DETERMINING TECHNOLOGICAL INNOVATION AND COMPETITIVENESS: A CROSS ORGANIZATIONAL ANALYSIS OF THE MALAYSIAN MANUFACTURING INDUSTRY

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Abstract This study analyzed the determinants of technological innovation in the Malaysian manufacturing industry. Its main purpose is to identify a set of management-related variables characterizing Malaysian innovative firms. Moreover, the study aimed to test whether the set of determinant differs for firms with different technological trajectories. A sample of 204 Malaysian firms was used for the investigation, with one respondent from each firm. The questionnaire measured the technological innovation, as well as 5 main potential determinants of innovation adopted from literature. Statistical analysis used, including bivariate correlation and multivariate regression, in identifying association between the technological innovation and the determining variables. The results of the analysis lead the researcher to the model of 5 important determining factors of technological innovation. The important factors were intensity of R&D, technological trajectories, intensity of marketing, engineers, scientist and managers with experience locally and technical competency of personnel. The analysis of technological trajectories confirmed the hypotheses that set of important determinants of innovation as well as the extent of technological innovation differs for firms in different innovation processes.
Technology and the Technological Development Process in Newly Industrialized Country

The term technology can be defined through a variety of approaches. It is derived from the Greek words “techne” meaning an art or a skill and “logia” meaning a science or study. In dictionaries, this term was described as the science or study of the practical or industrial arts, applied sciences and the science of the application of knowledge to practical purposes in a particular field (Nejad, 1997). Depending on the nature, role and impact of technology there were several major perspectives on technology. The first perspective, technology was defined as any tool or technique, any product or process, any physical equipment or method of doing or making by which human capabilities are extended. The second focuses on technology as the system by which a society satisfies its needs and desires. In this case, when technology is applied to an individual enterprise, it means the capability that an enterprise needs to provide its customers with the goods and services which it proposes to offer, present and in the future. The third perspective highlights the importance of “know-why”; the factual knowledge embodied in proven scientific theories and “know-how”; the knowledge of empirical evidence and that of experiences through the application of know-why in practical situations which concentrates on the role that skills play in gathering, using and updating knowledge.

The fourth perspective refers to technology as an integration of hardware and software. It describes technology including the interrelated components; humanware, technoware, infoware, and organoware. Humanware as people-embodied technology involves experiences, skills, knowledge, wisdom and creativity. Technoware is object-embodied technology and consists of tools, components; equipment, machines, vehicles and physical facilities. Infoware is document-embodied technology comprising all kinds of documentation pertaining to process specialization, procedures, theories and observations. Organoware is institution-embodied technology including the managerial skill and organizational structure which is essential to facilitate the effective integration of humanware, technoware and infoware (Rasiah, 1994). For technological development purposes of a country, it is crucial to develop these four inter-related components at the same time and in parallel.

Utterback (1999), in his study on the dynamic nature of technological innovation suggested there are two distinctive development processes for products and processes based on the different ages of firms. Furthermore, economists have increasingly appreciated that the rate of technical advancement depends not only upon the level of innovative effort, but also upon the composition of that effort. In this respect, research on technological innovation as a new pattern of the technology development process should be able to discover the most influential ingredients of intra-and extra-firm behavior and those environmental factors which exhibit the greatest impact on technological innovation in developing countries or newly industrialized countries.

United Nation (2002) reported over the last 20 years, with the advent of the advanced technologies, the pattern and pace of technical change has altered sharply. Although most developing countries have been placed in economic trouble, nevertheless a rise of newly industrializing countries with basic
infrastructure to accelerate their pace of growth can provide the opportunities, even for the others to improve their conditions if properly mobilized. In the past, developing countries have concentrated most of their science and technology efforts in establishing research institutes without higher investment commitment in the development, pre-investment studies, prototype production and market analyses that were really needed. An even larger effort is required to test and re-test products, to design the manufacturing facilities, to attract major capital, to acquire the operational expertise and eventually to reach profitable commercialization.

