organisation of production process that includes plant layout, materials management, work allocations, production schedules and quality management. The *information aspect* includes the means of communication with the outside agents like suppliers and customers as well as the ways of storing, processing and exchange of information within the unit. Of these, the transformation aspect is considered as the 'core' of technology. *Technological changes are referred to the changes in any one or a*

combination of the three dimensions of technology that are undertaken by a firm to improve its competitive strength either through cost reductions, or through quality or productivity improvements or a combination of all three.[27]

Further, we take technological changes that can be considered innovations[28] as an exception than a rule in the small-scale units of a developing nation like India. These units are almost the last set of imitators in the sense of adapting a technology long time after its commercialisation and has been widely practised.[29] Accordingly, *technological changes* in the selected industrial units *refer to the changes in their existing technologies in the form of addition of, or replacement by a later vintage technology that has already been in practice in the industry.*[30] Technological changes of this type can be *radical* like shifting from the manual methods of assembly of the components to automatic machinery, or *marginal* like the change of instruments like multi-meters in the electronic units.

In order to locate the decision-maker and technological capabilities within a firm, we consider, as mentioned earlier, small-scale industrial units to have a simple organisational structure with strategic apex and operating core. The operating core consists of all those workers involved in the basic production processes like movement of materials to the machines, machine operation and maintenance, and distribution of output from the plant. Their work is coordinated by strategic apex through direct supervision. In addition, strategic apex in the simple structure, as discussed earlier, deals with the relevant outside agents such as customers and suppliers, and formulates strategies as and when the need arises. To discharge all these duties, strategic apex in the simple organisational structures has the total decision-making power. The strategic apex in the small-scale industrial units often consists of one or two persons who are the owner-managers. These owner-managers take care of the three basic functions of coordination, outside dealings and strategy formulation. As regards the decision-making, *Owner-managers are the sole decision-makers in the small-scale units* and they take all, strategic as well as administrative,

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[26] We have added information aspect to the definition of technology given in Dahlman and Westphal (1982).
[27] This is the widely recognised purpose for which firms undertake changes in technology.
[28] In the literature, innovation is defined as the first commercial introduction of a product or process in the international economy (Cooper 1994: 13).
[29] After the innovator, the other larger units followed by smaller units of the industry in the developed nations where most of the innovations originate, may adapt a technology that is successful. The larger units of the developing nations may follow suit later. At the end of the diffusion process of a given technology comes the small-scale units in the developing nations like India.
[30] Here, industry refers to the units producing similar products not only in India but also in other countries.

decisions. Decision-making regarding technological change is strategic and depends on the owner-managers' perception of the business environment and its changes. Equally important are the owner-manager's capabilities to relate the available technologies to the changing markets, and adopt and manage technological changes.

As discussed earlier, firm-level technological capabilities include production capabilities, linkage capabilities, investment capabilities and innovation capabilities. Of these, we confine ourselves only to production capabilities, linkage capabilities and investment capabilities leaving innovation capabilities out of the study as we are dealing with the small-scale industrial units. Production capabilities, as specified earlier, refer to the knowledge and skills required for the operation and maintenance of the production systems as well as control and monitoring of these systems. As regards the skills to operate and maintain production systems, production capabilities are located in the workforce (i.e., labour) who does this job. And abilities to control and monitor the production operations are expected to be with the owner-managers as they perform these functions in a simple structure like that of small-scale units. Linkage capabilities, i.e., abilities required to transmit technology-related information and skills from the outside agents such as customers and suppliers are supposed to be with the owner-managers as they do all the outside dealings. It is again the owner-manager in the small industrial units who is responsible for the expansion of production facilities and hence, expected to possess the investment capabilities, viz., capabilities to search, identify, evaluate, select, negotiate and commission new production facilities. All these technological capabilities, as discussed earlier, depend on the formal education and training, on-the-job experience, and attitudes of the concerned individuals. In other words, in the small-scale units of any developing nation like India, it is the *owner-managers who are expected to possess investment, linkage and part of production capabilities* and these can be deduced from their education, experience and attitudes. *Labour or workforce needs to have the other part of production capabilities* required to operate and maintain production systems which further depend on their formal education, training, experience on-the-job and their attitudes.

4. Analysis of the Technological Change in the Small-scale Units

We consider the firm-level technological change as *a deliberately initiated process of search, selection, execution and absorption.*[31] To achieve change, concerned individuals/ units have to seek for it, search for alternatives, i.e., to get to know the available alternative technologies in terms of costs, content, their sources and mode of acquiring these. If alternatives exist, the unit has to select among the alternatives, then negotiate and acquire it. Then comes the execution which includes modification if need be, and the installation of the machinery, or implementation of the acquired technology if it is an organisational method like total quality management. With the execution, physical change of technology occurs in the unit. However, installation of a new machine, or implementation of a new method does not automatically ensure the purpose of having it. Workers take some time to know the machine and to be able to operate it smoothly, or to get used to the new methods of organisation. Thus, the actual process of technological change is completed only when the acquired changes are mastered, i.e., absorbed. It is the execution followed by absorption that ensures the attainment of the purpose of change, namely, improvements in the competitive strength of the firm.

Since the process of technological change is taken as a set of distinct though related stages, we consider the factors affecting this process stage-wise. Consequently, we analyse the factors initiating search, factors facilitating search, factors influencing selection, and factors affecting execution and absorption of technology. Following the salient features of the innovation process brought out by evolutionary economics, we take technological change as the result of an interaction of factors that are internal to the firm as well as external to it and hence analyse the factors under these two categories.

