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Role of Science Parks in the Development of Technology-Based Small and Medium-Sized Enterprises (SMEs) in Malaysia

by

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A thesis presented in fulfilment of the requirements for the degree of
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In memory of my parents

Malairaja and Thanikodi

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ABSTRACT

This thesis tests the widespread assumption that science park firms are more innovative and R&D-intensive resulting in greater innovation output, growth and profitability than off-park firms. Science parks are supposed to provide a value added environment to enhance innovation and competitiveness of small and medium-sized enterprises (SMEs) and facilitate commercialisation of technologies. Based on an extensive literature review of firm-level innovation and role of science parks, the study investigates a set of fifteen hypotheses based on R&D and non-R&D variables.

The hypotheses were tested against data from two independent but comparable sample groups of firms obtained from a longitudinal survey of technology-based SMEs from Malaysian science parks and off-park locations in 2002. The science park sample contained 22 firms drawn entirely from Technology Park Malaysia. The off-park sample comprised of 30 firms. Data obtained from these sampled firms were analysed using statistical techniques such as t tests and chi-square to determine whether there are significant statistical differences between the two groups of firms with regard to the fifteen variables.

The findings confirmed only four hypotheses, although overall science park firms appeared to perform better than off-park firms in all the variables, except in international research collaboration. There were no statistically significant differences between science park and off-park firms with regard to ten variables: R&D expenditure, R&D thrust, collaboration with universities, exports, access to venture capital, access to government grants, patents, copyrights, sales growth and profit ratio growth. Science park firms perform significantly higher only in employment of qualified scientists and engineers, inter-firm collaboration, launch of new products and processes, and employment growth. These findings question the rationale for making massive financial investments to build science parks. The study concludes that the science park strategy could be effective if the park management plays a more focused role in stimulating SME innovation.

INTRODUCTION

There is growing policy interest in science parks and their usefulness as a strategy for promoting innovation especially among small and medium-sized enterprises (SMEs). Property-based science park initiatives have already become an important instrument of technology policy in many countries, aiming to promote high-technology clusters (Metcalf 1994). Co-location of firms in a science park, it is argued, encourages networking and collaboration, which can foster innovation. Science parks thus provide an environment that assist firms to develop their technological and innovative capabilities. This study will put the case made for science parks to the test with reference to the experience of Malaysia.

1.1 BACKGROUND TO STUDY

It is apparent from experience that although incremental improvements to existing products and processes have been the dominant form of technological innovation, radical innovations are crucial for sustained economic growth (Branscomb and Auerswald 2002a). Developing countries are now aware of the need to increase investment in innovation activities in order to catch-up with advanced countries. Learning about research and development (R&D) and innovation is a critical type of learning for countries engaging in these activities for the first time (Teubal 1996). Tacit knowledge in particular is a crucial resource because it impacts an organisations's ability to gain sustainable competitive advantage (Nonaka and Takeuchi 1995). It is becoming increasingly clear that sustained technological progress is the primary engine of growth with emphasis on new and emerging technologies such as information and communication technologies and biotechnology. Social capital too has a role in explaining differences in economic growth between regions and countries (Putnam 1993).[1]

Schumpeter (1934) at first emphasised the role of the heroic entrepreneurs and small firms in fostering innovation but in later years (1942), he argued that large firms have the resources to innovate. Since then, numerous scholarly views have emerged on innovation and economic growth. Notable among them are learning by doing (Arrow 1962), learning by using (Rosenberg 1982), organisational routines in evolutionary economic change (Nelson and Winter 1982) and technological learning (Lundvall 1988). While Solow (1957) recognised exogenous role of technology in economic growth, Romer (1986) and Lucas (1988) attributed growth to endogenous role of technology driven by generation of knowledge and human capital. North (1990) emphasised the role of institutions in technology development. Recently, the role of social capital as an enabler of innovation is being highlighted (Putnam 1993, Fountain 1997).

In the last two decades, the concept of National Innovation System (NIS) has been advanced as a framework to analyse the role of innovation in economic development at national and regional levels (Freeman 1987; Lundvall 1992; Nelson 1993). In this scheme, the government plays a crucial role in identifying and overcoming systemic failures, which otherwise could hamper the smooth functioning of the NIS (OECD 1997a). It does this by linking up with academia and the industry, thus promoting the 'Triple Helix' system of generating and sustaining innovation (Etzokowitz and Leydesdorff 1997). Related to these new frameworks is the aspect of firm clustering and networking that could encourage innovation and enhance productivity. This has prompted, the emergence of concepts such as innovation cluster (Porter 1990), innovative milieu (Aydalot 1986) and regional network (Saxenian 1994).

The essence of all these theories, models and viewpoints is that innovation is crucial for technological change and economic growth. Innovation is increasingly viewed more as an interactive rather than a linear process (Kline and Rosenberg 1986), involving extensive networking (Rothwell 1992). It is a complex and risky activity (Dosi 1988) and is multi-dimensional (Pavitt 2003). Innovation is also increasingly

[1] According to Putnam (1995, p. 67) social capital 'refers to features of social organisation such as networks, norms and social trusts that facilitate coordination and cooperation for mutual benefit'. It enhances the benefits of investment in human and physical capital.

becoming a distributed process across several enterprises and other institutions (Coombs and Metcalfe 2000). Technological discontinuities (Tushman and Anderson 1986) and disruptive technologies (Christensen 1997) require firms to implement appropriate innovation strategies to stay ahead of market rivals.

Firms need to innovate to survive and to achieve competitiveness in order to perform better than non-innovative firms in terms of sales, output and employment. Successful innovation at the level of firm requires both internal and external resources (Bell 1984). Firms have to incur costs to exploit knowledge spillovers and invest in research and development (R&D), to develop their absorptive capacity (Cohen and Levinthal 1989). It is also necessary to utilise external knowledge as well as develop firms' dynamic capabilities to achieve competitive advantage (Teece and Pisano 1994). However, greater R&D input does not necessarily lead to greater innovation output. Besides technological determinants, other factors that matter in innovation include financial and education systems, co-operation between firms and research institutes as well as regulations. Location has a major influence on the innovative capacity of firms, especially SMEs (Saad and James 2001).

Large firms have more resources to innovate but small firms make substantial contribution to innovation (Audretsch 1995). In fact both biotechnology and the Internet were pioneered by small firms (Lerner 2000). Small and new innovative firms however suffer from shortfalls for R&D funding due to the high costs of capital that R&D activities involve. Consequently, demand for multiple technological competencies and global competition may worsen the disadvantages of size limitations faced by SMEs (Hall 2002; Narula 2004). There is a need for public policy to support the growth of SMEs, which may result in policymakers overlooking the vast majority of small high-tech firms. However, encouraging firms in certain sectors to operate in a cluster should not be construed as a strategy for picking winners insofar as it does not imply price distortion (Rodriguez-Clare 2004).

Low technological innovation in the world's poorest countries can be explained by the lack of public institutions. Technology capability is essential for growth of firms but developing countries face many hurdles to master the underlying learning process. Learning and mastering the tacit elements of domestic and imported technology require tangible and intangible investments (Archibugi and Pietrobelli 2003). The existence of market failures justifies government support for firm level innovation. Accordingly, technology policies and public institutions are instituted to support and sustain the innovative performance of firms. These policies complemented by industrial and competition policies facilitate funding of R&D, provision of infrastructure, tax credits and promote competition to create the environment necessary to stimulate innovation. Various initiatives have been undertaken by governments in partnership with academia and industry to stimulate innovation amongst firms. These include strategic research partnerships, science parks and technology incubators. Science parks in particular have emerged as a popular strategy in both developing and developed countries to assist SME innovation.

1.2 THE SCIENCE PARK STRATEGY

The rationale for building a science park is that it helps create a resource network for firms located in them (Westhead and Storey 1994). Science park is a type of technological infrastructure, set up to facilitate commercialisation of technologies, stimulate development of technology-based SMEs and promote regional development.[2] Firms located in an innovation cluster benefit from knowledge spillover from nearby universities, and research institutes (Jaffe 1989). This is apparent from the fact that all the science parks in the United Kingdom are located in or near universities (Siegel et al 2003). These parks also help create spin-offs, stimulate higher research productivity and promote entrepreneurship. Science parks in developing countries are "essential elements for a structured indigenous capacity in support of national technology diffusion approach" (UNIDO 2004, p.6). Science parks can also help reverse 'brain drain' by attracting migrant scientists and

[2] See definition of a science park provided by the International Associations of Science Parks (IASP) at URL: http://www.iasp.ws/. (accessed on 15 November 2004).

researchers to return to their country of origin as in the case of Hsinchu Science-based Industrial Park in Taiwan.

The world's first science park is the Stanford University Research Park in Palo Alto, California, which played a major role in the evolution of Silicon Valley as the most successful high-technology cluster.[3] This prompted policy makers elsewhere to emulate the Silicon Valley model leading to the establishment of science parks ranging from a size of less than sixty acres to parks covering thousands of acres[4] supporting firms including SMEs, involved in a variety of technology sectors. Currently, there are about seven hundred science parks in the world, also known as research parks (in the US), technopoles (in France), innovation centres (in Germany) and technology parks in many developing countries (Sanz 2002).

Science parks cannot be expected to play the role of an innovation cluster model, where the focus of business is on the real estate aspect (Felsenstein and Ergas 2002). Most state-led science and technology parks in Europe have remained as islands of technological excellence without any synergy and exchange of expertise between business and researchers (Igel 2002). Science cities or technopoles require huge financial investments but fail to produce the desired output in terms of entrepreneurial culture, wealth and jobs (Gibson et al 1999). Alternatives to science parks are other technology transfer institutions, technology networks and information technology infrastructure. Internet and advances in ICT will gradually reduce the role of distance in business activities. This may result in the emergence of virtual technopoles and virtual science parks[5] eliminating the need for spatial proximity in the location of innovation and R&D activities. This view is, however rejected by Lundvall (2002), who argues that personal contacts cannot be replaced by ICT networks, and interaction with remote partners involves risk and cost. Therefore,

[3] While many have acknowledged the role played by the park in the early growth of Silicon Valley. there are some who argue that proximity to university is not a sufficient condition for a successful cluster. See Dosi et al (2005) for elaboration.

[4] The largest science park in the United States is the Research Triangle Park covering more than 7,000 acres. The Aberdeen Science and Technology Park in Scotland is less than sixty acres.

spatial proximity will continue to play important role in location of R&D and innovation activities. This explains the popularity of science parks as a strategy for fostering interaction and innovation amongst firms. Most of the science parks around the world were built in the last twenty years.

Earlier studies[6] focused on the role of science parks as a tool in regional economic development; as an interface between university and industry; and as catalyst for the development and management of high technology firms. These aspects still continue to attract the attention of researchers but emphasis has shifted of late to the role of science parks in the development and growth of new technology-based firms (NTBF) and other activities associated with new and emerging technologies. Most of these studies focus on science parks in industrialised countries, particularly those in the United Kingdom (Westhead and Storey 1994), Sweden (Ferguson 1995) and the United States (Link and Scott 2003). However, empirical evidence so far shows mixed results regarding the performance and character of science parks in developed countries. On the other hand, with the exception of Singapore (Phillips and Yeung 2003), no such studies have been undertaken in Southeast Asia including Malaysia. This study aims to fill the gap by focusing on the role of science parks in Malaysia.

1.3 THE ISSUE

Malaysia has emerged as a major global producer and exporter of technologically sophisticated high value-added products. Although this achievement is normally associated with a mature industrial economy (UNCTAD 2003), the fact is that Malaysia did not achieve the level of technological competence to reflect such

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[5] Galbraith (2002) describes the Centuria Science and Technology Park near Bologna, Italy as a virtual park, specialising in food and agriculture. It functions more as a networking unit.

[6] A good account of the economic and social impact of science parks and innovation centres prior to 1985 can be found in Gibb (1985), which documented the proceedings of a conference held in Berlin on 13-15 February 1985. The forty-two articles in this book cover a wide range of issues ranging from growth and management of science parks and their impact on regional development, contributions of universities to science parks as well as a fairly good number of selected case studies. All except one article focused on science park development in the US and Europe. The one exception is an overview of science parks in the Far East, perhaps indicating that the phenomena in Asia, is one of recent and therefore not much can be described about it at that time.

'maturity'.[7] Foreign direct investment (FDI) played a major role in the transformation of the Malaysian economy from agriculture-based to high technology manufacturing. However, technological spillover from FDI-driven growth has not been encouraging in Malaysia (Tidd and Brocklehurst 1995), as it has been in Taiwan, Korea and Singapore.

The emergence of China as a more favourable destination for FDI than Malaysia, has also posed further challenges to the Malaysian economy. Malaysia can no longer rely on low cost factor and incentive schemes to attract FDI. Further, the emphasis on knowledge-based economy and increasing complexity of technologies requires Malaysian firms to acquire new knowledge and competencies. For technological learning and innovation excellence, technology-based Malaysian SMEs would need to:

- employ staff with specialised knowledge in science and engineering
- internationalise to overcome size limitations of national market
- participate in clusters to benefit from networking and synergies
- ensure interaction between marketing and R&D capabilities
- develop entrepreneurship and training

Malaysia has adopted best practice networking strategies to assist firms meet the above needs and enhance their capabilities. These include high-tech cluster development based on the Silicon Valley model, technology incubators, science parks, venture capital funds and other instruments under technology policy within the context of the NIS framework. However, Malaysia is a latecomer to the science park phenomenon. Though the first science park was set up in 1988, it was not a science park in the true sense of the term because it was housed in a small building with hardly any science-based activities going on in it. The first proper science park was launched in 1996. Currently, there are five science parks in Malaysia that meet some

[7] Such maturity would entail possessing manufacturing capabilities, existence of large clusters of high-tech activities with well-developed local supplier and subcontracting system, technically trained workforce and high level of industrial R&D (UNCTAD 2003, p.52). See also Narayanan and Wah (2000) for an account of Malaysia's technological maturity without a strong research base.

of the criteria of a science park as defined by IASP or UKSPA.[8] Unlike science parks in the advanced countries, there is direct involvement of the federal and local government in the planning, building and the operation of these parks in Malaysia. This is perhaps due to the fact that the private sector in Malaysia is not ready to emulate the private sector owned science parks in the developed countries. The question this study aims to address is whether science parks represent an effective way for Malaysia to build innovative and technological capabilities of firms and enhance commercialisation of R&D, given the limitations of the science park model.

1.4 OBJECTIVES, SCOPE AND METHODOLOGY OF STUDY

The objective of the study is to examine the effectiveness of science parks as a strategy for commercialisation of research and development (R&D) and development of high technology small and medium enterprises (SMEs) in Malaysia. Specifically, this study investigates the following issues:

(i) The significance of transfer of technology to industrial development in Malaysia;

(ii) The effectiveness of science parks as mechanism for technology transfer from universities and research institutes to industry;

(iii) The receptiveness of SMEs to science park-based innovation and

(iv) The centrality of science parks as a node in the national innovation system.

In order to investigate the above issues, the study focuses on innovation and R&D activities of companies located in science parks and elsewhere in Malaysia. There are five science parks in Malaysia. Two of these, namely Technology Park Malaysia (TPM) and Kulim High-Tech Park (KHTP), have been in operation for more than five years. This study is, however, based on the investigations of firms located in

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[8] UKSPA refers to United Kingdom Science Park Association and IASP is the International Associations of Science Parks (IASP).

TPM. Firms located in KHTP are excluded on the grounds that the park mainly caters for the needs of multinational companies and large local firms.

This study is longitudinal in nature based on a medium-sized sample. The unit of analysis is technology-based SMEs in science parks and elsewhere in Malaysia. The main design of the study involves comparing the characteristics and performance of SMEs located in Technology Park Malaysia with a similar group of SMEs found outside the park (off-park firms). This form of research design, involving the use of matched samples, is similar to the one employed by Westhead and Storey (1994) and Ferguson and Olofsson (2004), albeit with some variations to suit the Malaysian context especially with regard to identification of technology-based companies. A total number of fifteen hypotheses are tested to find out whether, science park firms are more innovative and perform better in terms of profitability and growth, compared with off-park firms. These hypotheses are derived from an extensive review of literature on the theory and empirical evidence regarding firm-level innovation in general and the role of science parks in fostering SME innovation, in particular. The theoretical frame for the study is based on five major strands in innovation studies:

i. The role of technology and innovation in driving economic growth.
ii. The National Innovation System (NIS) framework emphasising the interacting role of organizations and institutions in the production, flow and utilisation of knowledge.
iii. The contribution of small firms and new technology-based firms to innovation.
iv. The role of geographical proximity in location of innovation activities.
v. Science park as a policy instrument to stimulate development of innovative and entrepreneurial capabilities of SMEs.

1.5 DEFINITIONS AND KEY TERMS

The main terms and concepts used in this study include innovation, science park, science park and off-park firms, high-tech SMEs and government. Although these concepts and terms will be discussed in the review of literature chapters, it is useful to define them from the onset.

1.5.1 Innovation

There are many definitions of innovation as listed in Appendix II. These definitions cover products and processes, and organisational improvement. In this study innovation refers to the successful introduction of new or improved products and processes into the market.

1.5.2 Science Park

There is no universal or transferable model for a science park. In the USA, it is known as a research park while it is called a technopole in France. In some countries, science parks are referred to as technology parks. Other names quite often used include innovation parks and innovation centres. Another associated facility is called an incubator, which provides a variety of business services to support start-up businesses. These parks[9] and facilities have one thing in common: they offer well-equipped physical spaces suitable for the setting up of various types of technology-based companies. Various definitions for science park models are provided in Appendix I.

The two most-often quoted definitions of a science park are those given by United Kingdom Science Parks Association (UKSPA) and the International Associations of Science Parks (IASP). Both these definitions (see Appendix I) share three mains elements in terms of (i) knowledge and technology transfer through interaction between universities, R&D institutions and enterprises; (ii) growth of knowledge-

[9] Additional information on the different meanings with regard to a science park, technology park, research park, innovation centre, and incubator can be found at the website of the United Kingdom Science Park Association (UKSPA) at http://www.ukspa.org.uk. The UKSPA is an umbrella organisation representing over 50 science parks mostly university owned in the UK.

based and innovative companies; and (iii) creation of supportive environment. However, compared to the definition by UKSP, the IASP definition explicitly incorporates other elements such as of markets, wealth creation for community, high value-added services and management of the park by specialised professionals. These additional elements make the IASP definition the preferred definition for use in this study.[10]

1.5.3 High-Tech SMEs

There is no broadly accepted definition of what is meant by a high-tech SME (the European Commission 2002). This is not surprising considering the number of weaknesses identified in the classification of industry into high, medium and low technology by the OECD.[11] For example, Baldwin and Gellatly (1998) point out that some firms in an industry may be high-tech although the entire industry may be classified as low-tech. Markusen et al's (1986, p.16) define high-tech industries as 'those in which the proportion of engineers, engineering technicians, computer scientists, life scientists and mathematicians exceed the manufacturing average'. However, this definition is not suitable for application at firm-level classification. The rapid emergence of technology-based enterprises in the last three decades and the characteristics of the new economy phenomenon have prompted the coming into being of terms such as new technology-based firms, small high-technology based firms and high-technology small firms (see Oakey 1994; Oakey et al 1999). As a result of this lack of clear definition, the term high-tech SMEs is used interchangeably, with the above nomenclatures.

In this study, the term technology-based SMEs is used and is referred to business entities in Malaysia having high R&D and technology content, business turnover of

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[10] Further Technology Park Malaysia is a member of IASP.

[11] The six weaknesses of high-tech classification are: (i) use of R&D input measures only which excludes many other inputs into the innovation process; (ii) it ignores the use of advanced technologies such as CAD/CAM; (iii) it ignores informal R&D; (iv) it focuses on manufacturing only and excludes services; (v) R&D intensity variable is not suitable as it has little variance and (vi) it does not reveal the significance of the difference between of process and product innovation, for e.g. small firms show higher process innovation (see Balkwin and Gellatly, 1998, p. 6-8).

less than RM 25 million[12] and employing less than 250 workers. Only Malaysian SMEs that meet the criteria of technology-intensive companies set by MESDAQ[13] are included in the study. Currently, there is no comprehensive national database of technology-based SMEs in Malaysia, but there are some organisations that maintain business address registers of the SMEs they support.[14]

1.5.4 Science Park and Off-Park Firms

Science park firms or tenant firms are those firms located inside science parks. "Off-park" firms refer to those located outside the jurisdiction of park management. Only firms conducting R&D and innovation activities are included in the sample. Thus firms involved in banking and catering services or just selling products including high tech products are not included in the study.

1.5.5 Government

The term government in this study refers to Federal, State and Local Government unless the level is clearly stated.

1.6 STRUCTURE OF STUDY

This study is organised in nine chapters. The next two chapters are devoted to the review of literature on innovation and science parks. Chapter two examines the importance of innovation and technology for economic growth with particular focus on innovation at the level of the firm. In chapter three, the origin and growth of science parks is discussed with particular emphasis on the role of science parks in the

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[12] RM refers to Ringgit Malaysia, and denotes the currency of Malaysia. The exchange rate currently is US1$ =RM 3.77 and £1=RM 6.7.

[13] MESDAQ refers to Malaysian Exchange of Securities Dealing and Automated Quotations and functions as the stock exchange for technology-based business and it is part of Bursa Malaysia (formerly Kuala Lumpur Stock Exchange).

[14] Among the organisations include Multimedia Super Corridor (Technopreneur Development portal), Federation of Malaysia Manufacturers (FMM), Malaysian Technology Development Corporation (MTDC) and the Ministry of Science, Technology and Innovation (MOSTI) as well as science and technology parks such Technology Park Malaysia and Kulim Hi Tech Park.

commercialisation of research, the development of high-tech SMEs and the promotion of technology-based regional development. The rationale for setting up science parks as well as the strengths and limitations of the science park model are examined. Chapter four sets the hypothesis in a theoretical context drawing on the literature on innovation and science parks. Chapter five discusses the growth and transformation of the Malaysia economy - in particular its transition to a knowledge-based economy. This is followed by a discussion on the country's national innovation system in chapter six.

The research design, data collection, and the method used for data analysis are discussed in chapter seven. Empirical results deriving from analysis of the survey data are interpreted and discussed in the chapter eight. Findings of an interview-based study of selected science park and off-park firms are also discussed in chapter eight. The final chapter (chapter nine) provides a summary of the findings of the study and implications for all stakeholders involved in science park development in Malaysia.

1.7 SIGNIFICANCE OF STUDY

The importance of this study is apparent in its aim to shed light on the effectiveness of the science park strategy as the way forward to promote high-tech development involving SMEs in an emerging country like Malaysia. This is the first study of its kind undertaken in Malaysia enhancing our understanding of the role of Malaysian government in stimulating innovation amongst SMEs. Findings of this study have also important implications for the other countries, especially developing countries, which already have science parks, or are planning to set up such parks. The recommendations arising from this study could be significant for policy considerations aimed at enhancing the role of current science parks and the future planning of such parks in Malaysia. They would also provide a point of reference for considering the relevance of science parks as a strategy for industrialisation in developing countries.

1.8 CONCLUSION

This introductory chapter has given the outline of the study covering background, objectives and methodology of the study. The chapter pointed out the importance of innovation for economic performance by making references to various models and theories that have emerged in the last five decades to explain the relationship between technological change and economic growth. In particular it emphasized the contribution made by small and medium-sized enterprise (SMEs) to innovation despite limitations of size and resources. In this respect the emerging importance of the Science Park strategy as a major policy instrument to nurture the growth and development of high-tech SMEs and enhance commercialisation of research results was also highlighted. The next chapter will discuss in detail the importance of innovation to economic growth with focus on its role at national and firm level.

INNOVATION AND ECONOMIC GROWTH

2.1 INTRODUCTION

Empirical findings show that fifty per cent of economic growth achieved by advanced industrialised countries is due to technological innovation (Grossman 1991). Branscomb and Auerswald (2002b) claim that economic growth of all industrial countries comes from incremental improvements in productivity, products and markets. The continuous success of United States as the world's leading developer and supplier of high technology products and services is attributed to its "long commitment to investments in S&T, the scale effects derived from serving a large, demanding domestic market, and the U.S. market's willingness to adopt new technologies" (National Science Board 2004, p.36). But the emergence of new centres of innovation across the world is gradually challenging the technological leadership of the US (Council on Competitiveness 2004). Indeed, Abramovitz (1986) suggests that, in the long run it is possible for poorer backward countries to catch-up with developed countries, if the former acquire social capability to be able to absorb technologies they obtain through transfer mechanisms.[15]

The focus of this chapter is on the importance of innovation and new technologies for economic growth, in particular innovation at the level of the firm. Section two examines the link between innovation and economic growth. Section three discusses what the process of innovation is all about. The National Innovation System framework explaining the interacting role of organisations and institutions in the generation, flow and use of knowledge is discussed in section four. Section five explains role of government in innovation. Section six discusses in detail the process of innovation at the level of the firm. Some concluding remarks highlighting the role of science parks in stimulating growth will be made as a prelude for detailed discussion in the next chapter.

[15] But 'many developing countries are at risk of irreparable marginalisation, trapped into increasingly technology divide and investment gap' (UNIDO, 2001, p.4).

2.2 INNOVATION AND ECONOMIC GROWTH

Although the importance of innovation in driving economic growth is widely acknowledged, approaches to measure the contribution of innovation to growth are still being debated. The debate began with the views of Schumpeter (1934, 1939, 1942) on the critical role played by innovation in the growth and dynamism of a capitalist economy. But Schumpeter's qualitative account of the importance of innovation did not go very far to explain the factors that drive economic growth. It was Fabricant (1954) and Abramovitz (1956) who argued that economic growth cannot be explained in terms of capital accumulation. Nevertheless it was Solow (1957) who introduced the aggregate production function of labour and capital. Solow's seminal work thus was recognised as the first quantitative attempt to measure the contribution of technological progress to economic growth. Denison (1962) improved the analysis of the residual explained by Solow as part of productivity growth explained by technological progress. This was followed by emergence of new growth theories (Romer 1986, Lucas 1988) in the 1980s that gave importance to R&D, knowledge spillover and human capital in driving growth. Aghion and Howitt (1998) extended the NGTs to include the role of policies and institutions in stimulating growth, although it was North (1990), who articulated the importance of institutions.

The limitations in conventional microeconomic analysis led to the evolutionary theory of economic change (Nelson and Winter 1982), which focused on the behaviour of firms to succeed through the process of selection, adaptation and variation. Also in the 1980s, the systems approach to innovation emphasising the interacting role of institutions and organisations gave birth to the National Innovation System (NIS) framework. The NIS originated by Lundvall (1985) and further developed by others (Freeman 1987; Nelson 1993; Edquist 1997) became an important tool in OECD countries and recently in developing countries to study the impact of innovation at national and regional levels. Following this, Furman et al (2002) came up with the National Innovative Capacity (NIC) to explain why the rate of innovation growth varies across countries. These theories and frameworks on innovation and economic growth need further elaboration. It is appropriate to begin with viewpoints of Schumpeter since they formed the basis for subsequent debate on the role of innovation in economic growth.

2.2.1 Schumpeterian Hypotheses

It was Schumpeter (1912) who eloquently articulated the dynamic role of innovation in the economic development of a capitalist society. First, Schumpeter (1934) attributed technical change to the role of individuals as heroic entrepreneurs, who seek to introduce new products and processes through the process of invention, innovation and diffusion. This technological development may result in *gales of creative destruction*, which replace existing firms with new and innovative firms. Later Schumpeter (1942) argued large firms to be the principal agents of technological change on the grounds that the economies of scale factor favour them. Moreover these firms are endowed with the resources to set up their own facilities to conduct research and development. This view is supported by Galbraith (1952) who argued that R&D is so costly, that only large firms have the resources to be able to conduct it. These views of Schumpeter, which have come to be known as 'Schumpeterian Hypothesis', paved the way for further research into the role played by innovation in increasing productivity and generating wealth in a capitalist economy.

Schumpeter's viewpoints are not however without criticisms. Clark and Juma (1988) disagreed with Schumpeter's thinking because they considered it to be 'mechanistic', not engaging systematically with technological change as a dynamic process. Freeman (1988), while giving credit to Schumpeter for his contribution to innovation theory, also pointed out that Schumpeter did not incorporate issues such as international trade and international diffusion of technology in his analysis. Ruttan (2001) goes far to argue that it was Usher who originated the theory of innovation and not Schumpeter.[16] Despite these drawbacks, the Schumpeterian hypothesis

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[16] See Ruttan (2001) for Usher's explanation about novelty (inventions) that can be produced from cumulative synthesis of many items. Ruttan thus credits Usher as the originator of the theory of innovation.

continues to attract the attention of scholars analysing the process of technological change and its link to economic growth. One outcome of this is the emergence of two opposing views, with respect to the relationship between firm size and innovation. One view is that large firms produce more innovations while the second view claims that small firms are better innovators. This aspect of the link between size of firm and innovation will be discussed in a later section in this chapter dealing with innovation at the level of firm.

2.2.2 Solow's Residual and New Growth Theories

Prior to the 1980s, factor input accumulation was believed to be the driver of productivity and economic growth. The studies by Solow (1957) and Denison (1962) measuring productivity growth based on labour and capital as inputs into the production function, dominated much of the literature explaining the sources of economic growth. A major critical assumption underlying the neoclassical model is that the production function has constant returns to scale to its two inputs, capital and labour. Other assumptions include perfect market, production function exhibiting diminishing returns to labour and capital and absence of government involvement. In these two studies, technology was an important source of economic growth but was considered exogenous to the economic system. This is why Solow's model is also called the exogenous model of growth. Denison (1962) refined Solow's model by incorporating two more factors, namely improved allocation of resources and economies of scale.[17]

However, Solow's model suffered from a number of drawbacks. Firstly, it did not explain improvements to technology and attributed growth to capital accumulation and labour force improvements, both of which are subject to diminishing returns (Cortright 2004). Secondly, the model implies that there is no incentive to invest because all available income is used for capital and labour with nothing left for

[17] In a study of growth of output per worker between 1909 and 1949 in the United States, Solow (1957) found that 20% of the growth is attributed to labour and capital and the balance 80% could not be explained and therefore remains a residual (the famous Solow's residual). Denison 's study covering the period between 1929 and 1949 found the residual to be 69% (see Denison 1962).

innovation. Thirdly, the model predicted that countries with low population and higher savings rate will converge. With the exception of developed countries and East Asian countries experiencing convergence, the rest of the world experienced divergence.

These drawbacks prompted the search for alternative models to explain the significance of technological progress in driving growth. Thus from the mid-1980s onwards, attention shifted to the endogenous role of technology as a driver of economic growth. In this respect, the contribution of Romer (1986, 1990) and Lucas (1988) immensely influenced the economic thinking about the sources of growth. In Romer's view, technological innovation can become the source of long-term productivity and economic growth if the focus is on the promotion of innovation and R&D to create new knowledge. Romer notes that sustained economic growth is driven by 'countless large and small discoveries that are required to create more value from a fixed set of natural resources' (Romer 1986, p.343). Lucas (1988) emphasised the role of human capital in driving growth. Human capital refers to the accumulation of skills by the country's workforce over time. Both these views have come to be known as new growth theories (NGTs)[18] or endogenous growth models. Central to the NGT is the concept of increasing returns generated by new knowledge and technology. NGTs are thus explained in terms of factors such as profit motive driving R&D, firms enjoying temporary monopoly via patent system, first mover advantage through their R&D effort, and innovation diffusion from one firm to others creating a chain of subsequent innovations (Mankiw 2002). They have important implications for policy insofar as they explore the concept of path development and the role of institutions and geographical proximity in technological development and growth (Cortright 2001). This aspect will be examined later, when dealing with innovation at national and firm-level. However critics have dismissed these new growth theories as nothing new by arguing that similar explanations have been expressed before.[19]

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[18] See Cortright (2001) for a practitioner's guide to new growth theory.

[19] See Ross (1997) for a comprehensive account of viewpoints disagreeing with the newness of the new growth theories. Ross cites learning by doing by Arrow (1962), by Young (1928) and Abromovitz (1956) as earlier examples of viewpoints similar to NGTs.

2.2.3 Evolutionary Theory

Neoclassical theories failed to account for the heterogeneity of firms and behaviour of entrepreneurs to start businesses despite the disadvantages of size limitations. This drawback led to the search for more realistic framework for understanding how firm behaviour impacts technical change. Nelson and Winter (1982) came up with the so-called 'evolutionary theory', which focuses on firms search for more efficient techniques and the market's ability to select among innovations successfully produced by these firms. According to Metcalf (2001), the focus of the theory is on how firms manage their cognitive and imaginative processes and innovate and accumulate knowledge. Metcalf uses this concept of technological change to explain the success of South Korea and Taiwan in the global competitive market. Metcalf contends that these two countries were able to master relevant technologies in a short space of time "through processes of variation, selection and generation of technological capabilities, albeit with important differences in approach between them" (p.31). In this approach knowledge becomes central to the development of the firm because it determines the firm's capability and competence (Malecki 1999). As pointed out by Lundvall (1988) and Rosenberg (1982), an important aspect of the neo-Schumpeterian concern about the development of technological capability is 'technological learning'.[20] Ruttan (1997) pointed out that the evolutionary model did not emerge as a productive source of empirical research due to the simulation methodology used in the model, which led to easy plausible results. Thus it is considered to be more of a 'point of view' rather than a theory (Arrow 1995 quoted in Ruttan 1997).

2.2.4 Systems Approach to Innovation

Parallel to the emergence of EGT, another major new development took place in the field of innovation studies in the mid-1980s. This refers to the emergence of the National Innovation System (NIS) – a systems approach to innovation, which

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[20] According to Bell and Pavitt (1993, p.163-164), "technological capabilities consist of the resources needed to generate and manage technical change, including skills, knowledge and experience, and institutional structures and linkage'. Technological learning (or technological accumulation) 'refers to any process by which the resources for generating and managing technical change (technological capabilities) are increased or strengthened'.

focuses on the role of organisations and institutions in the production, flow, and utilisation of knowledge. The NIS provides an overarching framework for analysing the role of innovation in economic development at national and regional levels (Freeman 1987; Lundvall 1992; Nelson1993, Edquist 1997). The contribution of North (1990) to the understanding of institutional change and economic growth fuelled further debate on the sources of growth. According to Ross (1997), North's contribution constitutes a rival to the new growth theories. The NIS framework will be discussed in detail later in this chapter.