It is clear from Cooper (1994) that technological innovation studies can help to clarify the process of accumulation of technological capabilities for developing countries moving towards newly industrialized countries. Their strength is that they are firmly based, on clear ideas about institutions, whether these are the firms which do the innovation or the network of public and private agencies to which these firms relate. This perspective has often been lacking in the discussion of developing indigenous technological capability for developing countries or newly industrialized country.

**An Overview on Technological Innovation**

**Definitions of terms and concepts concerning technological innovation**

This study adopted the OECD definitions of technology and technological innovation (Oslo Manual, 1992) as the following:

i. *Innovation* is defined as the adoption of an internally generated or externally acquired product of manufacturing process perceived to be new by the firm (Oslo Manual, p.47).

ii. *Technology* can be interpreted broadly as the whole complex of knowledge, skills, routines, competence, equipment and engineering practice which are necessary to produce a product or service (Oslo Manual, p.47).

iii. *Technological product and process innovations* comprise implemented technologically new products and processes and significant technological improvements in products and processes (Oslo Manual, p.47). In this definition products included both goods and services.

iv. A *technologically new or radically innovative product* is a product whose technological characteristics or intended uses differ significantly from those of previously produced products. Such innovations can involve radically new technologies, can be based on combining existing technologies in new uses, or can be derived from the use of new knowledge (Oslo Manual, p.48).

v. A *technologically improved or incrementally innovative product* is an existing product whose performance has been significantly enhanced or upgraded. A simple product may be improved (in terms of better performance or lower cost) through use of higher performance components or materials, or a complex product which consists of a number of integrated technical subsystems may be improved by partial changes to one of the subsystems (Oslo Manual, p.49).

vi. *Technological process innovation* is the adoption of technologically new or significantly improved production methods, including methods of product delivery. These methods
may involve changes in equipment, or production organization, or a combination of these changes, and may be derived from the use of new knowledge. The methods may be intended to produce or deliver technologically new or improved products, which cannot be produced or delivered using conventional production methods, or essentially to increase the production or delivery efficiency of existing products (Oslo Manual, p.49).

vii. Technological innovation occurs when a new or changed product is introduced to the market, or when a new or changed process is used in commercial production. The innovation process is the combination of activities - such as design, research, market investigation, tooling up and management - which are necessary to develop an innovative product or production process (Gaynor, 2002; Greene & Harich, 2000; OECD, 1992).

**General perspective on technological innovation**

An overview of the process of technological innovation research shows that this subject is multi-disciplinary and interdisciplinary involving several disciplines, starting from economics, sociology, political science, design, manufacturing, industrial marketing, macro-organization behavior and the management of technology (Becker & Stafford 2001; Hislop, 2003; Nejad, 1997). As a result there are many perspectives about technological innovation. Some see innovation as a creative act, as an invention, as its originality, and its newness. Others see innovation as a thing, a piece of hardware and some see it as an idea and a design. Others emphasis its applicability, its use in the market and production process and some focus on its marketing features. In this study, the word innovation refers to technological innovation as opposed to any other form of innovation.

In an economic perspective, technological innovation is seen as the first commercial transaction involving the invention (Sorge, 1991; Hislop, 2003; Martin & Terblanche, 2003). It is argued that all inventions do not necessarily lead to technological innovations and in fact the majority does not, since they must fulfill the condition of being accepted by the market before they can be classified as innovations (Gupta & Singhal, 1995). Economists, generally, consider innovation as a more or less linear process of three stages such as invention, commercial innovation (prototypes into production) and the diffusion of innovations (Martin & Terblanche, 2003).

According to Zaltman, Duncan and Holbek (1973), Dougherty and Hardy (1996), and Gupta and Thomas (2001) there are three inter-related perspectives on innovation which are referred to as the process of developing the new item by the developer; the process of adopting the new item by the adopter and the new item itself as an integrative function of both. The developer and the adopter can be an organization, such as a business firm, a social group or an individual. The first perspective, referring to the creative or development process, starts with the recognition of a potential demand for an item, its related technological feasibility, and ends with its widespread utilization. Innovation, here, is depicted as the creative process that results in something new. The second perspective views innovation as the process whereby a new item is adopted and thus implemented by an adopter. Gupta, Iyer, and Aronson (2000) stated that the adoption of a change which is new to an organization
and to the relevant environment is an innovation. The third perspective focuses on the invention and newness of items.