We take the product market in terms of its structure and demand as the main external factor and technological capabilities of the decision-maker as the internal factor that is responsible for initiating a search for alternatives at the firm level. Since we are dealing with the imitator firms, it is the competitiveness of the product market[32] that creates a pressure on firms to go for

[31] This is a modified version of Dosi's (1988b) characterisation of the innovation process, which comes under evolutionary economics. We have modified it to suit the imitation.

[32] Competitiveness of the product market can be in terms of either an increasing number of suppliers, or improved performance of the other units of the industry, or entry of powerful players like multinational corporations, or demanding customers, or introduction of new substitutes, or a combination of all these.

technological improvements.[33] On the other hand, rising demand for the product[34] may provide incentives for the firms to go for technological improvements. How far a given unit acts in this direction depends on the decision-maker's perception of the demand situation, market competition and its likely impact on the unit, and his/ her capabilities to foresee the potential benefits of change or potential losses if not going for change. Hence, we consider the *product market, decision-maker's perception of market changes and his/ her technological capabilities especially investment capabilities as the factors that initiate search* for technological alternatives at the firm level.

A primary factor that facilitates search is the availability of information to the firm. Availability of information depends on the development of the informational infrastructure at the national level like documentation centres, trade journals, consultancy organisations and the extent of dissemination of information through trade fairs, seminars, etc. Widespread development of the informational infrastructure improves the access of small units to information and makes it easier for these units to obtain information. Equally important for gathering information is the awareness of the decision-maker that depends on his/ her linkage capabilities. In other words, it is the *firm's access to information sources together with the linkage capabilities of the decision-maker that facilitates (or constrains) the search* for available alternative technologies. These factors also determine the *degree of choice* that a unit has in terms of technology.[35]

Once the choice of technology is given, units need to select the technology that suits their requirements. The critical external factors that influence the selection of technology are the availability of finances, and complementary factors like materials and skills, and relative factor prices. Availability of finances is one of the basic factors that determine whether a unit can go for change, if so, what type of change. It further depends on the unit's access to the sources of finance and the cost of finance. Use of every technology requires specific materials and skills and their availability in the vicinity thus becomes another important factor in influencing the

[33] Studies that went beyond innovators to include imitators argue that innovators do better when competition is restrained and imitators do better when there is aggressive competition (Elster 1983: 145). Also see Mansfield (1961: 310).

[34] Demand for a product refers to the total market demand for product X but not the demand for product X produced by the given unit.

[35] This has significant theoretical as well as empirical implications. Its theoretical significance stems from the fact that the neoclassical economics, the most widely practised theoretical framework maintains that firms have easy access to all the available technologies and thus have a choice of technology.

selection of technology. However, the availability of complementary materials and skills[36] are important only when a unit is going in for a totally new technology that is not at all related with the existing technology. Availability of complementary skills depends on the national level (to be taken as the concerned region) technological capabilities. The existing relative factor prices is another factor that the decision-maker may keep in mind while selecting a technology so as to choose the one that uses more of a relatively cheaper factor.

As regards the internal factors, investment capabilities that are required to evaluate the available technologies, to select one of them and finally to negotiate, have a direct impact on the selection of technology. In addition, the decision-maker may look for such technologies that suit their scale of operation[37] and can be put in use by the existing production capabilities.[38] *In effect, relative factor prices, and availability of finance, skills and materials are the important external factors, and investment and production capabilities, and scale of operation are the internal factors that influence the selection of technology.*

At times, technological changes occur in terms of the production of additional products, i.e., product diversification. Product diversification not only changes the product composition but also brings changes in the other parts of transformation technology such as machinery and tools as well as organisational methods.

Once the new technology is selected, the *execution and absorption of it depends on the internal production capabilities and the workforce or labour*. Production capabilities are required to unpack, modify if necessary, install and finally to operate and maintain the technology. The

[36] The importance of availability of complementary skills can be seen from the following example. Ramming process is one of the many processes of metal castings. It involves ramming the sand around the model to achieve a compact mold in the form of the model. The quality of the sand mold critically depends on the compactness of the casting sand. It can be done manually or by machine. In the Howrah region, the traditional region for the metal castings, the availability of skilled mold makers who are capable of achieving greater uniformity of compactness by the hand ramming method is the major reason for the limited introduction of machine ramming techniques. In other regions of India where these skills are not available locally, machine ramming is in use. Little, *et al* (1987:140-41)

[37] The importance of scale in the selection of technology can be seen in the steam generation process of the garment industry. Steam is used for pressing the garments and it can be generated through the electricity-operated boiler or diesel-operated boiler. Electricity-operated boiler is inferior to diesel-operated boiler in terms of quality (specifically uniformity) of steam it generates. However, many small-scale units use electricity-operated boilers, as diesel-operated boiler requires a certain minimum scale. This example is taken from the field notes of the author prepared during the survey.

[38] The importance of the existing production capabilities is due to the 'path dependency theory' of Dosi discussed earlier.

behaviour and attitudes of labour are as important as their capabilities for absorption of technological changes.

In sum, we consider the *product market, decision-maker's perception of market changes, technological capabilities, scale of operation, availability of information, finance, complementary skills and materials, relative factor prices and labour* as the possible factors influencing the process of technological change in the small-scale units. All these factors are given in Table 1 below.

