THE ACQUISITION OF TECHNOLOGICAL CAPABILITY: TOWARDS AN ANALYTICAL MODEL

Dr. Zulkieflimansyah

Abstract

In neo-classical framework, technology is defined in a static way. It is a product, a package, that is produced by one set of firms or other institutions and consumed or used by another. And as firms all operate on a given production function, their technological tasks is merely to choose whichever technology is most appropriate to their needs. The firms can shift their position on the production function effortlessly in response to change in economic circumstances. The evolutionary approach, on the other hand, views technology in a more dynamic way. The successful adoption of technology involves more than merely the purchase of machinery and the learning of operating procedures. This means that firms can not shift effortless along the production function, nor operate any particular technique immediately at optimal efficiency.

Key words: Technology, Production Capacity, Technological Capability, Technological Learning.

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I. Introduction

In a market-oriented economy, it is believed that economic development is based on firms' success in achieving and maintaining competitiveness (Teece, 2000). And as addressed by Porter (1990) this only can be achieved by increasing the capacity of the firm and the industry to innovate and to upgrade its capability.

There are a number of different routes via which a firm or an industry might increase its innovativeness. It might make the same things as before but make them more efficiently, that is with fewer resources, and so release resources which can produce other valuable things. It might make better products or provide newer services, which are more highly valued by purchasers. It might open up new markets for products and services so as to be able to employ new factors of production or better utilise existing factors. It might open up or develop new sources of supply of raw material inputs to which it can add value. It might try to improve the supply or the quality of existing factors of production. It might try to improve the effectiveness of existing organisations so that more can be done with existing resources. In short, increasing the competitiveness of a firm or an industry will involve: improving production efficiencies, improving organisational effectiveness, developing improved products, finding new markets, finding a new source of supply, or a combination of these things (Schouller, 1998). And doing these activities very often involves using technology in some form. Thus, we can say that the mastery of technology is really needed by the firm to gain competitive advantage which in the end will enable them to perform specific activities better or differently than competitors (Porter, 1990).

The need to perform activities differently and better means firms continuously need to choose, use and master technology which is novel. Technological capabilities, the capabilities to generate and manage technical change are therefore a key issue for firms in this era of hypercompetition.

Since the issue of technological capability is very important, in this paper I will attempt to review the concept of technological capabilities and the learning process which generate them, with the aim of developing an analytical model that makes the idea applicable to the study of technological learning process at firm level.

Section 2 describes some common concepts about technology. Two different views from neo-classical economist and evolutionary approach and how these influence ideas about innovation and technology diffusion will be elaborated.

Section 3 brings out an important distinction between the essentially static capabilities or resources (production capacity) that enable firms to produce goods at given levels of efficiency with given combinations of inputs, and the related dynamic capabilities or
resources (technological capabilities) that enable firms to induce and
direct technical changes, so as to adapt or enhance productive capacity.

Section 4 examines the dynamic process of technological
learning at firm level. Consideration is given to theoretical ideas about
how learning takes place in cyclical ways, driven by both internal and
external resource in the firm’s innovation system. The relationships
between technological capabilities and production capacity is integrated
with the notion of learning cycles, so as to construct an analytical model
of a firm-level knowledge acquisition system.

Section 5 is concerned with the sources of technological
learning. And since firms almost never learn and innovate in isolation,
the notion of system of innovation will also be explained in this section.

Section 6 is concerned with how governments and business
enterprises might approach the technological learning process explained
in section 4. The learning stages will be elaborated in this section.

II. Definition and Concept of Technology
II.1. What is Technology?

Although mastering technology is important, technology is not an easy
term to define. In fact, there is no universally accepted definition of the
term that might serve as a natural point of departure. Definition is not
made any easier by the fact that the semantics of the term technology
differs in German and English – the former emphasising the science of
technology, the other the application of technical knowledge
(Meyer-Stamer, J, 1997). Summing up the widely accepted definition, it
is possible to delimit two variants – a narrow definition and the broad
one.

In a very narrow sense, technology is only technical information
contained in patents or technical knowledge communicable in written
form (Enos, 1989). Very often, technology refers to a class of
knowledge about specific product or production technique and
sometimes includes the technical skills necessary to use a product or a
production technique (Lan & Young, 1996). Technology thus is largely
identified with the hardware of production or technical artifacts.

Frances Stewart (1977) provided probably the broadest
definition of technology by including all skills, knowledge and
procedures required for making, using and doing useful things.
Technology in her definition therefore includes the software of
production - managerial and marketing skills, and extended to services -
administration, health, education and finance. Smillie (1991) describes
this broader definition of technology as "the science and art of getting
things done through the application of skills and knowledge ."