Rogers (1983), defined innovation as an idea, practice or object that is perceived as new by an individual or other unit of adoption. Furthermore, according to Rogers and Shoemaker (1991), and Fleming and Sorenson (2003) it matters little, as far as human behavior is concerned, whether or not an idea is “objectively” new as measured by the lapse of time since its first use or discovery, if the idea seems new and different to the unit of adoption, it is an innovation. This means that the same idea, product, process and system can be considered an innovation if it is employed by different companies in different markets at different times.

The concepts and meanings of technological innovation

Innovation has a number of related meanings. It is derived from the Latin word novus, meaning new. Also the term is alternatively defined by dictionaries as “the introduction of something new”, or “a new idea, method or device” (Nejad, 1997). Kristensen (1993) examined the definitions of “innovation” and concluded that many investigators fail to provide an explicit picture of this term; the employed definitions can be divided into a number of categories; and the aspects emphasized by the definitions change over time. Among the variety of definitions regarding technological innovation at the firm level, the following ones reflect the essence of it. Shane (1994) stated that when an organization learns to do something which it did not know how to do it before and then proceeds to do it in a sustained way, a process of innovation has occurred. Martin (1997) suggested that “an innovation” is the basic unit of technological change. This definition of innovation was based on the works of Schoemaker and Amit (1995) who believed that when an enterprise produces a good or service or uses a method or input that is new to its environment it makes a technical change, its action is innovative.

According to Cooper (1984) innovation can be referred to as a wide spectrum of activities from relatively low-cost search to high-cost R&D, the selection and creation of new production techniques, minor and major adaptation of production processes and subsequent investments in innovation as a part of diffusion. OECD (1992) identified that innovation can take many forms such as a familiar product manufactured from new materials; a different combination of existing products to give improved performance; adaptation of an existing product to meet new demands; a new product utilized to perform a new function; and a new process either to make an existing, modified or new product, or to reduce its costs. Dougherty and Hardy (1996) and Robert (1998) stated that innovation can be regarded as a comprehensive process which starts with the generation of an idea loads to the production and commercialization. It means innovation is invention along with exploitation, which covers all efforts of creation of new ideas and getting them to work (invention) and also includes the process of commercial development including the focusing of ideas or inventions toward specific objectives, evaluating these objectives, transfer of R&D results and the eventual broad-based utilization, dissemination and diffusion of the technology-based outcomes (exploitation).

Dosi, Freeman, Nelson, Silverberg and Soete (1988) and Greene and Harich (2000) argued although R&D is essential for innovation, it is more accurate to describe innovation as the result of a
succession of improvements attributable to “design, learning-by-doing and learning-by-using”. Technological innovation is the result of a cumulative learning process and is generated by the interactive process of various actors in multi-layer social networks (Gupta & Thomas, 2001). In a systemic approach, Parker (2002) stated that innovation is any change in the socio-technical systems of design, manufacture, distribution and/or product or of service to users and/or employees.

United Nations (2002) in the definition of innovation pointed out the importance of social and economic innovation as the accelerators of technological innovation and referred to incremental nature of innovation often through adaptation, always by diffusion of a better product, process or service. Rothwell (1992) introduced the innovation process at the firm level as a logically sequential, though not necessarily a continuous process, that can be subdivided into a series of functionally separate but interacting and interdependent stages. The overall pattern of innovation can be thought of as a complex network of communication paths, both intra-organizational and extra-organizational, linking together the various in-house functions and connecting the firm to the broader scientific and technological community and to the marketplace. In other words, the process of innovation represents the confluence of technological capabilities and market needs within the framework of the innovating firm. There are clearly a number of well-developed ideas concerning these reviewed pictures of innovation. Their concepts overlap to some extent with each other, yet each of them provides some unique insights to understand the nature of organizations.