Table 1: Factors Affecting the Process of Technological Change

Process	Internal Factors	External Factors
Factors Initiating Search	Owner-manager' perception of product market, Investment capabilities	Type of product market
Factors Facilitating Search	Linkage capabilities	Availability of information
Factors Influencing Selection	Investment and production capabilities, Scale of operation	Availability of finance, Availability of complementary skills and materials, Relative factor prices
Factors Affecting Execution and Absorption	Production capabilities, Labour	.....

It is important to note that although the significance of the analytical factors is discussed in the context of a specific stage in the process of technological change given their immediate importance at this stage, the influence of some of these factors goes beyond the specified stage. For instance, the scale of operation may influence all the stages. Availability of finance may initiate the process of technological changes at times.

Equally worth noting is that the above discussed analytical factors which are taken to influence the process of technological change primarily apply to the transformation (mechanisation) part of the technology. Organisation and information technologies are determined by a subset of these analytical factors. For instance, the form of business organisation and type of management are supposed to be determined by owner's preferences and convenience as well as scale of operation. Similarly, changes in communication technologies such as switch over to electronic media depend mainly on the technological capabilities of the owner-manager, type of product market and scale of operation. For instance, in the case of the auto components industry, the likelihood of larger units supplying original equipment to big vehicle manufacturers for adapting the latest information technologies using electronic media is greater as their customers are expected to possess these facilities compared to smaller units catering to the replacement market. The same reasoning applies to quality management systems. Work allocation system depends mainly on the technological capabilities of the owner-manager, labour and nature of production process.

We further elaborate on these factors in terms of the unit-level characteristics and their specific relationship with the technological change in the subsequent paragraphs.

The kind of product market a unit is serving influences the unit-level technological changes. The market can be international (exports), domestic but national (or regional), or composed of specific customers as for the original equipment manufacturers of components in any industry, or a replacement market as in the auto components industry. These markets differ widely in terms of the degree of competition and hence influence the firms differentially to go for technological change. For instance, exporting units are likely to face more competition and stricter quality norms that push these units to improve their technology relative to the units serving the domestic market. Similarly, we expect the units catering to the national market, which is wider compared to local markets, to have more incentives as well as pressures to go in for technological upgradation due to greater demand and more competition. Original equipment manufacturers for specific customers usually have more pressures to go for improvements in machinery, quality management system and other organisational methods in comparison with the units catering to the general market or replacement market.

The decision-maker or owner-manager's perception of product market changes can be taken in terms of their views on the demand for the product, market competition and the likely impact on

the concerned unit. If the owner-managers view that demand is a problem in the sense that it is stagnant or falling, they do not have an incentive to make improvements in the technologies of their plants. On the other hand, rising demand for the product induces units to go for technological upgradation. If the markets are becoming increasingly competitive in the owner-manager's view, units consider upgradation of technology to improve their competitive strength so as to maintain commercial viability. Finally, if the owner-managers consider the market changes as opportunities for growth, they go ahead with the technological changes.

Technological capabilities of the unit can be deduced from the formal education and training of the owner-managers, their experience in the relevant area of production and the extent of the use of professional labour. It is argued that the higher the education and experience of the owner-managers, the greater is the unit's capabilities to undertake and manage technological changes. The larger the proportion of professional labour, the easier it is for the units to master the new technologies and in lesser time.

Scale of operation, if taken in terms of annual sales turnover, reflects the actual size of the market the unit is catering to and provides an idea of the returns on its investments. Accordingly, a higher scale of operation implies a larger size of the market that ensures returns on new investments and increases the scope for exploiting indivisibilities associated with the new technologies compared to the smaller ones.

As regards the access to information on technology, it is easier for the unit to search for and select new technologies if it has better access to information. Access to information can be taken as better if the unit is making use of multiple sources of information rather than relying on one or two sources. Alternatively, inaccessibility of information can be deduced from the concerned unit's difficulties in obtaining it. If the owner-manager finds it a problem to get information about new technologies, we take it that the concerned unit has limited access to information about technologies.

With respect to the access to finance, the greater the access the easier it is for the firms to go for technological change. Better access to finance also widens the unit's choice and makes the selection among the alternative technologies easy. Access to finance can be considered better if the unit has been obtaining credit from the financial institutions including commercial banks

rather than relying solely on personal finances of the owner-manager.[39] Alternatively, whether the unit's access to finance is limited or not can be deduced from the unit's problems in obtaining credit.

The behaviour and attitudes of the labour or work force not only affect the absorption of technological changes but can also induce these changes. Attitudes of labour are taken in terms of their willingness to work and learn, i.e., whether labour gives the best even when the owner-manager is away and is willing to work on new machinery. If the labour attitudes are (negative) positive and hence (not) giving their best even when the manager is away or (un) willing to work on a new machine, it is (difficult) easier for the units to master the technologies and get maximum benefits. The behaviour of labour is considered in terms of absenteeism, turnover and unionisation of the work force. While absenteeism and unionisation problems are mostly associated with the regular workers, turnover generally presents among the casual work force. Of the three, turnover is the most common problem for the small-scale units. If a unit has severe labour problems either in terms of its behaviour or attitudes, it is difficult for these units to manage and absorb technological changes. Labour problems at an extreme level may even induce the growing units to go for technological change in terms of automation.