If we look at all the above definition, no matter how technology
is defined, most experts recognise that the concept implies a subtle mix
of know-how, techniques and tools. Technology in this sense is vested
in people - their knowledge, skills and routines - just as much as in the machine they use. Machines and tools are only the physical manifestation of a particular technology or technologies. Indeed, mere access to the physical elements of technology - even if accompanied by instructions for their use, and time to build up experience in using them - does not automatically lead to 'mastery' of that technology (Albu, 1997).

For mastering technology as stated by Clark (1991), should not consist just of the establishment of new production facilities along with ancillary manuals, charts, schedules, diagrams and people - embodied know - how. It requires also the knowledge and expertise for implementing technical change. This in turn involves both the underlying 'know - why' of the technological system itself as well as the various technomanagerial capabilities needed to evaluate and transform existing plant to meet new and innovative operating conditions. Thus, technological mastery here implies the capability to use knowledge about physical processes underlying that technology in order to assimilate, adapt and / or create novel elements, in response to changing needs (Dahlman & Westphal 1982).

II.2. Technology in Economic Literature

In the economic literature, the importance of technology has been known since the beginning of the discipline. Economists writing about economic growth for example have recognised technological advance as its key driving force (Smith, 1776; Marx, 1867; Schumpeter, 1911). In the 1950s and 1960s many studies tried to measure the contribution of technological change to economic growth in countries operating at the frontiers of technology (Solow, 1957; Denison, 1962). The conclusion was that productivity growth depends very heavily on the introduction and efficient diffusion of new and improved processes and products in the economic system.

Although the contribution of technology is well recognised in the economic literature, for long it was treated as a 'black box' (Rosenberg, 1982). As a result, it is still common to find technology being equated simply with machines and devices, in isolation from the human resources and social contexts of their use, which give these tools their technological value. In this light, technology is defined in a static way. Technology is a product, a package, that is produced by one set of firms or other institutions and consumed or used by another (Albu, 1997).

The conceptual framework underlying the static view was predominantly neo-classical. As firms all operate on a given production function, their technological task is merely to choose whichever technology is most appropriate to their local factor endowments and relative prices. It is assumed by the neo-classic framework that all firms
can shift their position on the production function effortlessly in response to change in factor endowments or relative prices, since they all have equal access to a global technology shelf, and are able to immediately operate the technology chosen with optimal efficiency (Rosenberg & Frischtak, 1985).

The implication of the neo-classical framework, technical change in industry has then conventionally been seen as involving two main activities. First, the development and initial commercialisation of significant innovations. Second, the progressively wider application of these innovations in a process that economists and others have described as ‘diffusion’. The first of these activities is assumed to be heavily concentrated in the developed countries, becoming significant in developing economies only as they approach the international technology frontier - a pattern which is becoming evident in the recent data on international patenting by firms in the more industrialised developing countries such as Korea and Taiwan. Before this stage, developing countries are assumed to be involved in the international diffusion of technology, and since this is seen simply as involving the choice and adoption / acquisition of established technologies, creative innovation is assumed to be irrelevant. From this perspective, “technological accumulation” in industrialising countries is seen as involving technology that is embodied in the stock of capital goods, together with the associated operating know-how and product specifications required to produce given products with given techniques at the relevant production efficiency frontier (Bell & Pavitt, 1993).

In the real world however, the evidence shows that the technology market does not function like a product market, and its 'goods' could not be transferred like physical products. The reality indicates that most developing countries are rather inept in using industrial technologies. They are in other words, technically inefficient in using the imported technologies. As a result, many industrial technologies are used at lower levels of productivity in developing than in developed countries.

According to Lall (1992, 1993) the technical inefficiency in developing countries can take several forms:
- The inability to find, choose and negotiate for the best imported technologies at the best prices, even when where market prices are undistorted, leading to high capital costs and low productive efficiency.
- The inability to master properly, in a static sense, the technologies that have been imported, i.e. technologies may be used below 'best practice' level of efficiency, needing too many inputs to produce a given level of output or producing output of inferior quality.
- Wide variations in efficiency levels among enterprises in the same industry. This implies that resources are being wasted by the
enterprises that fall below the technological levels of the best firms (which may themselves be below world 'best practice' levels).

- Lack of technological dynamism, of the ability to adapt or upgrade technologies to cope with changing circumstances at home or technological progress outside. Developing countries' enterprises may stay at the low value added end of the industrial spectrum, falling behind world technological frontiers as others forge ahead or as factor conditions change.

Thus, because of this technical inefficiency, developing countries then may stay at the low value added end of the industrial spectrum, falling behind world technological frontiers as others forge ahead (Lall, 1993).

The neo-classical approach to technological development was challenged on both theoretical and empirical ground by a number of 'alternative' more dynamic approaches that began to emerge in the second half of the 1970s. The new approach, which is much broader than its original perception that prevailed during the 1960s and 1970s, has been rapidly developing, particularly since the early 1980s.