To summarize, generally the above arguments highlighted the similarities in concepts and definitions of technological innovation. In this study technological innovation is considered as a multi-dimensional process which is science, technology and system based, and people related in nature. This process includes several factors affecting and affected by the firm’s internal capabilities, its networking and its technological learning ability, and influenced by its environmental factors. It would mobilize all existing potential resources to augment the firm’s innovation capacities, ending with the introduction of a new or better product, material and/or production process.

The core concentration in this study, however, is not necessarily upon everything that is new in the world or time and place. Rather, the emphasis is placed on those changes that involve human activities and artifacts which would be new for the innovation process in innovator or its economy, whether produced before elsewhere or not.

**Research Frame framework**

In order to answer the research questions, the researcher reviewed the literature, searching for potential determinants or firm competencies (independent variables) associated with technological innovation. The firm’s competencies were classified into sixteen variables as presented in the following Table 1 and covered the following: intensity of R&D, technical competencies, intensity of marketing.

The researcher adapted the framework of strategic influences and firm-specific competencies determining innovation of Souitaris (2001,2002) and made the necessary adjustment to fulfill the requirements of this study. Both empirical studies were carried out in
Greece. However, Greece and Malaysia were categorized as the newly industrialized country (NIC). The researcher positioned the technological trajectories as moderators of firm-level determinants of innovation. The decision to position the technological trajectories as the moderators was influenced by the empirical confirmation by Souitaris (2003) that firms in different trajectories of Pavitt’s taxonomy had differences in the technological innovation.

Figure 1. The Study’s Framework.

a. Intensity of R&D

Not surprisingly, industrial R&D was one of the first business practices positively associated with innovation (Souitaris, 2002). Duchesneau et al., (1979); Ettlie et al., (1984); Globerman (1975), Kim, Kwangsun and Jinjoo (1993) and Romeo (1975) provided strong statistical evidence of the positive relationship between number of employees and financial resources allocated for R&D activities and adoption of innovations. Therefore the following hypothesis was formulated:

\[ H1: \text{The extent of technological innovation of Malaysian firms is positively correlated with the intensity of R&D.} \]

b. Technical Competencies

Quality management was a major issue in the business literature in the 1990s and 2000s. Rothwell (1992) and Zairi (1996) associated positively the implementation of quality control procedures which included human resources with innovation. Chiesa et al. (1996), suggested and positively proved that the innovative firms integrate better process improvement with effective quality and human resource management system.

Research had proved the importance of skill and experience of human resources in adopting technological change (Kim et al., 1993). Li (1999) empirically established that the decision of innovation adoption very much and positively influenced by human resource competencies, organizational factors, environmental factors and tendency for technological improvement. Hence, the following hypothesis was proposed:

\[ H2: \text{The extent of technological innovation of Malaysian firms is positively correlated with the extent of technical competencies of human resources.} \]

Intensity of Marketing

Cooper (1984), Maidique and Zinger (1984) and Vazquez (2001) positively associated innovation with an effective marketing programme and a broad distribution system, which can access distant markets. Rothwell (1992) and Vazquez (2001) suggested that a strong market orientation is directly and significantly related to innovation. Hence, the researcher hypothesized that:

\[ H3: \text{The extent of technological innovation of Malaysian firms is positively correlated with the intensity of marketing.} \]
Technological Trajectories Moderating Firm-Level Determinants of Innovation

Pavitt (1984) identified different patterns of technological change (technological trajectories) in four sectoral classes of industrial firms. An empirical test in a sample of Greek manufacturing companies showed that firms in different trajectories of Pavitt’s taxonomy (1984) had differences in the rate of technological innovation. Specialized suppliers and science based firms were found to have higher rates of innovation than supplier dominated and scale intensive one. Most importantly different variables proved to be significantly associated with innovation for each category of firms (Souitaris, 2002).