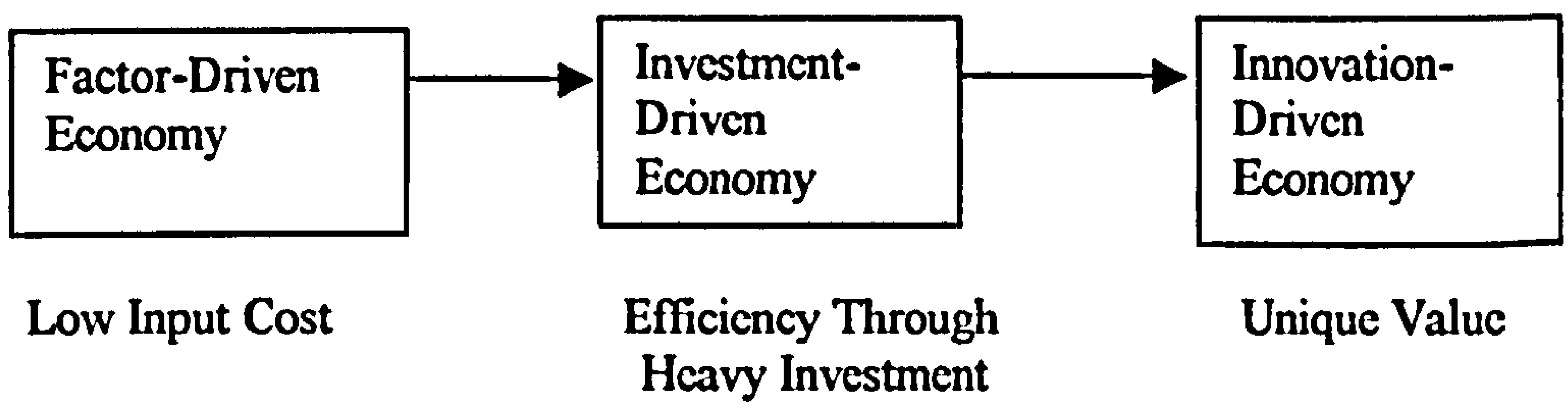
In recent years, Furman et al (2002) have formulated the National Innovation Capacity (NIC) framework. This new approach draws on three distinct areas on prior research namely the endogenous growth theory and national innovation system (NIS) discussed above, and the cluster-based theory of national industrial competitiveness popularised by Porter (1990). NIC refers to the ability of a country - as both a political and economic entity - to produce and commercialise technologies. According to Furman et al (2002), NIC depends on the level of technological sophistication and the labour force of a country as well as on the investments policies of both the government and private sector. As in NIS, public policy plays an important role in the development of NIC.

Thus the Solow model, NGTs, the evolutionary theory of economic change, NIS and the NIC are all attempts to understand the contribution of innovation and technology to economic growth, albeit with different focus and approach. But all these models seek to abstract from the growth and technological trajectories experienced by developed countries. The question is: can the above models adequately explain economic growth of developing countries? Consider for example, the debate on the sources of growth in East Asia. One argument has it that growth of the East Asian countries (Korea, Taiwan, Hong Kong and Singapore) derives largely from factor accumulation rather than improvements in total factor productivity (TPF) (Krugman 1994). This view is rejected by Nelson and Pack (1998) who claimed that technological progress, supported and promoted by the State through appropriate policy provisions, is responsible for the success of the East Asian countries. What about lack of technological progress in Africa and in many other poor countries in the Asia-Pacific region? Can it be attributed simply to lack of institutions? If so, can technological development in these poor countries be enhanced by putting in place appropriate institutional frameworks? How long will it take for these poor countries to catch-up with the newly industrialised countries, let alone the developed countries? Some explanation can be found in the models explained above but these models do not adequately account for the prevalence and persistence of underdevelopment in the poor countries. Nor do they offer practical solutions to solve the related problems.

Another dimension to the above debate on technological change and growth emerged when the United States experienced a surge in productivity growth in the second half of the 1990s with the focus on the role of information and communication technologies (ICT). Based on empirical studies in the United States and elsewhere three broad views emerged from the debate. At one extreme is the view that productivity growth is ICT-driven (Stiroh 2001). At the other extreme, it is argued that the surge in productivity growth is not due to ICT, but rather to cyclical factors (Gordon 2000). In between these positions, some maintain the view that productivity growth only took place within the ICT industry and not outside it (IMF 2000).

Despite the on-going debate as to the efficacy of on the above models and theories, technology and innovation is increasingly becoming crucial for productivity and competitiveness of firms, industries and nations. Boskin and Lau (1990) concluded that technical progress is the most important source of growth in the Group-of-Five countries in the post-war period.[21] Boskin and Lau explain that countries, which invest heavily in capital in the post-war period benefited from technical progress because the new technology produced augmented the value of capital, not of labour. Their argument is that there is no point in producing new technology if this technology is not put into effective use and this requires investments in capital, which in turn can have amplified effects on growth. In recent years there is much more greater awareness about the increasing importance of knowledge as a critical resource in the production process. Many countries have embarked on ambitious programmes to become knowledge-based economies. Governments in both developed and developing countries are paying greater attention to improving the innovative performance of their economies in order to reach the stage where innovation drives the economy (Porter 1990). See Figure 1.1 below, which shows Porter's Stages of Competitive Development.

Figure 1.1
Stages of Competitive Development



Source: Porter, M. E. (1990)

In recent years, the NIS framework has been increasingly used to formulate science and technology policies aimed at enhancing technological and innovative capability of firms. Before discussing this framework, it is important to understand what the process of innovation is all about. This will be examined in the next section.

2.3 WHAT IS INNOVATION?

The Industrial Revolution (IR), which began in England in 1760, is a major watershed in the history of innovations. The IR had a profound impact on the social and economic livelihood of people, and on the growth and development of the global economy. Central to the emergence of the IR is the introduction of innovations[22] such as steam engine, the factory system in the cotton textile industry and other

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[21] Group-of-Five countries refer to France, former West Germany (now Germany), Japan, United Kingdom and the United States.

[22] Dudley (2003, p.13) explains successful innovations of that era can be explained in terms of the role of two capable individuals, one who had the "capacity to understand and apply technical knowledge" and the other had the "ability to organise production and marketing".

remarkable inventions such as the electricity, telegraph and railroad, which transformed the economic landscape not only of Britain but also of Europe, the United States and other parts of the world. Questions have arisen, however, as to what facilitated these inventions and innovations - that is, whether they emerged as a result of individual efforts and capabilities or as a result of events in a systemised historical context.

2.3.1 Definitions, Models, Types and Sources

According to Dosi (1988), the innovation process involves various steps from the search for ideas to development and adoption of new products, processes and organisational set-ups. For OECD (1999) 'innovation at its core is the ability to manage knowledge creatively in responding to market-articulated demands and other social needs'. Based on these views, innovation can be appropriately defined as a complex, heterogeneous, uncertain, unpredictable, risky, multi-dimensional, multi-functional, integrated and ubiquitous process aimed at creating new or improved products, processes or services for commercial use. See Appendix II for various definitions of innovation.

Many models have been developed to explain the innovation process. One of these is the simple linear model in which basic research inputs at one end, results in outputs in the form of products and processes at the other end. There are two ways of depicting the model (see Figure 2.2). The origin of this model can be traced to post-war science and technology development in the United States. Vannevar Bush used the linear model to explain and justify an expanded role for U.S. Federal government support for scientific research (National Science Foundation 1995).[23]

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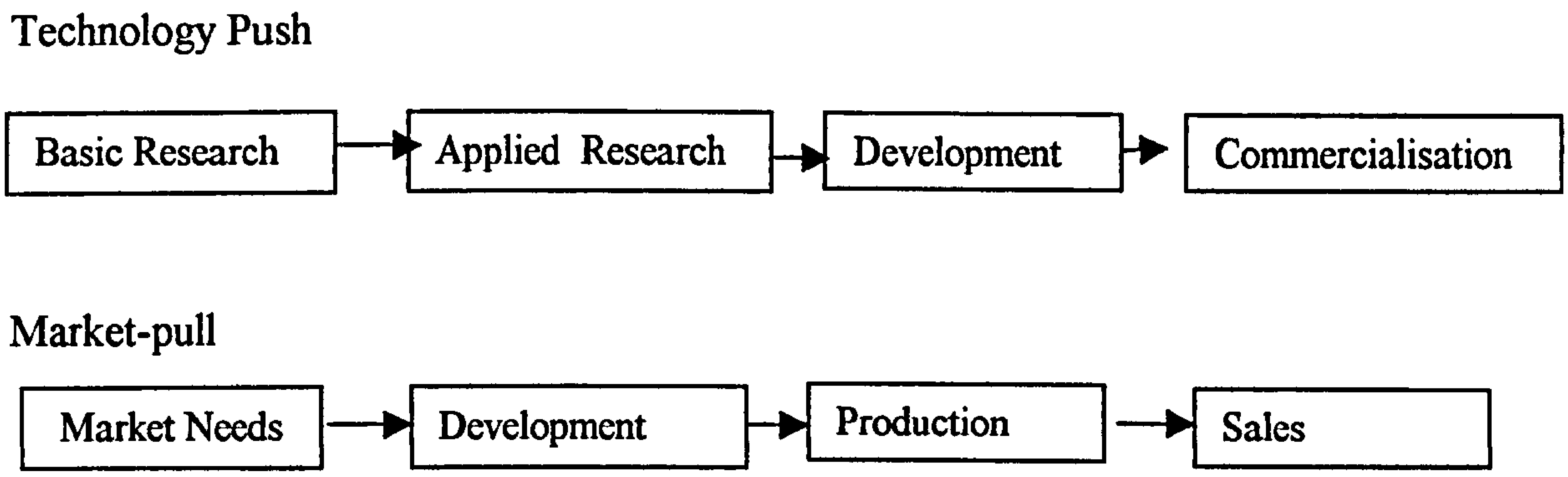
[23] See Bush (1945) for elaboration. Vannevar Bush at that time was the Director of the Office of Scientific Research and Development, US.

Figure 2.2: Linear Models of Innovation



The main criticism against the linear model is that it fails to take into account the importance of multiple knowledge sources and feedback loops. For example, innovation can emanate from any part of the innovation process and may even originate before basic research begins.[24] The linear model fails to recognise that users are important sources of innovation (von Hippel 1988; Dosi 1988). This shortfall makes the linear model involving corporate R&D and subsequent commercialisation increasingly inadequate as a characterisation of the innovation process. Rather, corporate R&D initiatives are likely to give rise to the emergence of networks, alliances and other co-operative arrangements (McFetridge 1995).

The above limitation of the linear model led to alternative explanations of the innovation process resulting in the emergence of non-linear, integrative models of innovation. The chain-linked model developed by Kline and Rosenberg (1986) is one such model, which shows possibilities for many pathways to innovation, with R&D interwoven along the central chain of innovation with feedback links from the production and marketing units. The latest model is Rothwell's Fifth Generation Model (Rothwell 1992), which is based on extensive networking and integration (see Table 2.1). This model, called the Systems Integration and Networking (SIN) model, involves collaboration between various actors in the innovation process, in particular

[24] There are cases where science was not the source of innovation.These include the development of the first airplane by the Wright brothers who did not know aerodynamic theory and the first xerographic cover developed by Chester Carlson who lacked thorough understanding of photoconductive materials. For details see U.S. Congress, Office of Technology Assessment (1995).

the suppliers, competitors and the customers to expedite the process as well as improve the quality of the innovation output. Thus the emphasis of the model is on the timely delivery of high quality new products and processes.[25]

Table 2.1: Five Generations of the Innovation Process

Type of Model/Period	Nature of the Process	Emphasis on	Links to Market/supply chain
First Generation 1G *Technology Push model* (1950s to mid 1960s)	Simple linear sequential process	R&D	Market receptacle to fruits of R&D
Second Generation 2G *Need-pull model* (mid 1960s to early 1960s)	Simple linear sequential process	Marketing	Market is source of idea for directing R&D
Third Generation 3G *Coupling model* (mid 1970s to mid-1980s)	Sequential, but with feedback loops. Push or pull or push/pull combinations	Integration at the R&D/marketing interface	R&D and marketing more in balance
Fourth Generation 4G *Integrated model* (Mid-1980s to early 1990s)	Parallel development with integrated teams.	Integration between R&D and manufacturing (design for makeability)	Strong upstream supplier linkages. Close coupling with leading edge customers Horizontal collaboration (joint ventures etc)
Fifth Generation *Systems Integration andnetworking model* (SIN) (Early 1990s to date)	Fully integrated parallel development. Use of expert systems and simulation modelling in R&D	Corporate flexibility and speed of development/ Increased focus on quality and other non-price factors	Horizontal linkages as in 4G model Customer focus at the forefront of strategy Links to CAD systems

Source: Derived from Rothwell, R. (1991), 'Successful industrial innovation: critical factors for the 1990s', *R&D Management*, 22 (3), pp. 221-239.

There are two broad categories of innovation - product and process innovation - each of which can be characterised as being of radical and incremental type. Product innovation is associated with a particular new product being developed whereas process innovation is the new process associated with the production of that particular product or any other product. The distinction between radical and incremental innovation is based on the level of uncertainty, the nature of products, processes or services involved and the duration of the innovation process involved.

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[25] Niininen and Saarinen (2000) used the SIN model to examine factors influencing the innovation process and found customers followed by subcontractors to be the most important factors in innovation processes involving vertical linkages and foreign competitors in those involving horizontal linkages.

Incremental innovation refers to step-by-step continuous improvements to products, processes or services and involves a low degree of risk and uncertainty. Radical innovation refers to totally new product or process as well as new markets and production systems. It is discontinuous and involves long gestation periods and high risk and uncertainty. A radical innovation can also be induced by incremental innovation taking place around it, although as Leifer (2001)[26] explains, such innovations occur as "breakthrough technology" rather than "breaking out of projects that begin as minor improvements".

Innovation changes not only products and processes but also ways of organising production and distribution (Fagerberg 2003). This is referred to as organisational innovation, and extends beyond what goes on within a firm to cover reorganisation of entire industries. In this respect, the term presentational innovation is also being used to refer to innovation in areas such as design and marketing (CORDIS 2003).

It is apparent from the above categorisations and models of innovation that there are many sources of innovation. Innovation can take place under different conditions in different places in different industrial sectors. Von Hippel's study (1988) shows that users are the most important source of innovation in sectors like scientific instruments, semiconductors and printed circuit boards, whereas manufacturers produce the most innovation in tractor shovel-related and engineering plastics. Suppliers produce most of the innovation in wire termination equipment. This pattern obviously varies across regions and countries according to variations in empirical conditions.

[26] Richard Leifer's gave these views on radical innovation during an interview with Ubiquity, which is a web-based publication of the Association for Computing Machinery based in New York. The interview is entitled *Richard Leifer on Radical Innovation*, and can be accessed at URL: http//www.org/ubiquity/interviews/r_leifer.1.html (Viewed on 25 August 2003).

2.3.2 Role of Learning and Knowledge

The evolutionary theory points out the central role played by knowledge in innovation and production (Malerba 2002). Knowledge embodied in the technologies may be codified or tacit (Dosi 1988; Kogut and Zander 1992). Codified (or formal) knowledge refers to knowledge that can be produced in a written form and therefore can be transferred easily in various forms - for example, in research papers and manuals. On the other hand, tacit or informal knowledge acquired through 'learning by doing' (Arrow 1962) and 'learning by using' (Rosenberg 1982) is not that easily transferable. Useful productive knowledge involves tacit elements (technological and organisational) that can only be learned through emulation and practice (Pavitt 2001). Tacit knowledge is an important resource because it impacts an organisation's ability to gain sustainable competitive advantage (Nonaka and Takeuchi 1995). At the level of firm, there is a need to incorporate learning as an important element of their innovation strategies. This aspect will be discussed later.

Technology development does not take place in a vacuum. It is influenced by the socio-cultural and economic environment, in which it is taking place. This environment is in turn is impacted by the technological progress occurring within it. The resulting learning experience and knowledge accumulation may lead to a successful and sustained innovation process, which can be appropriately described as "path dependent" in nature (David 1985). This "path dependent" nature of technological development is reinforced by other factors such as market conditions, and institutional and regulatory policy. One outcome of this "path dependency" is a situation of "technological lock-in" (Arthur 1989), which occurs when the technology produced even when inferior will be continuously developed for commercial use despite availability of other more competitive alternatives (David 1985; Arthur 1989). Two notable examples of such inferior technologies are the QWERTY keyboard (David 1985) and the internal combustion engine.[27]

[27] According to David (2001 cited Ruttan 2001), four factors that contribute to technological lock-in are increasing returns to scale, adjustment costs, switching costs and costs of maintaining parallel technologies

The phenomenon of "technological lock-ins" exhibited in the form of inferior and inefficient technologies like QWERTY did not, however, prevent the creation of other superior breakthrough and radical innovations. In fact, some technological breakthroughs have the effect of displacing existing technologies causing massive disruptions to existing product markets and heavy financial losses to the owners of the existing established technologies. The established technologies could possibly be forced to the margin due to substantial loss of their market share to the new disruptive technologies (Christensen 1997). Examples of disruptive technologies include the personal computer, which displaced the minicomputer and digital cameras replacing the photographic film.

2.3.3 Innovation in Developing Countries

Most studies on innovation are based on firms and industries in developed countries so that the suitability of the models arising from such studies for analysing innovation in developing countries has yet to be put to the test. The complexity and multi-dimensional nature of innovation makes the task of understanding and assessing the level of innovation in developing countries rather difficult. The experience of most developing countries with respect to socio-economic growth and technological development does not conform to the trajectory of industrialised countries, so that the lessons to be learned from the evolution of R&D is limited (Annerstedt 1994).

In an attempt to facilitate the understanding of innovation process in developing countries, Saad (2003, p. 24) portrays the process in five stages: identification of need to innovate, knowledge awareness, choice, planning, and implementation. This approach should be viewed with respect to getting an enhanced understanding of the mechanisms involved in the process of technology transfer to developing countries. Developing countries still rely heavily on foreign technology to drive their manufacturing and other production sectors. Learning and knowledge are essential components in the technology transfer process and requires tangible and intangible investments (Archibugi and Pietrobelli 2002). These investments at macro and micro level are critical to enhance innovation in developing countries. Heavy investments in research and development (R&D) and provision of science, engineering and technology education are essential for creating a workforce that is capable of adapting, adopting and utilising the imported technology.

Production, diffusion and utilisation of knowledge are important for technology development and economic growth. Equally important is the nature of institutional and organisational frameworks within which knowledge is produced and diffused. In this respect, the National Innovation System (NIS), which refers to the collective role played by various actors in facilitating the flow and utilisation of knowledge for technological development, is becoming an important objective of science and technology policy in many countries including developing countries. In developing countries, this constitutes a major aspect of the capacity building initiative for sustainability development.

2.4 NATIONAL INNOVATION SYSTEM

There is an increasing trend in the use of the national innovation system (NIS) to analyse and comment on the different development trajectories of both developed and developing countries. Lundvall (1985) was the first to phrase the concept of an innovation system but Freeman (1987) incorporated the term national to the concept, resulting in the national innovation system framework. The most notable document to date is the one prepared by OECD (1997), which provides clear definitions of concepts and elements of the NIS and relates them to the emerging economic development patterns of its member states. In recent years NIS has been extended to the study of innovation and economic development in transition countries and developing countries.

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2.4.1 Definitions and Use

Metcalfe (1995) defines NIS in terms of the creation of new technologies resulting from interactions between various individual institutions (e.g. firms, research institutes, universities) as well as with social institutions (such as values, norms, and legal frame works). Various definitions of NIS are listed in Appendix II. Figure 2.3 shows the interaction between these organisations and institutions in the production, flow and use of knowledge. Lundvall (2003) defines an innovation system in terms of elements (focus on firms), relationships (focus on interorganisational networks) and processes (focus on innovation process). Lundvall further explains that the innovation system differs in terms of specialisation (what they do), institutions and routines (how they operate) and mode of innovation (how they innovate). Edquist (1997) compares the systems approach to innovation (SI Approach) to the New Growth Theory (NGT) and explains that the SI approach is about the determinants of innovation whereas the NGT deals with the effects of innovation and knowledge.

However the NIS approach is not free from criticisms. For example, Edquist (1997, 1999) argues that the systems of innovation approach is more of a conceptual framework and therefore does not deserve the status of a 'theory' of innovation. Edquist also highlighted many weaknesses in the systems of innovation (SI) approach such as inconsistency in the use of concepts such as institutions and organisations by the 'founding fathers'.[29] Ernst (2000) points out that the NIS approach neglected the international dimension especially in the context of developing countries. However, Juma and Clark (2002, p.17) point out that "a more detailed assessment of national innovation systems may give us an idea of why some countries learn faster than others". The NIS provides a framework to governments to form and implement policies to influence the innovation process (Metcalf 1995).

Policy makers in emerging and developing countries are also turning to NIS. The technological catching-up process and the development experience of late industrialising countries such as Korea, Taiwan and Singapore can be understood in terms of the different national innovation systems prevailing in these countries (Kam

1999).[30] These different NIS models involve a different mix of firm strategies, innovative network structure and state intervention roles. Although the NIS has become a tool in developing countries to analyse endogenous capability for industrial development, the focus should be on micro-level events, which exhibit more delicate interactions between technology, institution and policy learning (Gu 1996).[31] Governments in Thailand and Malaysia have also found the usefulness of the NIS to review their existing science and technology policies.[32] The NIS approach is used in the formulation of the Science and Technology Policy II by the Malaysian government (MOSTE 2002). The Malaysian NIS will be discussed in detail in Chapter Six.

From the above definitions it is clear that the NIS is made up of two major components - organisations and institutions. The effectiveness of the NIS will depend on the quality of interaction between these components in technological development. Let us examine these institutions and organisations.

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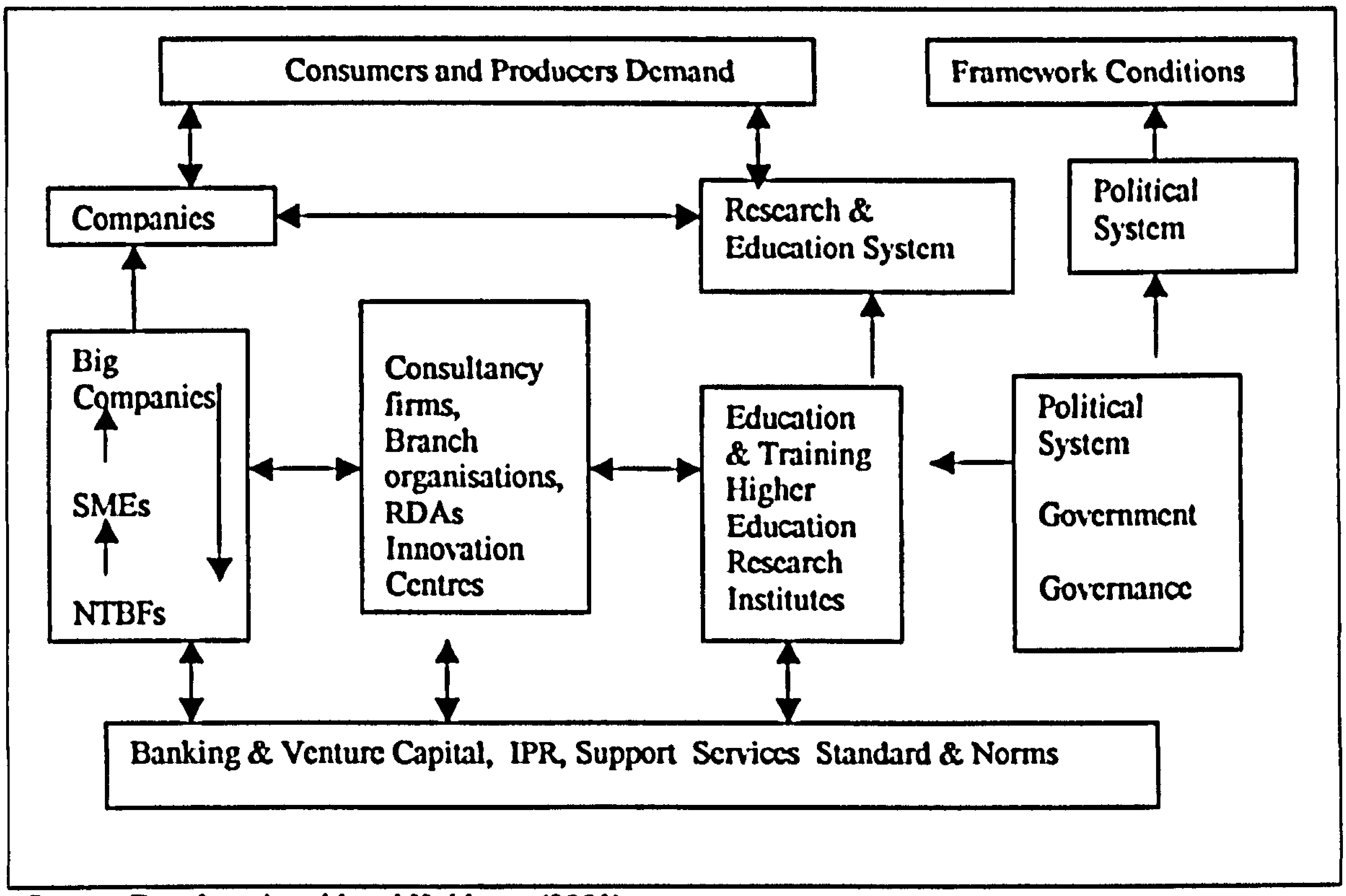
[29] For example, a patent office is an organisation whereas a patent law is an institution (Edquist 1999. p.5).

[30] Kim (1997) identifies two distinct phases in the evolution of the NIS in Korea. Prior to 1980s, imported technology rather than indigenous R&D, was the preferred mechanism to build local technological capabilities in Korea. But the scenario changed in the 1980s with greater private sector involvement in R& D in the form of in-house R&D centres and more allocation to conduct R&D.

[31] Chudnovsky (2000) explains how the development of a strong NIS in Argentina is hampered by lack of private sector R&D and lack of inter-organisational linkages between the private sector and public S&T institutions, suppliers, users and clients.

[32] For example, Chairatna and Intarakamnerd (2002) trace the evolution of Thailand's NIS and focus on the system's characteristics, besides analysing the S&T development strategy, role of government and the effects of globalisation.

Figure 2.2 Major Components of National Innovation System



Source: Based on Arnold and Kuhlman (2001)

2.4.2. Public Policies and Institutions

Neo-classical models of economic growth have focused too much on the proximate sources of growth, and have neglected the role of institutions. It was North (1990) who articulated the role of institutions in technology development.[33] Porter and Stern (2001, p.102) pointed out the 'the innovative activities of firms within a country are strongly influenced by national policy and the presence and vitality of public institutions'. These institutions are crucial to protect property rights, resolve contract and other legal disputes, to ensure efficiency of government spending and transparency in all levels of Government (Mcarthur and Sach 2001). According to the Asian Development Bank (2003), the competitiveness of a country depends on the quality of institutions, which help lower transaction costs, provide incentives and create a conducive environment for firms to operate. Another related issue is the link

[33] According to North (1994), "institutions are humanly devised constraints that structure human interactions. They are made up of formal constraints (e.g. rules, laws, constitutions), informal constraints (e.g. norms of behaviour, conventions, self-imposed codes of conduct) and their enforcement characteristics".

between corporate governance and innovation. According to O'Sullivan (2004), corporate governance[34] is necessary for firms to make strategic investments in collective learning process to produce innovations. However O'Sullivan points out that a corporate governance system that supports organisational control does not imply innovation will occur.

How relevant and important are the above institutions to developing countries? Chang (2002) argues that such institutions took decades and sometimes generations to develop even in the developed countries. Chang cautions the imposition of a time frame on developing countries to put in place policies and institutions to meet the demands of increasing globalisation and trade liberalisation.[35] In a similar vein, Amable and Petit (1999) point out the danger of copying and transferring of institutions from one country to another without taking into account the complementarities conditioning both the implementation and impact of institutions.[36]

2.4.3 Public and Private Sector R&D

Utilisation of science has brought about tremendous economic benefits, particularly to countries, which have devoted substantial amount of resources to academic research. For example, using 430,226 non-patent references, Narin et al (1997) have clearly demonstrated the contribution of public science to high technology in the U.S. According to Rosenberg and Nelson (1994, p.340), 'what the university research most often does today is to stimulate and enhance the power of R&D done in industry, as contrasted with providing a substitute for it'.

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[34] Based on O'Sullivan (2004, p.394), corporate governance is about institutions that influence how businesses allocate resources and returns.

[35] Chang suggests that developing countries should be allowed to adopt policies and institutions that are suitable to their conditions. This will help them to achieve faster growth in the long run which in turn will provide trade and investment opportunities, for the developed countries. He points out that it is tragedy of our time that the developed countries cannot see this reasoning.

[36] Amable and Petit (1999) distinguish two types of institutional complementarities. One, which is directly linked to the institutions' impact on economic issues, for example on innovation and growth, and the other which refers to the implementation level of rules corresponding to the institutions.

In the United States, public sector R&D has been instrumental in stimulating technological innovation; but in recent years the private sector has ben playing an increasingly important role. Similarly, governments in OECD countries have set R&D targets to stimulate both public and private investments in R&D (Sheehan and Wyckoff 2003). For example, under the science and innovation investment framework 2004-2014, R&D investment in the UK will be increased from the current level of 1.9 per cent to 2.5 percent of national income by the year 2014 (HM Treasury 2004). European countries also give priority to R&D as reflected in the higher GERD/GDP ratio but lack commercialisation efforts resulting in what is called the "European Paradox".[37]

R&D spending in low and middle-income countries is much lower than industrial countries. However, R&D comparisons between countries including developing countries is difficult due to problem of reliability rather than to intricacies of statistical methodology (Annerstedt 1994).[38] R&D funding for the defence sector also distorts comparison between countries (Klomp 2001). Although many developing countries have been increasing R&D expenditure, the output in the form of patents, and new products and processes has been dismally low. Lack of commercialisation is due to many hurdles such lack of absorptive capacity amongst firms and weak university-industry links. Science parks and incubators have been set up to enhance commercialisation but the results have been mixed. This aspect will be examined further in the next chapter.

2.4.4 University-Industry Links

University-industry link is a key component of the national innovation system.[39] This is because, universities are an important source of knowledge, and provide the

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[37] The European Paradox was first promulgated in the Green Paper on Innovation published by the European Commission in 1995. The European Paradox refers to a situation whereby European Union (EU) countries, despite being strong in academic research, are still unable to translate the research results into innovation and economic benefits.

[38] This is due to the fact that most developing countries do not follow the trajectory of industrialised countries in the evolution of R&D and innovation indicators (Annerstedt 1994).

[39] This link is a comparative strength of the Finnish national innovation system (Vestergaad 2003).

basis for innovation in emerging industries (Feldman and Kelly 2002). Besides, their role in teaching and research, universities are increasingly engaging in entrepreneurial and business activities, called as third stream activities. This phenomenon is attributed to the pressure exerted on the universities to commercialise their research findings to generate revenue to cover some of the operating costs including research costs. For example universities in the United Kingdom no longer can rely solely on the traditional sources of funding, namely government allocations for research and tuitions fees. The universities need to foster links with business enterprises to generate additional income. Another motivating factor is the success of academics as entrepreneurs in various technology fields (Owen 2001).[40] The role of government has been added as another dimension in this relationship resulting in the Triple Helix Model to help fill in the social capital and technological gaps in the development process (Etzokowitz and Leydesdorff 1998). The direct involvement of universities with industry can be seen in activities such as research funding, training partnerships and technical services contracts. Apart from these, industry also sponsors research centres and researchers and offers sponsorship or endowment of chairs (Laursen and Salter 2003; Siegel et al 2003).

Universities have set up Technology Transfer Offices to facilitate the transfer of technology from the university labs to markets and have also established mechanisms to create academic spin-offs. The emergence of this so-called entrepreneurial university is the driving force behind the triple helix university-industry-government interactions (Etzkowitz et al 2000).[41] A growing phenomena associated with this development is the setting up of science parks by universities to achieve the above objectives as is the case of the UK, where majority of science parks are owned by universities.

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[40] According to Owen (2001), some of the university-based star scientists who have succeeded in the biotechnology industry in the UK include David Lane of Cyclacel, Mark Ferguson at Renova and Greg Winter at Cambridge Antibody Technology and Diversys.

[41] See Etzkowitz (2000) for an account of the expanding role of universities from teaching and research to economic and social development. He explains how an university becomes an entrepreneur, by developing capabilities not only to assist the formation of new businesses but also to finance these firms as well as reap the rewards from undertaking such ventures by retaining part ownership of them. Hence, the meaning of entrepreneurial university.

However, too much emphasis on university research for industrial application may undermine the academic value of research in universities.[42] The role of universities, it is argued, is in the creation of knowledge and talent, which are crucial for the growth of a knowledge-based economy. But Howitt (2000) argues that attempts to weaken university-industry links would be counterproductive in view of the increasing mutual interdependence between universities and industry brought about by the biotechnology revolution.

Notwithstanding the above divergent views, there are many barriers and problems that affect university-industry collaboration. For example, problems exist between academics and industrialists in determining the type and suitability of research for industry needs. On one hand, academics cherish freedom in their research endeavour and do not want to be dictated by the whims of people from industry. On the other hand, industrialists complain that university research do not to a large extent meet the needs of industry. Johannessen and Rasmussen (2000) point out the existence of a mental and cultural gap between the universities and businesses, with the former preoccupied with 'idealistic search for the ultimate truth', while the latter's priority is to achieve success in the market place.

2.4.5 Educated Workforce and Human Capital

The endogenous growth models emphasise the role of R&D and human capital to drive innovation and economic growth. The availability of such manpower depends on the success of a country's educational system to produce a workforce capable of assimilating new technologies (Benhabib and Spiegel 1994). According to Florida (1999), 'smart people' are the critical resource for the success of a knowledge-based economy while Cervantes (2004) emphasise that scientists and researchers are the backbone of such economies. Highly skilled and educated professionals are viewed as the most important resource by high technology firms and thus human resource management becomes a critical issue (Cardy and Dobbins 1995). Brainpower is increasingly becoming more important than machinery and equipment in some

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[42] On the other hand, the introduction of measures such as the Bayh-Dole Act of 1980 might help in the commercialisation of university research (Florida 1999).

industries. This has led to increasing investment in training schemes at the level of the firm (Baldwin 1997).

Mani (2001) cites Singapore as an example, which has fiscal and non-fiscal components incorporated into its innovation policy. Malaysia, on the other hand, has introduced a number of funding schemes and tax incentives to support R&D activities, but suffers from serious lack of scientific manpower to undertake such activities in the private and public sector. Lack of human capital has constrained R&D activities and hence reduced innovative capacity in the two largest MNC-driven electronics clusters in Malaysia (Rasiah 2002). This aspect of lack of human capital in Malaysia will be expanded in the chapter on the Malaysian National Innovation System.