Bell and Pavitt, for example, give a more realistic view of the nature of technology. According to them, understanding of technological change requires the distinction between innovators and adopters to be rejected (Bell & Pavitt, 1992, 1993). The successful adoption of technology involves more than merely the purchase of machinery and the learning of operating procedures (Dahlman & Westphal 1982). In part, this is because of the tacit nature of much technological knowledge: making it difficult or very costly to effectively communicate the full range of skills and knowledge required in executing complex tasks. This means that firms can not shift effortlessly along the production function (Lall 1992), nor operate any particular technique immediately at optimal efficiency. For firms in developing countries therefore, while technology 'transfer' may be necessary, it is not sufficient. The effective adoption and mastery of technology requires the acquisition of knowledge about a set of procedures, understanding of why procedures work and skill in putting them to use (Albu, 1997). According to Bell and Pavitt (1993) it also involves firm-level processes in which:

2 The contributors of the approach include Teitel (1984), Dahlman, et al (1987), Enos and Park (1988), Forsyth and Solomon (1994), Lall (1987, 1992), Nelson (1987), Freeman (1982), Enos (1991) and Bell and Pavitt (1997). The approach is variously referred to as institutionalist, structuralist or evolutionary. Although the authors use different terms such as technological mastery, technological capacity, technological capability, technological promotion, technological development, technological accumulation, technological acquisition, etc, there is a consensus to the meaning of the concept, that the acquisition of technological capability is a dynamic process.
The basic features of a technology are adapted to meet the idiosyncratic needs of a specific situation, and:

- A stream of further incremental modifications improve the technology and/or adapt it to changes in the inputs or products demanded by a competitive market.

Evidence from studies of large-scale industrial plants in many countries, indicates both phases of adaptation require complex and creative activities, and have the potential to generate significant improvements in production and economic gains (Hollander, 1965; Dahlan & Fonseca, 1987). This suggests that innovation should be understood not as a distinct precursor to technical change in production, but rather as part of an integral process which takes place within the environment of the innovating firm. It is among other things, the process which involves matching technological possibilities to market opportunities (Freeman 1982). Furthermore, the incremental innovations - adaptations, modifications and enhancements to products and processes - which occur within firms may be just as economically important as major investments in new machines or changes in products that originate outside the firm (Bienayme, 1986; Albu, 1997).

II.3. The Technological Effort of Learning

The kind of improvements in industrial performance mentioned above, are often interpreted in most economic analysis as a natural consequence of doing production; the result of an automatic learning by doing process (Arrow 1962). This doing - based learning according to Bell (1994) has three remarkable properties:

- It arises quite passively. Little or no explicit action is required to capture the increased knowledge/skill and whatever benefits flow from that acquisition.
- The learning process is virtually automatic. Given a period of 'doing' some quantum of learning will take place.
- It is costless. Learning is acquired simply as a free by-product from carrying on with production. No expenditure beyond that needed for production is required to generate the increased knowledge and skill.

This 'something for nothing' model of the learning process leads inevitably towards certain kinds of policy prescription. Increased 'learning' requires increased 'doing', and hence various forms of protection for doing are seen as appropriate means for enhancing learning - the benefits of the learning gained will offset the inevitable cost of protection. Beyond that, the role of policy intervention is limited. Since experience accumulation is simply a function of time or of cumulated total output, questions about policy intervention designed to raise the rate of learning derived from a given stream of production activity are largely irrelevant (Bell, 1994).
However, studies of infant industries in developing countries (e.g. Bell et al. 1982) demonstrate that learning does not occur spontaneously, and that performance can easily stagnate or decline over the long-run.

Firms which do manage to master technology and initiate a process of incremental innovation, do so as a result of learning which is neither automatic nor effortless. Even minor innovation requires a spectrum of skills, knowledge and capacities for searching, selecting, assimilating and adapting techniques. Developing and maintaining these capabilities requires both a conscious effort by firms and the investment of significant resources (Albu, 1997). Thus, we can say that the acquisition of technological capability does not come merely from experience, though experience is important. It comes from conscious efforts - to monitor what is being done, to try new things, to keep track of developments throughout the world, to accumulate added skills, and to increase the ability to respond to new pressures and opportunities (Dahlman & Westphal, 1987).

The need for such effort has been emphasised in virtually every article on the subject of capability building. The term has a certain intuitive appeal because it affirms that capability building is not a trivial activity; however, effort is a very broad term and does not tell us a great deal about what the learning process involves concretely (Romijn, 1999).

An attempt to overcome this problem was made by Bell, who designed a useful classification of learning mechanisms based on the existing empirical evidence (Bell, 1984). In addition to identifying experience - based learning by operating, he distinguished five mechanisms as shown in figure 2.1 that are predominantly 'effort based'.