Taken in terms of firm's characteristics/ attributes, *the type of product market served, owner-manger's views about market demand and competitiveness of market, education and experience of the owner-manager, the extent of the usage of professional labour, sales turnover, sources of information and finances, difficulties in obtaining information and finance, and the attitudes and behaviour of labour employed* are the important factors that determine the technological changes at the unit level.

5. Traditional and/ or Household Sector[40]

Traditional/ household units differ from modern small-scale units in their characteristics as well as in the nature of their interaction with the business environment. Traditional/ household units such as those of shoe making are still a primitive form of industry. For instance, these units are

[39] Personal finances are the only source of finances for majority of the small-scale units and one of the major sources for the other small-scale units.

[40] This section is based on the author's discussions with her Dutch partner in the IDPAD project who is involved in the survey and analysis of tiny leather and marble units of Agra and pottery units of Khurja (U.P., India).

started mainly as a source of livelihood rather than a business concern with a profit motivation. These units are not structurally developed enough to fit into a formal theoretical characterisation of the concepts such as technology and technological capabilities. In this section, we endeavour to bring out these differences and the required modifications in the analytical framework.

Traditional/ household units are started by craftsmen or artisans as a source of employment and thus a regular income provision for their family. They have been passed on from one generation to another in the family. Goods are produced in these units manually with the help of little or no machinery and few tools. As a result, one finds an overlap between 'transformation' technology (i.e., mechanisation) and 'production capabilities'. These units are mainly operated by the family labour including distant relatives. These are least organised in terms of having standard and regular practices relating to production schedules or materials management or any other aspect of production operation. Decisions regarding these are taken in an informal way depending on the need of the hour and the immediate convenience of the labour. Work is coordinated through mutual adjustment. Only one means of communication, namely, personal visits, exists with the outside agents like suppliers and customers.

Since these units are run by family labour and they are all involved in all the jobs, i.e., production process as well as dealing with the customers and suppliers, the dividing line between the 'strategic apex' and 'operating core' is hazy. So, the strategic decision-making such as purchase of new machine or a tool is collective involving at least all the adult members. This decision-making is constrained by the social background and education of the owner's family as they set the perceptions about the business environment and attitudes towards technological change. All three technological capabilities, viz., investment, linkage and production capabilities are embodied in all workers of the unit. Further, these capabilities are acquired primarily through on-the-job experience in the unit as the owner-cum-labour have little or no education or any formal training.

In sum, technology in these units includes only transformation part that includes little machinery and few tools. These units are run by family labour and the owner-cum-labour is expected to possess all the technological capabilities that are acquired through on-the-job experience in the unit. Decision-making about technological change is collective and conditioned by their social background.

Equally important for study is the interaction of the traditional/ household units with their business environment. One of the basic characteristics of the traditional/ household industries is the strong presence of 'middlemen' who buy the product from these tiny units and sell it in the market. Most often, middlemen also supply inputs like materials and credit for these units. These middlemen are well to do, highly educated, well organised and control most of the market. Thus, these units deal with the market indirectly through the middlemen. Here, it is important to remember that it is the product market in terms of its structure and demand that induces firms to go for technological change. This important information about the market is filtered down to the immediate requirements of the middlemen and then passed on to the concerned units. In addition, the illiteracy and social background of owners coupled with their small size prevent these units to reach a market that is beyond the middlemen or other parts of environment like service organisations. These units' only contact with the environment is with that of similar other units of the industry that are in the vicinity. These other units are their main source of information. In such a situation, their relationship with the middlemen is very important in improving the demand for their products.

With the limited education and awareness coupled with the strong presence of middlemen in the market, traditional/ household units are not in a position to look for signals from the business environment. Their interaction with the environment is, thus, limited and less dynamic. As a result, these units do not follow any well-specified stages of a process of technological change sequentially. Rather these units go through certain stages of the process in an *ad hoc* manner. For instance, a machine can be bought by a unit without following any search or selection mechanism simply because its neighbours bought the same kind of machine.

So, *technological change in traditional/ household units is influenced by the social background and education of the owner's family and their relationship with the middlemen.* Social background affects not only their perceptions of environment, attitudes towards technological progress but also their technological capabilities. The nature of middlemen they are dealing with and the degree of their relationship with the middlemen is important for the technological upgradation of these units as these middlemen not only give the units a market for their product but also supply important inputs. For instance, if the middlemen deal with only local markets, then they may not bother to go for high quality products and hence do not insist on upgradation

machinery by the units. The number of middlemen and the nature of their relationship also matter. If the units serve a few middlemen and have developed a long run relationship with them then they are in a better position to deal with the market, which in turn may induce them to go for technological improvements. If they have been changing their middlemen now and then, it becomes difficult for them to have continuous demand, as the middlemen constitute the only source of demand for these units. Hence, it is essential to include middlemen and cover their characteristics in any study on technological change in the traditional/ household units apart from their own background.