2.4.6 Financial Institutions

A well-regulated and developed financial market (made up of the money market and capital market) is crucial for the effective functioning of NIS. Imperfections in the financial market may result in systemic failures that could seriously affect the business behaviour and innovative performance of firms, especially small-and-medium enterprises. Many financial institutions perceive lending to SMEs as high risk and high cost initiative. However, Block (2002, p.2) points out that "no attempt is made to analyse how finance affects growth through its impact on innovation'. Block also notes that the NIS approach does not adequately explain the effects of a country's financial system on the speed and character of technical change. The importance of finance as determinant of innovation will be further examined later in this chapter when discussing firm-level innovation.

Venture capitalists function as intermediaries between capital providers (financial institutions) and firms, which uses the finance.[43] Venture capitalists are small relative to other financial markets but they play a significant economic role because they

[43] According to OECD (1996, p.5), "the role of the venture capitalist is to screen investment opportunities, structure the transaction, invest and ultimately achieve capital gain by the sale of the equity stake, either through stock market flotation, a trade sale or a buy-back arrangement with the company".

specialise in investing in high growth companies (OECD 1996). Venture capital is becoming another important source of capital for technology-based businesses in many Asian countries (Mani and Bartzokas 2002). Venture capital-backed firms have created technological revolutions resulting in transformation of industries especially computer technology-related such as personal computers and software (OECD 1996). But this does not mean that venture capital is a prerequisite to the growth of high-tech cluster; rather, it is considered to be a consequence of it (Dosi et al 2005; Saxenian 1996).

2.4.7 Regulatory and Legal Framework

Patents, copyrights, trademarks, geographical designs and brands are increasingly becoming important legal tools to protect IPRs. But most countries in the developing world do not have strong IPR regimes in place. A weak Intellectual Property Right (IPR) regime in a country might deter foreign investors from investing in that country. This increases the pressure on developing countries to institute laws to protect innovation through IPR.

However, the issue has become contentious with the developed countries insisting on the need for strong IPR regimes, and developing countries arguing that IPR will prevent them from exploiting the benefits of R&D spillovers. Based on a theoretical model, Yang and Markus (2003) found that global innovation and technology transfer could be expanded through international agreements to strengthen IPRs. However, Yang and Markus cautioned that the overall impact of IPR on the economic wellbeing of developing countries is unclear because of the high cost per license and the increase in prices in these countries in spite of the IPR regime. In support for a strong IPR regime, Branstetter et al (2004) confirm that technology transfer by MNCs increases with an increase in IPRs and that improvements to IPR enhance firm profitability.

On the other hand, developing countries consider patents as being harmful because patents not only limit transfer of technology but they also hinder possibilities of R&D activities (Boldrin and Levine 2002; Lee 1990). Merges and Nelson (1994) [cited in Nuvolari (2001)], argue that patents protecting "cumulative systems technologies"[44] could effectively constrain technical progress. Bessen and Makin (1999) further challenged the standard economic rationale that patents are needed to protect innovators from imitation. They argued that innovative industries, such as software, computers and semiconductors, which historically had weak patent protection, have experienced rapid imitation of their products. This is because imitation in these industries promotes innovation, whereas patents inhibit it. In a similar vein, Shapiro (2002) claims that competition can promote innovation, as there is no systematic evidence to suggest that competition impedes innovation.

Notwithstanding the arguments for and against patents, many companies from developed countries prefer to do business with countries, which enforce IPR laws. For example, India can emerge as a major hub for biotechnology outsourcing if it can put in place an effective IPR regime. The country has abundant supply of skilled and talented people. It is also strong in chemical technology and R&D, especially in clinical research, but it lacks legislation to protect the IPRs of biotechnology products and processes. As a result, American companies are unwilling to enter the India to market their products or to engage in biotechnology outsourcing business.[45] However, OECD (2004, p.3)) has pointed out that "it might not be in the interest of all developing countries to adopt patent systems".

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[44] According to Nuvolari (2001) "cumulative systems technologies" are 'technologies constituted by a number of components and where current improvements are tightly related to previous innovations' (p12). Nuvolari's study of the steam pumping engines in Cornish mining district of Cornwall in the UK showed how the dissatisfaction for the innovative performance under Watts patent monopoly created an open "collective invention setting" which accelerated the pace of technological change. He also acknowledged that the term "collective invention setting" was coined by Allen (1983) and refers to settings in which rival firms share technological knowledge.

[45] These comments about the IPR situation in India were made by Steve Lawton at the Biotech 2004, a biotech summit of Asian countries held in New Delhi from 26-28 February 2004and reported by the Indo-Asian News Agencies on 26 February 2004. Lawton is the vice president of the United States Biotechnology Industry Organisation (BIO), which is an umbrella organisation representing 1,000 of the 1,500 US biotech companies involved in R&D of healthcare, agriculture, industrial and environmental biotechnology products.

2.5 ROLE OF THE STATE IN INNOVATION

The State plays an important role in promoting technological innovation for economic growth (see Landau and Rosenberg 1986).[46] Reinert (1997) traces the role of the State in innovation since the beginning of the Renaissance period. In Reinert's (p.286) words, "a principal historical role of the State from the Renaissance onwards has been precisely one of promoting and protecting new knowledge and innovation".

The success of a country in S&T depends on investments in science and engineering education and R&D, political stability, access to capital and infrastructure that can support technological and economic advancement (National Science Board 2002). The US Federal government played a central role in the development of electronic computers, computer software, semiconductors and the Internet (Mowery 2002). Similarly, the Small Business Innovation Research Program (SBIR) is a central element in US policy on innovation support for small businesses as it addresses the key elements of the NIS (Wessner 2000). Amsden et al (2001) explain how government promotion and support in the form of government labs, intellectual property protection and financial incentives encouraged multinationals, such as Hewlett Packard, Texas Instruments, Canon, Sony, Phillips and Toshiba, to conduct research and development in Singapore. Foreign companies hardly conduct R&D in most developing countries and thus the presence of active foreign R&D in Singapore is indeed an anomaly.[47] It is widely believed that Korea, Taiwan and Singapore achieved the status of newly industrialising economies (NIEs) or the Asian Tigers because their governments promoted, supported and assisted local technological development. In India, the government promoted local R&D by creating research infrastructure not directly related to production system as well as encouraging R&D

[46] According to Knoll (1976), despite the pervasive impact of government's role in innovation, this aspect is one of the most neglected areas of social research. Knoll points out that most research focused on topics such as incidence of taxes, firm behaviour subjected to rate of return, regulation and impact of antitrust policies. Other aspects of regulation such as standard setting and licensing, and government production and procurement have not received much attention.

[47] Singapore is no longer a developing country. But before becoming one of the four Asian Tigers (the other three being Korea, Taiwan and Hong Kong), Singapore was a developing country. The government played a pivotal role in the transformation of Singapore into a vibrant and progressive country with a notable degree of innovation and technological development.

activities within firms (Lall 1982). According to Mani (2001), the increasing role of governments in developing countries in supporting the creation of new technologies is attributed to four trends in global technology development. These trends are: global slowdown in R&D investments, lack of R&D internationalisation, market imperfections with respect to new technologies and lack of spillover from foreign direct investment (FDI).

But intense debates have emerged as to why, when and how the government should get involved in economic development in general and in technological development in particular. The famous justification for government intervention derives from the existence of externalities and market failures. For example, because of market failure, social returns to private sector R&D exceeds private returns, thus causing the private sector to under-invest in R&D. In the circumstances, government has to intervene to correct market failure.

There is, however, a limit to what the government can do. Politicians are increasingly questioning government spending of public funds not only on basic research but also on applied research, the outcome of both being uncertain. The opportunity cost of investment in R&D is high particularly in developing countries, where many would argue that the priority should be to fund poverty alleviation and improve public services. But Lall and Teubal (1998, p.1382) point out that, "as long as there are market failures and strategic needs, well-designed interventions will always promote faster development than free markets".

Excessive direct government involvement in technological development might not be compatible with the Washington Consensus, which prefers such a role to be played by the private sector in a free market economy. Governments' role rather should be confined to providing macroeconomic stability and establishing adequate legal and regulatory framework to encourage and sustain innovation and technological activities. But policy makers in developing countries argue that direct government intervention is important and necessary to initiate and continue the journey of technology development for some years before expecting the private sector to play a greater role. Even in the United States, which is considered the 'last bastion of free-market capitalism', there is so much discussion and debate on the role of Federal, State and local governments in technology-based economic development.[48] One must not forget that the creation of the Advanced Technology Programme (ATP) is a good example of the US government's intervention to correct market failure[49] in the early-stage technological development (Branscomb et al 2000). Similarly, the European Framework Programmes, which began in 1984, was aimed at promoting collaboration in R&D amongst European firms, so that they can compete with Japanese and US firms (Dumont and Tsakanikas 2001). Government role in innovation can be examined in the area of science and technology policy formulation, R&D funding, legal and regulatory provisions and technological infrastructure.

2.5.1 Technology and Innovation Policies

According to Mowery (1992), technology policies are 'policies that are intended to influence the decisions of firms (and public agencies and enterprises) to develop, commercialise and adopt new technologies'. [50] In the United States, technology policy focuses on education, building infrastructure, and creating a business climate that encourages growth, technological innovation and risk taking (Mitchell 1999). Rosenberg (2002) goes further to construe that all economic policies are also technology policies regardless of whether they intended to be or not.[51]

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[48] See Report prepared for the Office of Technology Policy (OTP) of the United States Department of Commerce (USDOC), which summarises the roundtable discussion on the Federal role in technology-based economic development hosted at USDOC on 4 December 2000 by the OTP. The highlight of the report is the broad consensus reached on the fundamental role that the federal government working in partnership with the states and localities should play, in promoting technology-based economic development.

[49] Branscomb et al (2002) citing various sources, attributes market failure to lack of incentives faced by commercial firms to engage in radical innovation, the erosion of US leadership in the high technology market following the rise of low cost and high quality Asian production, and systematic under-investment by firms in leading edge technologies as well as their failure to effectively commercialise their research results.

[50] Many countries have national policies and strategies aimed at enhancing innovative capabilities of firms to achieve national and global competitiveness. While some countries have formal and clearly defined innovation strategies such as in Canada, Australia and the United Kingdom, others such as the United States and Sweden have various initiatives in place of a formal and well articulated innovation strategy.

Lack of co-ordination between technology policies and other policies such as macroeconomic policies, industrial policies and regional policies may affect the efficiency and effectiveness of the NIS. Metcalf (1994) cautions against implementing technology policy without taking into account policies for competitive business growth. Hart (1998) points out the fragmented nature of the S&T policy formulation as reflected by lack of integration with other policies such as antitrust law, tax policy, trade policy, and labour law and regulations.

There are many examples to show the importance of integration between science and technology policy and other policies. For example, successful cluster formation requires co-ordination between industrial policy, regional policy, and science and technology policy. According to UNCTAD (2003 p.21), 'technology policy in developing countries should be seen as an inherent part of industrial development policy'.[52] Export-oriented and higher value-added policies raised the demand for technological learning in South Korean and Taiwanese firms (Rosenberg 2002). In a similar vein, Roeland et al (1997) suggest that competition policy and technology policy should be implemented simultaneously because the former creates economic dynamism while the latter stimulates vertical co-operation among firms. Equally important is the timing of innovation policy introduced to bring about the desired technical change because in the words of Edquist (1999, p.2), "innovation policy should serve as midwife; not provide support to the end of life".

Rycroft and Kash (1999) suggest that innovation policy should incorporate self-conscious leaning component to overcome increasing complexities of technologies on learning network. Similarly, appropriate financial policies need to be in place to encourage the risk-averse financial institutions to support innovation and R&D in SMEs. Mani (2001) argues that both fiscal and non-fiscal incentives must be incorporated in a country's innovation policy fiscal to stimulate private sector

[51] Rosenberg's view was made in the context of his suggestions on how India could further benefit from the expansion of its pharmaceutical and software industry. This can be achieved if India continues its market-liberalisation policies of the 1990s as well as further integrate into the global economy.

investments. Gristock (2000) suggests that science communication should be made an essential part of innovation policy to facilitate exchange of knowledge between actors (scientists, industrialists and policy makers) involved in the innovation process.

The task of formulating, implementing and co-ordinating a range of different policies to stimulate innovation in firms poses a daunting challenge. Borrus and Stowsky (1997), attribute the difficulty to the fact that there are disagreements or contentions on:

- how much academia, industry and government, should each invest in technology development;
- whether to directly fund R&D activities or just offer incentives (such as R&D tax credits) to private R&D;
- whether to use public funds to correct private market failures or focus on fulfilling government missions (e.g. defence) and social needs (e.g. health);
- whether new technologies are creators or destroyers of jobs; and
- whether to produce cutting-edge technology and enjoy first-mover advantages or be a technology follower first to reap spillover from investment made initially by competitors and later use this technological learning curve to begin own production.

2.5.2 R&D Funding

Governments now play an increasing role in promoting R&D and innovation in firms and industries across regions. The US government support for R&D has been a critical element of federal policy for more than 200 years.[53] Government intervention in research and innovation activities is necessary due to the appropriability problem and the high risks associated with these activities. The issue of appropriability can be traced to Arrow (1962) and refers to the ability of investors to appropriate the returns from their R&D efforts. The issue arises when investors

[52] This policy includes elements of technology policy (stimulating R&D, supporting SMEs) as well as providing setting for firms to learn and master technologies.

may not be able to appropriate the returns from their R&D investments because the spillover from R&D are not just confined to those who invest in it but are also reaped by others (non-investors) and rivals as well as competitors due to the factor of non-excludability. Investment in such R&D activities becomes not profitable because the social rate of return to such activities exceeds the private rate of return. In fact, according to Nadiri (1993), the social rate of return to R&D is around 50 percent compared to the private rate of return of about 20 to 30 percent. This gap reflects the inability of firms to appropriate the benefits of their R&D efforts (Nelson and Romer 1996).

Besides, R&D and innovation activities are not only time-consuming and costly, but are also highly vulnerable to the problem of risk and uncertainty. Thus, to those faced with resource constraints, especially small firms, it is not profitable to engage in R&D activities without the support of the government, at least until successful commercialisation generates sufficient profits for funding activities in the future. This clearly explains why many governments have to directly support R&D of both public institutions and private enterprises. According to Guellec and van Pottelsberghe (1999), there are three main public policy instruments to stimulate R&D. These are public sector R&D performed by government laboratories and universities; government funding of R&D undertaken by business enterprises; and fiscal incentives.

2.5.3 Laws and Legislations

Apart from laws and regulations to protect intellectual property discussed earlier, many governments are attempting to emulate legislations enacted by the U. S. government to encourage commercialisation of technology. These legislations include the Stevenson-Wydler Technology Innovation Act of 1980 and the Bayh-Dole Act of 1980. The Stevenson-Wydler Act is aimed at facilitating the transfer of technology from national laboratories to state and local governments and to the private sector. The provisions of the Bayh-Dole Act were designed to foster interactions between university and industry by allowing researchers to retain the

[53] See The White House, Office of Science and Technology Policy (2000).

title to federally funded inventions and encouraging universities to license inventions to industry. The Bayh-Dole Act has resulted in the increase of: the number of institutions having technology transfer programmes, patents granted to universities, licensing activities royalty income from patenting and licensing activities reaching invention disclosures, and new start-ups especially in biotechnology (see Bremer 2001). Another example of targeted legislation is the European Union Framework Programmes to enhance university-industry research joint ventures amongst firms in OECD countries (Siegel et al 2003).

However, are the above legislations and policy initiatives suitable for other countries? How relevant is a legislation, like the Bayh-Dole Act, to developing countries? India is drafting new legislations modelled after the Bayh-Dole Act to enable state-run institutions and universities to commercialise their research findings and new technologies. Whether this will enhance the country's technological capabilities, only time will tell. Malaysia is also considering implementing such legislation.

2.5.4 Provision of Technological Infrastructure

Besides providing financial support for R&D, governments in many countries also establish technological infrastructure such as research institutes, laboratories, science parks, and incubators to strengthen their national innovations systems. This trend is expected to increase especially in the developing countries where the level of R&D and S&T is low and private sector is unwilling and unable to undertake these costly and risky activities. The impact of these policies and programmes will obviously be felt at the level of the firm. In the words of Knoll (1976), "all form of government interventions alter the incentives faced by firms, and hence the rate and pattern of innovations they produce" (p.176).[54] This brings us to the next section on innovation at the level of firm

[54] According to Knoll (1997), despite the pervasive impact of government role on innovation, this aspect is one of the most neglected areas of social research. Most research focused on topics such as incidence of taxes, firm behaviour subjected to rate of return regulation and impact of antitrust policies. Other aspects of regulation such as standard setting and licensing, and government production and procurement have not received much attention.

2.6 INNOVATION AT FIRM LEVEL

The National Innovation System framework has clearly shown that the firm is the most important element and focus of study. This is because it is the combined innovation output as well as productivity and performance of firms in an economy that ultimately influence the overall growth and direction of that economy. Why do firms innovate? In which technology sector is innovation predominant? Does size of firms and location matter in innovation? Is innovation higher among exporting firms? Do science park firms innovate more than non-science park firms? What kind and amount of resources need to be allocated to stimulate innovation? Do regulations hamper the innovation process?

Pavitt (2003) classifies firm-level innovation into three broad and over-lapping sub-processes as shown in Table 2.2. Pavitt further clarifies that the innovation process varies according, *inter alia*, to sector, field of knowledge, type of innovation, size of firm, corporate strategy, and experience. From this perspective, it is clear that there are so many determinants of innovation. Before discussing factors that determine innovation in firms, it is important to find out first why firms innovate.

Table 2.2: Sub-Processes at Firm-Level Innovation

Sub-Process	Description
Cognitive	How firms generate and maintain the know-how to conduct their tasks
Organisational	How firms 'do things' internally or together with other organisations
Economics	How firms establish internal incentives to ensure innovation responds quickly and in the right direction

Source: Based on Pavitt (2003, p.3)

2.6.1 Why Firms Innovate

There are many viewpoints on why firms innovate. Whether they are large firms or small ones, whether they are involved in product or process development, innovation is increasingly important in the business world today. Rapid changes in the global economy, which arise from such factors as increasing competition, globalisation, technological developments, a more diverse work force and transition to knowledge-based economy, are posing strategic challenges to firms. Innovation helps firms to gain competitive advantage and cope with these challenges (Higgins 1996). Innovation enables firms to "respond to more sophisticated consumer demand and stay ahead of their competitors, both domestically and internationally (OECD 2004, p.51). The survival of firms in a market economy depends on their acquisition of the requisite level of technological competence as well as on their ability to keep up with the relevance trajectories of technological improvements (Metcalfe 2003).

Broadly, firms engage in innovation to improve existing products and design new ones, which are influenced by the life cycle of the products. They may innovate to reduce uncertainties affecting the profitability of their businesses or they may want to expand their market locally and by going global. Another form of innovation is improving organisational structure and business processes. The expected result of all these innovation efforts is cost effectiveness, product or process improvement and delivery on time. This in turn is depends on a number of factors that include technological determinants, institutions (financial and education systems) and organisational variables (co-operation between firms and research institutes), which are important in innovation (Unger and Zagler 2000). Micro and macro factors are important in firm-level innovation (Saad and James 1997) and so are economic determinants (Morck and Yeung 2001).

2.6.2. Does Size of Firm Matter?

Schumpeter initially (Mark I) advocated the role of the entrepreneur and small innovating firms in fostering innovation (Schumpeter 1912; 1939). But later (Mark II), Schumpeter argued that large firms, in particular monopolies and oligopolies, are in advantageous position to engage in R&D activities (Schumpeter 1942). This is because large firms have the motivations and the resources in the form of skills, expertise and money to undertake such activities. Market structure also impacts innovation of small and large firms. Concentrated market favours innovation in large firms compared to small firms (Schumpeter 1942). On the other hand, Scherer (1965) argues that competitive markets are more effective in stimulating innovation amongst firms. Gottschalk and Janz (2001) support Scherer's view by pointing out that inertia will set in if market power exists without strong competitive pressures.

Empirical studies on firm size and innovation have yielded mixed results with most of these concluding that small firms innovate more than large firms. For example, Schrerer (1965); Rothwell and Zegveld (1982); Acs and Audretsch (1990) and Chakrabarti (1991) have demonstrated that small firms are better innovators.

We are therefore confronted with a paradoxical situation - how is it possible for small firms with limited resources to be better innovators? The answer lies with the ability of small firms to exploit knowledge spillovers generated by other firms and R&D institutions (Audretsch 2002; Kirchhoff 2001). It is this ability that explains why small firms pioneered the biotechnology and Internet innovation, considered as two potentially revolutionary areas of technological innovation (Lerner 2000). Small firms are also noted for their flexibility, faster response time and adaptability to changing market conditions. Cooper (1964), cited in Canback (2002), argues that small firms conduct R&D more efficiently than large firms resulting in three to ten times higher productivity in their development than large firms. This is attributed to the ability of the small firms to hire better people by offering tailored incentives, small firms' engineers being more cost-conscious as well as more effective in internal communication and co-ordination. Walsh et al (2001) claim that small firms are better in solving problems arising from the commercialisation of disruptive technology. Peeters and van Pottelsberghe (2003) argue that though large firms better manage innovation competencies, it is the small firms that allocate the largest share of profits to finance innovative projects. Peeters and van Pottelsberghe also found that large firms invest more on basic and applied research but small firms invest more in development activities. In a similar vein, Shefer and Frenkel (2005) found that there is no positive relationship between firm size and R&D investments.

According to Olofsson and Wahlbin (1993), cited in Ferguson (1998), NTBFs not only exploit university R&D to contribute to employment and economic renewal, but also facilitate the process of technology transfer between the academic/institutional researchers and the business community. Kazuyuki (2004) argued that SMEs, despite lacking in-house R&D resources, are actively involved in basic R&D through university-industry collaboration in Japan.[55]

Laranja (1994) observes the capability of Portugues NTBFs in acquiring, accumulating and diffusing technologies by serving as intermediaries between local and foreign sources of technology and their local end users. In a study of Spanish firms, Sanchez (1994) found the increasing share of small firms in business R&D as well as in the adoption of new technology, such as robot and flexible manufacturing systems (FMS).

On the other hand, there are many who still support the Schumpeterian hypothesis by arguing that large firms contribute more to innovation than small firms (Tether et al 1998; Baldwin 1997; Lee 2004)). This is because the value of the innovation produced by large firms is far greater that of small firms despite being numerically weaker than small firms. Another argument is that the contribution of small firms to innovation is over-represented by the number of innovations introduced by them. Based on an enquiry of the database of SME innovation maintained by SPRU in the United Kingdom, Tether et al (1998) found that twenty percent of small firms need to be reclassified as large enterprises. As a result, the database no longer shows SMEs as "a disproportionate source of innovation in the manufacturing in the last years of the database" (Tether et al 1998, p.31). Baldwin (1997) and Lee (2004) found that large firms are more likely to innovate than small firms in Canada and Malaysia respectively.

In the area of university-industry links, large firms seem to have the advantages, as universities generally prefer to work with them than with SMEs. Story and Tether (1998) offer three reasons for lack of links between SMEs and universities:

(a) SMEs do not get the attention of researchers in universities because SMEs do not conduct R&D themselves;

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[55] Kazuyuki (2004) pints out the declining importance of firm size as a determinant of university-industry collaboration in Japan. Large firms with substantial in-house R&D resources used to dominate university-industry collaboration in Japan but in recent years younger firms are becoming active in such collaborations.

(b) Universities think it is more prestigious to have research collaboration with world class MNCs than forging such links with SMEs; and

(c) Universities consider it is more cost-effective to work with large companies who offer bigger contracts than SMEs

The above observations on small firm and large firm innovation show that there is no clear pattern on firm size and level of innovation. As pointed out by Scherer and Ross (1990, p.634), "technical progress thrives best in an environment that nurtures a diversity of sizes, and perhaps especially, that keeps barriers to entry by technologically innovative newcomers low".

2.6.3 Importance of Location and Clustering

There is a growing body of knowledge in the spatial agglomeration of firms and its links to technological development. Krugman (1991) points out that this aspect of economic geography has been neglected and seems to have played only a marginal role in economic theory. However, it is now increasingly becoming important for measuring and understanding firm performance and location decisions (Cohen and Paul 2004). While it was Marshall (1920) who first introduced the concept of agglomeration effects arising from co-location of firms, it was Porter (1990) who popularised the concept of cluster in terms of its impact on competitiveness of firms, industries and regions.

Related to clustering is the concept of geographical proximity and its effects on innovation at the level of the firm. Physical distance can hinder exchange of tacit knowledge because it is associated with higher transfer and transaction cost (Porter 1998; Baldwin 1997; Dosi 1988). Perhaps this is why the level of innovation in high-tech firms located in metropolitan areas is significantly higher than firms located in peripheral areas (Shefer and Frenkel 2005). In Porter's (1998, p.90) words, "geographic, cultural and institutional proximity leads to special access, closer relationship, better information, powerful incentives and other advantages in productivity and innovation that are difficult to tap from a distance". In support of this view, Malmberg and Maskell (2002) claim that spatial proximity can:

- Intensify face-to-face interaction;
- Shorten cognitive distance;
- Enable use of common language;
- Foster trustful relations between actors; and
- Facilitate easy observation and immediate comparison.

Clusters affect competition by enhancing productivity and fostering innovation of firms in the cluster as well as stimulating formation of new businesses (Porter 1998; Swann 1998; OECD 1999). According to Porter (1998), firms in a cluster tend to have better knowledge of markets than isolated companies due to the co-existence of sophisticated buyers in a cluster. This is evident in Silicon Valley and Austin, Texas where computer firms are better positioned to respond to consumer needs and trends at a speed that cannot be matched by firms located elsewhere. Porter (p.84) further argues that inter-firm relationships amongst cluster firms enable them to "learn early about technology, components and machinery availability and marketing concepts", and that this kind of learning is "facilitated by the ease of making site visits and frequent face-to-face contact". Clusters enable high technology firms to develop alliances due to the competitive advantage they derive from proximity, socialisation, and globalisation effects (Bagchi-Sen 2001).

The benefits of clustering depend on many factors, such as current level of the firms' competencies and capabilities. Firms in a cluster that were strong in their own industry will be more innovative and experience faster growth rate than those operating in an isolated manner (Swann and Baptista 1998). However, Mytelka (2001) argues that the mere presence of a pool of trained scientists does not make a cluster more effective in stimulating innovation. It is the ability of participating firms to access a continuous flow of new knowledge that is more important. This new knowledge is gained by participating in seminars and employing graduates including, Ph.D. holders who are closer to the frontiers of knowledge.

Cantwell and Santangelo (2000) point out the importance of face-to-face interaction for the development of science-based technologies such as ICT, biotechnology and new materials as well as an industry's core technologies. If so, why do MNCs relocate some of their R&D operations to other parts of the world? The answer to this is that due to locally embedded specialisation, some technologies cannot be developed elsewhere However, certain types of technology are developed in other geographical locations due to the firm's global strategy to enhance technological learning through international networking (Cantwell and Santangelo 1999).

On the other hand, some believe that technological advancements in communications especially the Internet and ICT will gradually reduce the role of distance in determining location of business activities. This 'death of distance' argument popularised by Caincross (1997) seem to have found support in recent years. For example, technology transfer institutions, technology networks and information technology infrastructure (Komninos 1997) and virtual technopoles and virtual science parks (Giunta 1996) should be considered as alternatives to science parks insofar as such support structures eliminate the need for spatial proximity in the location of innovation and R&D activities

Lundvall (2002) and Olivier and Blakeborough (1998) disagree with the above 'death of distance' argument. Lundvall points out that ICT networks cannot replace personal contacts, because interaction with remote partners involves risk and cost. The study by Olivier and Blakeborough on UK technology firms found little evidence of the rise of the virtual product development team because their study sample firms show clear preference for spatial concentration. They argue that face-to-face interaction is crucial to solve problems in later stages of projects, reflecting how networks are operated and co-ordinated. This, Olivier and Blakeborough (1998, p.158) claim, will become a 'feature of multifirm product development projects in the foreseeable future'. This is supported by Bagchi-Sen (2004) who found that face-to-face recommendations and personal contacts are important to facilitate collaboration among firms in biotechnology clusters in the US. In a similar vein, Sonn and Storper (2003) claim localised technological interactions are increasing, especially in certain types of patentable knowledge. However, Sonn and Storper point out that both arguments (the demise of distance argument versus importance of proximity) are complementary because each deals with a different dimension of the innovation process. It stands to reason, therefore, that spatial proximity will continue to play important role in the location of R&D and innovation activities. In the words of Feldman (2002, p.55), 'after all we are physical and not virtual entities and need to be somewhere'.

Despite the benefits of clustering discussed above, there are limitations in the use of cluster policy for promoting regional high-tech development. Each region has its own assets and limitations that influence the type of development envisaged. Martin and Sunley (2002) identified two limitations of the cluster policy. First, the highly elastic nature of the concept 'cannot provide a universal and deterministic model on how agglomeration is related to regional and local economic growth (p.47). Second, and related to the first limitation, is that the success of a region need not be mainly caused by a causal relationship between the region's high-tech industries and the various forms of geographical concentration. In the words of Saxenian (2000), "neither the concept of external economies nor that of an industrial cluster can account for the divergent trajectories of apparently comparable regional economies." These limitations serve important lessons for policy makers elsewhere, especially in developing countries trying to emulate the Silicon Valley model and the science park strategy to promote high-tech development. This does not, however, imply that these models are totally irrelevant as there are some useful elements, such as entrepreneurial culture of risk taking, networking benefits and support for SMEs innovation, that certainly will be of interest to the adopters of the model.

2.6.4 Internal R&D and R&D Collaboration

Firms need to invest in R&D to produce new knowledge and to develop their absorptive capacity. This involves conducting in-house R&D, integrating advanced equipment into their production processes, engaging consultants, licensing patented information, employing skilled people and undertaking joint R&D projects (Sandven 1996). Other activities include conducting technical training for workers, fostering links with R&D institutions, engaging in strategic alliances and inter-firm co-operation and utilising assistance provided by government.

2.6.4.1 Research and Development

Bell (1984) identifies three factors, including engagement in research and development (R&D), learning-by-doing and networking, as the way forward to develop firms' technological capabilities. Contrary to the characterisation of knowledge as a pure durable good (Nelson 1959; Arrow 1962), it is now believed that firms have to incur costs to exploit knowledge spillovers. In particular, firms need to invest in research and development (R&D) to develop their absorptive capacity[56] (Cohen and Levinthal 1990) to utilise external knowledge as well as develop their dynamic capabilities to achieve competitive advantage (Teece and Pisano 1994).

However, increasing R&D input does not necessarily bring about the desired innovation output in terms of new products and processes. Fraser and White (1992) have rejected the assumption that companies, which invest heavily in R&D, are necessarily the most successful innovators. Fraser and White cautioned that focusing too much on technology to drive innovation is damaging to business because of high R&D costs,[57] excessive commitment to a technology and lack of market forces. Similarly, Shervani and Zerillo (1997) also point out that a narrow focus on product innovation can result in the neglect of other functions and business processes, which may have the potential to generate greater profits. These other functions and business processes themselves can also be areas for innovation. Firms should focus on broad-based innovation, or innovation in multiple functions and business processes.

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[56] According to Cohen and Levinthal (1990), 'absorptive capacity is the ability of a firm to recognise the value of new, external information, assimilate it, and apply it to commercial ends is critical to its innovative capabilities. It's a function of the firm's prior knowledge'.

[57] R&D accounts for 10-15 percent of the total investment of an innovation process and the balance 85-90 percent of the investment is devoted to downstream activities such as "design, manufacturing, applications engineering, and human resources development". Most of the activities involved in downstream investment are not purely technical. These activities as socio-technical "because they involve changes in organisation and human relations as well as technology" (see Brooks 1995)

2.6.4.2 Collaboration and Inter-firm Networking

Risk and uncertainty associated with the innovation process have resulted in two opposing views with regard to the need to rely on networking and collaboration strategies for firm-level innovation. On one hand, the view is that firms should engage in networking with technology suppliers, R&D institutions and other firms to build their technological capabilities (Rickne 2001; UNCTAD 2001). On the other hand, some, like Freel (2003), are of the view that firms should rely on their own efforts and capacities through employment of internal strategies to enhance their innovation output. See Table 2.3 for various forms on inter-firm relationship that involve R&D, and innovation activities.

Table 2.3: Forms of Inter-Firm Relationship

Type of Relationship/Mechanism	Nature of Relationship
Licensing	Agreements that allow unilateral technology access (involving a patent) to a licensee involving payment of a fee.
Second-sourcing agreement	Technology transfer through technical product specifications to create exact copies of products
Customer-supplier relationship	Co-production contracts and co-marketing relations that regulate long-term contracts between independent companies that collaborate in production and supply
Joint R&D pacts and joint development agreements	Jointly funded R&D projects by companies subjected to contractual agreements
Joint ventures	Two separate companies having equity investment in business ventures that involve production, marketing & sales, or even R&D

Source: Based on Hagedoorn (2001)

In a sample study of 73 biomaterial new technology-based firms in Sweden, Ohio and Massachussets, Rickne (2001) found a positive relationship between a high degree technology sourcing and firm performance. Rickne's study suggests the need for firms to have a wide span of search to acquire technology externally through networking with many partners. Similarly, a study by Chang (2003) on integrated circuits and biotechnology firms in United Kingdom and Taiwan confirmed the importance of firm's network capability with suppliers, customers and knowledge-creating organisations to enhance firm innovativeness. .

Narula (2001), however, points out the downside of R&D collaboration in terms of the need to maintain some level of in-house R&D competence to integrate various technologies and the low success rate of R&D alliances. The demand for multiple technological competencies and global competition may worsen the disadvantages of size limitations faced by SMEs despite having advantages of flexibility and rapid response.

Studies show that companies which have links with university to source for information and as a partner are more successful than those that do not, in terms of increased market share, improved quality of products and services and lowered costs (HM Treasury 2003).

Table 2.4: Relationship between business performance and collaboration

	Increased range of goods and services	Opened new market or increased market share	Improved quality of goods and services	Reduced unit labour costs
Enterprises which do not use universities as a partner	42 %	40 %	46 %	33 %
Enterprises which do use universities as a partner	82 %	81 %	85 %	65 %

Source: Community Innovation Survey (UK), DTI/ONS, 2001

The link between the universities and industry take many forms. It can be formal as well as informal and depends on resources available in the universities and needs of the industry. For example, some firms require laboratory equipment available in the university to do testing on their products. Others tap on to the skilled manpower of universities, which includes the academics and graduate students. There are also cases of university-industry collaborative R&D schemes.

