



# Technology Measurement: Searching for a Useful Framework

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It is true that there is a wealth of study on the measurement of technological level (see, for example, Salter 1960, Brown 1966, Kennedy and Thirwall 1972, Enos 1962, Hollander 1965, Nelson and Winter 1982, and Heertje 1983). Nevertheless, it is also true that, as yet, there is still no satisfactory framework for analyses. Most analyses have either emphasized quantitative aspects or tackled qualitative dimensions. As is widely recognized by both economists and technologists, technology measurement (measurement and assessment of technological level) is a very complicated and difficult task. On the one hand, economists have been using production functions (see, for example, Heathfield 1971) while on the other, technologists have employed their own knowledge and expertise to make such judgments.

Through various forms of production functions and their modified models, economists have developed their own tools to assess and measure the level of technology of a production unit, firm, or country. The results could yield figures to differentiate one production unit, firm, industry, and country from another. For the sake of analysis, however, this method leaves out many details in order to comply with mathematical models. Also, the outcome has remained in aggregate form (see Solow 1956 and 1957, Nelson 1967, Ferguson 1969, and Jones 1975). First, the technology level includes everything, except labor and capital, which causes differences in productivity. This surely includes management and marketing effects. Second, the technology level includes all types of technology. Technical separation, therefore, is almost impossible.

Technologists have employed various methods of measurement, such as expert judgments, peer group reviews, and Delphi methods, to differentiate technological levels of a process, production unit, firm, industry, or country, giving a clear explanation and insight into the technical details of each. There is, however, no fixed form of assessment or unit of measurement. The methods of assessment and measurement tend to vary between different groups of experts, as do the outcomes. Conformity, therefore, is almost impossible.

Both types of measurement and assessment tend to depict only one side of the coin, without discovering informative findings and useful policy implications. Hence, the main objective of this paper is to lay down a framework for technology measurement or assessment in an attempt to search for a useful framework for analyses and policy formulation which complements traditional methods and frameworks of measurement. By using a new framework, it is possible that technology measurement and assessment can be less subjective, although not entirely objective. Also, technical details can be spelled out, rather than being lumped together in an aggregate form, thus, deriving more useful information and policy formulation.

## THE FRAMEWORK

The technology audit method (TAM) is a technique traditionally employed to support various technological forecasting methods, such as the technology tree method. This method is mainly used to measure and assess technological processes of technologies under a technology tree. The auditing method, therefore, is only useful for technological forecasting, as it gives merely a technical analysis of the profile and path of various comparable technological processes, without giving policy implications—why processes differ, which processes are desirable, why they are desirable, and how such desirable processes are attained.

To use TAM for other purposes, in particular for technology measurement/assessment, such as technology transfer, level, and status, an integrated framework modified from technological measurement/assessment frameworks is needed (see application for assessment of technology transfer in Tiralap 1992). Among

others, the framework of technological embodiment (see Sharif 1991), technological capability, and technological content (see TDRI 1991) seems very useful to extend the traditional auditing method.

The main measurement and assessment of the modified technology audit method examines the technology audit schema that comprises production process, technological content, technological capability, and technological embodiment. The concepts of each technological component are shown in [Figure 1](#).

## **Production Process**

The production process seeks to identify the scope and extent of a firm's production activities—designing, processing, manufacturing, and assembling. Each step of the production process is detailed according to a firm's existing production activities. A firm may have only one production process, or it may have more, depending on internal factors and the external environment. In other words, it may have only an assembling, manufacturing, processing or designing process, or it may include all of these.

The assembling process involves the process of final assembly of all required parts and components into workable and ready-to-use products. This includes all assembling, testing, and packaging activities.

The manufacturing process covers the physical transformation of all parts and semi-products into parts and/or components for final product assembly.

The processing process refers to the property transformation of raw materials, such as mineral and agricultural materials, into semi-products or parts for further manufacturing and/or assembly.

The designing process includes all activities relating to conceptual layout, drawing, patterning, prototyping, and research and development (R&D).

## **Technological Content**

The technological content seeks to explain a firm's technological components. Theoretically, if a firm possesses all technological components—production-management technology, process technology, product-specific technology, and design technology—its production and technological bases tend to be stronger than those which do not. Consequently, it tends to achieve lower production costs, gain higher value-added, and have more spillover effects between products and processes. The technological content of each firm will strongly determine its technical performance which, one way or another, will affect its business performance.

Production-management technology comprises basic engineering and management techniques. These are vital to a firm's production process, especially the assembly process. To achieve high production efficiency and product quality, however, process technology also is required.

Process technology refers to the core production know-how and technology embodied in machinery and equipment. It is mainly required in the physical and/or property transformation process. In addition to the assembling process, process technology is crucial to the manufacturing and processing processes, although the latter requires more product-specific technology than the former.

Product-specific technology refers to the specific procedure, know-how, and knowledge which determines the crucial functions, specifications, and designs of a product. Apart from supporting the processing, manufacturing, and assembling processes, it is essential in the designing process. Without product-specific technology, a firm's activities tend to be limited to only the assembling and/or manufacturing process.