6. Approaches to Study Firm-level Technological Change

Methodologically, one can examine the factors affecting technological change at a firm level in two ways. Firstly, it can be studied through a case study method. Secondly, one can examine the changes in technologies and its possible determinants in a sample of units through the survey and analyse these changes. The case study method enables the study of minute details relating to technological change and the factors responsible for this through a series of interviews with all those concerned individuals. It is useful when the units are bigger, have a greater number of persons of different expertise involved in the decision-making process making it complicated. It, however allows the study of a few units only as it takes more time on each unit. Since small and household units are simple in structure, technological change in these units is a relatively simple process and hence can be captured even in survey. In the survey method, one can investigate the technological changes in two ways. First, through the analysis of the differences in the units that has undertaken change and units without any such changes. Alternatively, one can analyse the differences in the levels of technologies of different industrial units. Technological changes further can be seen as the changes undertaken in the technologies of a unit over time, or within a specified time interval or changes undertaken after a benchmark year. Benchmark year refers to a watershed year for a specified phenomenon, for example, 1991 in the Indian context. Since the technological changes almost always refer to improvements in technology, we can analyse them in terms of differences in the levels of technologies. These levels of technologies can be specified against a benchmark technology or any other indicators. For example, mechanical devices, electro mechanical devices and electronic devices can be treated as three different levels of technologies with mechanical devices falling to the lower end of the scale and electronic devices positioned at the upper end and electro mechanical lying in the middle. These

indicators of levels of technology differ from industry to industry depending their nature and the level of development.

Information relating to the technological change and the factors influencing it can be collected through a set of direct and indirect questions framed in a structured questionnaire. Both the subjective opinions and/or objective criteria can be used to collect the relevant information. For instance, to assess the unit's relation with the middlemen in the traditional/ household units, one can obtain the owner's opinion about the extent of their dependence on the middlemen both for the product market and for the supply of materials and finance. Alternatively, one can make use of an objective criterion like the actual number of middlemen, changes in the set of middlemen and so on. Questions can be categorical (yes or no type), or can have an ordinal scale. If possible, numerical data for output and inputs can be obtained.

References

Bell, M. and K. Pavitt (1992). "Accumulating Technological Capabilities in Developing Countries" in the *Proceedings of the World Bank Annual Conference on Development Economics*, pp. 257 - 82

Biggs, T., Manju Shah and Pradeep Srivastava (1995). *Technological Capabilities and Learning in African Enterprises*. World Bank Technical Paper No. 288, Africa Technical Department Series

Bos, Antonio, and William, Cole (1994). " Management Systems as Technology: Japanese, US and National Firms in the Brazilian Electronic Sector" in *World Development*, 22 (2): 225 - 36

Cohen, W. (1995). " Empirical Studies in Innovative Activity" in Stoneman, Paul (ed) (1995). *Handbook of Economics of Innovation and Technological Change*. Oxford: Blackwell, pp. 182-264

Coombs, R., P. Saviotti and V. Walsh (1987). *Economics and Technological Change*. London: Macmillan

Cooper, C. (1994). "Relevance of Innovation Studies to Developing Countries" in Cooper, C. (ed). *Technology and Innovation in the International Economy.* England: Edward Elgar

____ (1994). "Relevance of Innovation Studies to Developing Countries" in Cooper, C. (ed). *Technology and Innovation in the International Economy.* England: Edward Elgar

Dahlman, Carl and Larry Westphal (1982). " Technological Effort in Industrial Development" in Stewart, Frances and Jeffrey James (eds). *The Economics of New Technology in Developing Countries.* London: Pinter Publishers, pp. 105 - 137.

Dahlman, C.J., Bruce Ross-Larson and L.E. Westphal (1987). "Managing Techological Development: Lessons from the Newly Industrialising Countries" in *World Development.* 15 (6): 759 - 75

Dosi, G. (1988a). "Sources, Procedures, and Microeconomic Effects of Innovation" in *Research Policy*, vol. 26, September, pp. 1120 - 71.

____ (1988b). "The Nature of the Innovative Process" in Dosi, G., Freeman, C., Nelson, R., Silverberg, G., and Soete, L. (Eds) (1988). *Technical Change and Economic Theory.* London: Pinter Publishers, pp. 221 - 39.

Dosi, G. and L. Orsenigo (1988). "Co-ordination and Transformation: An Overview of Structures, Behaviours and Change in Evolutionary Environments" in Dosi et.al. (eds). *Technical Change and Economic Theory*.

Dosi, G., and R.R. Nelson (1994). "Evolutionary Theories in Economics" in *Journal of Evolutionary Economics*, 4: 152 - 71.

Douma, S., and Hein Schreuder (1998). *Economic Approaches to Organizations*. Second edition, London: Prentice-Hall.

Elster, J. (1983). *Explaining Technical Change.* Cambridge: Cambridge University Press.

Garud, R., P.R. Nayyar, and Z.B. Shapira, (eds) (1997). *Technological Innovation: Oversights and Foresights*. Cambridge: Cambridge University Press.

Hicks, J.R. (1932). *The Theory of Wages.* London: Macmillan

Karshenas, M and P. Stoneman (1995). " Technological Diffusion", in Stoneman, Paul (ed) (1995). *Handbook of Economics of Innovation and Technological Change.* Oxford: Blackwell, pp. 265-294

Lall, Sanjaya (1992). "Technological Cpabilities and Industrialization" in *World Development*, 20 (2): 165 - 86.

Little, I.M.D, D. Mazumdar, and J.M. Page (1987*). Small Manufacturing Enterprise.* New York: Oxford University Press

Mansfield, E. (1961). "Technical Change and the Rate of Imitation" first published in *Econometrica* (October). Later reproduced in Rosenberg, N. (Ed) (1971). *The Economics of Technological Change*. Baltimore: Penguin Books, pp. 284-316.