2.6.5 Access to Finance

SMEs are generally unfavourably positioned with respect to access to finance because banks usually prefer not to finance R&D activities, which involve high risk and uncertainty. Such firms have high variable returns, information asymmetry and inability to provide sufficient collateral (Carpenter and Petersen 2002). Thus, lack of access to finance is one of the major impediments to the growth of innovative firms (Westhead and Storey 1997). Consequently, equity financing rather that debt financing is considered to be a better option for small high tech firms lacking sufficient collateral to obtain funds from banks (Himmelberg and Petersen 1994). A study by Carpenter and Petersen (2002) on a panel of 2, 400 public traded high-tech firms in the United States has shown the importance of equity finance for the growth of small high-tech firms. Carpenter and Petersen point out that comparatively few firms use external financing once they have gone public. Venture capital is becoming another important source of capital for NTBFs. Mani and Bartzokas (2002) found a positive relationship between venture capital investments and growth of high technology sector in Asia. However, Murray and Lott (1995) found that venture capitalists in the UK apply different and rigorous criteria for assessing technology-based projects because of the risk associated with technology investments.

2.6.6 Entrepreneurship and Organizational Factors

The generation, diffusion and application of innovative ideas and concepts can be accelerated by entrepreneurial activity (OECD 2004). Entrepreneurs "facilitate the realisation of innovation, as firms are formed to commercialise and advance new ideas" (Feldman 2002, p.15). Underlying the spirit of enterprise is the ability to innovate and harness new technologies that provide the basis for the creation of new firms and new jobs (Schamm 2004).

One of the major factors driving the dynamic growth of high-tech clusters worldwide is the role played by entrepreneurs. The phenomenal growth of the Oxfordshire high-tech cluster in the United Kingdom is attributed partly to the entrepreneurial role played by individuals like Sir Martin Wood and Lady Adrey Wood who set up Oxford Instruments that created many spin- offs.[58] In this respect, initiatives such as

[58] See research report prepared by Chadwick et al (2003) for the Oxford Economic Observatory (OEO). The spin-offs include Oxford Analytical Instruments and Oxford Magnetic Technology.

the Graduates Enterprise in the United Kingdom can equip young people with the skills and knowledge, so that they can initiate start-up firms or work for growing SMEs.[59] This is reflected in the study of Henry et.al (2001), who stress the importance of entrepreneurship education and training to support the creation and growth of innovative SMEs and technology-based start-ups.[60]

Firm's marketing capability is crucial to achieve success in high-technology markets. Dutta et.al (1999) found the interaction of marketing and R&D capabilities and, particularly, consideration of market needs to be crucial for the innovation performance of firms. Dutta et al also observed that firms with strong R&D base are the ones to gain most from strong market awareness. On the other hand, in a study of start-ups in Singapore, Foo and Tan (2000) found the human resource management factor more critical than finance, sales and marketing issues during the first two-years of operation . Consequently, they suggest that young firms should focus on human resource systems in the early stages and should not delay these measures to the growth stage.

2.6.7 Internationalisation

Firms seek entry into global markets to overcome the limitations of national markets to support the growth of high technology industries Technology-intensive small firms need to go global especially to sell their products (Keeble et. al 1997, Kobrin 1994). A study by Burgel et.al (2000) of 600 British and German high-tech start-ups confirms that firms with international sales have higher sales growth than firms that sell their products and services only domestically. Burgel et.al further claim that 60%-70% of these firms consider the potential of foreign markets for long-term company growth as their main motive for international business activities.

Dunning (1993) had suggested that firms set up subsidiaries in foreign countries via foreign direct investment to exploit the proprietary advantages of their own core

[59] See Wicksteed (1999).
[60] According to OECD (2001, p.89), entrepreneurship refers to "enterprising individuals who display the readiness to take risks with new or innovative ideas to generate new products and services".

technology. However, in recent years, such subsidiaries are being set up as part of the firms' learning-by-investment strategy to exploit local knowledge spillovers and to use the technology of domestic firms of the host countries resulting in reverse technology transfer (Cantwell and Narula 2001). This change in strategy of firms expanding overseas is attributed to the globalisation of technology and economic activities.

2.6.8 Government Support Schemes

According to Storey and Tether (1998), SMEs and NTBFs face numerous constraints due to a number of characteristics associated with them[61]. These constraints include the following, among others:

- uncertainty in recovering the returns from their R&D endeavour;
- difficulty in assessing the potential of a new product or service introduced in the market;
- risk of business closure if investments are not made at the right time due to the short 'window of opportunity'; and
- lack managerial skills despite being run by highly educated people.

In view of these constraints, need has arisen to design and implement public policies to support new technology-based firms (NTBFs) in the European Union countries (Storey and Tether 1998; Laranja 1994) and in Canada (McDoughall and Swimmer 1997). The shift in the UK technology policy since the early 1990s has been intended to enhance innovation opportunities particularly for SMEs, as reflected by its concern for the development of innovation infrastructure and innovation networks and the promotion of technology transfer and innovation awareness (Metcalf 1994). In terms of government funds for small businesses innovation, the best example is the Small Business Innovation Research (SBIR) programme in the United States. This programme involves an annual budget of US$1.2 billion given to ten agencies

[61] According to the Bank of England (2001), the key characteristics are: their value linked primarily to longer-term growth potential derived from scientific knowledge and intellectual property; lack tangible assets which may be used as collateral; their products initially have little or no tract record, are largely untested in markets and sometimes subject to high rates of obsolescent.

and departments to channel R&D funds to small businesses.[62]

In the words of Rodriguez (2004, p.9), 'SME policies are typically justified as ways to achieve higher levels of innovation, competitiveness and growth'. However, policy makers have to choose the appropriate SME-specific policy measures like, for example, whether to target niche market players or academic spin-offs or provide funds or tax credits. On the other hand, a narrow policy focus on a particular group of small high technology firms may be counter-productive. For example, Quince and Whittaker (2003)[63] warned that emulating the success of academic spin-offs of the Silicon Valley and the Boston region in the United States may fail to address the needs of the vast majority of small high- firms. Quince and Whittaker point out that schemes such as the Teaching Company Schemes (TCS) should not be overlooked because they may assist long-term prosperity of existing high-tech firms. Autio and Magnus (1996) also remind policymakers not to focus too much on the physical setting and institutional embeddedness, but instead support the SMEs through active hands-on development programmes and tailored activities, such as the SMIL in Sweden and Spinno in Finland.[64]

Issues and problems faced by SMEs are also discussed at various international and regional forums such as OECD[65], European Union and APEC. These groupings initiate numerous policy recommendations to support SME innovation. An example

[62] See Wessner (2003) for more details about SBIR.

[63] Quince and Whittaker (2003) conducted case studies of twenty-five small existing high-tech firms in the UK. Their findings seem to have important policy implications for addressing the needs of this group of firms. The study reinforced the view that, the creations of these firms is iterative and collaborative and suggests that changes were brought about entrepreneurs' motivational factors. They argue that there is a need for policy to take into account the concerns of the broad group of small high-tech firms, "the 'beer', and not blinded by the attraction of the 'froth', that is the research based spin-out" (p15).

[64] SMIL is aimed at business stimulation for new ventures while Spinno is a development oriented incubator programme. Both these programmes are aimed at supporting start-up, growth and consolidation of small technology-based firms. For more details see Autio and Klofsten (1996).

[65] The First OECD Ministerial Conference on Small and Medium Enterprises (SMEs) was held in June 2000 in Bologna, Italy with the theme 'Enhancing the competitiveness of the SMEs in the global economy: strategies and policies'. The outcome of this conference is the Bologna Charter to provide the frame of reference to improve the efficiency of polices and programmes to further the objectives as reflected in the conference theme.

is the SME innovation services offered by the International Network for SMEs (INSME) based in Italy.[66] Policy initiatives to enhance technological capabilities of SMEs include provision of tax incentives and direct funding for physical infrastructures. Science parks have become a popular strategy in both developed and developing countries to facilitate commercialisation of R&D and support the growth of technology-based SMEs, including NTBFs. The origin, objectives, impact and drawbacks of the science park strategy will be examined in the next chapter.

2.6.9 Implemetation Issues

Overall business strategy of a firm incorporates various other strategies especially those related to technology, financial, marketing and human resource development. Effective co-ordination of these strategies is crucial for successful innovation and competitiveness. Terziovski et al (2001) suggest firms can develop innovation capability along two key dimensions, namely the hard innovation (HI) and the soft innovation (SI). They explain that HI requires putting in place structures (e.g. organisational schemes and procedures) to support innovation activities. SI on the other hand, refers to management of the HI by developing the organisational culture to create innovation orientation, which requires the role of a sensitive leadership. In short, firms need to establish and operate in an environment that promotes and supports innovation.

2.6.10 Measuring Firm Level Innovation

Innovation happens when firms succeed to introduce new products and processes into the market. But this merely defines the meaning of innovation in terms of the firm's attempt to profit from the sale or use of new products, processes or services What is more important to the firms is whether innovation enhances their productivity, profitability and growth. According to Gellatly and Peters (1999, p.2), 'the success of an innovation depends on its commercial value'. This will involve

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[66] Services offered by INSME include technology watch to provide updated mapping of technologies about SMEs process and product innovation; technology audit to assist SME assess their innovative technology needs; experts identification to identify experts who are able to define and implement innovation projects, and identification of grants and public funds for investments in sectors of research and technology.

measuring innovation, and linking the measurements to the performance of the firm. But the complex and multi-dimensional nature of innovation poses conceptual and practical problems in measuring it. According to Hagedoorn and Cloodt (2003), a generally acceptable indicator of innovative performance has yet to be designed. Hansen (2001) argues that innovation cannot be measured because of the interaction of many different resources within and among firms resulting in a wide variety of outputs that cannot be measured along any single dimensional scale.

Despite the above limitations, organisations and researchers have long used a number of indicators to measure both innovation input and innovation output. The most widely used input indicators include R&D expenditure and number of qualified scientists and engineers (QSE) employed. The output indicators include patents[67], innovation counts and new products and processes launched. Patents, R&D, publications and citations are described as traditional measures of innovativeness (Loof et al 2001). The economic performance and competitiveness of some regions in the U.S is measured by using innovation output indicators such as patents, establishment formation, venture capital investments, initial public offerings and fast growth firms (Porter 2001). Similarly, national innovation surveys in many countries use patents and new products and processes, as innovation output indicators. Based on the Community Innovation Survey (CIS), two other measures that respectively act as "substitutes and complements to the traditional measures are: total expenditures on innovation activities and sales revenue associated with the introduction of new innovative products and services into the market" (Loof et al 2001, p.2).

Yoguel and Boscherini (2000) point out that over reliance on the above indicators results in a biased learning economy, and neglect the importance of incremental innovation occurring throughout an organisation. In their study of industrial SMEs in Argentina, Yoguel and Boscherini used an innovative capacity indicator that takes into account six factors: quality assurance, training efforts, scope of development

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[67] See Griliches (1991) for a comprehensive account of patent as an economic indicator as well as Cohen and Merrill (2003) for a detailed discussion on the issue of patent in the knowledge-based economy.

activities, participation of engineers and technicians in the development team, value of new products launched and formal and informal technological co-operation. Baldwin (1997) suggests the use of sources of innovation, including internal technical sources (such as R&D unit and production unit) and non-technical sources (marketing), as an alternate measure of innovation.

Input and output indicators have widely been used; but the literature of national innovation system suggests that these can scarcely capture the whole gamut of the innovation process. What is important about innovation is not the measure of quantitative inputs or outputs, but the dynamics of the process invvolving organisational, institutional and behavioural changes, which are difficult to indicate in quantitative terms.

2.7 CONCLUSION

This chapter has discussed the importance of innovation for economic performance. It examined various theories and frameworks that have emerged in the last five decades to explain the relationship between technological change and economic growth. Prior to 1980s, the exogenous role of technology in driving growth dominated the debate on technology as a driver of economic growth. In the last two decades, a new growth theory focusing on the role of R&D, knowledge and human capital took center stage in explaining the sources of growth. The importance of the evolutionary theory focusing on the behaviour of firms and market response is also noted in connection with its attempt to further open the technology black box.

In line with the shift from the linear model of innovation to the integrated model of innovation, the national innovation system (NIS) framework became an important policy tool in both developed and developing countries to analyse the role of innovation in economic development. The emphasis of the NIS is on the collective role of organisations and institutions in the production, flow and use of knowledge. The role of government is crucial so as to identify and overcome systemic failures that could hamper the smooth functioning of the NIS. Appropriate technology policies are formulated within the NIS framework to support firm level innovation especially amongst the small and medium size enterprises (SMEs), which are fast emerging as an important contributor to the creation of jobs, income and national output.

Success of innovation at firm, industry or national level depends on the effectiveness of addressing implementation isssues at each of these levels. Quality of institutions and organisations are crucial for ensuring the success of the NIS. For example, lack of corporate governance can hamper efforts to create an innovation culture. Similarly lack of trust amongst management and staff can stifle strategies aimed at fostering firm level innovation. These issues are confronted in both developed and developing countries although the degree varies from one country to another. Malaysia is no exception to the problem of corporate governance. The 1997 Asian Financial Crisis has shown how this problem caused massive loss to the Malaysian economy with negative impact on local technological development.

Among the strategies adopted to stimulate SME innovation include the establishment of science and research parks and incubators supported by various funding schemes and incentives. The Science Park strategy has become a major policy instrument to nurture the growth and development technology–based businesses and to enhance commercialisation of research results. However based on studies of science parks in Europe and the US, questions have been raised about the effectiveness of science parks as a strategy to support technology-based businesses. No such study has been undertaken in Malaysia where more than five science parks have been built since 1988. This study will attempt to fill the gap by examining the role of science parks in stimulating innovation amongst local SMEs and enhancing commercialisation of research. The science park strategy to foster SME innovation will be examined in the next chapter.

SCIENCE PARKS AND SME INNOVATION

The preceding chapter has examined the role of technology and innovation in productivity and economic growth. It highlighted the importance of innovation at firm and national level and its determinants, including the role of government policies and programmes, among other factors. Science parks are part of the technology policy, which can help create an enabling environment for SME innovation. This chapter will discuss the role of science parks in the commercialisation of R&D and the growth of high-tech SMEs, including new technology-based firms (NTBFs).

3.1 THE SCIENCE PARK PHENOMENON

3.1.1 Definitions and Characteristics

There is no universal or transferable model for a science park. The United Kingdom and most of Europe use the term 'science park' while in France it is called a 'technopole'. In the United States, it is known as a 'research park' or 'research and technology park'. In some countries, science parks are referred to as 'technology parks' or 'innovation parks' while in Germany they are known as 'innovation centres'. Another associated facility is called an incubator, which provides a variety of business services to support start-up businesses. These parks[68] and facilities have one thing in common: they offer well-equipped physical spaces suitable for the setting up of various types of technology-based companies. According to European Commission (2004), science parks are technology transfer institutions that offer services such as licensing, support for contract research and patenting for inventions to spin-offs. Science parks differ from other parks, (for example industrial parks), in terms of clients, manpower, products and product cycle as shown in Table 3.1. Based on these elements, science parks are supposed to host high-tech firms with R&D

[68] Additional information on the different meanings with regard to a science park, technology park, research park, innovation centre, and incubator can be found at the website of the United Kingdom Science Park Association (UKSPA) at http://www.ukspa.org.uk. The UKSPA is an umbrella organisation representing over 50 science parks mostly university owned in the UK.

capability that employ technical manpower to generate new and innovative products that have complete product cycles.

Table 3.1: Science Parks versus Industrial Parks

Science Parks	Industrial Parks
High tech firms with R&D capability	Manufacturing firms
Technical Manpower	Low wage labour
New, innovative products	Matured products
Complete product cycle	Manufacturing only

Source: Ho (1999)

There are some features that need to be present for a proper functioning of a science park irrespective of location and ownership. These features can be classified as *essential* and *important*, as shown in Table 3.2 below. One essential feature is the science park firms' links with universities for joint R&D collaboration and for use of university resources to enhance their R&D capability. It is this essential feature that distinguishes a science park from an industrial park, besides the three other elements shown earlier in Table 3.2.

Table 3.2: Science parks: Essential and Important Features

Essential Features	Important Features
Formal organisational links to world class research organisations	Communal Areas
Access to networks	Focal point or physical presence
Mission statements/strategy/objectives	On-site management and daily contact
Access to finance and mentors	
Company selection policy	
Guidance/assistance available	
Flexibility of space and terms	
Reflects local science base and terms	
Access to specialist facilities	
Singular or complementary sector focus	
International research com. facility on-site	

Source: South West of England RDA (2003)

Hauschildt and Steinkuhler (1994) outline types of science-based parks in a continuum with science parks or research parks on one end, and business incubators on the other. Between these two extremes are technology parks and innovation centres. Science parks also vary in terms of size, ownership, technology focus and type of facilities and support services available. For example, the West of Scotland Science Park, covering 61 acres, is a joint initiative between Glasgow Development Agency and the Universities of Glasgow and Strathclyde. The Sandia Science and Technology Park, covering an area of 200 acres in the city of Albuquerque, New Mexico in the US, is owned by eleven partners, notably the State, the city, Economic Development Administration and Sandia National Laboratories.

Cox (1986) identifies two distinct phases in the development of most science parks. The first phase is the institutional phase, which involves getting the science park ready in terms of facilities and support services and attracting the potential tenants. This may take up to three years as in the case of Central Florida Research Park. The second phase is the entrepreneurial phase and is more difficult to predict, as it requires the availability of critical mass of scientists and innovators supported by favourable conditions. In countries where the requirements of local authorities are stringent, it may take longer before the park is given the go ahead to start operation. UNIDO (2004) describes five phases for the establishment of science parks: conceptualisation, planning and designing, establishment and capacity building, operation and management and monitoring and continuous improvement. UNIDO emphasises the need for clear objectives from the very beginning for the operation and sustainability of the park.

3.1.2 Growth of Science Park Movement

The guiding example for science parks throughout the world is the Stanford Research Park in Palo Alto in California, which played a pivotal role in the evolution of Silicon Valley. The tremendous success of Silicon Valley as the most successful high-tech cluster became an inspiration to governments and policy makers in developed and developing countries to establish similar parks to spur high-tech development. The approach to emulate Silicon Valley involves "co-locating research centres and innovation-intensive firms in science and technology parks, and in some cases designating whole cities as Science Cities and Technopoles" (Cooke 2001, p.2). Among the well-known science parks that have achieved success include the Research Triangle Park in USA, the Cambridge Science Park in United Kingdom and Turku Science Park in south-west Finland.

Prior to 1980, there were only less than seventy science parks in the world. Of these, sixty were in the United States and the rest were distributed across Europe and Japan. European countries began building science parks in early 1970s followed by Asian countries in the 1980s. The first science parks in the UK, the Cambridge Science Park and Heriott Watt Science Park, were built in 1972. Another was later built in 1982. Since then the number of science parks in UK has risen to about 70.

In Asia, some of the prominent parks include Hsinchu Science-Based Industrial Park in Taiwan and Singapore Science Park in Singapore. Similarly, Technology Park Malaysia and Kulim Hi-Tech Park in Malaysia are also gradually gaining international prominence. From just three technology parks prior to the 1990s, there are currently 23 such parks in Australia, nine of which have incubation facilities and eight are linked to universities, with five of this being situated on or adjacent to a university campuses (Smith 2001). China registered the fastest growth in the number of science parks. According to Macdonald and Deng (2004), China currently has 53 national science parks (also known as high-tech zones) and more than 50 provincial science parks. The first science park in the Middle East is the Prince Abdullah bin Abdulaziz Science Park (PASP) in Dhahran, Saudi Arabia, which was established in 2002.

Currently there are an estimated 700 science parks in the world. The distribution of these parks across regions is shown in Table 3.3.

Table 3.3: Global Distribution of Science Parks

Region	Estimated Number of Science and Technology Parks
North America	300
Europe	240
China	80
Asia-Pacific	30
Rest of the world	50

Source: Based on Sanz (2003)

3.2 RATIONALE BEHIND SCIENCE PARKS

3.2.1 Science Parks as Clusters

In the preceding chapter, we have discussed the role of geographical proximity in the location of innovative activities and the production of knowledge spillover. Distance matters in the creation and utilisation of knowledge, especially tacit knowledge, which is important for technology development. As noted by, Audretsch (2000, p.77), 'creation of new ideas based on tacit knowledge cannot easily be transferred across distance'. This justifies the location of science parks close to knowledge creation centers such as universities and research institutions. Since SMEs are resource-constrained to set up their own R&D units, they can manage to produce substantial innovations by exploiting knowledge spillover generated by the universities and other higher education institutions (HEIs). Thus the science park environment is conducive for the growth and development of start-ups and technology-based businesses. But is science park a cluster?

UNCTAD (1998) categorises clusters into two types: (a) artificially constituted clusters and (b) spontaneous clusters. The former is public policy induced while the latter is informal. Science park is a form of artificially constituted cluster.[69] However, based on the definition of a cluster by Porter (1998), one may ask whether

[69] The other types of artificial constituted clusters include technopoles, incubators and export processing zones. Example of spontaneous cluster is the Italian industrial districts.

is science park truly a cluster. For example, Cooke (2001) points out that *technopoles* such as Sophia Antipolis in France and Tsukuba Science City in Japan are not clusters because there is no evidence of interaction between firms. However, based on the essential and important features of science parks shown in Table 3.2 and the definitions of science parks given by UKSPA and IASP (see Appendix I), a science park or a *technopole* can be construed as a planned cluster. The effectiveness of a science park in generating clustering effects is debatable; but still, it has the characteristics of a cluster. The size of a science park may range from less than sixty acres to more than 2,000 acres. Besides, diversity in the type of companies in the science park does not mean that the science park cannot function as a cluster. This is because science park companies are supposed to be involved in technology sectors, which involve co-operation and collaboration with universities, and research institutes as well as with other firms in the park and with those located elsewhere. Sandia Science Park is an example of a science park, whose experience gives credence to the hypothesis that proximity enhances technology transfer (Brown 1998). Besides, as pointed out earlier, there are many cases of science parks specialising in one or two technology sectors - in particular, information technology and biotechnology. So there is good reason to believe that science parks should be viewed as 'clusters of independent firms and support organisations that normally operate in the same or related lines of industries'(Ylinenpaa 2001, p.2). The debate should be on the effectiveness of science parks in fostering firm-level innovation rather than on whether they are clusters or not.

3.2.2 Reasons for Setting up Science Parks

There are many reasons for the establishment of science parks depending on ownership patterns, location (including availability of sufficient land), industry needs and policy objectives. In some places science parks began as a real estate phenomenon. In other places, science parks were set up by local or regional authorities to regenerate lagging regions because these parks were believed to be creators of jobs, new businesses and wealth for the local economy. For example, the Warwick Science Park was set up in 1984 to create long-term technology-led employment opportunities. Science park policy has now become an integral part of regional clustering policy to promote clustering of high-tech industries (Romijn and Albu 2001). The technopoles in France not only involve cross-fertilisation between universities, research and industry but also urban development (OECD 1997b). In Korea, high-tech parks were built to induce national industrial opportunities by exploiting the special features associated with high-tech development and to revitalise regional economic development (Bae 2001).[70] In Thailand, science Parks are meant to assist technology-based start-ups and to attract R&D investments from both local and international companies.[71]

Motivations for establishing science parks can be identified by examining the parks' organisational mission statements. Some commonalties can be found in these mission statements regardless of who owns them or where they are located or on which technology sector they focus. For example, most parks endeavour to assist in the nurturing of start-ups and new technology-based companies that are capable of creating new and improved products, processes and services. Another mission is to foster university-industry partnerships for creating world class R&D output. Some aspects of the missions of a few selected science parks are shown in Table 3.4 below.

Expansion of science parks is often prompted by the needs of rapidly increasing technology-based companies. These companies are looking for locations that will improve their business performance and growth. The prestigious image of the park is an important pull factor (Westhead 1997) while access to university research facilities and academic staff is also important in attracting companies in various technology sectors to science park locations (Link and Scott 2003). The science park environment stimulates innovation amongst tenant companies, and enables them to

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[70] According to Kang (2004) building science parks in Korea was a useful policy to solve an economic crisis when the country was under the International Monetary Policy (IMF) because they were effective in changing the industrial structure.

[71] This was stated by Chachanat Thebtaranonth of the National Science and Technology Development Agency (NSTDA) of Thailand. For more details about the recently launched Thailand Science Park, refer to Thebtaranonth's article at http://atpac.org/park.htm. (Viewed on 14 July 2003).

create new products and processes (Keeble 1994).

Table 3.4: Objectives of First Science Park in Selected Countries

Name of Science Park	Year Started	Objectives
Kanagawa Science Park	1989	To serve as base for creation and nurturing of high-tech ventures and to promote exchanges among residents and visitors to the Park
Singapore Science Park	1980	To provide a focal point for research, development and innovation in Singapore and the region
Cambridge Science Park	1970	To provide a favourable location to house and encourage the success of local high-tech industry, research institutes and UK subsidiaries of multinational companies
Stanford Research Park	1951	To provide a productive environment in which to grow ideas and build companies
Technology Park Malaysia	1995	To facilitate private sector and government R&D and innovation and as well as facilitate partnership between the two sectors.

Source: Derived by accessing the web-site of respective science park.

To attract firms to it, a science park would be expected to be capable of adding value to the activities of tenant companies (Sanz 2001).[72] Citing the Silicon Valley experience as a classic case, Brannback and Heinonen (2003) view science parks as knowledge catalysts that provide a context for networking entrepreneurial learning.

The motives for setting up science parks also influence the type of companies attracted to these parks. This is reflected in the criteria for the selection of tenant companies. For example, the Hong Kong Science Park (HKSP) admits companies, which are involved in technology-intensive business, carry out technology research and are engaged in new product development. In recent years, policy emphasis on the development of knowledge-based economy has heightened the need for some governments to establish parks as a strategy for promoting specific technologies, especially ICT and biotechnology. For example the International Technology Park in Bangalore (India) is established to spur the growth of IT-based businesses. The San Raffaele Biomedical Science Park in Milan, Italy is entirely focused on biomedical

[72] Sanz (2001) further explained that if science parks do not add value to the companies, they must not be considered as science parks, but just simple conventional industrial settlements.

and biotechnology research. The Yokosuka Telecom Research Park, located in the Tokyo Metropolitan Area, specialises in radio telecommunication technology. The Sandia Science Park in the State of New Mexico in the U.S. houses national security-related enterprises focusing on technologies that have both military and civilian applications.

3.3 IMPACT OF SCIENCE PARKS

Science parks are set up to:

- encourage networking amongst firms;
- facilitate joint sharing of resources;
- provide support services including professional services, such as legal, insurance and banking;
- facilitate access to university facilities, especially if the park is owned by the university, or has formal links with the university or located in close proximity to the university; and
- offer technology transfer services such as licensing and patenting.

According to Lowegren (2001), science parks function as a resource network for tenant companies. Lowegren (2001) classifies these resources as university-related, science park facilities and cluster effects (see Table 3.5). However, the quality and quantity of these resources vary from one science park to the other. For example, those owned by universities and located near universities are expected to have greater access to university-related resources.

The impact of science parks can be studied with respect to their role in three broad areas: support for technology-based SMEs; facilitating commercialisation of university research; and promoting regional development.

Table 3.5: Science Park as a Resource Network

Type of Resource	Description
University-related	University links, access to university resources, university education, academics and graduates as skilled manpower
Science park facilities	Business advisory services, venture capital, flexibility of premises, car parking, administrative facilities, science park management
Cluster effects	Image, reputation and credibility of location and collective learning

Source: Based on Lowegren (2001)

3.3.1 Support for technology-based SMEs

SMEs are now viewed as major contributors to a nation's economy in terms of the creation of wealth, job opportunities and innovation. While SMEs' impact on the US economy can be traced to the post war period, their contribution to the economic growth of Europe and Asia only became apparent in the last three decades. There are many underlying factors for this development. For example, Rothwell (1994) attributes the increasing formation of new technology-based firms (NTBFs) in Europe to a more favourable business and investment climate. This includes the provision of infrastructure development such as, science parks and innovation centres; emergence of knowledge intensive technologies such as, IT that open up new market niches; rapid increase in venture capital; and expansion in government SME support schemes. Science parks can help stimulate the growth and development of new technology-based SMEs, which include (NTBFs), start-ups and spin-offs. This role of science parks should be viewed in the context of the challenges faced by SMEs in a knowledge economy as shown in Table 3.6.

Table 3.6: SME features versus the Knowledge Economy

Strengths:	**Weaknesses**
• Enthusiasm • Flexibility	• Financial shortage • Information shortage
Threats: • Globalisation • Speed of changes • Local Mentality	**Opportunities:** • Globalisation • New business niches • International mentality

Source: International Association of Science Parks (IASP)

However, studies of the impact of science parks on the development of SMEs and NTBFs have produced mixed results. Keeble (1994) attributes the creation of an innovation milieu for NTBF development in the Cambridge high-tech cluster in the UK to the role played by science parks in the region. Keeble cites the case of St. John's Innovation Park in Cambridge, which experienced low failure rate of businesses compared to the high businesses failure rate elsewhere during the severe national recession period from 1990-93.[73] On the other hand, Hauschildt and Steinkuhler (1994) argue that it is generally worthwhile for a company to be a tenant of a science park because the park provides better opportunity for strong companies to develop and gives better chance of survival to weak firms. However, the study by Hauschildt and Steinkuhler found that science park firms do not differ in terms of size and growth from off-park firms.

Another reason attracting SMEs and NTBFs to science parks is the networking potential and the benefits thereof. Stockport and Kakabadse (1994) suggest how NTBFs may utilise information and resources available in a science park environment to reduce business risk and increase the benefit arising from inter-organisation networks. However, serious questions have been raised as to the real motives of firms locating in science parks. Are firms attracted to science parks because of incentives such as grants and tax credit offered by the government? Are they there because it is prestigious to be located in a science park environment in terms of image that helps in positive consideration by financiers and for forging strategic alliances with both domestic and foreign companies?

Ferguson (1995) argues that the science park environment provides advantages to its tenants in terms of access to new customers and enhanced business image, thus making the position of off-park firms relatively unattractive. Westhead (1997, p.57) observed that "...... some firms have moved to science parks simply because of the

[73] According to Keeble (1994), the failure rate of the St. John's Innovation Park was 12% (13 failures out of 110 companies over 5 1/2 years, or only 2% per year). Citing his previous study (Keeble, 1990), he claims that this is a far better performance than the 50% failure rate for any cohort of new firms over 7 years based on VAT registration data.

image and overall prestige of the site rather than because of access to the facilities of the HEI/centre of research". Case studies by Lowegren (2001) of two biotechnology and two information technology firms in the Ideon Science Park in Finland showed that image of location in a science park can be a source of competitive advantage to firms. Lowegren's study suggests that the combined use of resources available in the park, such those related to university links, park facilities and cluster effects, can also be source of competitive advantage to the firms. However, a study by Ferguson and Olofsson (1998) found little indication of an added-value benefit (prestigious address and image) in a science park location. They also noted firms leaving the science park because the park could not or would not meet the firms' specific needs.

Another issue is the extent to which SMEs in science parks engage in research and development activities. Science parks prefer to have companies that conduct R&D as tenants. However, the evidence deriving from the experiences of many science parks is mixed. For example, based on the experience of the Warwick University Science Park (which has been in existence for more than 15 years) in the United Kingdom, very few NTBFs conduct high-level R&D. In a similar vein, Dodgson (2000) points out the concern raised by senior officials of the Korean Ministry of Economic Affairs about some companies on Hsinchu Science Park being more concerned with simple manufacturing than with conducting R&D technologies, despite enjoying the accompanying five-year tax break. But Yuan and Wang (1995) claims that the Hsinchu Park companies have succeeded technologically and have also developed sophisticated management strategies, such as managing international strategic alliances.

3.3.2 University-Industry Collaboration

Universities and research institutions throughout the world are struggling to commercialise their research findings. They have to overcome many obstacles that stand in the commercialisation route. Schramm (2004) points out that a great deal of research in life sciences (e.g. drugs and medical therapies) and in computing and engineering have not been successfully brought into the market place for practical use. Despite setting up technology transfer systems to enhance commercialisation, the commercialisation success rate is still low. Schramm cites bureaucracy and lack of applied skills and resources in universities as impediments to the commercialisation process. Can science parks including those owned by universities help enhance commercialisation of research results?

Science parks are built to foster enhanced university-industry partnership leading towards greater utilisation of university research results. These parks are perceived as effective interface between university research and industrial application that can also assist in the creation spin-offs and enable academics to become entrepreneurs. Science parks in the United States were designed to 'serve the needs of the entrepreneurial-minded academics and utilisation of university-industry linkages' (Anttiroiko 2004, p.302). In fact, it was the research universities' location factor and the establishment of science parks by these universities that triggered the growth and development of Silicon Valley, Boston Route 128 and the Cambridge Phenomenon. For example, Stanford Research Park (SRP) in the United States offers a successful illustration of university-industry interaction.[74] SRP encourages companies to:

- Sponsor joint research projects with the Stanford faculty and students;
- Conduct seminars and workshops that encourage the exchange of technical information;
- Offer internships to students;
- Recruit Stanford graduates;
- Invite faculty to join corporate boards;
- Retain faculty as consultants;
- Consult with Stanford's Office of Technology Licensing; and
- Obtain access to the University Library systems.

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[74] The success of this university-industry partnership is attributed to two mechanisms set up by Stanford Research Park. They are: Stanford Instructional Television Network (SITN) and the Stanford Affiliates Program. The SITN broadcasts more than 250 graduate level engineering and science classes to some 5,000 engineers, scientists and technical managers. The Affiliates program facilitates communications between faculty and Research Park company scientists and each of these programs also offers individual contact between representatives of a company and faculty and students in the program.

Another success story can be found in the Cambridge high-tech cluster (better known as the Cambridge Phenomenon) in the Cambridge region in the United Kingdom.[75] The growth of this cluster is attributed to the role played by the Cambridge Science Park (CSP), set up in 1972 by the Trinity College of Cambridge University. Although the size of park proper is not comparable to other parks such as Stanford, RTP or Sophia Antipolis in terms of number of tenant companies and employees, CSP's contribution to the overall development of the Cambridge region cannot be ignored. The Cambridge region (not just the park) is currently home to over 1,200 technology-based companies employing 35,000 people.

Link and Scott (2003) have demonstrated how the existence of a formal relationship with a science park enables universities to generate more scholarly publications and patents as well as allowing them to place Ph.D. students and hire outstanding scholars. Their study on the influence of U.S science parks on the academic missions of universities also suggests a direct relationship between the proximity of the science park to the university and the probability of the academic curriculum shifting from basic to applied research. Using econometric models, based on a sample of 89 science park firms and 88 non-science park firms in the United Kingdom, Siegel et.al. (2003) found that firms located on university science parks record slightly higher research productivity than firms not located on university science parks. Similarly, Lilian and Inaki (2003) found that firms operating in Technology Parks in the Basque region in Spain experiencing highest growth have formal collaborative R&D agreements with universities and innovation centres in the region.