**Figure 1.1: Different Learning Mechanisms**

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(6) Research and Development

(5) Change Capacity

(4) Change Task

(3) Operating Capacities

(2) Operating Task

Enterprise Performance
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According to Bell as shown in figure 1.1, the process of learning consists of the following elements:

(1) Learning by Doing / Operating
Bell points out that the most elementary form of learning is learning by operating, a variant of learning by doing (doing-based learning arises passively, is virtually automatic as 'doing' occurs, and it is a costless, free, by product from carrying out production) and by using. On the whole, the enhancements to operating capacities which result from learning process are rather small.

(2) Learning by Changing
Bell refers to learning by changing as the improvement upon equipment and techniques subsequent to gaining experience with them. When the 'black box' of technology is opened by investment in successive project, technical change can be quite major as principles are acquired and confidence in manipulating technology is gained. In this kind of learning there is introduction of innovative technical changes (attempts to adapt, diversify, improve quality, and bring out new products or variants of production processes).

(3) Learning by Evaluating (Learning from Performance Feedback)
This kind of learning involves monitoring and recording the performance of a technology. This can generate understanding about why certain things work and others do not. We can say then that this kind of learning is generated from feedback of regular monitoring of changes and performances in production.

(4) Learning through Training
Transmission of skills and further improvement during periods explicitly set aside for those purposes
(5) Learning by Hiring
Technological capability can also be improved by hiring consulting services and taking specialist advice, outside the firm.

(6) Learning by Searching
In this kind of learning, it is assumed that an organisation has the capability to investigate various sources of information, to absorb 'disembodied' knowledge and information about several types of technology, and to choose the most suitable one. This requires an explicit allocation of resources for non-production tasks, usually R&D.

Although it is shown in the diagram, the flow of knowledge that is generated by R&D activities is excluded in Bell's discussion. With the concept of learning defined broadly to encompass all forms of knowledge acquisition, this is somewhat arbitrary. If one defines R&D in the conventional manner, it does not produce technical change as such. It produces the knowledge upon which technical change can be based. In principle, then, R&D, and the flow of knowledge it generates, might be considered a 'learning' mechanism that is equivalent to all the others.

III. Technological Capability

III.1. The Emergence of the Concept of Technological Capability

As already mentioned earlier in section 2, the emergence of the concept of technological capabilities was a respond and challenge to the neo-classical approach to technological development. Building up technological capabilities then has been the focus of attention in the last 20 years.

Technological capability was defined in the early 1980s as 'the ability to make effective use of technological knowledge ... It inheres not in the knowledge that is possessed but in the use of that knowledge and in the proficiency of its use in production, investment and innovation' (Westphal, Kim and Dahlman, 1985:171). This concept was interchangeable with other concepts that referred to the same idea, such as technological effort (Dahlman and Westphal, 1982; Lall, 1987) or technological capacity (Bell, 1994; Katz, 1986). Later on the concept of technological capabilities became more widely used.

III.2. Taxonomy of Technological Capabilities

Although technological capability is a key issue for the firms in developing countries, interpreting and comparing studies of capability acquisition is not easy, in part because the resources firms accumulate are diverse and difficult to categorise. They comprise both human capabilities: skills, experience and knowledge vested in people, along
with institutional resources: the internal procedures, routines and organisational structures of the firm, and the external linkages cemented with other firms and institutions. An easy trap to fall into, is to associate 'technology' only with production activities, for example product design, manufacturing processes and the organisation of production. However, this ignores the importance of capital goods; in raw materials supply, and in distribution of products (Lall 1992; Albu, 1997). One common approach is to distinguish three general types of capabilities: production capabilities, investment capabilities and innovative capabilities (Lall 1992; Albu, 1997; Romijn 1999).

Production capabilities involve those skills, knowledge and resources needed to use existing plant and processes efficiently to make established products. These capabilities enable firms to monitor raw materials inputs, schedule production, control output quality, maintain and replace machinery, and generally deal with day to day problems.

Investment capabilities involve those skills, knowledge and resources which enable firms to expand workshop facilities, procure and install standard equipment; as well as to search for, evaluate and select technology and its sources for new production projects.

Finally and crucially, innovative and adaptive capabilities consist of the skills, knowledge and resources which enable firms to assimilate, change and create technology via such activities as capital stretching, adapting processes and modifying products (Albu, 1997).

However, to give these three categories equal status is to miss an important distinguishing dimension. Lall for example points out that the process of developing capabilities occurs gradually and cumulatively. In general, it leads from simple routine activities in which learning is based on experience, through more complex adaptive and duplicative activities requiring searching functions, to the most innovative activities based on more formalised research (Lall, 1992).

Bell and Pavitt (1993) introduce a general distinction between basic production capacities and dynamic technological capabilities. This distinction applies across the full range of firm activities and adds a new dimension to the taxonomy of capabilities.

Production capacities are static attributes. Knowing a firm's production capacities gives a 'snapshot' of the firm's ability to use existing production facilities, make standard investment decisions, expand established processes.