Mintzberg, H. (1979). *The Structuring of Organizations*. Englewood Cliffs, N.J: Prentice-Hall

Nelson, R. and S.G. Winter (1977). "Dynamic Competition and Technical Progress" in Balassa, B. and R. Nelson (eds). *Economic Progress, Private Values, and Public Policy: Essays in Honour of William Fellner.* Amsterdam: North-Holland

Piramal, G. (1996). *Business Maharajas of India*. New Delhi: Penguin

Rosenberg, N. (1969). "The Direction of Technological change: Inducement Mechanisms and Focusing Devices" in *Economic Development and Cultural change*. October 1996, pp. 1-24

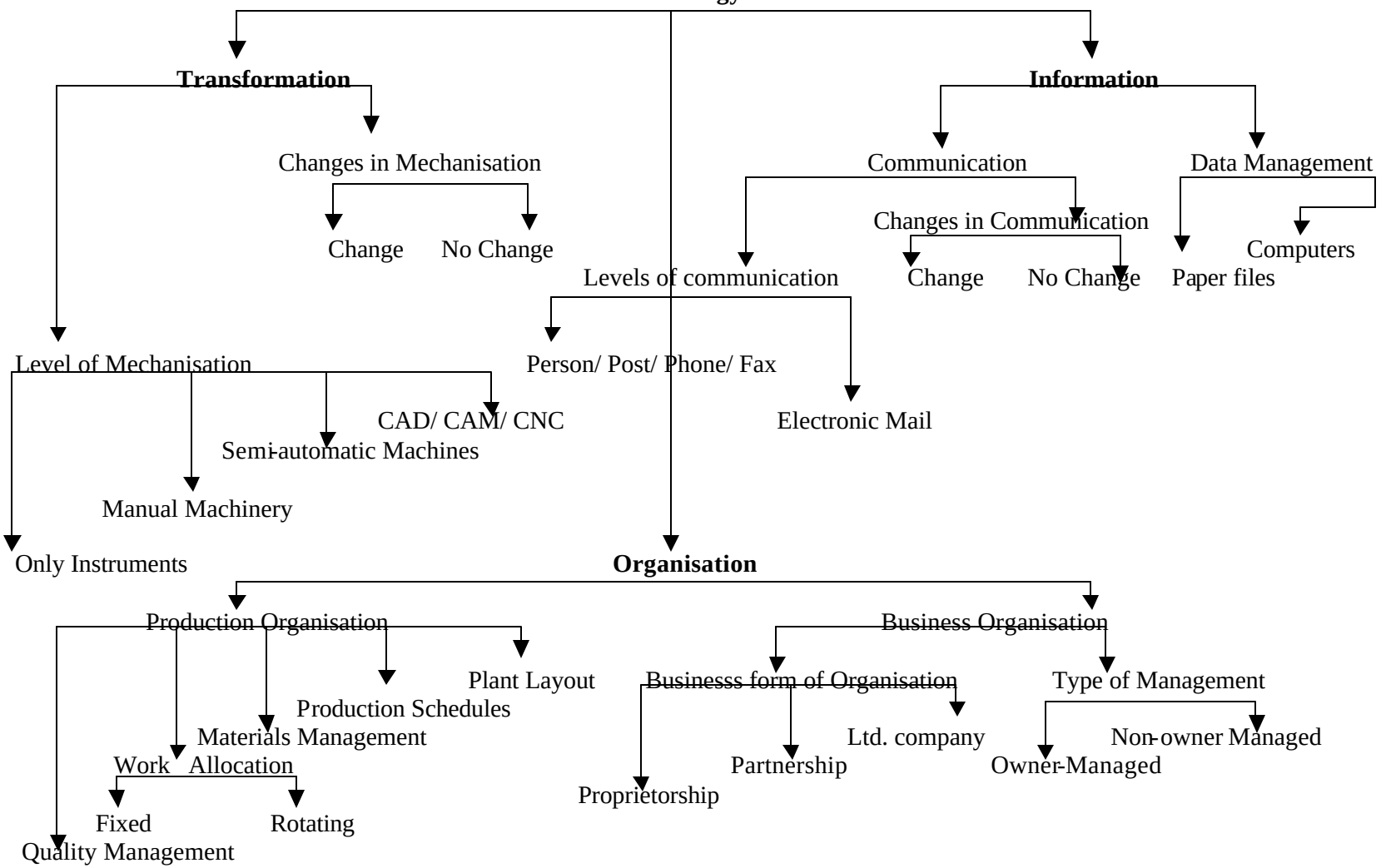
Saviotti, P.P. (1996). *Technological Evolution, Variety and the Economy*. Cheltenham, U.K: Edward Elgar

Saviotti, P.P., and J.S. Metcalfe (eds). 1991. *Evolutionary Theories of Economic and Technological Change*. Paris: Harwood Academic Publishers