On the other hand, there are studies showing lack of university-industry links involving science parks (see Hansson et al 2005; Harper 2003; Dierdonck et al 1990). According to a survey conducted by the Manchester Science Park (MSP) in

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[75] The term Cambridge Phenomenon was mentioned in Segal and Quince (1985). Segal and Quince refer the phenomenon to the economic development process in and around the town of Cambridge in the United Kingdom, which was driven by local high technology industries. They highlighted two factors that contributed to the phenomenon. The first is the nature of Cambridge town in terms of its small and compact size, relative remoteness and its attractiveness to live and work. The second factor is the presence of the Cambridge University that provides world-class science, medicine and engineering education.

2003, 46% of the companies in the MSP have no links at all with higher educational institutions (HEIs).[76] In a similar vein, based on the perspectives of the universities' academics and that of science park firms, Dierdonck et al (1990) found lack of collaboration between Belgian universities and local science park firms. Hansson et al (2005) also concluded that firms in the Symbion Science Park in Copenhagen have poor links with higher educational institutes in the area. Similarly, with the exception of Infopark in Budapest, other science parks in Hungary have yet to develop technology-based relations with universities (Buzas and Szanyi 2004).

What then are the reasons for lack of university-industry partnerships in the context of science park firms? According to Warwick University Science Park (WUPS), the greatest problem in university-industry links is the conflict of interests between universities and the NTBFs.[77] For instance, the Research Assessment Exercise (RAE) requires university researchers to deliver a minimum of two papers per year in certain high rated scientific journals; and this would constrain them from attending to the problems and needs of NTBFs. The NTBFs would on their part prefer the collaborative works not to be published, and would also expect the partner universities to offer solutions to their problems within weeks or months and not years. But WUPS admits that this is not the case in every university-NTBF link though the problem is prevalent.

The critical role of universities to the development of high technology firms in science parks is also being questioned. For example, the early growth of Sophia Antipolis in France, which is the largest science park in Europe, was not attributed to

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[76] This detail was obtained from the findings of the 2003 MSP Tenant Company Survey reported in Harper (2003). To address the issue of lack of links between MSP and the universities, the survey suggested that a customised service jointly provided by the MSP and the universities to introduce companies to relevant university departments and academics.

[77] See memorandum submitted to the UK Parliament Select Committee on Science and Technology at URL:http://www.publications.parliament.uk/pa/cm199900/cmselect/cmsctech/185/195ap.87.htm (accessed on 20 September 2003).

its proximity to world-class research universities (Laffitte 1985). Only in recent years has there been greater interaction between the Sophia Antipolis and nearby institutions, including the University of Nice. Dosi et al (2005) argue that the growth of the Silicon Valley and Route 128 high-tech clusters is attributed more to the massive increase in government defence funding and new research priorities rather than proximity to universities.[78]

3.3.3 Regional Economic Development

Science Parks are generally intended to help stimulate regional economic development (Luger and Goldstein 1991; Braun and McHone 1992; Geenhuizen and Nijkamp 1995). They contribute to regional development through formation of new knowledge-intensive businesses, creating jobs and wealth and generating spillover effects that help in the regeneration of lagging regions (Zhang 2000; Luger and Goldstein 1991).[79] In both developed and developing countries, science parks are thus used a strategy for promoting technology-based development by attracting investments from local firms (including SMEs) and multinational companies.

Glassmeier (1991) explains how competition between science parks becomes a source of innovation, efficiency and of collective effort to create a better place where to live and do business. According to Lin (1996), although Hinschu Science-based Industrial Park (HSIP) in Taiwan was not planned for regional development purposes, its economic success has brought tremendous benefits to the surrounding region.

In Germany, the science park concept is adopted as an important instrument to improve regional economic structure and this is reflected by the active involvement of local authorities in about eighty per cent of the parks (Hauschildt and Steinkuhler,

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[78] Dosi et al (2005) point out that similar views have been expressed by Saxenian (1988), and Mowery and Sampat (2005).

[79] A report published by Lambert Smith Hampton warns of a brain drain unless more science parks are built in the Yorkshire area in the UK.

1994). According to Schmitz-Borchert and Jung (2002, p.9), science parks have the potential to play the "role of initiators and managers of complex regional development" schemes. Schmitz-Borchert and Jung cite the case of Science Park Gelsenkirchen, which played a crucial role in the development of the solar energy industry cluster in the city of Gelsenkirchen located in the Ruhr region of Germany. Of the twenty-five companies located in this park, six are involved in solar technologies.

However, there are not many examples of science park-led local economic development (Felsenstein 1994). Nor is there consensus on the effectiveness of science parks as a strategy for regional development. For instance, using county-level panel data, Wallsten (2004) found that science parks in the United States have no net impact on job growth, number of firms and amount of venture capital attracted to the county. Steinkuler (1989), cited in Hauschildt and Steinkuhler (1994), is also critical of science-park approach to regional development for the following reasons:

- Small size of park firms is not favourable to providing adequate jobs
- Subsidies provided to the tenant companies are used as private cost
- Companies are artificially maintained because they will not be able to survive without support
- Science park will be unable to attract new tenants during an economic recession
- Competition between regions to offer subsidies might increase regional disparities

Science park-led regional development in Asia has also produced limited positive results. In a study of 52 national-level science and technology parks in China, Hu (2003) concluded that these parks did not generate the expected external economies needed to ensure sustainable growth. But Hu's study also found that cities that host technology parks experience faster growth, which is attributed largely to policy incentives that raise private return to investment. Another notable finding of Hu's study is that firms in the technology parks gained considerable benefits from inward foreign direct investment, which produced dynamic effects in terms of labour productivity growth in these parks.

Shin (2001) claims that science parks in Korea also did not create the desired economic impact or synergistic effects. But his study of the Daeduk Research Complex (DRC) in the Taejon region found some positive effects of DRC on the development of technological start-ups. In particular, Shin's study revealed how local research institutions and universities assisted technologies and manpower of start-ups considerably.

If science parks do not generate the spill over effects to stimulate regional development, why do policy makers continue to rely on this strategy? Are science parks often just a political quick fix to industrial decline, as observed by Jowitt (1991) or a politically attractive option to show some appearance of economic development activity followed by some appearance of success when companies move into the park (Walsten 2001)? Or could this cluster strategy work only in regions that already have strong industrial and scientific infrastructures in place (Porter 2003)?

3.4 CRITICAL SUCCESS FACTORS

Science park development involves heavy investments, long gestation period and high opportunity costs. There are many stakeholders who are interested in the progress and success of such costly ventures. Obviously, the owners of these parks who have devoted so much time and financial resources to the planning and implementation would want to reap the returns in the shortest possible period. Thus to them, faster uptake of the vacant lots and low annual operating costs (those not borne by the tenants) enhances their profitability. If the owner were a university, besides revenue, they would be interested in the quality of links between the university and the tenant companies. The university will also be interested in the number of academic spin-offs created via the park as well as the number of its graduates employed by the tenant firms. If national or local government is involved, it has wider socio-economic objectives as outlined earlier. Evaluating the effectiveness of the strategy is not only important to the owners of the park but also other stakeholders, in particular the tenant companies.

Hauschildt and Steinkuhler (1994) adopted a five-pronged approach to evaluate the success of a science park, including:

- views of prospective tenants regarding the kind of services they expect in the park;
- park manager's or tenant firms' assessment of the park;
- feedback from former tenants (who have left the park) about the support they received when they were operating in the park;
- external assessment to evaluate the success of the science park;
- external assessment to evaluate the success of the park tenants, as well as compare park tenants with comparative off-park firms.

The focus of the approach is on tenants, both existing and former. This approach is practical and effective because science parks are set up to provide support services (both hard and soft) to technology-based SMEs. The most appropriate approach to determine the added value of a science park is by examining the characteristics and evaluating the performance of tenant firms (Monck et al 1988). It is also important to get the perspectives of the other stakeholders (local authorities, universities and private investors) involved in a science park venture. Based on both negative and positive perspectives of the effectiveness of science parks, Harper (2003, p.6) suggests a pragmatic approach to evaluate the performance of science parks, particularly their role in stimulating university-industry links. Harper argued that since huge investments have gone into science park development in the United Kingdom, 'it would be more sensible and appropriate to take a less negatively critical approach to the subject and to focus on improving the role of science parks from a more broader qualitative perspective'.

To evaluate the success of science parks, it is also important to refer to the objectives for establishing the science parks in the first place. As discussed above, the objectives vary across parks, depending on the stakeholders involved. If the mission is to create world-class companies, then the criterion is the number of such companies produced by the science parks. To the developers of science parks, no vacant lot may be the success metric. To the university, which might be full or part owner of the park, the number of academic spin-offs and graduate employment could be the success indicators. To the owner of a tenant company, profits, sales and market share through innovation output are important objectives. UNIDO (2004) points out the failure of the science park model in developing countries to be due to the fact that right from the beginning there are no clear objectives for the operation and sustainability of these science parks.

Geenhuizen and Nijkamp (1995), however, warn of the danger of diverging interests and goals due to the multiplicity of actors involved in a science park venture. In the words of Hansson et al (2005, p.1040), "science parks serve many masters with different interests and expectations". Brown (1998) points out that conflict with the authentic success of a science park could arise if too much attention is given to economic viability. This may result in the science park evolving into a low-tech manufacturing or retail centre with outward appearance of commercial success but making no contribution to its technology development mission. Capello and Morrison (2004) argue that it would be misleading and wrong to evaluate the effectiveness of science parks as innovation creators and incubators for NTBFs if the institutions involved do not host any R&D activity.

To a large extent, the performance and profitability of a science park depends on the ability of the team managing the park. As pointed out by Sanz (2003, p.22), 'the relation of park managers with their resident companies really begins when the company enters the Park'. The park management should be able to provide the services and infrastructure needed by tenant firms (Luger 2001). However, the management team is often confronted with a host of problems. Besides attending to the day-to-day operational problems, management has to balance between maintaining admission criteria and ensuring that vacant lots are sold as quickly as possible. This balancing act may require management to relax stiff admission criteria to generate rental revenue from tenant occupancy. As noted by Westhead (1997, p.57), "to maintain rental income some park managers have relaxed their selection criteria for tenants". This may mean admitting companies, which may not conduct innovation and R&D activities, thus compromising the objective for setting up the park in the first place. Alhassan (2003) observes this practice in the management of the Nigerian Technology Park in Lagos, which was set up in 1992.

Luger (2001) suggest an appropriate marketing and development strategy that takes into account the region's resources and culture to build a successful science park. Other success factors, according to Luger, include visionary leadership and co-operation, adequate financing, as well as patient, good time and good luck. Petree et al (1997) suggest that based on local skills and professional tradition, a science park can choose a commercial niche to develop competitive edge. For example, in Bulgaria, policy makers would do well to consider the country's potential in software development and information technology when developing science parks. Bulgaria has computer specialists and engineers with excellent mathematical training and programming talent.

The success of science parks ultimately depends on the success of companies located in them. In this respect, entrepreneurial abilities play a very important role to steer their organisations to success in terms of performance, profitability and growth. A study by Ressico and Rolfo (2003) confirmed the importance of educational background and previous work experience of entrepreneurs for the success of NTBFs in the Sophia Antipolis Science Park in France and the Area Science Park in Italy. The science park environment also promotes the development of entrepreneurship (Brannback and Heinonen 2003), but, often, this depends on the disposition and ability of park managers to provide the quality services needed by the tenant companies. Link and Scott (2001) attribute the success of the Research Triangle Park in North Carolina, U.S. to the continuous role played by entrepreneurial leadership.[81]

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[81] See Link and Scott (2001) for detailed account of the growth of Research Triangle Park in North Carolina, USA. They single out Archie Davis for his inspiration and vision in guiding the park to emerge as the largest and most dynamic science park in the USA. They point out that 'the most successful science parks are those that have benefited from a continuity of enterprpeneurial leadership. Thus, companies are eager to adopt the park's innovative environment and as a result the park grows'.

3.5 CRITICISMS OF SCIENCE PARK MODEL

Some critiques dismiss science parks as no more than property-based initiatives (Komninos 1997; Fazey 1997), while others view science park as a reflection of a linear model of innovation, without interaction between the actors linked to the park (Cooke 2001; Sung et al 2001). Komninos (1997) attributes the failure of science parks to produce the desired impact in terms of new firm formation, university-industry links, employment growth and high-tech enterprise growth to the following reasons:

(a) Emphasis on property management that results in the neglect of technology resources and job creation;
(b) Emphasis on marketing and image strategies by science park management that did not appeal to potential innovative companies to become tenants; and
(c) Low institutional links between science parks, HEIs and research institutions

When science parks cease to function as "technology–supporting mechanisms", they become property-intensive rather than knowledge-intensive schemes. Fazey (1997, p. 44) described UK science parks, (including the business innovation centres housed in them), to be 'no more than pleasantly designed industrial estates, usually with an elegant pavilion style for most of the buildings'. In a similar vein, Gibson et al (1999) point out that planned or managed science cities or technopoles[82] have become financial drains needing continuous public financial support. According to Cook and Joseph (2001), the science park model are out-dated and policy-makers in the Asia-Pacific region would do better focusing on strategies that are capable of creating an environment to stimulate creativity and innovation, rather than focusing on buildings in the guise of science parks. Walsten (2004 , p.15) also pointed out that "successful research parks seem to be the exception rather the rule and subsidies spent on them are likely to be ineffective".

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[82] Gibson et al (1999) singled out a number of technopoles that include Tsukuba and Kansai Science cities in Japan, Taedok Science Town in South Korea, Pudong in China, Multi-Function Polis in Australia and the Multimedia Super Corridor in Malaysia. However they did not point out which one of these needs continuous public financial support.

The above criticism on the physical aspect of science park construction is however of limited significance. Science parks are associated with the development of new high-tech technologies, which require a conducive environment to stimulate creativity and innovation. This explains why developers of science parks pay attention to the physical aspects of the park in terms of landscape, modern architecture, facilities and equipment. Besides, science parks are competing to attract technology-based businesses, which may need such an environment and also the best talent, including new graduates. So the issue is not in the park-like setting atmosphere, nor in the modern facilities, but more importantly whether science parks can help assist commercialisation of technologies and encourage the formation of technology-based start-ups. Of course, too much attention on the physical aspects may result in the neglect of the park's support for innovation activities of tenant companies. The questions is: how many science parks behave like this, given that not all science parks qualify as failures?

Cooke (2001, p.23) recognises science parks (including technopoles) as a valuable element in a localised or regionalised innovation strategy. But he notes a major drawback in the "linear" and "hierarchical" nature of their organisation and management and the absence of any proactive effort to create linkages. As an alternative, Cooke (p.23) advocates an innovation cluster that evolves organically and in which " networking is promoted and linkages stimulated". The criticism that science park reflects a linear model of innovation is rejected by Phillimore (1999) whose study on the Western Australia Technology Park (WATP) clearly shows significant interaction taking place within WATP and between the park's resident companies and Curtin University. This prompted Phillimore (p.679) to challenge the 'one-size fits all' approach to technology transfer within technology parks. For all that, it can be argued that investment in science parks can trigger the emergence of high-tech clusters. This is apparent from the role of the Cambridge Science Park in the evolution of the Cambridge high tech region in the United Kingdom, and the experience of the Research Triangle Park in North Carolina in the U.S.

Another issue often raised is direct government involvement in building and managing science parks. Governments typically view research parks as a new industrial space, defined both by the location of the new industrial sectors and by the use of new technologies in all sectors (Drescher 1998). The role of government in promoting science parks has been quite significant in China. Xue (1995) notes, "national governments provided the funds to build infrastructure and supporting environment; offered tax incentives to attract firms to locate in these parks, and in many cases administration functions in the park are provided by government and quasi-government agencies". Currently, there are fifty-two national level science and technology parks built and operated by the Chinese government.

3.6 CONCLUSION

This chapter has examined how the science park environment is perceived to confer locational advantages to tenant firms. It explained the origin of the science park model and the diffusion of its adoption to many countries. Specifically, it has discussed both the theoretical and empirical studies on the role of science parks in (a) supporting the development of new technology-based firms (NTBFs), high-tech SMEs, start-ups and spin-offs; (b) commercialisation of research results, through joint collaborative research between tenant firms and university researchers; and (c) contribution to regional development through formation of new businesses and spillover effects. It has shown why science parks are established as an instrument under technology policy to promote cluster-driven network formation.

Despite the limitations of the model, science parks are continuously being set up all over the world. This is because building science park is not about real estate development but about creating businesses, jobs and wealth for local and national economy. More importantly, it is about creating a culture of innovation, new technologies, entrepreneurship and competitiveness. But all these come with costs and risks. Building science parks are costly which require heavy investment with long gestation period and high opportunity cost.

There is no universal model for a science park. What worked in one region might not work in another region. However there are some guiding principles that need to be followed no matter where a science park is located. Fundamental questions that need to be asked include the following: Why do we need a science park? Where to locate it? Where will the money to build it come from? Who will run it? Who should occupy it? What kind of services should it provide? Careful planning, marketing, a right mix of activities, good management support, entrepreneurial leadership and patience are some of the ingredients for success in science parks.

The science park strategy is increasingly becoming an important element of technology policy of many countries including developing countries like Malaysia. Malaysia is fast emerging as a global player in high-technology development. The economy has been successfully transformed from one that is based on primary commodities to one that focuses on high technology manufacturing. In recent years, policy in Malaysia has been gradually shifting attention towards more knowledge-based industries. Consequently, science parks are expected to play an important role in Malaysia's transition to a knowledge-based economy. The next chapter will examine the conceptual framework of the study based on the literature of science parks discussed in this chapter and innovation at firm-level in the preceding chapter.

CONCEPTUAL FRAMEWORK AND HYPOTHESES DERIVATION

4.1 INTRODUCTION

The preceding two chapters have discussed the theoretical and empirical bases of innovation at the level of the firm and the role of science parks in creating the enabling environment for nurturing the growth of technology-based firms and enhancing commercialisation of research results. This chapter will focus on specification of the hypotheses of the study including the conceptual framework within which the hypotheses will be empirically investigated.

4.2 CONCEPTUAL FRAMEWORK OF THE RESEARCH

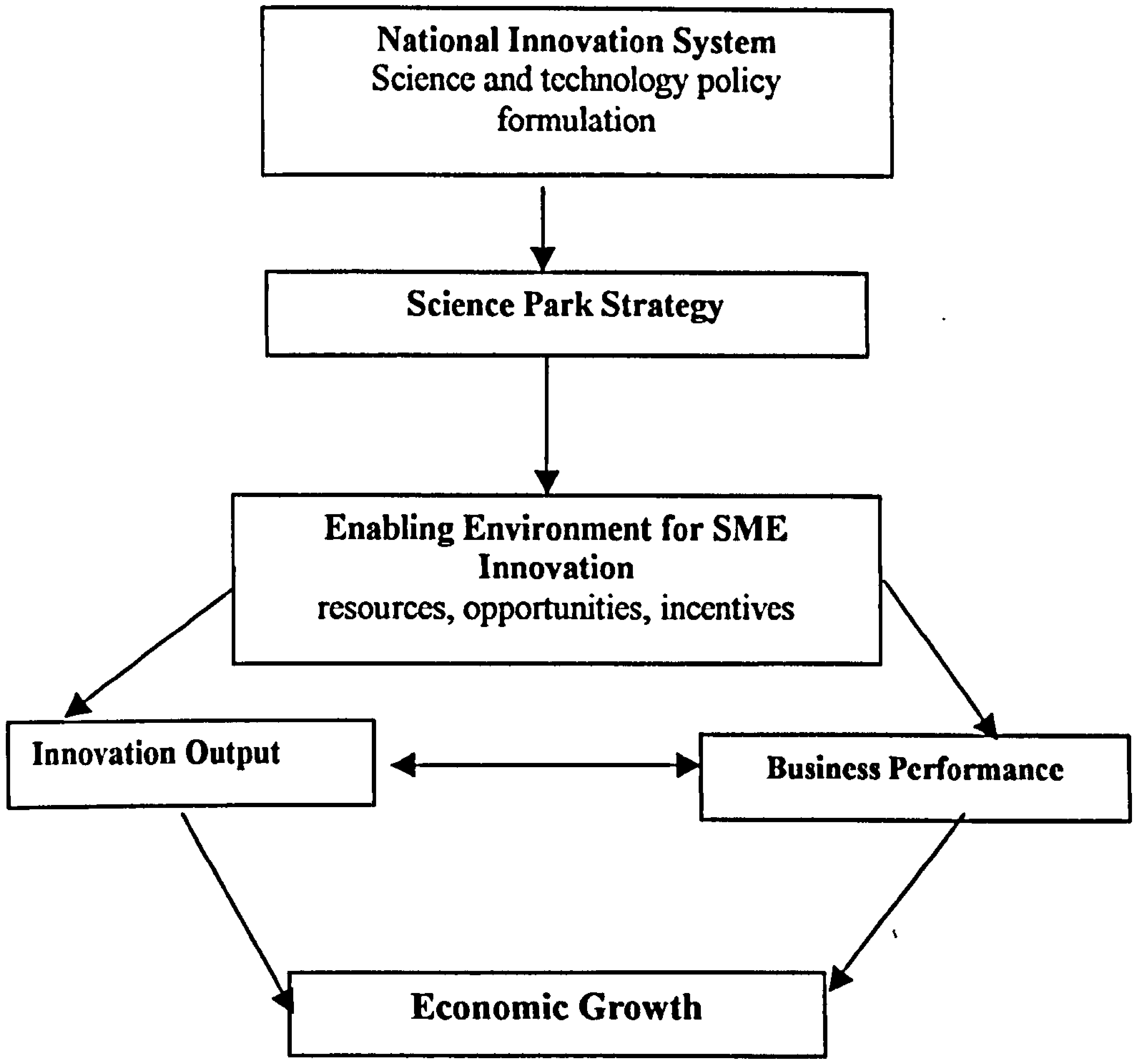
Based on our discussion of the importance of innovation for economic growth and the role of science parks in stimulating firm-level innovation in Chapters two and three, Figure 4.1 below shows a schematic outline of the conceptual framework of the study.

Science parks continue to be a popular strategy policy makers would adopt to assist the development and growth of new technology-based firms (NTBF); facilitate commercialisation of research results; and foster SME interaction and innovation. Most of the science parks around the world were built over the last twenty years. Within the conceptual framework provided in Figure 4.1, this study will investigate the effectiveness of science parks as a policy instrument to support SMEs innovation and enhance commercialisation of university research results. Specifically, the study aims to investigate the following issues:

- The significance of transfer of technology to industrial development in Malaysia;
- The effectiveness of science parks as mechanism for technology transfer from universities and research institutes to industry and factors affecting this process;
- The receptiveness of SMEs to science park-based innovation; and

- The centrality of science parks as a node in the national innovation system.

Figure 4.1: Framework of Study



4.3 FORMULATION OF HYPOTHESES

Compared with off-park firms, science park firms are generally perceived to be more innovative and to show better business performance because they have better access

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[84] The role of Stanford University Research Park in Paolo Alto, California in the evolution of Silicon Valley as the most successful high-technology cluster, became the guiding model for the development of science parks elsewhere.

[85] Other four approaches are views of prospective tenants regarding the kind of services they expect in the park; park manager's or tenant firms' assessment of the park; feedback from former tenants (who have left the park) about the support they received when they were operating in the park; and external assessment to evaluate the success of the science park ((see Hauschildt and Steinkuhler 1994).

to resources needed to develop their technological capabilities. This perception prompted researchers like Westhead (1994), Felsenstein (1994), Ferguson (1995) and Lofsten and Lindelof (2001) to find out the effectiveness of science parks in stimulating firm-level innovation by comparing the characteristics and performance of firms located in science parks with a similar group of firms found outside the parks. This form of research design involves testing a number of hypotheses that link the variables identified for the study.

Performance and growth of science park firms depend on the transformation of the inputs (e.g. R&D expenses) and throughputs (R&D collaboration) into output (innovation output). For example, Westhead (1997) used R&D inputs and R&D output to evaluate the business performance and growth of science park firms in the UK. Other factors, such as inter-firm co-operation and collaboration (including international collaboration) will be construed as throughputs (Kemp et al 2003; Klomp 2001). The success of the firm, which depends on the commercialisation of its products, is reflected by the firm's profitability and growth. The hypotheses for investigation are based on the following questions:

(i) Do science park firms invest more on research and development and engage in greater R&D co-operation and collaboration than off-park firms?

(ii) Do science parks have better access to venture capital and government grants than off-park firms?

(iii) Do science park firms show higher international orientation than off-park firms in terms of exports and international research collaboration?

(iv) Do science park firms produce greater innovation output and show better business performance and growth than off-park firms?

In order to frame the hypotheses for the study, the above four questions are further classified into six dimensions. These dimensions are (a) research and development inputs; (b) R&D co-operation and collaboration; (c) access to finance; (d) internationalisation; (e) innovation and R&D output; and (f) business performance and growth. The hypotheses for the study will be framed based on each of the dimensions elaborated in subsection 4. 3.1 to 4.3.6 below.

4.3.1 R&D Inputs

R&D is a generally risky, uncertain and often costly activity. The degree of risk associated with R&D ventures varies depending on the type of R&D undertaken - for example, whether it is for process or product development. Despite this, firms need to conduct R&D to enhance their absorptive capacity (Cohen and Levinthal 1990) and to develop their dynamic capabilities to gain competitive advantage (Teece and Pisano 1994). A firm's internal problem-solving capability can be reinforced through investments in R&D firms. High-technology firms spend 10% of their revenues on R&D compared to 3% spent by traditional firms (National Research Council 1996). Equally important is the recruitment of qualified scientists and engineers (QSE) to conduct firm-level R&D. Employment of QSEs is an indicator of the level of technological sophistication, although Westhead (1994) contests its effectiveness as a robust indicator. For technological learning and innovation excellence, SMEs need staff with science and engineering degrees (especially those with specialised knowledge in these fields) or with higher education in design (Albaladejo and Romijn 2001). SMEs would limit their ability to be innovative if they did not employ graduates and enhance the skills of their existing employees (Bowen et al 2004). Technological sophistication and capability in firms can also be reflected by the nature of R&D conducted - that is, whether the firm is undertaking significant innovation or is simply engaged in just minor product improvement.[86] High-tech firms are usually associated with radically new research.

Science parks are perceived to be an important intermediary for technology transfer between the university and the industry. This perception is based on the presumption that science parks firms conduct more R&D than off-park firms although empirical studies have produced mixed results (UKSPA 2003; Westhead 1997; Felsenstein 1994). A study by UKSPA (2003) found that there was no difference in the intensity

[86] R&D thrusts cover five types of activities categorised as product improvement, extension of existing range of products, development of complementary products, radical new research and no

of R&D investments between science park firms and off-park firms in the United Kingdom. Most of the firms located in Singapore Science Parks focus on 'development' aspect of R&D (Phillips and Yeung 2003). Also based on the selection criteria for science park admission of firms and the on nature of technology business undertaken, science park firms are perceived to conduct more R&D than off park firms. Science park firms devote more resources, financial and manpower, to R&D activities with the view to enhancing their productivity performance. This usually involves spending more on R&D, employing greater number of QSEs and purchasing the required equipment and machinery to conduct the R&D activities. Companies in science parks in the United Kingdom are reported to employ more QSEs than companies located in other areas (UKSPA 2003). Science park firms being involved in high-tech activities are also believed to conduct radically new research. This is confirmed by Westhead (1997), who, however, found that there was no significant difference in the nature and direction of R&D, between science park and off-park firms. These arguments lead to the first three hypotheses:

H1: Science park firms record higher level of R&D spending than off-park firms.

H2: Science park firms employ more qualified scientists and engineers (QSEs) than off-park firms.

H3: Science park firms are more inclined than off-park firms to conduct radically new research than off-park firms

4.3.2 R&D Co-operation and Collaboration

SMEs have limited R&D facilities or do not have in-house R&D facility due to resource constraints. They lack financial resources to employ qualified scientists and engineers (QSE) and to purchase laboratory equipment. Therefore the need arises for SMEs to engage in collaborative research activities with universities, research institutes and other firms including foreign companies. Collaboration and cooperation may also be needed to complement its internal R&D activity due to the tacit nature of knowledge involved in technology development. This kind of

particular focus. This categorisation is based on Ettlie and Rubenstein (1987) and used in the study of UK science parks by Westhead (1997) collaboration may take the form of co-operative R&D or R&D consortia, which is viewed as a distinct mechanism for the production of knowledge (Branstetter and Sakakibara 1998).

Empirical studies on R&D collaboration focusing on both the motivations for and impact of such co-operation have yielded mixed results (Negassi 2004; Fritsch and Franke 2004; Cooks and Wills 1999). In a study of French firms, Negassi (2004) found that R&D collaboration plays a minor role for achieving a large innovation output compared to size, human capital, market share and R&D; but plays greater role than that played by pure technological spillover. A study by Fritsch and Franke (2004) also confirmed the minor role played by R&D co-operation as a medium for knowledge spillover.

But Cooke and Wills (1999) found that initial non-networking SMEs reap widespread gains by engaging in collaborative innovation programmes both domestically and internationally. According to an interview-based study covering 25 biotechnology firms in the US (Bagchi-Sen 2004), R&D collaboration between firms and industry partners is important to attract investors, improve learning and quality of R&D and enhance risk management. Similarly in a study of R&D co-operation in German firms, Becker and Dietz (2004) observed that joint R&D enhances not only firms' R&D intensity and research productivity, but also the probability of developing new products. According to Fosfuri and Ronde (2003), research joint ventures (RJVs) are common among high-tech clusters because RJVs allow firms to co-ordinate their R&D investments and share the returns from such investments.

Another important aspect of R&D collaboration is the link between firms and universities. Growth companies with university links have productivity rate almost 60 per cent higher than comparable companies, which do not have such links.[87] Companies, which have links with a university, are more successful than those that do not, in terms of increased market share, improved quality of products and services and lowered costs (HM Treasury 2003). This link between firms and universities is

[87] This was reported by Coopers and Lybrands (now PriceWatersCoopers) in Trendsetter Barometer

considered fundamental to the concept of science parks (Lofsten and Lindelof 2003). That science park firms conduct more R&D than off-park firms also reflects the presumption about the existence of close interaction between science park firms and local universities (Felsenstein 1994). In the United Kingdom all science parks are located on or near universities (Siegel et al 2003). Firms in such science parks are consequently expected to have greater links with the universities concerned than firms located elsewhere. This gives them the leverage to exploit the knowledge spillovers generated by university research and teaching.

Westhead and Storey (1995) report the survival rate of science park firms having university links to be higher than off-park firms, which do not have such links. A study on Scandinavian science parks by Bengtsson (2003) shows the existence of synergies between science park firms and universities and also between the firms themselves. Based on a study of firms in three technology parks in the Basque region of Spain, Lilian and Inaki (2003) found that the firms that experience the highest growth rate are those that establish formal links with R&D-intensive universities. Mascio and Torlo (2003) found the organisational conditions in the Novum Research Park in Stockholm to be conducive for R&D co-operation between the academic and industry in activities such as consulting, patenting and co-authorship.

Vedovello (1997) also emphasised the importance of geographical proximity for greater interaction between university and science park firms as evident by both informal links, such as personal contact with academic staff, and human resource links such as student involvement in industrial projects. However, Vedovello found that the proximity factor is not important for formal links related to the research activities of the university academic community. Link and Scott (2000) also pointed out the importance of closer geographical proximity between a university and science park research partners and found that this factor influences the university to move away from basic research to applied research. But despite the above potential benefits, there are also evidences of lack of synergies between science park firms and nearby universities (Ferguson 1995; Felsenstein 1994; Dierdonck et al 1990).

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at URL:http//www./barometersurveys.com (Viewed on 25 August 2003)

Not much study has been done to date on university-industry links involving science parks firms in developing countries. However, based on the mission statements and the objectives of science parks in developing countries, it would be fair to assume that these parks encourage their tenant companies to establish links with institutions of higher education. Science park firms are supposed to be involved in high-technology activities, which may require information from external sources as well as the need to conduct some level of R&D either through in-house facility or through collaboration. Universities, especially those located near science parks, fill in this gap. (International research collaboration, involving science park firms is discussed in section 4.4.4 below).

The above reasoning on local R&D co-operation and collaboration between science park firms and universities as well as with other research institutions and firms, lead to the following three hypotheses:

> **H4: Science park firms engage in greater R&D co-operation with other firms than off-park firms (inter-firm collaboration)**
>
> **H5: Science park firms have greater links with universities than off-park firms.**

4.3.3 Access to Finance

Sufficient financial resources are crucial for sustained innovation and learning; but most high-tech small firms do not have enough funds for R&D, particularly during the first 5-6 years of their operation (Albaladejo and Romijn 2001). This is because banks usually prefer not to finance R&D activities, which are construed as "intangible, risky and uncertain", because of high variable returns, information asymmetry and inability to provide sufficient collateral (Carpenter and Petersen 2002).

In view of the difficulties small high technology firms face to access loan capital (Westhead and Storey 1997), Carpenter and Petersen (2002) suggest equity finance to be a better option for such firms. It is not perhaps surprising therefore that Mani and Bartzokas (2002) found a positive relationship between venture capital investments and growth in the high technology sector.

Hyytinen et al (2003) argue that companies with access to external finance, including government funding, invest more in R&D and tend to be growth-oriented. Science park firms, unlike off-park firms, are in an advantageous position to benefit from networking and the availability of business advisory services offered by the park management to seek government grants and incentives to conduct R&D. For example, the UKSPA helps its member science parks and their tenants to get affordable banking services, which include reduced rate of interest up to 1 per cent on borrowing, arrangement fees capped at 1 per cent and fee for technology business appraisal service at 50 per cent of commercial rate.[88]

Based on our discussion above, we generate the following hypotheses for investigation:

H6: Science Parks firm utilise more venture capital than off-park firms.

H7: Science Park firms have easier access to government research funds than off-park firms.

4.3.4 Internationalisation

Firms' motivations to internationalise their operations include seeking new overseas markets and strategic alliances such as joint ventures. SMEs are, because of resource constraints and lack of capabilities, unable to compete in international markets and therefore exporting their products and services is not a priority concern for them (Westhead et al 1998). Some studies however show that high-tech SMEs do internationaise for survival and strategic reasons (Burgel et.al 2000; Malinen and Sinervo 2000).

For the typical high-tech firm, it is a question of when rather than whether to internationalise (Burgel et.al 2000). Bengtsson and Lowegren (2000) suggest that NTBFs should engage in early stage internationalisation to face the challenges of international competition due to globalisation of technology and to be able to overcome the constraint they face due to the smallness of the domestic market. International new ventures or 'born global firms'[89] internationalise within two years of commencing their operations or even become international from inception. On the other hand, Westhead et al (1998) observed that new and small firms have neither the inclination nor the ability to become exporters. Even when small firms are capable of some degree of innovation, Wakelin (1998) argues that they would not be keen to export due partly to the high cost of entering export markets, and partly to the opportunities of competitive advantage they gain over non-innovating firms to service the local market. This view is corroborated by Lee (2004), who using Malaysian innovation survey data found a negative correlation, between the propensity to innovate and the share of exports in sales.