Design technology refers to the translation of conceptual ideas and layouts of a product into formulas, specifications, drawings, and/or prototypes, and the use of equipment and tools to design a product. A firm needs both design and product-specific technologies to design a product because, while design technology provides the general framework and basic equipment and tools, product-specific technology yields specific

conditions, specifications and/or formulas for product design.

## **Technological Capability**

The concept of technological capability seeks to explain a firm's technological levels. Clearly, the production and technological bases of one firm may differ from those of another, not only in terms of the components of technology, but also in technological levels. Two firms may have identical technological components, but different levels of manufacturing and design capabilities. This can widen the technological gap between firms and, hence, their production and technological bases, and technical and business performances.

Manufacturing capability refers to the ability to efficiently use (operate, control, and maintain) a firm's machinery and equipment. This requires an ability to run the production line, transforming production inputs into desirable outputs (both quantity and quality). Manufacturing capability requires a knowledge of basic engineering and management techniques (production-management technology) and of core production know-how and technology embodied in machinery and equipment (process technology) to achieve the highest production efficiency and product quality. To some extent, it also requires the ability to search, assess, negotiate, and procure the most suitable raw materials, to install the most relevant machinery and equipment, and to apply the most appropriate know-how for production.

Design capability covers the ability to reproduce (absorb, digest, and command) the existing products and/or production processes, the ability to modify (rectify, improve, and enhance) the core technology or main function of the existing products and/or production processes, and the ability to create (develop, research, and invent) a new product and/or production process. This requires the specific procedure know-how to determine the crucial functions, specifications, and designs of a product (product-specific technology), and the knowledge and ability to translate the conceptual ideas and layouts of a product into formulas, specifications, drawings, and/or prototypes, and ability to use the equipment and tools to design such a product. Design capability also requires the ability to search, assess, negotiate and install the most relevant and suitable ideas, information, methods, procedures, know-how, and knowledge for product design.

## **Technological Embodiment**

Technological embodiment seeks to explain the factors that affect a firm's technological levels and components. Technological embodiments (namely, man, machine, management, and information), then, are factors which cause differences in technological capabilities (manufacturing and design capabilities) and, hence, differences in a firm's technological content (production-management, process, product-specific, and design technologies). Technological embodiment determines a firm's technological path (the rate and direction of technological progress), through changes in its human-embodied ability, equipment-embodied facility, institution-embodied management, and document-embodied information.

The term "man" refers to human-embodied abilities, such as experience, skill, and knowledge. These are abilities to acquire, use, reproduce, modify, create, and manage all of the equipment facilities, institutional management, and documented information for production.

The term "machine" refers to equipment-embodied facilities, such as production machines, machine tools, measuring instruments, and other production-related equipment and tools. Such facilities enhance human capabilities in transforming inputs into outputs.

The term "management" refers to institution-embodied management frameworks, such as management techniques and practices. These frameworks are used to organize all equipment facilities, human abilities, and documented information into an integrated force for production.

The term "information" refers to document-embodied information, such as minutes, manuals, texts, specifications, and designs. These documents support the efficient and effective use of human abilities, equipment facilities, and institutional management for production.

## CONCLUSIONS

Although the framework proposed is preliminary, it nonetheless provides a complementary conceptual framework for technology assessment for economists, who normally employ production functions and their modified forms as the main tools of measurement to assess technological levels, and for technologists, who judge the level of technology based on their own knowledge and expertise. Albeit without presenting mathematical models, this framework is less subjective than traditional methods, it can also provide a great deal of technical detail, instead of lumping together technological types. Management and marketing effects can be spelled out, thereby yielding more useful information and deriving policies. The following points, at least, could be addressed and, hence, their policy implications derived.

- If the production function shows that the technology level of industry A is higher than that of industry B, a further assessment can be made to determine which technology types are responsible and the extent of responsibility. Thus, we can differentiate between industry A and B in greater technical detail and, hence, better determine resource allocation.

As concerns policy implications, the government will then know when to intervene and what type of incentives or impositions to apply to remedy a situation or strengthen a particular industry, as opposed to across-the-board cuts. Otherwise, there is no need to allocate resources. Because technology differs, the ways in which and the extent to which government intervention can be effective, and whether such intervention should be long- or short-term, largely depends upon the types of technology essential to an industry, such as production management, process, product-specific and design technologies.

- If expert judgment concludes that the technological status of industry A is higher than industry B, conformities of measurement make the reconfirmation process more feasible, as does technical categorization. Thus, we can collect data and information and make a consistent technological assessment of industries A and B.

As concerns policy implications, the government will then be better able to decide when to lift or impose protective measures, and on what basis, as different technological formations require different time spans and resources. Abruptly granting or abandoning protective shields tends to result in non-competitive industrial performance. To enable it to make effective determinations, the government also has to know what technical supports and/or requirements are needed.

Policy issues, therefore, basically comprise the analytical framework of technology assessment and the role of government. The policy of "tariff protection without technology accumulation" in the past seems to have resulted in tragic consequences for local industries, leaving aside the recent trend of "no protection and no technology given." Thus, the question: Which policy should be pursued? Generally, the policy needed should constitute "technical support not economic protection." Firms and industries should be encouraged to be competitive; hence, economic protection should not be given. However, technical support is strongly recommended to offset the acute adverse effects of lifting economic protection.

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