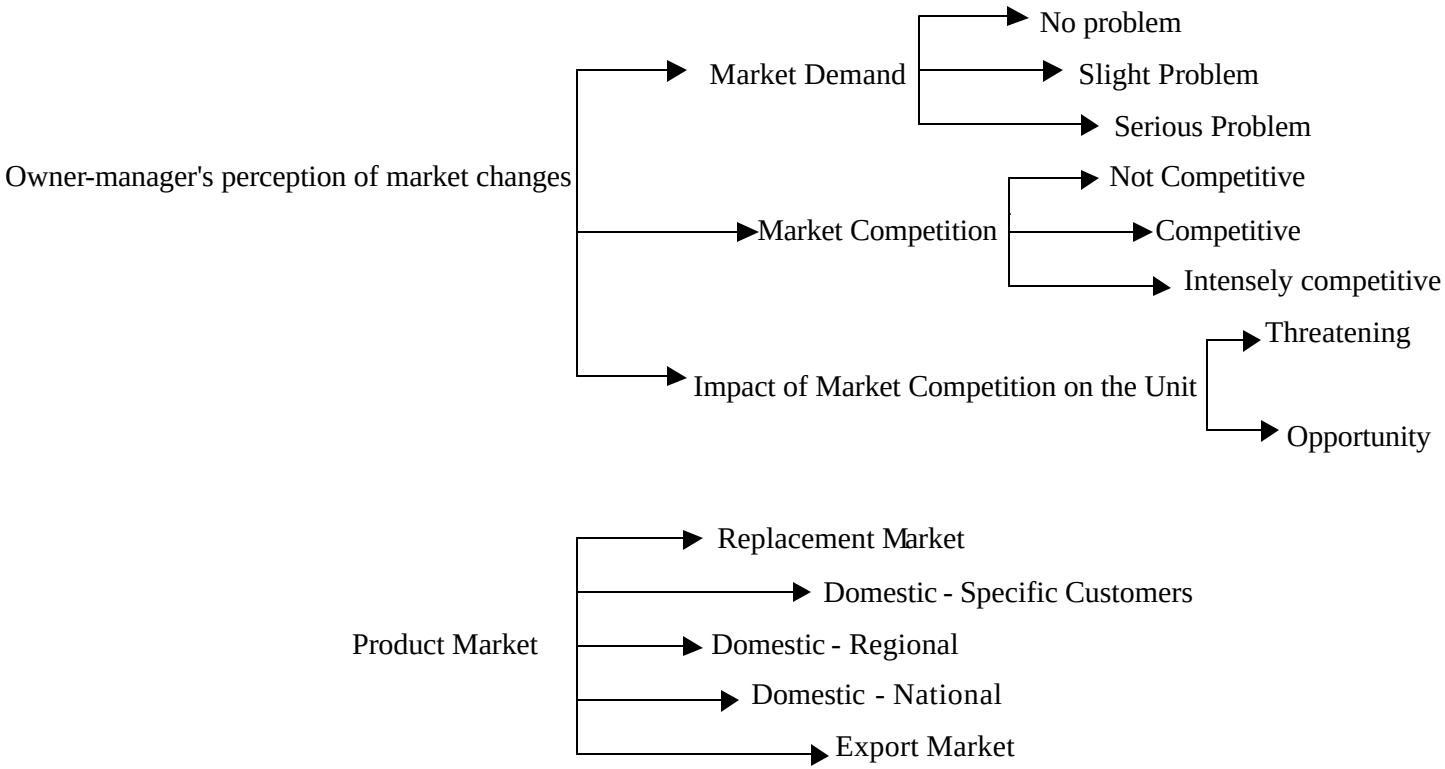
Schmookler, J. (1962). "Economic Sources of Inventive Activity" first published in *Journal of Economic History.* Later reproduced in Rosenberg, N. (Ed) (1971). *The Economics of Technological Change*. Baltimore: Penguin Books, pp. 117-36

Teitel, S and L.E. Westphal (1984). "Introduction" to the Symposium on Technological Change and Industrial Development in *Journal of Development Economics*, vol. 16 (1-2) (September - October): 1-12

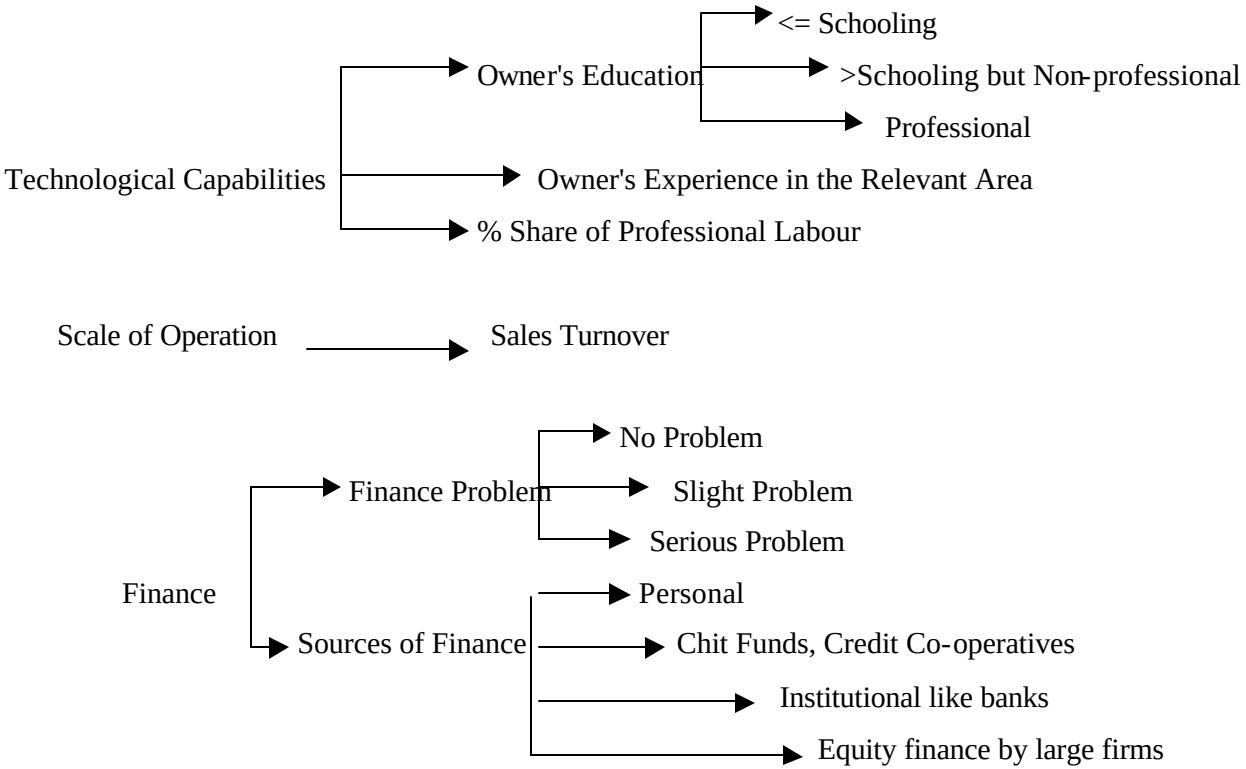
A1: Firm-Level Characteristics Representing Technology