Technological capabilities on the other hand are dynamic resources, which encompasses the skills, knowledge and routines involved in generating and managing technical change, whether they concern production activities, investment activities or relations with other firms. The table in figure 1.2 below illustrates the differences between the respective types of capabilities by showing the kinds of activities associated with each.
Figure 1.2
Production Capacity and Technological Capability

<table>
<thead>
<tr>
<th>Production Capacities</th>
<th>Technological Capabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ability to do production activities such as</strong></td>
<td><strong>Ability to do supporting activities such as</strong></td>
</tr>
<tr>
<td>Investment Activities</td>
<td>- Construct workshop facilities.</td>
</tr>
<tr>
<td></td>
<td>- Procure standard equipment</td>
</tr>
<tr>
<td>Process &amp; Production Organisation</td>
<td>- Improve layout of workshop.</td>
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<tr>
<td></td>
<td>- Improve maintenance procedures</td>
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<tr>
<td></td>
<td>- Adapt and improve production process.</td>
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<tr>
<td></td>
<td>- Design organisational change</td>
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<tr>
<td>Product Centred Activities</td>
<td>- Replicate fixed specifications and designs.</td>
</tr>
<tr>
<td></td>
<td>- Do routine quality control</td>
</tr>
<tr>
<td></td>
<td>- Adapt products to changing market needs.</td>
</tr>
<tr>
<td></td>
<td>- Improve product quality</td>
</tr>
<tr>
<td></td>
<td>- Design new products</td>
</tr>
</tbody>
</table>

Source: Albu (1997)

Bell and Pavitt call the learning process involved in building the underlying dynamic resources as 'technological accumulation' or 'technological learning' (Bell & Pavitt 1993). The relationship between these different terms and concepts is represented schematically below in figure 1.3;
Figure 1.3: Technological Accumulation: Basic Concepts and Terms

The resources needed to generate and manage technical change:

1. Knowledge, skills, and experience
2. Institutional structures and linkages:
   - In firms
   - Between firms
   - Outside firms

(a) Introduction of technology embodied in new plants and/or new products and/or through 'major' investment project
(b) Incremental adaptation and improvement of existing production capacity

Components of given production systems:
- Fixed capital
- Operating labour skills and know-how
- Products specs / design
- Input specs
- Organization and procedure of production

Source: Bell and Pavitt (1993)

By using Bell and Pavitt conceptual model, it is easy to see how a firm with a fixed set of technological capabilities might generate a stream of improvements in production capacity over time. Such improvements may be important in enabling the firm to modify or scale-up production. A firm with no technological capabilities at all would be rigidly unable to adapt to any changes in its environment, and would not survive long. However, the fact that a firm has a limited set of technological capabilities, and uses these to gradually improve production capacity, may not always be adequate either. In the long run, such a firm may not be able to change radically enough to bridge the discontinuities that occasionally arise in technical change, and may be out-competed by those that can. If this conceptual model reflects reality, then a most important task facing firms in the long run is technological learning; the acquisition and strengthening of their technological capabilities (Albu, 1997).
IV. The Acquisition of Technological Capability at the Firm Level

IV.1. Learning Cycle

In figure 1.3, the relationship between technological learning, technological capabilities, technical change and production capacity was shown for simplicity, as a linear process; A leads to B leads to C. It is widely accepted however, that learning process are best represented by cycles. Van der Heijden (1996) for example, describes the learning cycles devised by Dewey, Deming, Kolb and Kofman as shown in figure 1.4 starting at the top:

Figure 1.4: The Learning Cycle

- We have experiences, some of which are important to us. These include, for example, what we perceive as the results of our previous actions.
- We reflect upon these experiences, looking at what our action has created in relation to other events. The product of this reflection is the awareness of new patterns and trends in events we did not perceive before. Reflection is related to our ability to differentiate between our existing mental model and perception of a different reality.
- Through 'cues of causality' we develop new theories on how our ideas about the world need to change as a result of these observations and reflections. The old mental model and the new reality are integrated in new theory.
- Then we use these theories to plan new steps, and effectively test the implications of our theory in new situations by taking new actions.
- This brings us back to the top. We obtain new experiences resulting from our actions, which only partly overlap with our expectation. And so we learn! Our new reflection shows us that our theory needs developing again. And the process continues.

By analogy, the same cyclical process can be applied to learning in organisations and firms. Organisations which monitor their own performance, analyse their strengths and weaknesses, plan strategically, etc are more likely to learn and improve than ones which are constantly in fire-fighting mode, reacting to external events (Albu, 1997).
IV.2. Technological Learning Cycles

Combining this cyclical view of learning with the system of technological learning terms used by Bell and Pavitt in figure 1.5, Albu (1997) gives a model of two interlocked learning cycles shown in figure 1.5.

In this model, the lower cycle represents the technical change process. At the very bottom, production capacity is used to convert material inputs into goods. A certain amount of production experience (knowledge feedback) may be derived from the production process, and used to augment a process of technical change whose outcomes are improvements in productive capacity. Note however that without the presence of technological capabilities to generate and manage technical change, the feedback from production experience is of limited value.