However, less is known about the internationalisation and export behaviour of SMEs located in science parks. As technology-based firms that exploit niche markets and the profit potential of their products, which have short life-cycles, SMEs in science parks are usually expected to seek markets beyond their national borders. Based on their study of firms located in technology centres in Ireland, Malinen and Sinervo (2000) found the entire sample of firms either actively operating in foreign markets or having increased their overseas operations, with the UK and the US as the major markets. Similarly, a survey by Bengtsson and Lowegren (2000) on science parks in Baltic and Nordic countries reveals that 58 per cent of the tenant firms have strong intent to internationalise and that 47 per cent find it very important that the parks provide services to facilitate internationalisation. However, firms located in these parks lack the vision, strategy and plan to internationalise their operations systematically. Not only do SMEs lack sufficient knowledge of international markets and customers, but they also are not competent enough to manage the internationalisation process (Tekes 2004)[90]. This knowledge deficit of SMEs would

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[88] For details see UKSPA at http://www.ukspa.org.uk/?channel_id=3496

[89] According to Oviatt and McDougall (1994. p.49), an international new venture or a born global firm is " a business organisation that, from inception seeks to derive significant competitive from the use of resources and sale of outputs in multiple countries".

[90] Tekes is the National Technology Agency of Finland, which functions as the main body for financing applied and industrial R&D in Finland.

be removed if science parks offered real support for high-tech SMEs in international co-operation, as in the case of science parks in Latvia (Stabulnieks 2002).

The above discussion on science park firms' experience of internationalisation gives rise to the following set of hypotheses:

H8: Science park firms have more international joint research collaboration than off-park firms

H9: Science park firms record higher exporting activity than off-park firms.

4.3.5 Innovation and R&D Output

According to Gellatly and Peters (1999, p.2), 'the success of an innovation depends on its commercial value'. The main innovation output indicators are patents, copyrights, innovation counts and new products and processes. Science park firms are expected to perform better than off-park firms in terms of all these performance indicators in view of their locational advantages.

Science park firms are expected to be better informed about patents and copyrights and hence to be more innovative than off-park firms. However, Westhead (1997) and Monck et al (1998) show in their respective studies that the difference between science park and off-park firms in terms of number of patents, copyrights and new products and processes launched is far from statistically significant.

Hence the following set of hypotheses for investigation in this study:

H10: Science park firms record higher number of new products/processes launched than off-park firms.

H11: Science park firms record higher number of patents granted or applied than off- park firms.

H12: Science park firms record higher number of copyrights granted or applied than off- park firms.

4.3.6 Business Performance and Growth

A firm's business objective changes over time. For example, smaller and newly established firms prefer to increase their scale of operation rather than focus on short-term profits (Nas and Leppalahti 1997). This is because securing market share will form the basis to subsequently enhance the firm's profit. Technology-based businesses, such as the Internet start-ups, view an initial public offering (IPO) as the ultimate measure of success (Chang 2004). In view of the difficulty of obtaining data on market share and IPO, the hypotheses on business performance and growth will only focus on three popular indicators, namely sales, profits and employment growth. These measures will be discussed in the next chapter on research methodology.

High-tech firms have greater orientation to engage in R&D activities to generate new products and processes compared to other group of firms. This will lead to productivity gains and business expansion reflected by an increase in market share and creation of new product markets (Rausch 1998). Innovative firms perform better than non-innovative firms in terms of sales and output (Sandven and Smith 1993), and employment (Geroski et al 1993).

Ferguson and Olofsson (2004) show how science park firms with better growth and survival rate performance than off-park firms based on an analysis of sales and employment data. UKSPA (2003) also establish the commercial performance of science park firms to be greater than that of off -park firms. In a study of science parks in Sweden, Lofsten and Lindelof (2001) found that the park milieu has positive impact on sales of new-technology-based firms (NTBFs), but their study did not find any relationship between science park location and profitability of the NTBFs.

Employment growth is another popular indicator of firm growth. The impact of innovation on employment varies across type of technology sector and between process and product innovation. For example, Harrison et al (2005) argue that process innovation displaces employment, whereas product innovation enhances employment growth.[91] High-tech SMEs grow faster and create more jobs than other type of firms in Europe (European Commission 2002) and innovative firms create more jobs than non-innovative firms (Alonso-Borrego and Collado 2001). Firms launching market novelties as well as those successfully pursuing product imitation strategies are capable of creating new jobs (Peters 2004). The superior employment performance of active R&D firms compared to non-active R&D firms have been observed in a study of Irish firms by Ruane and Kearns (1997). However, there are too few of such firms for employment growth to be significantly impacted (Kirchhoff 1994).

Monck et al (1988) did not, however, find any significant difference between the employment growth of science park firms and off-park firms. Similar a study by Wallsten (2003) found no net positive impact of science parks on job growth in the US.

In view of this experience, it would be worth the while investigating the following set of hypotheses:

H13: Science park firms record higher sales turnover than off-park firms.

H14: Science park firms record higher profits than off-park firms.

H15: Science park firms register higher employment growth rate than off-park firms.

4.4 CONCLUSION

This chapter has focused on the empirical basis of the research questions for our study comparing science park and off-park firms in Malaysia for their innovation performance. Six broad issues were identified which gave rise to a set of fifteen hypotheses. These fifteen hypotheses involved examining fifteen variables: R&D

[91] The reason for this difference is that process innovation increases productivity, which results in the use of less labour whereas product innovation creates new employment opportunities through demand enlargement effect (Harrison et al 2005).

expenditure, employment of qualified scientists and engineers (QSE), R&D thrust, collaboration with universities, inter-firm collaboration, international research collaboration, exports, access to venture capital, access to government grants, launch of new products and processes, patents, copyrights, sales growth, profit ratio growth and employment growth. In order to test these hypotheses, data on the fifteen variables were collected from a longitudinal study of technology-based SMEs located on science parks and off-park locations in Malaysia. Before discussing how these data was collected from the survey samples and the method developed to test the hypotheses, the next ctwo chapters will focus on Malaysia, which has been chosen as the location of study. While the next chapter discusses Malaysia's transition to a knowledge-based economy, the chapter that follows (chapter six), will examine the country's national innovation system, which among others highlights the role of government in promoting SME innovation expecially through the science park strategy.

MALAYSIA: TRANSITION TO A KNOWLEDGE-BASED ECONOMY

5.1 INTRODUCTION

Malaysia has emerged as one of the world's leading manufacturers and exporters of semiconductor devices, computer hard disk drives, audio and videos and room air-conditioners in the space of three decades. The Malaysian economy grew at an unprecedented rate of between 7 percent and 10 percent per annum from early 1970s to 1996. This growth rate slowed down, albeit temporarily, following the 1997 Asian Financial Crisis. This chapter will discuss Malaysia's transition from an agricultural-based economy to an economy based on high-tech manufacturing and in recent years towards a knowledge-based economy.

5.2 CHANGING ECONOMIC STRUCTURE

5.2.1 Development Success Story

In 1993, the World Bank recognised Malaysia as one of the eight highly performing Asian economies (HPAEs).[92] The impressive economic growth of 7 to 10 per cent per annum, achieved for the period 1970s to mid-1990s, which would have qualified Malaysia to become the fifth Asian Tiger, was disrupted by the Asian Financial Crisis of 1997. Even so, Malaysia still remains a development success story (Athukorala and Menon 1996). According to the World Trade Organisation (1997), Malaysia's impressive growth and economic transformation is attributed to its pursuit of open trade policies and its attractiveness to foreign direct investment (FDI) .

Prior to independence, Malaysia (referred to then as Malaya) was the single most profitable British colony with its export earnings channelled to finance British post-war reconstruction (Jomo and Rock 1998). The twin pillars of the economy - namely, rubber and tin - contributed to the economic prosperity of the country during as well as after colonial times. Since then, the economy has undergone massive transformation, first by agricultural diversification followed by large-scale industrialisation. In the words of Jomo and Rock (1998, p.5), " Malaysia's considerable export earnings ensured that it did not suffer from shortages of either savings or foreign exchange, contributing to investments, growth and structural change".

Table 5.1 shows the percentage share of Gross Domestic Product (GDP) by industrial origin from 1980 to 2000.

Table 5.1 GDP of Malaysia – percent by industry of origin

Industry	1980	1990	2000	2004
Agriculture, Fishing and Forestry	22.9	16.3	8.3	8.5%
Mining and Quarrying	10.1	9.4	10.3	7.0%
Manufacturing	19.6	24.6	34.8	31.6%
Construction	4.6	3.5	4.1	2.9%
Services	40.1	46.8	42.5	57.4%

Sources: Ministry of Finance, Malaysia, Economic Report 2000/2001
Department of Statistics, Malaysia, Bank Negara Malaysia 2004

The above transformation process brought about profound impact on the Malaysian economy and society in terms of rising living standards and related developments. This is clearly reflected in the changing composition of the country's gross domestic product (GDP), employment and trade patterns as shown in Table 5.2. In the words of the former Malaysian Prime Minister, Mahathir Mohamad,

> "In 46 years, from a country, which depended only on rubber and tin, we have become an industrial nation and have gone on to become a sophisticated and information-based industrial nation. The per capita income has almost reached US$4,000 dollars with a literacy rate of 94.1 per cent. We have also

[92] The other seven countries are Japan, South Korea, Taiwan, Hong Kong, Singapore, Thailand and Indonesia.

produced 94,320 professionals, including 13,869 doctors, 41,747 engineers and 10, 685 lawyers."[93]

Table 5.2: Major economic indicators, Malaysia, 1996-2003

Item	1997	1998	1999	2000	2001	2002	2003
GDP growth	7.3	-7.4	6.1	8.5	0.3	4.1	5.2
Per Capita GDP	5.0	-8.5	3.6	4.9	-1.8	1.9	1.9
Inflation	4.9	2.6	3.3	2.8	1.4	1.8	1.2
Unemployment	2.4	3.2	3.4	3.1	3.6	3.5	3.5
Money supply (M2)	22.7	1.5	13.7	5.2	2.2	5.8	11.1
Merchandise exports	0.7	-7.3	17.1	17.0	-10.3	6.1	23.0
Merchandise imports	1.2	-26.6	13.5	26.3	-10.3	8.1	5.4
Current account balance/GDP	-5.9	13.2	15.9	9.4	8.3	7.6	13.0
Debt-service ratio	7.4	7.0	6.3	5.6	6.8	6.7	6.1

Source: Asian Development Bank Outlook, 2003 and 2004

Jomo and Edwards (1993) identified three phases in the Malaysian industrialisation process: import substitution industrialisation (ISI) from 1957 to late 1960s; export-oriented industrialisation (EOI) from late 1960s to early 1980s; and ISI involving selective heavy industrialisation without abandoning EOI in the mid 1980s. This was followed by high-tech manufacturing, from mid 1980s to mid 1990s, after which the emphasis shifted to knowledge-based industries.

The economic transformation process is also reflected in the changing pattern of the country's labour force (see Table 5.3). Industrialisation and urbanisation resulted in rapid rural-urban migration. The share of the labour force in agriculture declined from 26.0% in 1990 to 12.0% in 2005, while its share in the manufacturing sector increased from 19.9% to 29.5% in 2005. In recent years, the service sector has emerged as the major contributor to employment, its share rising from 47.2% in 1990 to 50.0 % in 2005.

[93] These remarks were made by the then Malaysian Prime Minister, Dr. Mahathir Mohamad while tabling the Mid Term Review of the Eight Malaysian Plan (2001-2005) in the Malaysian Parliament on 30 October 2003. The full content of the speech can be accessed at the website of the Economic Planning Unit, Prime Minister's Department at http://www.epu.jpm.my

Table 5.3: Employment by Sector in Malaysia from 1990-2005

Sector	1990	1995	2000	2005
Agriculture, forestry, livestock & fishing	26.0	18.7	15.2	12.0
Mining & Quarrying	0.6	0.5	0.4	0.4
Manufacturing	19.9	25.3	27.6	29.5
Construction	6.3	9.0	8.1	8.1
Electricity, Gas & Water	0.7	0.8	0.8	0.8
Transport, Storage & Communication	4.5	4.9	5.0	5.1
Wholesale & Retail Trade, Hotels & Restaurants	18.2	16.5	17.1	17.3
Finance, Insurance, Real Estate & Business Services	3.9	4.7	5.5	6.0
Government Services	12.7	11.1	10.6	9.8
Other Services	7.2	8.5	9.7	11.0
Total	**100.0**	**100.0**	**100.0**	**100.0**

Source: Asian Development Bank Outlook, 2003 and 2004

5.2.2 Role of Government

The Malaysian government has been playing an active interventionist role in the economic development of the country. The occasion of inequalities between regions and the various ethnic groups in terms of income distribution, employment, and educational opportunities has prompted the government to introduce policies such as the New Economic Policy and National Development Policy involving affirmative action plans to correct the imbalances. Economic-based policies and plans such as the Privatisation Policy, Industrial Master Plan and National Agricultural Plan were also introduced to overcome structural problems of the economy. In recent years, the Knowledge Economy Master Plan has been introduced to assist the transition from production-based economy to one that is knowledge-based. These policies and plans are ultimately aimed at helping the country achieve its Vision 2020 that is, the vision to join the category of industrially developed countries by the year 2020. However, the implementation of these plans are not without drawbacks due to lack of co-ordination, wrong focus and approach and other barriers.

The racial riots of May 13, 1969 and the ensuing tension and instability in the domestic socio-political environment prompted the government to introduce an affirmative policy called the New Economic Policy (NEP) in 1970. Strategies and programmes under this policy were developed and implemented under the first ten year Outline Perspective Plan I (OPP I) which also included the Second Five Year Malaysian Plan (2MP) beginning 1971. The NEP involved a two-pronged strategy: to restructure society with the view of eliminating the identification of race with economic function and eradicate poverty irrespective of race. The focus of the policy was to give the Malays (Bumiputras) a larger share of the country's economic wealth by increasing their holdings of corporate assets and creating a class of Bumiputra wealth (Ariff et al 1998). The entire government machinery was involved in the implementation of the policy, which greatly influenced the pattern and trends of the nation's economic development from 1971-2000. As noted by Rasiah and Shari (2001, p.75), "the NEP, however distressful it was to certain groups, was a conjunctural result of the socio-political events of the 1960s. Its implementation required the state to be actively involved in the economy".

However, the policy did contribute towards preserving racial harmony, political stability and national unity. The State got actively involved not just to pursue growth but for equity and structural transformation in an ethnically diverse society (Bahari et al 1996). Thus, the overriding objective of this affirmative policy was to ensure peace and stability, which are vital for creating a conducive business environment. However, the NEP did bring about adverse effects to the economy (Rasiah and Shari 2001) by causing inevitable distortions to the functioning of a free market economy.

The deep involvement of the government in the economic management of the country can be better explained by the existence of government-linked companies (GLCs). There are currently forty public-listed GLCs, accounting for 5% of the total number of companies in the Bursa Malaysian (formerly the Kuala Lumpur Stock Exchange) and 34% of the total market capitalisation, estimated at RM232 billion (US$61 billion), more than half of Malaysia's GDP. This, according to ADB (2004, p.50), has led to "politicisation and inefficiency in policy making and management". Investments in these GLCs are held by the Government investment arms, such as Khazanah Nasional Bhd, Permodalan Nasional Bhd (PNB), Employees Provident Fund (EPF) and Petroliam Nasional Bhd (Petronas).

5.3 ROLE OF FOREIGN DIRECT INVESTMENT

Foreign capital, in general, and FDI, in particular, played a crucial role in the structural transformation of the Malaysian economy (Kiong and Jomo 2001; Athukorula and Menon 1996). While in the early 1960s, the bulk of the FDI went into plantation agriculture, dredge mining and international trade, the period between 1971and 1979 witnessed the emergence of the manufacturing sector as a major recipient of FDI (Kiong and Jomo 2001). In fact, before the Asian Financial Crisis of 1997,[94] Malaysia was acknowledged as one of the leading recipients of FDI in the developing world (see Table 5.4). FDI inflow into Malaysia increased ten-fold between 1987 and 1991 being the fastest rise compared to any other ASEAN member countries. Also, between 1991 and 1997, Malaysia was the best performer in terms of FDI inflow among the ASEAN countries (Asian Development Bank 2000). More than 70% of the country's inward FDI went to the states of Selangor, Penang and Johor in Peninsular Malaysia, particularly in the electrical and electronic (E&E) industries.

Overall, Malaysia's success in attracting FDI is attributed to a conducive investment climate, created by the pro-business policy of the Government, excellent communications and transport facilities, skilled labour force and a package of incentives that include tax holidays and import duty exemptions. Both external economic conditions and internal investment climate influenced the FDI inflow; and the impact of these factors varied over the period. For example, the country witnessed a rapid rise in FDI inflow in the mid-1980s due to the relocation of Japanese investment to cheaper production location like Malaysia to counter the effects of Yen appreciation following the Plaza Accord of 1985 (Abidin and Fah 2003; Athukurola and Menon 1996). Huang (2002) noted that Malaysia depended on labour-intensive FDI to develop its export capabilities in the 1970s and 1980s.[95]

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[94] The crisis was attributed to a number of factors including the presence of policy uncertainty (Krause 1998) and the reckless borrowing, panic and 'herd behaviour' amongst investors and the subsequent contagion effect (Yan 1998). Immediate policy response in Malaysia to minimise the effects of the crisis worsened market confidence resulting in high offshore interest rates and price volatility in the stock market (Kadir 1999).

Table 5.4: FDI flow to Selected Asian Countries 1996-2003 (US$ million)

Country	1997	1998	1999	2000	2001	2002	2003
Malaysia	6788	2708	2473	1762	287	1299	1104
Indonesia	4525	-356	-2745	-4551	-5877	-7066	-2100
Philippines	1113	1592	608	1348	1953	1733	161
Singapore	1281	4695	8551	11919	-2025	2030	5873
Thailand	3298	7360	5742	3372	3540	841	954
Vietnam	1900	669	358	459	273	397	622
S. Korea	-1605	5221	10598	10186	4863	3679	4806
Taiwan	-2995	-3614	-1494	-1773	-1371	-3441	-5226
China	41674	45463	40319	40715	46878	52743	53510
India	3557	2480	2167	3272	4741	3611	3585

Source: Asian Development Bank (2003)

The largest foreign investor in Malaysia is the United States. Other major investors are Japan, Taiwan and Singapore. The bulk of the FDI goes into the electrical and electronics and oil and gas sectors, which together accounted for 75 % of total FDI inflow into Malaysia in 1999. The United States has invested RM83.7 billion in the last twenty-five years with almost 72 per cent of the investments going to the oil and gas and petroleum sector, followed by the electronics and electrical sector (see Table 4.5). However, in line with global FDI decline, US investments in Malaysia fell from RM3.411 billion in 2001 to RM2.182 billion in 2003 (ADB 2003).

[95] Quoted by Lagace (2002).

Table 5.5: U.S. Accumulated Investment in Malaysia

Industry	Estimated Accumulated Investment (RM million)
Oil & Gas/Petroleum	52,598
Electronics & Electrical	27,289
Aerospace	666.0
Pharmaceutical	104.6
Consumer Products	269.6
Automotive	65.4
Other Manufacturing	1,152
Financial Services	10,767
Services/Distribution	1,515
Total Accumulative Investment (less financial services sector)	83,660

Source: Based on AMCHAM Research 2002[96]

Malaysia is gradually losing its large-scale, low cost manufacturing advantage to other countries in the region. The biggest rival is China, which has become the 'vacuum cleaner' for FDI due to its low labour costs, huge domestic market and world class manufacturing capabilities. Thailand is another country that is fast catching up in terms of FDI attraction. Following the Asian Financial Crisis of 1997 and the rise of China as a more favoured destination for FDI, the flow of FDI into Malaysia has declined. For example, FDI plunged from US$,7.3 billion in 1996 to US$ 2.7 billion in 1998 and dropped further to US 1.1 billion in 2003 (Asian Develoment Bank 2004). The Global Business Policy Council (2002) reported that Malaysia's investment attractiveness is dropping due to leadership transition uncertainty, terrorism fears and the complex politics-business relationship existing in the country.[97] However, with the exception of the terrorism factor, the other two

[96] The latest figures show that American companies have invested about US $106.8 billion in the last twenty-five years and currently employ 124, 000 workers mainly in the electrical and electronics industry and services sector. This information was provided by Tim Garland, President of American Malaysian Chamber of Commerce (Amcham) and reported in the local news paper The Star on 16 January 2004 under news item, 'Amcham: New US investments getting smaller'. Amcham is the business association representing the interests of American companies operating in Malaysia.

[97] How could one explain the emergence of China as a favoured destination for FDI despite being ruled by a communist regime, prevalence of a weak IPR and the on-going conflict between China and Taiwan, (with China threatening to invade Taiwan if the latter pushes for independence). The fact is that investors are attracted to China's huge domestic market and low cost labour and therefore willing to take risks on other uncertainties.

factors have been present since the 1970s, and yet Malaysia was one of the largest recipients of FDI amongst developing countries prior to the 1997 Asian Financial Crisis.

Nevertheless the shortage of high-skilled labour and increasing labour costs are of great concern to Malaysian policy makers. Already a number of MNCs have shifted their operations to China due to China's fast improving competitive position, though this is not taking place at an alarming rate. The recent slump in FDI resulting from China becoming a more favourable destination for FDI could adversely affect the growth of the Malaysian economy. In view of this, efforts should be intensified to attract more FDI to Malaysia. Chowdhury and Mavrotas (2003) suggest that the emphasis should be on the overall role of growth as a crucial determinant of FDI taking into account other factors such legal and regulatory framework, quality of human capital, tax systems as well as the role of ICT. However Hansen et al (2003) advise policy makers to pursue a policy of creating a growth enhancing environment to stimulate FDI which could have long term impact on the economy. This is precisely what the Malaysian government is doing with policy emphasis now shifting more and more to the knowledge-based and service sectors and also to SME development. This aspect will be dealt with later in this chapter.

5.4 TRADE AS ENGINE OF GROWTH

Malaysia has a long-term commitment to an open and liberal trade and investment policy regime (Athukorala and Menon 1996). At present, though, it is less open and more restrictive than what it aspires to be. But still, it is ranked as the 17th largest trading nation in the world with the electronics and electrical sector accounting for almost half of the exports (Matrade 2005). The external trade is estimated to be twice the size of the country's gross domestic product (GDP). Total trade increased from RM 714.14 billion in 2003, to RM 880.37 billion in 2004. This reflects an increase of 22.9%, which is the largest since 1995 (Matrade 2005).

Malaysia's exports grew from RM49.3 billion in 1980 to RM398.9 billion in 2003, with the country's share of global exports increasing from 0.64% in 1980 to 8.0% in 2003. Total merchandised exports increased by 20.5 % to RM480.72 billion in 2004. This increase was twice the growth rate forecast for developing countries by the International Monetary Fund (Matrade 2005). The major export markets are Asean countries, the United States, European Union, Japan and Hong Kong. The success of Malaysia as a major exporting nation is attributed to a conducive macroeconomic climate with ASEAN as a pan-regional market as well as FDI policy and export incentives (Boston Consulting Group 2004). The promotion of external trade is entrusted to Malaysian External Trade Development Corporation (Matrade) under the Ministry of International Trade and Industry (MITI).[99] The changing export structure from 1960 to 2000 is shown in Table 5.6.

Table 5.6: Malaysia Export Structure 1960-2000 (% of total exports)

Export	**1960**	**1970**	**1980**	**1990**	**2000**
Manufactured goods	8.5	11.9	21.6	59.3	85.6
Crude oil & Gas	4.0	3.9	23.8	16.2	5.8
Palm oil	1.7	5.1	10.3	6.2	2.7
Forestry	5.3	16.3	14.1	8.9	1.0
Rubber	55.1	33.4	16.4	3.8	0.7
Tin	14.0	19.6	8.9	1.1	0.1
Others	7.9	9.8	4.9	4.5	4.1
Total Exports (RM million	**3,633**	**5,163**	**30,676**	**79,646**	**373,307**

Source: Note: Figures for 1980 and 1990 as well as data for manufactured goods and Crude oil for the year 1960 were obtained from Jomo and Rock (1998) based on Bank Negara Malaysia Annual Report.

Malaysia's imports increased by 25.8 % from RM 317.75 in 2003 to RM 399.65 billion in 2004. This increase is mainly due to the increase in the imports of

[99] Matrade was set up in 1993 as a focal point for Malaysian exporters and foreign importers to source trade related information. Its functions include formulating and implementing export marketing strategies and trade promotion activities, undertaking commercial intelligence and market research and organise training programmes to enhance international marketing skills for Malaysian exporters. Matrade has set up offices in twenty-four strategic locations abroad to assist Malaysian exporters and foreign buyers.

intermediate (71.9 %) and capital goods (13.9%0 to sustain high levels of industrial activities and capital formation from investment initiatives.[100] The major imports are electrical and electronics products, machinery, appliances and parts, and chemicals and chemical products.

Malaysia is under increasing pressure from advanced countries and the World Trade Organisations (WTO) to have more open trade policies. Trade liberalisation and the emergence of other countries like China as favoured destination for FDI could alter the competitive position of Malaysia in manufacturing activities and the export of various products. As Malaysia does no longer have the low labour cost advantage to be able to compete with other countries in the region, particularly China and India, prospects for its future growth and its place in the international market as a competitive player largely depend on its ability to increase its skilled labour force, enhance indigenous R&D capabilities and diversify exports and export markets (Siew-Yean 2001).

5.5 TRANSITION TO KNOWLEDGE ECONOMY

In line with the stages of competitive development suggested by Porter (1990), Malaysia has embarked on ambitious programmes to become a knowledge-based economy driven by innovation. The rapid growth in the information and communication technologies (ICT) and the Internet revolution has provided opportunities and challenges to the Malaysian economy. The country can no longer compete with emerging low labour cost countries like China and India, which are becoming favoured destinations for FDI. Hence, the recent policy shift in Malaysia towards new sources of growth that will transform Malaysia, into a knowledge-based economy. This will see Malaysia find its own niche in the global market, through high value added manufacturing and services, including the development of design and R&D capabilities in new and emerging technologies such as ICT, biotechnology and photonics. But this requires the right policy framework and strong links between government, industry and the universities; and the government has seen the need for

[100] These figures and information were based on Preliminary Release on Malaysia External Trade

this. Moreover, both the Federal government and the State governments have been giving priority to the development of the ICT sector in Malaysia. In the words of the Chief Secretary to the Government,

> "It is no secret that Malaysia hopes to leapfrog conventional development stages through the extensive application of ICT with information and knowledge serving as the primary factors of change and value creation. Knowledge-based development with the help of ICT has become our development imperative. Hence our preoccupation with everything IT or ICT".[101]

A massive project to emulate the success of the Silicon Valley of California has been launched near Kuala Lumpur in 1996 by the Federal government (Malairaja 2003). This project known as the Multimedia Super Corridor (MSC) aims to leapfrog the nation into a knowledge-based economy within twenty years. The MSC will be further examined when discussing the Malaysian national innovation system in the next chapter.

An example of initiative at the state-level is the Knowledge-Information Communications Technology (K-ICT) blueprint launched by the Penang State government to make Penang a smart island by 2010.[102] To achieve this objective, five strategic efforts have been identified: k-worker development, connectivity, electronic good governance, e-economy and digital equity. The blueprint will help Penang increase its connectivity from current level of 85% to 100% by 2005 (The Star 2002).

Statistics dated 3 February 2005 issued by MATRADE at URL: http://www.matrade.gov.my

[101] This remark made by Abdul Halim Ali, the then Chief Secretary to the Government of Malaysia, appeared in his forward message to NITC (2000), *Access, Empowerment and Governance in the Information Age,* Building Knowledge-Based Societies Series, Volume 1. National Information Technology Council (NITC), Malaysia.

[102] This K-ICT blueprint launch was reported in local daily, the Star on 19 September 2002. As the name suggests, k-worker development refers to human resource training. The electronic good governance is to create a completely networked e-government. E-economy will focus on the use of e-commerce and e-business as well as enhanced value-added business.

Apart from ICT, other emerging technologies that will feature prominently in the government programmes include aerospace, biotechnology, photonics and other new technologies. Malaysia has the potential to emerge as a leading biotechnology hub as the country is endowed with rich diversity of flora and fauna and vast experience in agricultural (oil palm, rubber and rice) and forestry sectors.

5.6 CONCLUSION

The discussion in this chapter has focused on Malaysia's economic transformation and its transition to a knowledge economy. Malaysia's transition to a knowledge economy will however greatly depend on the ability of the country to harness the creative and innovative capacity of Malaysians and provide the environment for risk-taking and entrepreneurship. However, lack of investment in R&D is hampering the country's transition to a knowledge-based economy. Other factors that could impede this transition include shortage of skilled manpower and entrepreneurial abilities. Malaysia's competitiveness ranking had dropped from 16 in 2004 to 28 in 2005. This has become a matter of concern to policy makers given the country's strong export performance including high-tech exports, high FDI inflow and low inflation.

Consequently, the government has adopted the NIS (national innovation system) framework to review existing science and technology policy and evolving strategies to strengthen the country's S&T capabilities through support to local firms, especially small-and-medium enterprises (SMEs). The Malaysian NIS, including science parks, will be explored in the next chapter.

NATIONAL INNOVATION SYSTEM OF MALAYSIA

6.1 INTRODUCTION

Malaysia's impressive growth in high-tech exports and gross domestic product has been achieved without the development of strong research capabilities (Narayanan and Wah 2000). This situation begs the question about prospects for the sustainability of the long-term growth of the economy. In recent years, policy in Malaysia has shifted towards emphasising the need for technological capability development, as discussed in the preceding chapter.

Policies to promote technology development in Malaysia stem from the adoption of the linear model of innovation based on formal R&D (Konstadakopulos 1999). But this simplistic view of innovation has changed in recent years following the government's decision to use the national innovation system (NIS) framework as the basis for formulating the Second Science and Technology Policy in 2002. Section two will give an overview of Malaysian NIS focusing on the role of organisations and institutions. Section three will focus on measures to promote technology development and identify sectors that have attained some level of technological progress. Reasons why Malaysia has not achieved the desired level of technological capabilities despite attempts to emerge as a knowledge-based economy will also be highlighted. The factors affecting the effectiveness of the NIS will be explained in section four. Some concluding remarks in will be made in section five.

6.2 MALAYSIAN NIS: AN OVERVIEW

In order to strengthen the NIS, the government recently launched the National Innovation Agenda with focus on research that has commercialisation potential, is based on Malaysia's competitive advantage and would harness the country's intellectual capital in science and technology. This involves upgrading the components of the Malaysian NIS, which include the financial infrastructure, R&D

facilities, technology acquisition systems, human resource development, public awareness in science and good governance with the government playing a co-ordinating and facilitating role.

6.2.1 Policy Formulation and Implementation

Prior to mid-1980s, Malaysia did not have a formal policy to incorporate strategies and programmes to spearhead the S&T agenda despite being involved in ambitious industrialisation programmes. The various agencies involved in S&T capacity building, ranging from infrastructure development and R&D to human resource development, were pursuing their own missions. Even trade and investment policies were implemented in isolation (Mei Ling and Yong 1997). This lack of co-ordination in policies and action plans was not favourable for S&T development in the country (MOSTE 2002).

The turning point emerged when the first S&T policy was introduced in 1986 to provide a broad framework with objectives to accelerate economic growth based on industrial development. According to MOSTE (2002), the S&T policy was also designed to support other policies such as the National Industrial Masterplan I, the Natural Agricultural Policy and other related sectoral policies.

A number of Ministries are involved in the policies and strategies related to science and technology (S&T), all responsible to the Cabinet, which is the highest S&T policymaking body. The Ministry of Science, Technology and the Innovation (MOSTI) co-ordinates and implements S&T development programme as well as provides research funding to public research institutes (PRIs), and to private sector firms to develop new technologies in collaboration with local PRIs and foreign institutions and companies. In formulating policies, strategies and programmes, MOSTI is advised by the National Council for Scientific Research and Development (NCSRD).[103]

[103] This Council is chaired by the Chief Secretary to the Government who is also an ex-officio member and Secretary of the Malaysian Cabinet. The Secretariat for NCSRD is based at MOSTI and is headed by the Ministry's Secretary General. Members of the NCSRD include the secretary-general of the Ministry of Trade and International Trade (MITI) and of the Ministry of Education, vice-chancellors of leading local public universities and selected captains of industry.

The Ministry of International Trade and Industry (MITI) formulates policies on industrial and technology development, including R&D incentives. The Malaysian Industrial Development Authority (MIDA), an agency under MITI, spearheads the nation's industrialisation programmes, including regulating international technology transfer involving Malaysian companies. Similarly, another agency, the Small and Medium Industry Development Corporation (SMIDEC) promotes the development of Malaysian SMEs and co-ordinates programmes to assist technology development of this sector.

The Malaysian Technology Development Corporation (MTDC) of MITI channels venture capital for start-ups and funds to small and medium industries for commercialisation of R&D and for acquisition of new technologies from abroad. The Standards Industrial Research Institute of Malaysia (SIRIM) is responsible for assisting product development and innovation in Malaysian firms. Another important government agency is the Malaysia Industry-Government Group for High Technology (MIGHT)[104] whose activities include identifying opportunities in new and emerging technologies and assisting the research community to undertake R&D

6.2.2 Public Sector R&D

There are two sources of funding for research conducted by thirty-six public research institutes (PRIs) in Malaysia. (See Appendix III for the full list of the PRIs). The main one is the research funding provided directly by the Ministry of Science, Technology and Innovation (MOSTI) through the programme called the Intensification of Research under Priority Areas (IRPA).[105] The other source of

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[104] MIGHT was launched in 1993 under the jurisdiction of the Office of the Science Adviser in the Prime Minister's Department and became by a company by guarantee (functions as a non-profit entity) in 1994. Its main role is to undertake prospecting activities to harness science and technology through business-driven confidence building.

[105] IRPA was launched during the Fifth Malaysian Plan (1986-1990) but funding commenced in 1988. Any research activity seeking funding under IRPA must adhere to one or more of the criteria established. The research project should: be of high national priority; address the needs of the industry; encourage collaborative efforts among research institutions; and enhance R&D linkages between the private and public sectors.

funding is the contract research bodies made of government bodies and non-governmental organisations including foreign entities.