The process of classifying the sample of Malaysian companies into technological trajectories was related to the study’s which involved the following:

a) to test whether technological innovation differs for the different trajectories
b) to test whether the determining factors of technological innovation differs for each trajectory.

Hence, the following research hypotheses were developed:

\[ H_4 : \text{Firm’s technological innovation differs for the different technological trajectories.} \]

\[ H_5 : \text{Determining factors of innovation differ for firms in different technological trajectories.} \]

Methodology

To carry out this study 204 Malaysian manufacturing firms of this study were categorized according to these four technological trajectories. Obviously, the classification is somewhat subjective and arbitrary, as the criteria are qualitative in nature.

Profile of Respondent Firms

It is obvious from the table, that the percentage of very small and small firms is considerably lower in the sample compared with those in the total population. Consequently, the percentages of medium and large firms are higher in the sample. In other words, larger firms are over represented in the sample, a fact that was expected from the way it was designed.
Table 1. Technological trajectories of the respondent firms

<table>
<thead>
<tr>
<th>Trajectory</th>
<th>Frequency in the sample</th>
<th>Percentage of the sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier dominated</td>
<td>74</td>
<td>36.3</td>
</tr>
<tr>
<td>Scale intensive</td>
<td>20</td>
<td>9.8</td>
</tr>
<tr>
<td>Specialized supplier</td>
<td>39</td>
<td>19.1</td>
</tr>
<tr>
<td>Science based</td>
<td>71</td>
<td>34.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>204</td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

Table 2. Size comparison of respondent firms and the total population

<table>
<thead>
<tr>
<th>Size</th>
<th>Frequency in the sample</th>
<th>Percentage of the sample</th>
<th>Frequency in the population</th>
<th>Percentage of the population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very small</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Small</td>
<td>53</td>
<td>26.0</td>
<td>850</td>
<td>28.3</td>
</tr>
<tr>
<td>Medium</td>
<td>119</td>
<td>58.3</td>
<td>1700</td>
<td>56.7</td>
</tr>
<tr>
<td>Large</td>
<td>32</td>
<td>15.7</td>
<td>450</td>
<td>15.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>204</td>
<td>100</td>
<td>3000</td>
<td>100</td>
</tr>
</tbody>
</table>
Table 3. Sectoral comparison of respondent firms

<table>
<thead>
<tr>
<th>Industry</th>
<th>Frequency in the sample</th>
<th>Percentage of the sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automotive assembly</td>
<td>7</td>
<td>3.4</td>
</tr>
<tr>
<td>Automotive parts and components</td>
<td>7</td>
<td>1.5</td>
</tr>
<tr>
<td>Food and beverages</td>
<td>20</td>
<td>.5</td>
</tr>
<tr>
<td>Building materials</td>
<td>6</td>
<td>2.9</td>
</tr>
<tr>
<td>Chemical and fertilizer</td>
<td>16</td>
<td>5.9</td>
</tr>
<tr>
<td>Concrete and structure</td>
<td>1</td>
<td>.5</td>
</tr>
<tr>
<td>Electrical and electronic</td>
<td>35</td>
<td>5.4</td>
</tr>
<tr>
<td>Telecommunication</td>
<td>3</td>
<td>1.5</td>
</tr>
<tr>
<td>Food packaging</td>
<td>6</td>
<td>1.0</td>
</tr>
<tr>
<td>Furniture</td>
<td>2</td>
<td>1.0</td>
</tr>
<tr>
<td>Gas (LPG)</td>
<td>3</td>
<td>1.5</td>
</tr>
<tr>
<td>Hospital products</td>
<td>1</td>
<td>.5</td>
</tr>
<tr>
<td>Leather and leather products</td>
<td>3</td>
<td>.5</td>
</tr>
<tr>
<td>Machine tools and assembly</td>
<td>2</td>
<td>.5</td>
</tr>
<tr>
<td>Marine products and food processing</td>
<td>3</td>
<td>.5</td>
</tr>
<tr>
<td>Medical products</td>
<td>3</td>
<td>1.5</td>
</tr>
<tr>
<td>Cosmetics</td>
<td>1</td>
<td>.5</td>
</tr>
<tr>
<td>Metal based furniture</td>
<td>1</td>
<td>.5</td>
</tr>
<tr>
<td>Metal stamping and fabrication</td>
<td>12</td>
<td>2.5</td>
</tr>
<tr>
<td>Palm Oil</td>
<td>10</td>
<td>4.9</td>
</tr>
<tr>
<td>Paper</td>
<td>5</td>
<td>1.5</td>
</tr>
<tr>
<td>Plastic and petrochemicals</td>
<td>15</td>
<td>3.4</td>
</tr>
<tr>
<td>Power generation</td>
<td>5</td>
<td>2.5</td>
</tr>
<tr>
<td>Precision engineering</td>
<td>3</td>
<td>.5</td>
</tr>
<tr>
<td>Rubber and rubber products</td>
<td>11</td>
<td>1.0</td>
</tr>
<tr>
<td>Semiconductor</td>
<td>4</td>
<td>2.0</td>
</tr>
<tr>
<td>Steel</td>
<td>6</td>
<td>2.9</td>
</tr>
<tr>
<td>Textile and garment</td>
<td>6</td>
<td>.5</td>
</tr>
<tr>
<td>Tobacco</td>
<td>1</td>
<td>.5</td>
</tr>
<tr>
<td>Wood product and furniture</td>
<td>4</td>
<td>.5</td>
</tr>
<tr>
<td>Total</td>
<td>204</td>
<td>100.0</td>
</tr>
</tbody>
</table>
Conclusions