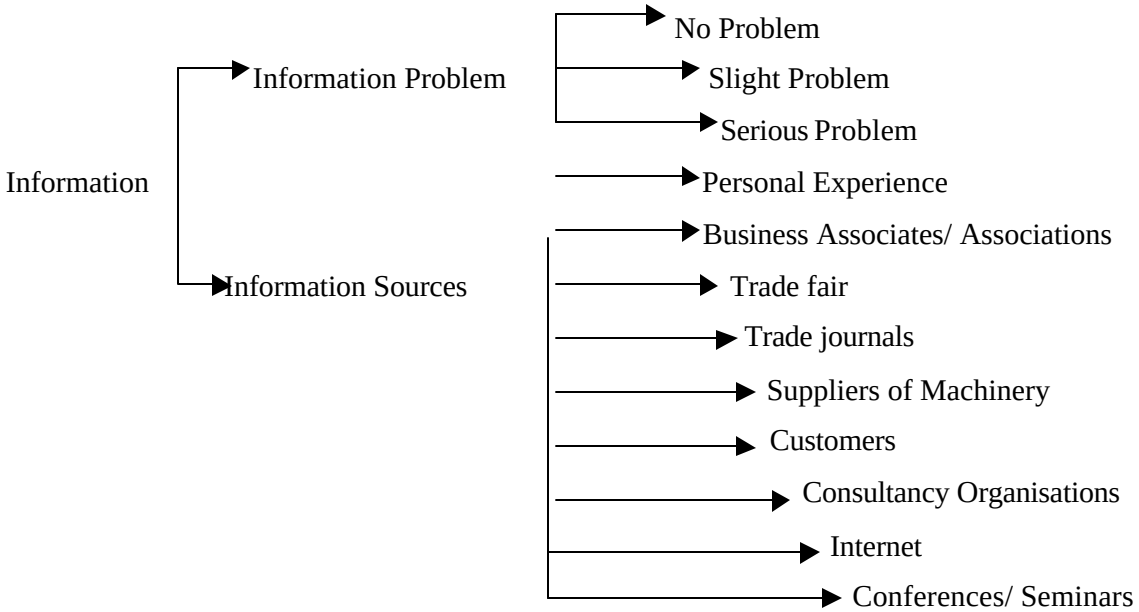
A2: Firm-level Characteristics taken to Determine Technology

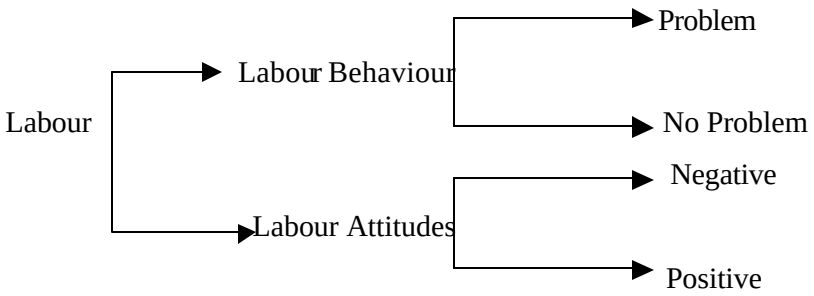


A2. Contd…..


<= Schooling
Owner's Education
>Schooling but Non-professional
Professional
Technological Capabilities
Owner's Experience in the Relevant Area
% Share of Professional Labour
Scale of Operation
Sales Turnover
No Problem
Finance Problem
Slight Problem
Serious Problem
Finance
Personal
Sources of Finance
Chit Funds, Credit Co-operatives
Institutional like banks
Equity finance by large firms

A2 Contd.


Information
Information Problem
No Problem
Slight Problem
Serious Problem
Information Sources
Personal Experience
Business Associates/ Associations
Trade fair
Trade journals
Suppliers of Machinery
Customers
Consultancy Organisations
Internet
Conferences/ Seminars


Labour
Labour Behaviour
Problem
No Problem
Labour Attitudes
Negative
Positive