The government has allocated RM 2.3 billion since 1991 to fund various projects under IRPA. An evaluation of these projects conducted by the Universiti Putra Malaysia (UPM) has identified a number of shortcomings in the implementation of IRPA. These include research projects that are not industry-oriented; lack R&D project monitoring; and are characterised by bureaucratic delays in the disbursement of the research funds to the researchers. The government recognises the need to focus on expanding the R&D capacity to support technological development. Consequently, the Second National Science and Technology Policy in 2002 sets out the following objectives to enhance R&D capability:

- To increase R&D spending to at least 1.5 % of GDP by the year 2010 from the 0.5 % in 2000; and

- To achieve a competent work force of at least 60 RSE (research scientists and engineers) per 10,000 labour force by year 2010 from that of 15 RSEs in 2000.[106]

Attainment of these objectives will, however, depend on the ability to increase student enrolment in science education up to tertiary level, from the current arts to science ratio of 70:30 to 60:40 in favour of science. It will also depend on future GDP growth to permit increased allocation to R&D. Any external shock like the 1997 Asian Financial Crisis in the future could have adverse effects on the implementation of the S&T policy.

6.2.3 Private Enterprises

According to official records, there are about 620, 000 private enterprises, including also foreign companies. Of these, more than 90% are small-and-medium

[106] RSE refers to research scientists and engineers.

enterprises.[107] There are an estimated 52,000 SMEs (about 10% of all SMEs) involved in manufacturing activities. As stated in chapter one, there is no national database on the number technology-based SMEs in Malaysia, although a number of organisations maintain registers of many such businesses. However, many SMEs have become component manufacturers for MNCs especially in electronics and automotive sectors. They have also grown to become exporting companies.

There are about 4,500 foreign companies including MNCs from all over the world doing business in Malaysia. The inflow of FDI led to an increase in the number of foreign companies mostly subsidiaries of foreign multinationals dominating the electronics sector. For example, American companies have invested about US $106.8 billion in the last twenty-five years and currently employ 124, 000 workers mainly in the electrical and electronics industry and services sector.[108] Foreign firms have also formed joint ventures with Malaysian enterprises in a wide spectrum of business sectors. These include JVs in manufacturing, retail and distribution, consultancy, banking and financial and R&D.

6.2.4 Educational Institutions

Skilled labour is an important driver of productivity in the Malaysian manufacturing sector (Mahadevan 2001). In view of this human resource development (HRD) has been the focus of policy in the various five-year development plans implemented since mid-1960s. The government introduced the Action Plan for Industrial Technology Development (APITD) in 1990, which among provide for the setting up of private universities by local private enterprises and allowing foreign universities to set up branch campuses in Malaysia and establishment of a human resource development fund.

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[107] Hashim and Sulaiman (1996) point out the changing definitions of SME, different agencies adopting different criteria to define a SME and high number of government ministries and agencies involved in SME support programmes.

[108] This information was provided by Tim Garland, President of American Malaysian Chamber of Commerce (Amcham) and reported in the local news paper The Star on 16 January 2004 under news item, 'Amcham: New US investments getting smaller'. Amcham is the business association representing the interests of American companies operating in Malaysia.

There are currently eleven public universities and fourteen private universities in Malaysia. Despite massive investments to provide education up to tertiary level, the country is facing serious problems in human resource development. Graduate unemployment is on the rise. For instance, by March 2005, the number of unemployed graduates had reached 80,000 (New Straits Times 2005). This appears somewhat of a paradox considering the fact that there are almost two million foreign workers in Malaysia, but it reflects the extent of mismatch in the demand for and supply of skills in Malaysia and hence the mismatch between university education and training and needs of the industry. In view of this, universities have been urged to offer courses that are relevant to the needs of the industry.

6.2.5 Financial System

Banks and financial institutions are generally risk averse to SME activities, particularly more so in financing risky and uncertain activities like R&D and innovation. In view of this, Bank Negara Malaysia (BNM), the country's central bank introduced various measures to improve SMEs access to finance: These include establishing:

- SME Special Unit in May 2003 to provide financial advisory services to SMEs and assist them obtain information on financial schemes available;
- Debt resolution mechanism in October 2003 to facilitate loan restructuring of SMEs constrained by NPLs; and
- Special funds such as Fund for Small and Medium industries (FSMI) and New Entrepreneurs Fund;

6.2.6 Regulatory and Legal Framework

The intellectual property rights (IPRs) regime in Malaysia is governed by four laws passed by the Parliament. These are the Trade Description Act of 1972, the Patent Act of 1983, the Copyright Act of 1987 and the Industrial Design Act of 1996. The

Ministry of Domestic Trade and Consumer Affairs (MDTCA), is responsible for the enforcement of these intellectual property laws.[109]

MDTCA has so far registered 6,000 patents, 18,000 copyrights and 1,000 industrial designs. The official record also shows that 96% of the 6,000 patents belong to intellectual property owners from abroad. Determining the authenticity of patent application is a time consuming task as it may require up to five years for a patent to be registered. This and lack of mechanism for IPR enforcement are among the many factor affecting the Malaysian NIS.

Another aspect is the importance of creating and maintaining a business environment that allows competition to thrive. As discussed earlier, the various economic policies implemented since independence have helped transform Malaysia into a high-tech manufacturing country. New policies, such as those aimed at developing the ICT and biotechnology sectors, as well as SME-specific policies, are being introduced to assist Malaysian companies achieve global competitiveness.

6.3 TECHNOLOGY DEVELOPMENT MEASURES

In line with the emphasis on knowledge-based economy, the government has introduced various programmes and projects to promote the development of technology-based businesses. These include providing research funds to universities and business enterprises, encouraging inflow of foreign technology, provision of technological infrastructure and venture capital through the setting up of the following: (a) Multimedia Super Corridor (MSC), (b) science parks and technology incubators, (c) support for technology-based SMEs and (d) promotion of venture capital and establishment of Mesdaq.[110] Of all the initiatives, the Multimedia Super

[109] The Intellectual Property Division of MDTCA receives applications for registration of six categories of intellectual property: patent, copyright, brand, geographical markers, integrated circuit board designs and industrial designs. The applications for these categories come from both local and foreign applicants.

[110] MESDAQ function as function as a stock exchange for high growth companies and local Technology-based companies, like the Nasdaq of New York

Corridor is the most ambitious in terms of physical scale, infrastructure development and investment involved. These initiatives are discussed below.

6.3.1 Funding for Research and Infrastructure

Table 6.1 shows that the Government has allocated substantial amount of money for science and technology development under the five-year development plans since 1991 .[111] The largest allocation is for the funding of S&T infrastructure, which involves building science parks and incubators. The second biggest allocation goes for direct research funding programme called the Intensification of Research for Priority Areas (IRPA) discussed earlier. Under this programme, 36 public research institutes (see Appendix III) including universities are provided funds to undertake both basic and applied research.

Table 6.1: Development Allocation for Science and Technology 1991-2005 (RM million)

Programmes	*Sixth Plan 1991-1995*	*Seventh Plan 1996-2000*	*Eight Plan 2001-2005*
Direct R&D	629.0	755.0	1,000.0
Malaysia MIT Partnership Programme	-	35.0	-
Technology Development for SMIs	-	58.0	30.0
Technology Acquisition Fund	-	118.0	250.0
Commercialisation of Technology	-	208.0	610.0
S&T Infrastructure	807.7	1,496.7	2,818.9
Total	**1,436.7**	**2,611.2**	**4,708.9**

Source: Adapted from GoM (2001)

6.3.2 Technological Infrastructure

Infrastructure development and provision of venture capital featured prominently in the government's support for local technological development. These include the establishment of science and technology parks, technology incubators and the Multimedia Super Corridor. These physical development initiatives involve offering affordable office spaces and access to modern facilities (e.g. telecommunications), linkages to researchers, networking and venture capital funding. The first science park, Technology Park Malaysia, was set up in 1988 but was housed in a small building until a huge park was developed in Bukit Jalil in Kuala Lumpur. Since then the number of science parks has grown to four and that of incubators to five, as shown in Table 6.2.

Table 6.2: Science Parks and Technology Incubators in Malaysia

Name/Location of Science Park	Size (acre)	Year set up	No. of firms	Technology Focus
Technology Park Malaysia Kuala Lumpur	750	1995	120	ICT, biotechnology
Kulim Hi-Tech Park Kulim, Kedah	630	1996	33	High-tech manufacturing
Selangor Science Park	478.4	2001	n.a	
Technovation Park UTM Campus, Skudai, Johor	130	1995	21	High tech activities
UPM -MTDC Technology Incubator Centre One	18	1997	32	IT and multimedia
UKM-MTDC Smart Technlogy Centre	6	1999	10	Biotechnology, pharmaceuticals
UTM -MTDC Technology Innovation Centre One	n.a	1999	n.a	Advanced electronics, advanced manufacturing
MSC Central Incubator	n.a	2000	35	IT and multimedia

Apart from science parks, technology incubation centres[112] have also been set up within local universities to nurture the growth of small high-tech companies and start-ups. These include three such centres set up by Malaysian Technology Development Corporation (MTDC) and the MSC central incubator set up by Multimedia Development Corporation.[113] The biggest incubator is the UPM-MTDC Technology Incubator Centre One, based at University Putra Malaysia, which caters for 32 companies. The MSC central incubator is home to 20 start-ups.

[111] The first five-year plan began in 1965. S&T for the first time featured as a separate chapter in the plan document in the implementation of sixth plan.

[112] Md. Nor (2000) describes a technology incubator as technology development cluster (TDC) and defines this cluster as an incubator established within a university to allow companies within specific industries such as biotechnology and multimedia to operate in close collaboration with lecturers and scientists.

The biggest project ever undertaken is the Multimedia Super Corridor (MSC) launched in 1996 to promote and develop ICTs and multimedia activities. The MSC is based on the Silicon Valley model to propel the country into a knowledge-based economy through technological leapfrogging.

6.3.3 Inflow of Foreign Technology

Foreign investors need to obtain the approval of the Malaysian Industrial Development Authority (MIDA) before undertaking manufacturing projects licensed under the Industrial Co-ordination Act of 1975, including those involving technology agreements.[114] As shown in Table 6.3, 1263 technology transfer agreements were signed between 1990 and 2000, of which almost 50 % come under the category of technical assistance followed by licenses & patents (15%).

Table 6.3: Technology Inflows by Types of Agreement: 1995-2000

Type of Agreement	*1996*	*1997*	*1998*	*1999*	*2000*	*1996 - 2000*	*1990 - 1994*
Joint Venture	6	0	1	2	0	9	31
Technical Assistance	58	58	56	80	78	330	349
Licenses & Patents	31	6	27	20	28	112	138
Know-how	3	5	5	4	4	21	69
Trade-Mark	9	5	11	15	15	55	41
Management	1	2	1	0	0	4	12
Turnkey & Engineering	0	0	0	0	0	0	9
Services	2	4	2	2	6	16	27
Sales, Marketing/Distribution	0	0	0	0	0	0	1
Supply & Purchases	0	1	1	0	0	2	0
Others	6	5	3	3	0	17	20
Total	116	86	107	126	131	566	697

Source: GoM (2001).

[113] There are also technology incubators in Technology Park Malaysia and Kulim Hi Tech Park and those operated by companies set up by universities such as Unsains Holdings as well as those found in private establishments. (for details access website of MSC Technoprencur Development Flagship).

[114] MITI only regulates technology transfer involving joint ventures in the manufacturing sector. Joint ventures set up in the Multimedia Super Corridor (MSC) come under the jurisdiction of the Multimedia Development Corporation (MDC), which acts as a one-stop agency to spearhead the development of MSC. Joint ventures in sectors such as retailing and services involving technology transfer elements are also on the increase but data on this type of activities is not readily available.

In terms of sector, most of the agreements were in electrical and electronics (40 %), followed by transport equipment (13.8 %) and chemicals and chemical products industry (13.8 %) (GoM 2001).

Joint ventures are part of the government strategy to facilitate inflow of foreign technology to assist the country's industrialisation programmes. Government agencies such as the Malaysian External Trade Development Corporation (Matrade), MTDC and MIDA organise seminars, trade missions, trade fairs and exhibitions to provide a platform for foreign and local companies to explore the possibility of establishing strategic business alliances, joint ventures and other forms of partnerships.[115]

Malaysian companies are also participating in strategic alliances and joint ventures particularly in ICT, biotechnology and defense-related sectors, but the number of such ventures is small as shown by Table 6.3. Tidd and Broklehurst (1999) found isolated cases of indigenous firms forging strategic alliances and joint ventures to enhance their technological capabilities and marketing skills. The government of Malaysia, through its wholly-owned companies, is also directly involved in a number of joint ventures particularly in areas related to space and defence technologies.[116]

JVs in the area defense technology seem promising as Malaysian firms possess limited technological capability to design and manufacture many highly sophisticated high technology defense products. Defence contracts to procure submarines, jet fighters, missiles and tanks have been signed with a number of European and American suppliers. The Malaysian government imposes the technology transfer

[115] For example, the Government organises the annual Langkawi International Maritime and Aerospace Exhibition (LIMA) to provide opportunities to international aerospace and maritime companies for smart partnerships with Malaysian companies.

[116] Not all international joint venture (IJVs) activities explicitly involve transfer of technology elements. This makes the evaluation of their impact difficult. The mere presence of large MNCs with some form of linkages with local companies in the country does not necessarily generate the desired technological spillover. Overall the level of local technology development is far from satisfactory due to a number of factors.

conditions in these joint venture defense or vendor development agreements to enable local companies to engage in the design and production of certain parts and components locally.

6.3.4. Support for SMEs

The SME sector has been long neglected despite its potential contributions to economic growth. It is only in recent years that the Ministry of International Trade and Industry (MITI) and its agencies have begun paying attention to the growing needs of the SME sector. The MITI, which formulates the policy framework, has set up a specialised agency, the Small and Medium Industry Development Corporation (SMIDEC), in 1996 to implement various programmes to assist SMEs.

Thus, under the industrial linkage programme, assistance is provided to SMEs to become suppliers of parts, components and services to MNCs and other targeted industries. A good example is the collaboration between SMIDEC and Tesco Malaysia Sdn Bhd (Tesco) to assist local food product manufacturers, who are mainly SMEs, to become suppliers to Tesco. But Tesco sets certain standards and specifications that have to be met by potential suppliers to safeguard its reputation and status as a globally renowned hypermarket chain. These suppliers have to ensure that their products supplied to Tesco are of good quality, competitively priced and delivered on time. This type of MNC-SME relationship in the supply chain directly enhances learning amongst local SMEs and will contribute to their long-term growth and competitiveness.

The Ministry of Science, Technology and Innovation (MOSTI) provides grants to SMEs under the Industrial R&D Research Grant Scheme (IGS) to undertake collaborative project with local PRIs and/or foreign institutions in research that has commercialisation potential. Of the total 80 companies which have received funding under the IGS since 1998, 11 companies with a combined IGS grant of RM25.12 million have successfully commercialised their technologies with returns amounting to RM63.08 million, which represents 251% of the total grant disbursed to all companies. Among the notable commercialised technologies are the domestication and commercialisation of pitcher plants, the solid gasification/thermal oxidation plant and the electronic kiosk management system.

6.3.5 Multimedia Super Corridor (MSC)

This massive project is undertaken by the Government of Malaysia to drive the nation's economy through technological leapfrogging. The MSC is being implemented in three phases over a period of twenty-five years from 1996 to 2020 (see Table 6.4).

Table 6.4: Development Plan of the MSC – 1996-2020

Phases	Period	Objective	Tasks to be achieved
Phase 1	1996-2003	Create a Multimedia Super Corridor	• One corridor • 50 world-class companies • Launch six flagship applications • A global framework of cyber-laws • Cyberjaya as a world-leading intelligent city
Phase 2	2003-2010	Link the MSC to other cyber cities in Malaysia and elsewhere in the world	• A web of corridors • 250 world-class companies • Setting of global standards in flagship applications • Harmonising the global framework of cyberlaws • Linking 4-5 intelligent cities to other global cybercities
Phase 3	2010-2020	To transform Malaysia into knowledge-society	• 500 world-class companies • Global test-beds for multimedia applications • International Cybercourt of Justice in MSC 12 intelligent cities linked to other global information highways

Source: Based on information from website of Multimedia Development Corporation (MDC)

The MSC was set up to drive the economy towards higher productivity through technology and high value-added economic activities. Besides, it was set up to exploit opportunities for socio-economic transformation presented by the Information Age and Converging Technologies, and to make up for the loss of competitive advantage in traditional economic sectors due to increasing labour costs.

The corridor covering an area 15 kilometres by 50 kilometre extends southwest from the Petronas Twin Towers in the city centre of Kuala Lumpur towards the Kuala Lumpur International Airport. The development of this corridor in an established region with adequate infrastructure and amenities is in line with the views of Porter (1998) that a high-tech cluster cannot be started from scratch. Among the locational considerations are factors including proximity to a number of public and private universities and research institutes, network of highways and feeder roads, availability of skilled and semi-skilled workers, good communications systems and power, and availability of support services like banking and legal services provided by the metropolitan city of Kuala Lumpur and other townships in the Klang Valley region.

Another unique feature of the MSC is the development world's first Smart Cities within the corridor: Putrajaya, the new federal administrative capital of Malaysia and Cyberjaya, an intelligent city with multimedia industries and R&D centers. The electronic backbone of the development is a digital fiber-optic network that will link the corridor to the United States, Japan and Europe.

The government established the Multimedia Development Corporation (MDC) to plan, implement and develop the MSC. This agency serves as the facilitator, partner and promoter of the initiatives undertaken within the MSC. The MDC is seen as a one-stop agency, which manages and markets the MSC. The MDC has also the task of creating Malaysian 'technopreneurs' by providing market access, human resource development and training, R&D grants, venture capital financing and incubation facilities.

Companies seeking MSC status need to fulfil three criteria:

- being providers or heavy users of multimedia products and services;
- employ a substantial number of knowledge workers; and,
- ability and willingness to transfer technology / knowledge to Malaysia, or otherwise contribute to the development of the MSC and the Malaysian economy.

The MDC conducts annual surveys to evaluate the growth of the MSC in terms of such key indicators as number of companies (see Table 6.5), investments, revenues and profits made by these companies, the number of knowledge workers, patents, copyright, number of R&D personnel and R&D expenditures.

Table 6.5: Growth in the Number of MSC-Status Companies

Companies	1997	1998	1999	2000	2001	2002
Total	94	197	300	429	621	812
Malaysian-owned	47	107	181	276	410	543
Foreign-owned	44	84	112	144	198	248
Joint Ventures	23	31	34	38	50	54
World Class	3	6	7	9	13	21

Source: Official website of Multimedia Development Corporation

Following are the main findings of two surveys conducted by MDC in 2003 and 2004 to gauge the success of MSC-status companies[117]:

(a) Total workforce in the MSC-status firms has exceeded 19,000 with 16,000 classified as 'knowledge workers' (based on 620 companies responding to the survey)

(b) The number of full-time R&D personnel increased from 2,648 in 2001 to 3,349 in 2002.

[117] These surveys were based on more than 76% response rate.

(c) R&D expenditure by MSC-status companies increased from RM9.5 million in 1997 to RM474 million in 2002, but declined to RM428 million in 2003.

(d) A total of 276 patents, industrial designs and trademarks were registered in 2003, and 39 patents and 107 copyrights in 2002

(e) Well-known global conglomerates like Sun Microsystems, Intel, Motorola, Oracle, Cisco, Lucent and BAT have set up offices within the MSC

(f) Locally owned MSC firms have managed to graduate into world-class companies, although the number of world-class companies, which was 21 in 2002, falls short of the set target of 50.

6.3.6 Technology Development in Selected Sectors

Certain sectors have benefited technologically from the transformation process of the Malaysian economy from agricultural based to high value added manufacturing and mong them include the electronics and electrical, automotive and aerospace sectors.

6.3.6.1 The Electronics and Electrical Sector

The electronics and the electrical industry is the largest industry in Malaysia, in terms contribution to industrial output, sales, exports and employment in the manufacturing sector (MIDA 2004). The industry has been a 'powerful engine for economic growth in Malaysia for three decades' (Best and Rasiah 2003, p.15). The sector's contribution to the total exports of manufactures has consistently exceeded 50% since 1988 (Ismail 2001). The success of the electronics sector has been attributed to the country's market-oriented economy, young educated workforce, excellent infrastructure and a business-friendly environment created by a committed government (MIDA 2004). According to Mei Ling and Yong (1997), technological development in the electronics and electrical sector is reflected by increase in product complexity and labour expertise; increasing automation in assembly and testing operation signalling an upward migration in the production hierarchy; and diversification into original equipment manufacturing.

These developments are confirmed in a study of electronics firms in two clusters, in Penang and Klang Valley by Ariffin and Figueiredo (2004). This contrasts with an earlier study by Boston Consulting Group (1994) who showed the overall R&D capabilities in the electronics sector to be negligible, as shown in Table 6.6. However many studies still point out the lack of indigenous R&D capabilities (Tidd and Brocklehurst 1995; Albert 1998). Therefore, the study by Ariffin and Figueiredo (2004) appears to be more of an isolated case confirming the finding of earlier study by Tidd and Brocklehurst (1995).

Table 6.6: Malaysia: Electronics Industry Capabilities

Industry Sector	**R&D**	**Design**	**Manufacturing**	**Marketing & Sales**
Components & Peripherals	Negligible	Negligible	Weak	Negligible
Consumer Electronics	Negligible	Negligible	Moderate	Weak
Telecommunications	Negligible	Weak	Moderate	Negligible
Parts & Components	Negligible	Negligible	Moderate	Weak

Source: Boston Consulting Group (1994)

6.3.6.2 Automotive Sector

The car manufacturer, Proton, together with its vendors and after-sales services, has created an estimated 100,000 jobs in the last twenty years. It is also believed that for every one person employed, another four benefit resulting in an estimated 500,000 Malaysians dependent on the local automotive sector. Proton also employs 1,000 engineers worldwide with 50% of them based in Malaysia. Despite government's support, the automotive industry has yet to evolve as a competitive sector.

Based on the country's strong foundation in the electronics and electronic manufacturing services (EMS) attributed to three decades of industrialisation, the Malaysian government is offering incentives to encourage design and R&D in automotive component and parts module manufacturing. This has enabled

HICOM[118] and other local vendors to acquire capabilities in the design, testing and production of many car components. For example, the Japanese-Malaysian joint venture in the production of the national car (Proton) has greatly increased the capability of HICOM (local partner) and other local vendors in the design and manufacture of car components and parts. There are currently over 350 automotive component manufacturers supplying over 4,000 components with some having acquired design and development capabilities. The venture development programme in the automotive industry has enabled a number of local component suppliers to become exporting firms. But Albert (1998) points out that Malaysia still lacks indigenous R&D capabilities in the automotive sector.

6.3.6.3 Aerospace

The aerospace industry is becoming an increasingly important sector in Malaysia. In 2002, the sector contributed RM12.7 billion or 3.5% of the gross domestic product and provided employment to 50,000 people. Its contribution to the GDP is expected to increase to around 5 - 8 % in the year 2015. The high technology requirements associated with the industry offers great potential for spin-off activities in advanced technologies such as electronics, materials, manufacturing and systems integration, Malaysian firms have neither the financial resources nor the technological capabilities to compete with global aerospace companies. However, they have the potential to emerge as niche players within the industry by focusing on the production of parts, components and small aircrafts. The acquisition of scientific and technical knowledge in micro-satellite design and development marked the first step in Malaysia's space technological development journey (Arshad 2001). But government support is needed for further expansion. The establishment of the Malaysian Aerospace Council in the Prime Minister's Department is expected to boost the growth of the local aerospace industry. The major entities that have so far got involved in the sector are Malaysia Airlines, Composite Technology Resources Malaysia (CTRM), Airod Sdn Bhd, SME Aerospace and Astronauctic Technology Sdn Bhd.

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[118] HICOM is the Heavy Industries Corporation, a government-linked company (GLC).

6.3.7 Why Malaysia Lags in Technological Development

Why has Malaysia failed to achieve technological capabilities comparable to that of the Asian tigers despite its long industrialization experience and the massive government efforts to promote technology development?[119] For Lall (2003, p.52), Malaysia's record of impressive growth performance largely derives from high-tech export-oriented FDIs that found their way to the country "more by good luck than by deliberate targeting". There is no evidence to show that strategies to promote FDIs and export processing zones (EPZs) have helped the development of innovation capability in the country. Indeed, EPZs and industrial parks appear to have masked the failure of policy in achieving sustainable firm-level competitiveness (Asian Development Bank 2003). Tidd and Brocklehurst (1995) found that the large flows of FDI to Malaysia did not translate into local design, development and research capabilities. Most Malaysian firms acquire only basic operating and maintenance of skills through transfer agreements, and typically acquire very little of the particular kinds of know-how and expertise that are needed for technology upgrading and innovation (World Bank 1996). Malaysia's failure to move up the technological ladder can be examined from two perspectives: lack of technological spillover from FDI and lack of absorptive capacity.

On the supply side, some studies suggest that foreign companies are more profit motivated and not keen to impart technical know-how to local firms (Fong 1987; Enos 1989). Narayanan and Wah (200) found that MNCs were slow in transferring R&D to Malaysia, although they brought in many aspects of production technology. Ravenhill (2000) revealed that Japanese subsidiaries transfer less technology to Malaysia compared to American subsidiaries. This is partly attributed to the dominance of Japanese nationals in key management and technical positions (Ismail 2001). Other factors include lack of autonomy for the affiliates in sourcing, and the development of supplier networks involving local investment by Japanese.

On the demand side, Malaysia has lacked the absorptive capacity to assimilate imported technology and to develop and produce new technologies. This is attributed to lack of R&D investments, lack of skilled manpower and lack of local research culture. There are also administrative barriers that adversely impact technological development. The World Bank/UNDP (1996) identified a number of limitations in the policy governing transfer of technology, such as, for example, the prevalence of complex approval processes; lack of incentives to SMEs to acquire technology from foreign partners; and absence of mechanisms that would enhance the use of technology transfer for strengthening domestic innovative capabilities. Malaysian SMEs face numerous problems and challenges to compete in domestic and the global market despite various government assistance schemes to assist them upgrade their technological capabilities.[120] The problems they face include:

(a) Lack of internationalization (exports)
(b) Lack of marketing skills
(c) Lack of autonomy in decision-making which limits the SMEs from entering the world market independent of the MNCs even though their products meet world standards
(d) Lack of time, funds and resources to engage in R&D
(e) Workers not well trained
(f) Threats of competition from low cost countries such as China, Thailand and Vietnam.

While Malaysia has achieved some progress in certain sectors such as electronics and electrical, automotive and aerospace sectors, as highlighted earlier, overall it lags behind Korea, Taiwan and Singapore in terms of technological progress. This will be apparent by focusing on the functioning of Malaysian national innovation system (NIS) and the factors affecting the NIS, as we will do in the next section.

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[119] Asian Tigers refer to South Korea, Taiwan, Hong Kong and Singapore.

[120] These problems were highlighted by Deloitte Consulting Malaysia in a press release dated 31 May 2004. This press release can be accessed at url: http://www.delloitte.com./dtt/press_release/0,1014

6.4 FACTORS AFFECTING MALAYSIAN NIS

Overall, the culture of innovation in Malaysia has not made much headway. This can be attributed to the lack of investments in R&D, in long-term strategic planning and foresight studies and in business intelligence gathering. It is also due to as the lack of exposure to cutting edge technologies.[121] The absence of a robust innovation culture and its implication for the development of technological capabilities in Malaysian firms can be examined within the context of the Malaysian National Innovation System.

6.4.1 Lack of Research and Development

Malaysia's allocation for research and development (R&D) has been relatively low (see Table 6.7) compared to many countries, which are striving to catch-up with advanced countries. It has never exceeded one per cent of the gross domestic product (GDP). Many studies have singled out this lack of R&D for low technological capabilities amongst the firms (World Bank/UNDP 1996, Tidd and Broklehurst 1999). In a study of technological capabilities of Malaysia firms, Tidd and Broklehurst (1999) found that Malaysian firms possess limited R&D resources, which are devoted largely to improving the efficiency or quality of production processes rather than to developing new products and processes. According to this study, FDIs in high technology sectors failed to transfer R&D and marketing capability to Malaysian firms. The study also pointed out the lack of strategic intent to exploit alliances and lack of indigenous expertise as the major problems impairing the promotion of high technology and service-based industries.

Tidd and Broklehurst attribute the lack of strategic intent to the failure of Malaysian firms to manage IJVs and strategic alliances as opportunities for technology transfer. They observed that past FDIs transferred little technological and marketing know-how but acknowledged that the Malaysian firms gained significant manufacturing capabilities from the FDIs. According to Albert et al (1998), Malaysia lacks indigenous R&D capabilities in IT, health, automotive, EPTL and advanced

[121] This explanation was given by the Prime Minister of Malaysia, Dato Seri Abdullah Ahmad Badawi in his keynote address at the National Forum on Leveraging on Emerging Technologies, Sirim Berhad, Shah Alam Selangor, Malaysia on 31 May 2005.

materials. This is reflected in the prevalence of inefficient patenting activity in these sectors. But can firms manage to enhance productivity and performance without engagement in R&D, given that R&D is costly, risky and time-consuming and may not translate to new products and processes (Fraser and White 2001)?

Table 6.7: R&D Expenditure and Number of Scientists and Engineers for Selected Countries

Country	R&D Expenditure (% of GDP)	Scientists and Engineers (per million population) 1985 - 1995
Australia	1.7	3,166
Canada	1.6	2,656
China	0.7	350
India	0.7	149
Ireland	1.5	1,871
Japan	2.9	6,309
South Korea	2.7	2,636
Malaysia	**0.4**	**500***
New Zealand	1.0	1,778
Singapore	1.8	2,728
United Kingdom	1.9	2,417
United States	2.5	3,732

Sources: *The World Competitiveness Yearbook*, 2000;
World Development Report, 1999/2000

Mahadevan (2001) acknowledges the contribution of R&D to technological development and suggests that the policy to promote R&D should not be done at the expense of developing skilled manpower. In Mahadevan's words, " the common prescription that R&D (should be promoted) to enhance to technological capacity of the economy ... is overrated. Given the huge sunk costs of R&D as well as Malaysia's (position), this should be treated only as a long-term goal and not fussed about or blamed for the current poor TFP growth experienced by the economy" (p.594).

6.4.2 Weak University-Industry Collaboration

Universities in Malaysia have established various mechanisms to facilitate links with the industry, especially in the area of technology transfer and commercialisation of research results. One noticeable effort is the setting up of investment arms or business units to market expertise, skills and technology that could be utilised by private enterprises. A good example is Usains Holdings Sendirian Berhad (Usains) formed in 1997 by the Universiti Sains Malaysia (USM) in Penang. Two additional units to complement and work together with Usains were established by USM in April 2002, and are known as Engineering Innovation and Technology Development (EITD) unit and Medical Innovation and Technology Development Unit (MITD).

A general survey conducted by the EITD unit in USM to gauge its perspective about university-industry collaboration yielded the following findings:[122]

- insufficient innovative products for commercialisation;
- lack of research results worthy of commercialisation;
- culture of conducting quality research for commercialisation is still not widespread; and
- lack of conviction and commitment amongst academic staff to participate in research.

According to Ali (2003), the constraints faced in university-industry collaboration include:

- Dominance of foreign investments in the critical sectors of manufacturing
- Lack of really effective funding by government and industry
- Lack of highly capable scientists who can lead in terms of knowledge frontiers
- The nascent venture capital industry
- Lack of innovative entrepreneuriship

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[122] See Sadullah (2002).

- Focus of universities towards teaching, thus creating a divergence of objectives between university and industry

6.4.3 Lack of Commercialisation

Lack of commercialization is attributed mainly to lack of industry- relevant R&D projects and lack of finances (GoM 2001). But according to Hnn-Hui (2003), there are many other factors that explain lack of commercialisation in Malaysia (see Table 6.8). One drawback of Hnn-Hui's list is that it does not include external factors to give a balanced view of factors affecting commercialization in Malaysia. The blame should not squarely fall on the universities, researchers and the government. What about the role of the industry, including MNCs, in the commercialization process? Malaysian companies seem to show lack of enthusiasm in local research results. Is this due to poor marketing of research results by the universities and PRIs or is it due to lack of interests on the part of the industry?[123]

Table 6.8: Factors Explaining Lack of Commercialisation in Malaysia

Factors	*Explanation*
1. Inappropriate funding mechanisms	Lack of Pre-seeding capital No explicit criteria in IRPA for commercial output Lenient progress monitoring resulting in lack of accountability Perception that IRPA funds easy to get
2. Researchers awareness level low	Commercialisation not a concern in their work Lacking desire to pursue commercial applications Lacking skills to detect commercial opportunity
3. Lack of Research Management Practices in universities and PRIs	Lack of expertise in commercialisation Shortage of project managers equipped with requisite skills
4. Manpower constraints	Lack of S&T personnel for technology development Lack of effective officers in technology transfer officers in universities and PRIs
5. Research focus mainly publications driven	Lack of market-driven research Researchers occupied with own work resulting

[123] For example, the Ministry of Education (MOE) has been organising an annual exposition since 2002 to showcase research and development output of public sector higher educational institutions (HEIs). But the participation of the private sector in two such expositions held so far is reported to be very disappointing.

	lack of time for commercialization Persistence of publish or parish culture Researchers interested in publications only
6. Lack of incentives and rewards	Inappropriate pay and reward system to encourage commercialisation Lack of incentives for commercialization Adverse effects of brain drain
7. Weak networking mechanisms	Researchers face problem getting collaborative partners Weak university-industry links Research findings poorly marketed to businesses
8. Weak innovation infrastructure	Lack of centers of competence in S&T and engineering Good hardware but modest software
9. Limited technology diffusion mechanisms	Lack of effective technology transfer agencies and technology brokers Both not effectively linked to universities and PRIs
10. Lack of feasibility studies on market outputs	Lack of participation by commercial partners in initial R&D planning Researcher hardly conduct market feasibility studies before commencing research

Source: Based on Hnn-Hui (2003).

Another factor explaining lack of commercialisation is the domination of foreign MNCs[124] in the nation's industrial structure especially in the electrical and electronics sector. Most of these foreign companies conduct their R&D in the home country and thus do not see the need to collaborate with local HEIs or research institutions to undertake joint R&D to improve their product performance. For example, Dyson of UK set up a factory in Malaysia in 2001 to produce washing machines and vacuum cleaners. But the R&D to manufacture these products is undertaken in Dyson's headquarters in the UK. Similarly, many foreign companies make limited use of facilities and equipment available in local universities because of the same reason. However, collaboration is seen in the design of educational courses conducted by HEIs in order to produce certain category of skilled manpower to work in the MNCs, but this is not widespread. For example, Intel Malaysia collaborates with UTM and

[124] MNC domination in R&D deprives smaller firms in high tech clusters in Europe from enjoying externalities generated by R&D. This observation was made by Luc Soete in "Silicon Valleys Take Root in Europe," *International Herald Tribune*, Special Reports, March 18, 1999.

USM in the design of courses, which are of relevance to jobs in Intel (Yeoh et al 2005).