A generalization of the findings of the Malaysian case leads to the hypothesis that the most important determinants of innovation in newly-industrialized countries are those that are generally missing in the country-specific institutional context. In other words, the most innovative companies are the ones that manage to overcome the traditional rigidities of the institutional context and incorporate uncommon attitudes and practices for the local business environment (Souitaris, 2001). This hypothesis has to be tested by future innovation research. In general, the researcher supports the call for more empirical research on the international differences in innovation management (see for example Patel & Pavitt, 1994; Moenaert et al., 1994). We need more robust evidence to understand and support theoretical claims about the influence of the complex, multi-dimensional and difficult to define national ‘institutional context’ on the factors and best practice that lead to innovation. This study was an initial step towards this direction.

The study’s compact set of important strategic determining factors can have immediate practical application in Malaysia and other newly industrialized countries with similar environments. Several types of users could benefit from the results, including industrial managers in search of innovation and growth and venture capitalists trying to identify potential innovative companies and also the national technology policy maker. The findings demonstrated to the practicing managers the importance incorporating R&D, marketing activities, strategic business planning, favorable organization structure, education and training, interdisciplinary teamwork, internal communication, and utilization of professional staff and shop floor employees as sources of innovative ideas.

Also, the finding that innovation is driven by owner-managers with a perception of intense competition and changing customer needs could be a hint for policy-makers to support entrepreneurship, deregulate the economy and encourage competition.

Policy makers too have something to learn from the study. For them there is a message to encourage and possibly increase the funding for industrial research and help small firms with training. Also, the public education system has to be assessed and modernized in order to help the industry to recruit key personnel with relevant qualifications. Moreover, the importance of previous work experience in other companies and countries calls for the encouragement of knowledge transfer through human-resource mobility and the provision of incentives towards a more open labor market.

In relation to the technological trajectories in moderating firm-level determinants of innovation, this study indicated that firms in different trajectories of Pavitt’s taxonomy had differences in performance and determinants of innovation. Hence, the main theoretical contribution of this study is the positioning of Pavitt’s taxonomy as an integrative tool, bridging two distinct literature streams—the economic and management studies on technological innovation.

The empirical results in the Malaysian context supported that the important determinants of innovation differ in the four classes of Pavitt’s taxonomy. Therefore, the study contributed to the economic and management perspective as well as methodology in identifying the distinguishing characteristics of innovative firms in the future.
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