One particularly important technological capability in this context, is the ability to systematically gather information from one's own production experience and use it to generate knowledge about underlying technological processes.

The upper cycle represents the true technological learning process. Technological capabilities are used to generate and manage a process of technical change whose product is production capacity. A certain amount of change experience (knowledge feedback) may be derived from the process of technical change, and used to augment the process of technological learning whose outcomes are improvements in technological capabilities.

In figure 1.5, it is clear that knowledge feedback is very important in both processes of technical change and technological learning. At this point, it is important to classify two dimensions of knowledge: explicit and tacit. Explicit knowledge refers to knowledge that is codified and transmittable in formal, systematic language. Thus, explicit knowledge may be acquired from books, technical specifications, designs, and material embodied in machines. In contrast, tacit knowledge is so deeply rooted in the human mind and body that is hard to codify and communicate and can be expressed only through action, commitment and involvement in a specific context. Tacit knowledge can be acquired only through experience such as observation, imitation and practice (Kim, 1997, Nonaka & Takeuchi, 1995).

The firm according to Nonaka and Takeuchi (1995) develops and creates the knowledge through building both explicit and tacit knowledge and, more important, through the dynamic process of four different types of conversion between these two dimensions of knowledge: tacit to tacit, explicit to explicit, tacit to explicit, and explicit to tacit as depicted in figure 1.6.
Figure 1.5: Technological Learning Cycle

Figure 1.6
Four Modes of Knowledge Conversion

Source: Nonaka & Takeuchi (1995)
The Acquisition of Technological Capability ... (Dr. Zulkifli Mansyah)

Conversion from tacit to tacit, called socialisation, takes place when tacit knowledge within an individual is shared by another through training, while conversion from explicit to explicit (combination) takes place when an individual combines discrete pieces of explicit knowledge into a new whole. Conversion from tacit to explicit (externalisation) can be said to have taken place when an individual is able to articulate the foundations of his or her tacit knowledge, whereas conversion from explicit to tacit (internalisation) takes place when new explicit knowledge is shared throughout a firm and other members begin to use it to broaden, extend, and reframe their own tacit knowledge. Technological capability at a firm is not a collection of explicit knowledge; rather, it is largely a collection of tacit knowledge (Kim, 1997).

V. Sources of Technological Learning and The Innovation System

If the acquisition of technological capabilities is a learning process, it then raises all sorts of interesting questions like:
- What stimulates or drives the learning process?
- What internal knowledge feedback supports the learning process?
- What external resources/inputs support the learning process?

These questions are very important and must be addressed because, as stated by De Geus (1997), the natural learning process is slow and also closes options. Therefore, it needs stimuli to accelerate the learning process.

V.1. Sources of Technological Learning

The stimuli or causes of technological learning can be external and internal pressures or ambitions that motivate a firm to increase its capabilities. One must be careful to distinguish between the common place stimuli to increase or improve productive capacity, and the distinctive stimuli which induce a firm to seek long run improvements in its capacity to manage and generate technical change. The former may arise from short term competitive pressures or changes in demand. The latter may stem from management strategies, awareness of long run trends or even government policies (Albu, 1997, Romijn, 1999).

The possibility of internal knowledge feedback has already been described in the learning cycle above. Systematic feedback from the process of engaging in production and distribution contributes to the process of technical change. For example, interaction with customers can provide information about desired modifications to products - which leads to improvements in production capacity. Feedback from the process of technical change - for example: from the experience of
purchasing and installing new machinery - can contribute to a firm's capability to manage future investments (Albu, 1997, Romijn, 1999).

The **external resources or inputs** which firms use to build capabilities include a variety of skills, knowledge, technical and financial services available from the labour market, from the interactions with others and from supporting institutions. Again, one needs to distinguish between the external resources which contribute directly to processes of technical change - for example: technical advice and investment credit - and the external resources which support the acquisition of technological capabilities (Albu, 1997, Romijn, 1999).

Thus, when the above stimuli and external inputs are included in the technological learning model developed earlier, the result is a more comprehensive analytical model of what can be called the **Knowledge Acquisition System** of a firm, illustrated in figure 1.7 below. Illustrative examples of the stimuli, inputs and feedback relevant to each level of learning are shown in the accompanying table in figure 1.8;

**Figure 1.7: Illustrative Framework for Knowledge Acquisition System**

<table>
<thead>
<tr>
<th>Stimuli</th>
<th>PROCESS OF TECHNICAL CHANGE</th>
<th>PROCESS OF TECHNOLOGICAL LEARNING</th>
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<tbody>
<tr>
<td></td>
<td>- Short term changes in demand</td>
<td>- Government policy encouraging innovation</td>
</tr>
<tr>
<td></td>
<td>- Competitive Threats &amp; Opportunities</td>
<td>- Culture and norms of social environment</td>
</tr>
<tr>
<td></td>
<td>- Demonstration effects</td>
<td>- Strategic awareness of economic trends</td>
</tr>
<tr>
<td>Knowledge Feedback</td>
<td>- Skills and Knowledge gained from experience of production</td>
<td>- Skill and knowledge gained from investment projects</td>
</tr>
<tr>
<td></td>
<td>- Interaction between producers and users</td>
<td>- Insight gained from effecting improvements and modification</td>
</tr>
<tr>
<td>External Input</td>
<td>- Training in operating skills</td>
<td>- Training in strategic planning, design and management of technology.</td>
</tr>
<tr>
<td></td>
<td>- Hiring skilled labour</td>
<td>- Collaboration between research and industry</td>
</tr>
<tr>
<td></td>
<td>- Technical advice services</td>
<td>- Consultancy services</td>
</tr>
</tbody>
</table>

Source: Albu (1997)

As shown in figure 1.8 below, the acquisition of technological capability occurs over time and is influenced by many factors. The process is characterised by complicated feedback mechanisms and interactive relations involving science, technology, learning,
production, policy and demand. Because of this complexity, firms then almost never learn and innovate in isolation.

Figure 1.8: Firm Level Knowledge Acquisition System: A Framework for Analysis

- Stimuli
  - Government Policy encouraging innovation
  - Strategic awareness of Economic Trends
  - Culture & Norms of Social Environment

- External Input
  - Consultancy Services
  - Collaboration between research & industry

- Process of Technological Learning
  - The Acquisition of technological capabilities

- Knowledge Feedback
  - Skill & knowledge gained from investment projects
  - Insight gained from effecting improvements and modifications

- Stimuli
  - Short term change in demand
  - Competitive threats & opportunities

- Technological Capability (Resource Needed to Generate Change)
  - Knowledge, Skills, & Experience of Change
  - Institutional Resources, Structures and Linkages

- Process of Technical Change
  - Incremental Adaptation & Improvements
  - Intro. Of new machines

- Production Capacity (Resource Needed to Produce Goods)
  - Fixed Capital
  - Operating Skills & Know-how
  - Production Procedures

- Knowledge Feedback
  - Knowledge & Skill gained from experience of production
  - Interaction between producers & users

- External Input
  - Training in Operating Skills
  - Technical Advice Services

Source: Bell and Pawitt (1992) and Albu (1997)
V.2. The Innovation System

In getting the stimuli, external input and feedback, the firms interact with other organisations. These organisations might be other firms (suppliers, customers, competitors, etc) but also universities, research institutes, investment banks, schools, government ministries, etc. Through their innovative activities firms often establish relations with each other and other kinds of organisations; therefore it does not make sense to regard innovating firms as isolated, individual decision making units (Edquist, 1997).

The behaviour of firms to gain, develop, and exchange various kinds of knowledge, information, and other resources according to Edquist (1997) is also shaped by institutions that constitute constraints and/or incentives for innovation, such as laws, health regulation, cultural norms, social rules, and technical standards. Interaction between various organisations operating in different institutional contexts is important for the firms’ process of innovation. The actors as well as these contextual factors are all elements of systems for the creation and use of knowledge for economic purposes. Innovations emerge in such systems which is called by many experts 'System of Innovation' (Freeman, 1987, 1988, 1995, Lundvall, 1988, Nelson, 1993, Edquist, 1997).

For the firms in catching-up countries as stated by Kim (1997, 2000), the system of innovation is also very important as sources of learning. And it may be broadly categorised into three groups: the international community, the domestic community, and in house efforts at the firm level. Kim also emphasised that there are five important factors that significantly influence the learning process: market and technology environment, public policy, formal education, socio-culture, and organisational structure. Figure 1.9 depicts the major sources of technological learning, the firm’s interactions with these sources, and the factors influencing the interactive process.

If we look at Kim’s model, the in house efforts at firm level is actually similar to the technological learning cycle proposed by Albu. And if we put Albu’s model in Kim’s model on system of innovation we can then get a more dynamic learning process at firm level as depicted by figure 1.10.
Figure L.9: System of Innovation in Catching-Up Countries

Source: Kim (1997)
VI. Technological Learning Stages

VI.1. Product Cycle

Since building the technological capabilities occurs gradually and cumulatively, the firms then learn through several stages. This approach to technological learning is usually called as stage approach (Clark, 1993).

In a stage approach, technological learning is viewed in terms of a process of evolution which proceeds through 'stages' or 'phases' of increasing sophistication. Utterback and Abernathy (1975), for example postulate that industries and firms in advanced countries develop along
a technological trajectory made up of three stages — fluid, transition and specific.

According to Utterback and Abernathy’s model, firms in a new technology exhibit a fluid pattern of innovation. The rate of radical, rather than incremental, product innovation is high. The new product technology is often crude, expensive, and unreliable, but it fills a function in a way that satisfies some market niche. At this stage, technical entrepreneurs form small firms and new venture divisions within existing firms, competing on the basis of their capability in product innovation. Product changes are frequent, as are the changes in the market, so the production system remains fluid and the organisation needs a flexible structure to respond quickly and effectively to changes in market and technology (Utterback, 1994; Kim, 1997).

As market needs become better understood and alternative product technologies converge or drop out, a transition begins toward a dominant product design and mass production methods, adding competition in price as well as product performance. Cost competition leads to radical change in process, driving cost rapidly down. Production capability and scale assume greater importance in order to reap scale economies. And as industries and their markets mature and price competition grows more intense, the production process becomes more automated, integrated, systematised, specific and rigid to turn out a highly standardised product. The focus of innovation shifts to incremental process improvements, in search of greater efficiency (Utterback, 1994; Kim, 1997).

Figure 1.11 depicts Utterback and Abenhathy’s model of stage approach of innovation or technological learning. As shown in figure 2.11, the frequency of radical product innovations is high during the fluid stage but diminishes rapidly, while that of radical process innovations is high during the transition stage. In the specific stage, both radical product and process innovations are low.

**Figure 1.11: Utterback and Abernathy’s Model of Innovation**

![Diagram of Utterback and Abernathy’s Model of Innovation](image_url)

Source: Utterback (1994)
VI.2. Technological Learning Stages in Catching-Up Countries

In the case of firms in catching up countries as stated by Kim (1997), the stage of technological learning has been somewhat different from that of advanced countries. He then developed a three stage model — acquisition, assimilation, and improvement — to extend Utterback and Abernathy’s.

According to Kim (1997), during the early stage of their industrialisation, catching up countries acquire mature (specific-state) foreign technologies from industrially advanced countries. Lacking local capability to establish production operations, local entrepreneurs develop production processes through the acquisition of packed foreign technology, which includes assembly process, product specifications, production know-how, technical personnel, and components and parts.

Market opportunity and rapid competition then usually spurs indigenous technical efforts in the assimilation of foreign technologies to produce differentiated items. And by assimilating imported technology, local firms are able to develop related products through imitative reverse engineering without the direct transfer of foreign technologies.

The relatively successful assimilation of general production technology together with the increase of local scientific and engineering personnel, lead to the gradual improvement of technology. Imported technologies are applied to different product lines through local efforts in research and development, and engineering. In proceeding along this trajectory at acquisition, assimilation and improvement, firms in catching-up countries reverse the sequence of research and development in advanced countries (Kim, 1997).

Linking the technological trajectories of Utterback and Abernathy with Kim’s postulate that the three stage technological trajectory in catching up countries takes place not only in mature technology in the specific stage but also in growing and emerging technologies in the transition and fluid stages, as shown in figure 1.11, firms in catching up countries that have successfully acquired, assimilated, and sometimes improved mature foreign technologies may aim to repeat the process with higher level technologies in the transition stage in advanced countries. Many industries in Taiwan and Korea as stated by Kim have arrived at this stage. If successful, they may eventually accumulate indigenous technological capability to generate emerging technologies in the fluid stage and challenge firms in advanced countries.
VII. Summary

The paper has described some common concepts about technology. Two different views from neo-classical economist and evolutionary approach and how these influence ideas about innovation and technology diffusion has been addressed. It also brings out an important distinction between the essentially static capabilities or resources (production capacity) that enable firms to produce goods at given levels of efficiency with given combinations of inputs, and the related dynamic capabilities or resources (technological capabilities) that enable firms to induce and direct technical changes, so as to adapt or enhance productive capacity.
Special attention has also be given to the dynamic process of technological learning at firm level. Consideration is given to theoretical ideas about how learning takes place in cyclical ways, driven by both internal and external resource in the firm’s innovation system. The relationships between technological capabilities and production capacity is integrated with the notion of learning cycles, so as to construct an analytical model of a firm-level knowledge acquisition system.

And since firms almost never learn and innovate in isolation, the notion of system-of-innovation, the learning stages, sources of technological learning and also the impact of the accumulation of technological capability on corporate growth have also been discussed.

It is very clear from the chapter that the acquisition of technological capabilities or technological learning is not effortless or simply the result of an automatic learning by doing. Firms which do manage to master technology and initiate a process of incremental innovation, do so as a result of learning which is neither automatic nor effortless. Even minor innovation requires a spectrum of skills, knowledge and capacities for searching, selecting, assimilating and adapting techniques. Developing and maintaining these capabilities requires both a conscious effort by firms and the investment of significant resources. The acquisition of technological capability does not come merely from experience, though experience is important. It comes from conscious efforts—to monitor what is being done, to try new things, to keep track of developments throughout the world, to accumulate added skills, and to increase the ability to respond to new pressures and opportunities.

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