The government has recently drawn up various plans and programmes to enhance commercialisation activities at local universities and research institutes. For example, plans to provide incentives to scientists and researchers to enhance R&D and commercialisation activities at the universities, is in the pipeline.[125] The incentives package includes entitling scientists and researchers to partial ownership of the intellectual property, increased research funding and incentives to form collaboration with foreign universities.

6.4.4 Lack of Human Capital

Malaysia still faces serious skilled manpower shortages despite the massive resources devoted to enhancing HRD to support the manufacturing and high-tech sector. Rasiah (2002) shows the occurrence of such shortages in two of the country's largest electronics clusters - Penang and Klang Valley. According to Rasiah the factors that impede local firms transition to higher value added activities, include the mismatch in the demand for and supply of skills; the difficulties envisaged in attracting Malaysian scientists from abroad; and the restrictive immigration policy which makes recruitment of foreign high-tech labour difficult. Japanese MNCs in Malaysia face constraints such as shortage of local skilled personnel for research and development and lack of industrial technologies in development and design areas (Yoshimura, 1998). Sadoi (2000) also documents shortage of skilled workers in the automotive parts sector.[126]

According to the National Economic Action Council (NEAC), Malaysia needs 201,000 engineers by the year 2010: 33, 000 in the civil field, 64, 000 in electrical and electronic, 45, 000 in the mechanical and 29, 000 in the chemical. This is a big

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[125] This was reported by the local daily The Star via its online service, The Star online, on 15 October 2004. At the time of writing this dissertation, the Ministry of Science, Technology and Innovation (MOSTI) was awaiting approval from the Cabinet to implement the incentives scheme.

[126] Sadoi (2000) attributes the problem to lack of government support, employers' lukewarm attitude, unfavourable skill environment and weak individual interest.

challenge for Malaysia, considering that the total number of engineers in the country was only 64, 000 in 2000. Achievement of this target depends on so many factors, including students' interest to pursue engineering as a career, the capacity of local universities and costs of overseas higher engineering education.

The issue of high-tech human capital will become increasingly critical with the current emphasis on the development of ICTs to leapfrog the country into a knowledge-based economy. The NEAC[127] estimates that the number of systems and hardware engineers required in the year 2010 to be around 37, 000 compared to 15, 000 in 2000. The demand for software development engineers is expected to rise from 10, 400 in 2000 to 26, 000 in 2010 while that of business analyst from 25, 000 to 71, 000 (NEAC website).

But a recent report[128] showed that many ICT graduates are finding it difficult to get jobs reflecting a mismatch between the production of ICT graduates and employment opportunities in the job market. This report attributes the failure of local ICT graduates to fill in the job vacancies to the lack of in-depth knowledge, and lack of communication skills and work ethics.

Malaysian authorities have acknowledged that the quality of education is low in Malaysia compared to international standards (Taylor and Lewis 2001). For example, a Deputy Minister is reported to have associated the generally poor quality of Malaysian graduates partly to their poor command of English".[129]

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[127] NEAC is the National Economic Action Council formed by the Malaysian government in 1998 as a consultative body to deal with issues arising from the Asain Fanancial Crisis of 1997. For details access its website at URL: http://neac.gov.my/

[128] This was based on data by the Association of the Computer and Multimedia Industry (PIKOM) and reported by the Computimes Business News of the New Straits Times on 19 February 2004.

[129] These comments were made by Dr. Tan Kee Kwong, the Deputy Land and Regional Development Minister and reported in a local daily the New Straits Times on 24 February 2004. He urged the Ministry of Education to review university courses and teaching techniques.

Despite these setbacks, the government continues to focus on HRD by introducing various bold measures, such as making English as the medium of instruction for the teaching of science and mathematics from primary school to university level beginning 2003. Another plan is to give university-status to all the teacher training colleges and, increasing the number of scholarships for further studies at local and foreign universities.

6.4.5 Lack of Strong IPR Regime

Patent application and registration is a long and costly process. An innovator needs to wait up to five years to know the outcome of his application for patent registration. This causes frustration amongst patent filers who understandably turn to other countries such as Australia where patent registration takes much shorter time. The more serious issue is lack of enforcement of Intellectaul Property Rights (IPR) laws to protect both local and foreign IPRs.

Malaysia has often been accused by many developed countries of not doing enough to protect IPR. Losses resulting from software piracy has for instance, increased from US$ 66 million in 1995 to US$ 316 million in 2001.[130] This is partly attributed to lighter punishments in the form of lower fines imposed by the courts on those involved in software piracy including those who commit the offence repeatedly. Of late, however, the Malaysian government has been introducing tougher measures to eradicate software piracy. For example, the DTCAM has begun using sophisticated high tech forensic technology to raid and arrest manufacturers of pirated optic discs.

Other measures adopted include:

- Increasing raids by law enforcement agencies against infringers of copyright laws;
- Opening of an intellectual property training centre in March 1998 to develop and offer programmes for government officials, attorneys and judiciary;

[130] The US Ambassador to Malaysia disclosed that Malaysia has earned the reputation as the number one exporter of counterfeit digital video compact discs (DVDs) and compact discs (CDs). He warned that if this problem is not addressed it could affect the future flow of investments from US to Malaysia. This was reported by Bernama, the local news agency, on 11 March 2005.

- Setting up of an interagency task force in April 1999 to develop and implement a regulatory regime for optical media production; and
- Crackdown on corporate entities using unlicensed software. For example, the MDTCA and the Business Software Alliances (BSA) jointly launched an enforcement operation called "Crackdown 2000", in July 2000.[131]

The government is also considering setting up special courts to deal with cases related to intellectual property rights, as the present system is inadequate in terms of knowledge and expertise to resolve such cases.

6.4.6 Lack of Corporate Governance

Lack of transparency, market openness and corporate governance can erode investors' confidence and affect the overall investment and business climate. In fact, it was the absence or lack of these critical elements in the financial institutions that largely led to the outbreak of the Asian Financial Crisis in 1997. The crisis had grave implications for the Malaysian economy, with thousands of business closures, corporate and individual bankruptcies and widespread unemployment.

The Asian Financial Crisis offers important lessons in areas related to transparency, financial management and capital market openness. It has shown how the failure of one component (financial system) in the Malaysian NIS can have disastrous effects on the Malaysian economy in general and on technological and innovation activities of businesses. It is therefore crucial to address this systemic failure by putting in place effective monitoring mechanisms to prevent the recurrence of such crisis in the future. The government's decision to incorporate a chapter on corporate governance in the formulation of Ninth Malaysian Plan (2006-2010) is a step in the right direction.

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[131] Business Software Alliance (BSA) is a global network organisation set up in 1988 to promote a safe and legal digital world. It is the voice of the world's software industry before the governments and the international market place. BSA has regional offices in Washington, DC, London and Singapore.

6.5 CONCLUSION

Building innovative and technological capabilities are important for Malaysia to succeed in an increasing globalised world with knowledge as the key driver of economic growth. This chapter has shown that hitherto, the apparently impressive economic growth in Malaysia has been achieved through export-led FDI without strong R&D capabilities. Malaysia will continue to be viewed as an assembly depot for MNCs if it fails to enhance its R&D and innovation capabilities (Chow 2004). Ritchie (2001) attributes Malaysia's inability to further develop its technological capacity to the politics of the country, which is hampering efforts to forge linkages that could enhance private sector participation. Lessons could be learned from the technological trajectories of developed countries and Newly Industrialised Countries. This does not mean Malaysia should imitate blindly, import inappropriate technologies or abandon its efforts to acquire indigenous technological capabilities. Likewise policy makers should realise that allocating more funds for R&D or increasing S&T personnel and institutions do not guarantee enhanced capabilities in technology and innovation. The lesson learned from the Multimedia Super Corridor is that physical infrastructure is not the key to successful technological development though it is an important factor. The government has indeed made the right move by reviewing the implementation of the Biovalley project by focusing on the effective use of existing facilities rather than coming up with mega physical projects to support the development of the biotechnology sector.

Rather, the focus should be on the systemic failures that affect the functioning of its national innovation system and hinder the flow of knowledge and technology resulting in the reduction of the overall efficiency of national R&D efforts (OECD 1997). It is hoped that the National Innovation Agenda recently announced by the government to focus on market driven research, will address the systemic failures plaguing the NIS. This will require not only the provision of physical, human and financial investments, but also the political will to introduce the necessary institutional and organisational reforms. As pointed out by Ritchie (2001, p.38) "without the political and social will to overhaul the NIS, especially the bureaucracy responsible for S&T and R&D, Malaysia is likely to remain mired in technological mediocrity". This overhaul should also involve evaluating the effectiveness of existing programmes including the building of science parks created to enhance science and technology development. Feedback from this evaluation could be used as input to design an appropriate institutional framework for implementation of effective policies that facilitate long-term development of technological capabilities of firms, sectors and industries. In this context the present study will certainly serve as an important feedback to policymakers in view of the centrality of science parks as a node in the NIS. The next chapter will discuss the research methodology of the present study.

RESEARCH DESIGN AND METHODOLOGY

7.1 INTRODUCTION

In chapter four, we discussed the conceptual framework, the research questions and the hypotheses of this study to determine whether science park firms perform better than off-park firms in terms of innovation, business performance and growth. In order to test these hypotheses, data were collected from two samples of technology-based SMEs in Malaysia - one consisting of science park firms and the other a comparable group of off-park firm locations. This chapter will focus on the methodology used to test the hypotheses. Section two will give an overview of the study location. Section three will discuss the research design. Section four will explain the target population and the sampling procedure. Data collection procedures will be discussed in section five. Section six will explain the statistical techniques used for analysing the data in this study.

7.2 RESEARCH DESIGN

7.2.1 Matched Sample Approach

The present study used a matched sample research design, which involves a comparative analysis of the characteristics and performance of firms located on science parks and a comparable group of firms sited off-park, to see whether there are significant differences between these two groups of firms. This approach used extensively in previous studies investigating research questions similar to those of the present study, has produced the desired research output despite some minor limitations (Monck *et al.* 1998; Westhead and Storey 1994, Ferguson, 1999). According to Weiss (1972) (cited in Lofsten and Lindelof 2001), the use of comparative evaluation approach has been found to be appropriate particularly when real issues emerge that require policy makers to choose between alternative strategies with similar aims and involving similar design an action plan.

A major drawback of the matched sample design is that it is vulnerable to the risk of sampling bias arising from the difficulty of associating the observed differences between the two groups of firms being compared to the issues being investigated (Ferguson and Olofsson 2004). However, this limitation does not have major impact on the current study as the risk of sampling bias has been overcome by proper sampling selection and detailed steps to achieve two comparable group of firms as in the study by Lofsten and Lindelof (2003).

The current study is also longitudinal in nature, which is more effective than cross-sectional studies of firm growth. According to Davidsson and Wiklund (1999), real time growth and development of firms can only be effectively studied by using longitudinal method rather than the cross-sectional approach. Davidsson and Wiklund point out that 'only with longitudinal data can satisfactory analyses of testing and development of theory be undertaken' (p.4).

7.2.2 Two-Phase Study

In order to undertake this quantitative longitudinal study, the research process of the current study is divided into two interrelated sub-studies. The first phase involved a mail survey study based on the administration of structured, questionnaire, which forms the main part of the overall study. The second phase involved an interview study to complement the main study and through case studies of a four high-tech SMEs.[133] Bryman (1988) has well documented the case for such qualitative information obtained from interview studies.

The purpose of the survey and the interview is to collect quantitative data and information about the characteristics and performance of firms located on science parks and comparable firms located elsewhere (off-park locations). The small size of four firms for the case studies obviously does not represent the population under study. However, the qualitative information obtained combined with the quantitative

[133] It is not to 'provide a major challenge to a theory and provide a new source of new hypotheses and constructs simultaneously' (Cooper and Schindler 1998) but merely to complement the main survey, in order to get a better insight of innovation at enterprise level.

data obtained from the mail survey was used to present fairly detailed case studies of those selected SMEs to enhance our understanding of complex issues such as innovation and technology development at the level of firm.

7.3 LOCATION OF STUDY

The science park strategy has been adopted by the government in Malaysia to stimulate innovation amongst small-and-medium sized enterprises (SMEs) and enhance university-industry collaboration. To date, five science parks have been set up throughout the country by the Federal and State governments. These are Technology Park Malaysia in Bukit Jalil in Kuala Lumpur, Kulim Hi-Tech Park in the northern state of Kedah, Selangor Science Park (SSP) and UPM-MTDC Incubation Center in the state of Selangor,[134] located in University Putra Malaysia (UPM) and Technovation Park based at the UTM Campus in Skudai in the state of Johore.

The proximity of these parks to universities and research institutes is intended to enhance prospects for the development of technology-based companies through university-industry collaboration. As Porter (2003) argues, clusters cannot be started from scratch.

Of the above five science parks, only Technology Park Malaysia (TPM) and Kulim Hi Tech Park (KHTP) seemed suitable for study because they have been in operation for more than five years while the other three are either recently set up or do not contain sufficient member of companies. However, KHTP was subsequently excluded from the study because almost all the companies located in this park are multinational companies and locally owned large enterprises involved in high-tech manufacturing. Thus, inclusion of KHTP was not considered to be of much use to the study where the focus is on shedding light on the impact of science parks on Malaysian SMEs involved in technology-based businesses. Only companies located

[134] There are several technology incubators in public and private establishments but these will left out of the study because they do not conform to definitions of IASP and also were only set up in recent years.

in TPM were chosen for the sample study of science park firms in Malaysia. TPM located near universities and research institutes has been in business for more than five years, and has since its establishment shown substantial development in terms of physical expansion and growth of tenant companies. It has to date 120 tenant companies.

7.4 POPULATION AND SAMPLE SELECTION

7.4.1 Target Population

The focus of analysis in this study is on high-tech SMEs in Malaysia. For the purpose of the study, an SME is defined as a business entity employing not more than 150 employees and having a turnover of not more than M$25 million (£3.7million).[135] This is the definition adopted by the Ministry of International Trade and Industry of Malaysia (MITI). In order to focus only on technology-based SMEs, the definition provided by MESDAQ was adopted. According to MESDAQ, technology-based businesses refer to enterprises involved in twelve technology priority areas.[136] The study also included firms, which are subsidiaries of large companies or government companies so long as they are separate legal entities and fall within the definition of an SME and qualify as a technology-based business.

As stated earlier, the research design for the study involves comparison of the characteristics and performance of SMEs in science parks and those located elsewhere. The population of SMEs in science parks was easily determined as there are currently only five science parks in Malaysia with the number of technology-based companies located on these parks obtained by accessing the websites of these

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[135] Hashim and Sulaiman (1996) point out that the changing definitions of SME, different agencies adopting different criteria to define a SME and high number of government ministries and agencies involved in SME support programmes.

[136]These technology sectors are advanced electronics and IT, telecommunications, equipment/instrumentation, automation and flexible manufacturing system, biotechnology, bioconversion and genetic engineering, healthcare, electro-optics, non-linear optics and optoelectronics, advanced materials, energy, aerospace, transportation, emerging technologies and services.

parks. It was found that there are 220 technology-base SMEs in Malaysian science parks.

However, it was difficult to determine the appropriate sample for off-park firms because there is no population statistics on technology-based businesses in Malaysia. This is because at the moment there is no national database on high-tech SMEs in Malaysia.[137] Even SMIDEC who is responsible for implementing the SME Development Plan does not have a database on high-tech SMEs. Nevertheless there are a number of organisations, which have lists of technology-based SMEs even though these lists do not cover all such SMEs located outside science parks.[138]

7.4.2 Sample Selection

The research design calls for the selection of two types of samples for the mail survey study. Accordingly, the sampling frame used in the study was drawn from two types of data set. The first sampling frame consists of the entire population of 101 firms located on Technology Park Malaysia (TPM), and another sample, comprising a comparable group of firms from off-park locations. All SMEs in the TPM were selected for the first sampling frame and constituted the "treatment group". The reason for using non-random sampling in the case of TPM was because the total number of SMEs in this park did not exceed 108 firms and almost 95 % of the firms are involved in various technology sectors.

However companies involved in providing services such as banking, catering and business support services were excluded from the sample. This was matched by a sample of 160 off-park SMEs selected on a stratified sampling basis to constitute the

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[137] Information about Malaysian SMEs is not only inadequate and inconsistent but also not readily available. This is attributed to lack of efforts on the part of relevant supporting agencies to collect quality information on SMEs on a regular basis. (see Hashim and Sulaiman 1996).

[138] These organisations include the Multimedia Super Corridor Technopreneur Development portal, Federation of Malaysia Manufacturers (FMM), Malaysian Technology Development Corporation (MTDC) and the Ministry of Science, Technology and Innovation (MOSTI).

'control group'. The reason for using stratified sampling is to ensure that characteristics and profile of the off-park SMEs match that of the science park firms.

The sampling frame consisting of 101 technology-based companies in Technology Park Malaysia is more than a reasonable representation of all such type of companies located on science parks in Malaysia. This is because TPM is the largest science park in terms of number of tenants. Even the combined number of tenants of the other four science parks in operation at the time of study, do not exceed that of TPM. The complete list of firms located on TPM was obtained in person following a discussion with an official of TPM management. (See Appendix IV for the full list of tenant companies in Technology Park Malaysia).

The sampling frame for off-park firms was drawn from the database of SMEs maintained by Malaysian Science and Technology Information Centre (MASTIC), Multimedia Development Corporation (MDC), Federation of Malaysian Manufacturers (FMM) and Small and Medium Industries Development Corporation (SMIDEC). These databases is were found useful as they contain the business address register of companies that fall within the definition of an SME used by MITI and meet the criteria of a technology-based business set by MESDAQ.

7.5 DATA SOURCES AND PROCEDURES

The investigation covered a period of five years from 1997 - 2001 during which TPM was in existence as an operating entity.

7.5.1. Mail Survey

Data for the mail survey was collected through a written survey questionnaire based on the research questions, variables and hypotheses of the study. The design and preparation of the questionnaire in line with the studies by Openheim (1992) and Bell (1999), which aimed to keep respondent rejection rate to the minimum possible. Response rates are important because fundamental differences between the characteristics of non-respondents and respondents will cast doubt on the quality of information obtained by the survey (Hansen 2001). Factors that influence the response rate such as the type of question, layout, piloting and distribution of the questionnaire were taken into account in the preparation of questionnaire. In particular, care was taken to ensure that the questions were carefully worded to achieve simplicity and clarity. Reference was made to well-established innovation surveys, in particular the Oslo Manual (OECD/Eurostat 1997)[139] as well as previous studies to draft the questions on innovation activities of firms so that the respondents do not encounter difficulties when answering such questions.

Since decision to innovation is firm, sector and country-specific, a compromise was reached in terms of data that could be reasonably elicited. For example, it was found out that the share and value of output attributed to introduction of new products or processes[140] is difficult to obtain because companies in Malaysia do not keep such records. Instead the focus was on obtaining other equally important data that reflect the input (i.e. expenditure), throughput (i.e. co-operation and collaboration) and output (i.e. patents, copyrights etc.) of R&D and innovation activities as indicated in the variables.

The questionnaire was divided into six sections containing a total of twenty questions and covered both 'structured' and 'attitude variables'. Structured variables refer to general details of the company such as year of establishment, ownership, type of technology sector/activity, number of employees, R&D inputs and output, sales/turnover and profits. Attitude variables refer to reasons/factors influencing SMEs choice of location, their expectations as well level of benefits obtained by locating in present location (science park or elsewhere). The questions eliciting data on these variables were specific and closed-ended - straight forward 'yes' or 'no' categorical questions, as well as multiple choice questions, numerical and ordinal type of questions. A copy of the questionnaire is appended as Appendix VI.

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[139] See Hansen (2001) for an extensive discussion on technological indicator surveys which include the First and Second Oslo Manual, First and Second Community Innovation Survey, Canadian innovation surveys and other European surveys.

[140] This is an important measure of innovation output and used extensively in many national innovation survey surveys (see Hanson 2001)

Respondents from both groups of firms (science park and off-park) were asked to provide data on R&D and non-R&D activities. For example, they were asked to report their annual R&D expenditures (in Ringgit Malaysia) and employment of qualified scientists and engineers (QSE) for five years covering the period 1997-2001. A pilot test was conducted on a few SMEs to find out whether there are any weaknesses in the questionnaire design and instrumentation. Feedback from this pilot test was used to review and make necessary changes to the questionnaire.

7.5.2. Interview Survey

The interview part of the study sought to elicit in-depth data and information from four SMEs from both the science park and off park firms drawn from the respondents of the mail survey. The interviews were conducted face-to-face and through e-mail correspondence with Chief Executive Officers (CEO) or senior managers responsible for R&D of the four SMEs. The aim was to get further insight into how these SMEs go about to develop their technological and innovative capabilities to achieve competitiveness and to find out how the different geographical location aspect impact their business strategies. The interviewers were notified in advance through e-mail and/or letters regarding the objective of the survey, which also indicated the possible dates of the interview. Of the four, only one was available for interview in person while the rest responded via e-mail correspondence. The output of this interview process was used to present case studies as a supplement to the main mail survey study. Respondents to this interview survey were asked questions related to the origin of company and whether they benefit from science park location. The full list of questions raised in the interview is included in Appendix VII.

7.5.3 Other Sources of Data

The secondary data and other relevant qualitative data used in this study was obtained from the following sources.

- (i) directory of science parks
- (ii) annual reports of the science park management

(iii) annual company reports of the science park tenants

(iv) annual company reports of off-park SMEs

(v) other archival sources

7.6 VARIABLES AND MEASURES

7.6.1 Variables

The six dimensions developed to test the hypotheses of the study are fully discussed in chapter six. These are: (a) research and development (R&D), (b) R&D co-operation and collaboration (c) access to finance, (d) internationalisation, (e) innovation and R&D output and (f) business performance and growth. In order to analyse these dimensions, the study identified sixteen variables encompassing R&D and non-R&D activities as shown in Table 7.1.

Table 7.1: Study Dimensions and Variables

Dimension	Variables
R&D Input	R&D expenditure, employment of qualified scientists and engineers (QSEs) and R&D thrust
R&D Collaboration	collaboration with universities, strategic alliances (joint ventures and collaboration) with local firms
Access to Finance	access to venture capital and government research grants
Internationalisation	export and international research collaboration
Innovation / R&D Output	patent, copyrights and number of new products/processes launched
Business performance and growth	sales, profits ratio and employment growth

R&D expenditures and employment of qualified scientists and engineers (QSEs) are widely used indicators in the study of high-technology development (Markusen et al 1986)[141] and have been used to study the effects of science parks on SME innovation (Westhead 1997; Westhead and Storey 1994). However, the drawback of R&D

spending is that it only measures the amount of resources a firm devotes to innovation but not its ability to commercialise its R&D output. R&D thrust (direction of R&D) is a measure of how ambitious a firm is in its research thrusts (see Westhead and Storey 1994).

Co-operation and collaboration in R&D can be construed as throughputs in the innovation process (Kemp et al 2003; Klomp 2001). These include co-operation and collaboration of a firm with local universities and research institutions; and alliances and joint ventures with other firms. Access to finance is critical for technology-based SMEs to engage in R&D and innovation activities. In this study, two variables developed to reflect access to finance are (a) venture capital and (b) government R&D grants. The internationalisation aspect was examined using two variables: international research collaboration and exports. The former is in fact an R&D throughput indicator while the latter is an indicator of business performance and growth of a firm.

In order to examine innovation output three variables were used: namely patents, copyrights and launch of new products and processes. Patent data provide a good output indicator of R&D activities (Ernst 2001). Patents and copyrights might not indicate commercial success but are rough indicators of how successful a firm is in its R&D and innovation effort. The introduction of new products and processes is another popular indicator of a firm's innovation output. The limitation is that this indicator does not reveal about the quantity or quality of innovation undertaken by the firm (Harris et al 1999). Despite their limitations, patents, copyrights and launch of new products and processes are used in most innovation surveys as well as in studies on the performance of science park firms (Westhead 1997; Monck et al 1988).

The present study uses sales, employment and profits as indicators of business performance as these are the most popular measures of firm growth (Delmar 1997).

[141] According to (Markusen et al 1986, p. 16), high-tech industries are 'those in which the proportion of engineers, engineering technicians, computer scientists, life scientists and mathematicians exceed the manufacturing average' (p.16).

These measures also, 'directly reflect the underlying political goals of public science park policy, namely business and job creation, and economic activity' (Ferguson and Olofsson 2004, p.10). Numerous studies on science park firms have also used these three indicators.[142] Sales or revenue has emerged as the best measure because it is easily obtainable and it reflects both short and long-term changes in the firm. Employment growth is a good measure of economic growth and technology-based firms are said to be good job creators. Another widely used measure is profits earned by the firms. Calculating profits is important for production decisions as it helps to distinguish between viable and non-viable production projects (Lewin 1998).[143]

7.6.2 Operationalisation of Variables

This section discusses how the variables shown in Table 7.1 in section 7.6.1 of this chapter were measured. There are three types of data obtained for these variables from the mail survey: quantitative longitudinal, quantitative non-longitudinal and categorical. Longitudinal data for the period 1997-2001 were collected for R&D expenditures, employment of QSEs, sales, profits and employees. Quantitative non-longitudinal data were obtained for innovation output (patents, copyrights and new products and processes) whereby respondents were asked to give the total number of the output for the period 1997-2001. For the remaining seven variables the categorical data obtained are in the form of indications (yes or no answer) and the number of valid cases for each of them is recorded.

Based on the three types of data explained above, the study proceeded to measure them by examining the actual numerical value (as in the case of quantitative longitudinal data) and the number of counts (for non-longitudinal quantitative data and categorical data). The longitudinal data collected on R&D inputs - namely, annual expenditure on R&D and employment of QSE were analysed to get the two

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[142] Lofsten and Lindelof (2001) used the criteria of sales, profitability and employment to evaluate the performance of science park firms and off-park firms in Sweden. Similarly Westhead and Storey (1994) used sales, employment and profits as performance indicators in their evaluation of science park firms and off park firms in the United Kingdom

types of group means, the mean annual R&D intensity and mean annual QSE intensity respectively. The mean annual R&D intensity was obtained by dividing the mean annual R&D expenditure by the mean annual sales. Similarly the mean annual QSE intensity was calculated by dividing the mean annual QSE employment by the mean annual employment.

All the seven categorical variables with the exception of R&D thrust were assigned binary values of one (1) for indication of 'Yes' and zero (0) for an indication of 'No'. Thus for example, the total value obtained by science park firms having collaboration with local universities is the same as the number of firms indicating such collaboration. This is repeated for the other five variables: inter-firm R&D collaboration, use of venture capital, use of government R&D grants, international research collaboration and exports. Due to difficulty of getting data on the value for exports, respondents were merely asked whether they are engaged in exporting.

Apart from overall score of one (1) for a 'yes' response and zero (0) for a 'no' response in the case of collaboration with university, further scores were given to each of the six types of university links developed for the study. Respondents can respond to more than one than one of these categories. These six links were given score of 1 to 5. Informal contact with academics and university as a customer were given a score of one (1) with a score of two (2) for sponsorship of research trials/projects. This was followed by a score of three (3) for employment of academics on a part time consultancy basis, and a score of four (4) for access to equipment and other facilities. The highest score of five (5) was given to conducting joint/ collaborative research. These scores were then analysed for mean and standard deviations.

In the case of R&D thrust, respondents were asked to report on the R&D thrusts or direction of their R&D activities.[144] Respondents can respond to more than one than

[143] Nas and Leppalahti (1997) point out that profitability of companies is difficult to measure because business accounts are discretionary, profits vary over time, and across sectors and industry and market characteristics.

one of these five types of R&D thrusts, which were given score of 1 to 5. A score of one (1) was given to no particular focus followed by a score of two (2) for product improvement; three (3) for extension of existing range of products, four (4) for development of complementary products and the highest score of five (5) for radical new research The scores are totalled and the means of the overall R&D thrust as well as that radical new research is calculated based on the total number of valid cases.

The three R&D output variables, namely patents, copyrights and launch of new products and services were construed as count variables. Respondents were asked to provide data on the total number of each of these count variables for the period 1997-2001. Based on this total, the mean of each of these count variables is determined for science park as well as for off-park firms.

In the case of business output variables (sales, profits and employment), the annual growth rates of each of these variables were calculated. The annual sales growth rate was calculated by dividing the difference in sales between 2001 and 1997 by 1997 sales and then dividing the value by the number of years. Based on the above approach, the annual profit ratio[145] growth rate and employment growth rates were also obtained.[146]

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[144] These activities are categorised as product improvement, extension of existing range of products, development of complementary products, radical new research and no particular focus. See Ettlie and Rubenstein (1987) cited in Westhead (1997).

[145] The mean annual profit ratio was obtained by dividing the mean annual profits by the mean annual sales.

[146] The mean annual profit ratio growth rate is calculated by dividing the difference in mean profits ratio between 2001 and 1997 by mean profit ratio in 1997, and then by dividing the value by five years. The annual employment growth rate was calculated by dividing the difference in annual employment between 2001 and 1997 by the employment in 1997 and then, dividing the value by five years.

The measures to operationalise the above fifteen variables are shown in Table 7.2 below.

Table 7.2 Study Measures

No.	Variable	Description
1	RDintensity	Mean R&D expenses expressed as percentage of mean sales
2	QSEintensity	Ratio of mean qualified scientists & engineers to mean total employee
3	RDThrust	Indication of radical research
4	RDCoop	Number of strategic alliances forged
5	Univlinks	Number of links with local universities
6	Vcapital	Indication of use of venture capital
7	Govtgrants	Indication of use of govt. R&D grants
8	International RD	Indication of International R&D Collaboration
9	Exports	Indication of Exporting Acrtivity
10	Patents	Number of patents applied/grant
11	Copyrights	Number of copyrights Applied/grantEd
12	Newprods	Number of new products or processes launched
13	SalesGrowth	Mean Annual Sales Growth Rate
14	Profit Growth	Mean Annual Profit Ratio Growth Rate
15	Employment Growth	Mean Annual Employment Grow Rate

7.7 STATISTICAL METHODS

The focus of this study is on the observable differences between science parks firms and off-park firms with respect to a number of performance indicators discussed earlier in this chapter. The variables were analysed using statistical methods that were appropriate for comparisons between the two groups of firms.[147] These techniques range from frequency tabulation, mean and standard deviation to T-tests and chi-square test. The various types of data obtained through the mail survey and interviews were analysed quantitatively, using the Excel software and other statistical

[147] A survey of previous studies on science parks' impact on firm growth shows that researchers have used a range of statistical techniques that includes simple descriptive statistics, correlation, regression, discriminant analysis, factor analysis to more advanced techniques, like economic modelling and log-linear modelling. The type of technique used depends on the nature of study (for example exploratory or formal), quantitative or qualitative, sample size and objectives of study.

tools available online.[148] Data obtained from the interview survey were also analysed for interpretation and discussion as case studies of four selected SMEs.

The analysis proceeded from simple tabulation where frequency and percentage were displayed. The use of frequency and means in simple tabulations has been proven to be a useful and easily understood approach to statistical analysis. This technique involves plotting the number or percentage of firms in both science parks and off-park locations sharing similar responses to certain variables to observe whether there were any notable differences.[149]

The two main statistical techniques used in the present study were t-tests and chi-square tests. These techniques were chosen based on the nature of the hypotheses of the study, number of samples involved, types of data obtained, sample size and research design. The study is about performance of two independent but comparable groups of firms (two independent samples) with respect to the fifteen variables identified for the study. The study hypothesised that science park firms perform better than off-park firms on all these fifteen variables and this means the hypotheses are directional in nature. It was therefore found that one-tailed "t" tests were appropriate to determine whether the difference between two sample means with regard to structured variables are statistically different or not. The reason for using one-tailed t-test is because all the fifteen hypothesis of the study discussed in the last chapter are, as stated earlier, directional in nature. Although many have criticised the use of one-tailed test, in the case of present study it was found to be appropriate and adequate for reasons mentioned above. In fact, Westhead and Storey (1994) and Westhead (1997) in the study of science park firms in UK, have extensively used one-tailed "t" tests to determine whether the difference between two sample means

[148] The software available online is the Graphpad Software at URL: http://www.graphpad.co..quickcals.index.cfm

[149] In fact Ferguson (1995) opted for these simple techniques after his attempt to use logic regression analysis to explore the underlying factors of science park location, did not prove to be meaningful. The use of logic regression analysis proved meaningless because of the limitations in terms of the assumptions of the model as well as due to the relatively small population size in Ferguson's study.

with regard to R&D inputs (e.g. R&D intensity and R&D outputs (e.g. patents) were statistically significant or not.

Apart from using t-test, the study also employed chi-square method in analysing data that are categorical in nature. This method was used as a supplement to the t-tests in seven of the fifteen variables: radical research (R&D thrust), inter-firm R&D collaboration, links to university, international research collaboration, exporting activity, venture capital and government R&D grants. Respondents were asked to indicate whether they were involved in these activities. Based on the Yes and No answers, chi-square tests were performed to detect whether there are any significant statistical differences between the two groups of firms with respect to the seven related categorical variables.

The means and standard deviations of the fifteen variables for both science park and off-park firms were tested using t-tests technique to find out whether there are any significant differences between them at 5% significance level. Where the significance level obtained from the statistical analysis exceeded 0.05 (i.e. $p>0.05$) the alternative hypothesis (study hypothesis) concerned was rejected and the null hypothesis accepted. The reverse was done in the case $p<0.05$. Similar analysis was undertaken (supplementary analysis) using the chi-square for the seven categorical variables of the above fifteen variables, where the response was in the form of 'Yes' and 'No'.

7.8 CONCLUSION

This chapter has examined the research methodologies to test the fifteen hypotheses that were framed to determine whether science park firms perform better than off-park firms in terms of innovation, business performance and growth. The focus of the chapter is on the appropriate research design for the study encompassing target population and sampling selection, data collection procedures and statistical techniques that will be used in current study. The chapter has justified why the matched sample research design is the most appropriate method to test the hypotheses. It involves comparing two independent but comparable groups of firms with respect to the fifteen variables identified for the study. The chapter also highlighted that the two main statistical techniques used in the present study are the t-tests and the chi-square tests. The testing of these hypotheses and the results will be discussed in the next chapter.

ANALYSIS OF SURVEY DATA, RESULTS AND DISCUSSION

8.1 INTRODUCTION

This chapter is devoted to the analysis and discussion of the fifteeen variables discussed in chapter seven. The data for this analysis were obtained from a mail questionnaire survey administered on technology-based businesses located in Technology Park Malaysia and off-park areas in Malaysia. The chapter is organised in three parts. The first part is a discussion of the characteristics of both the science park and off-park firms covered in the sample survey, which is used as the basis for the empirical analysis in this study. The second part presents the results of the statistical tests (t-test and chi-square test) on the fifteen hypotheses formulated for the study. The results emerging from the hypotheses testing procedure are discussed in the third part. The main findings of an interview-based study of four selected respondents of the questionnaire survey will also be discussed in part three.

8.2 THE STUDY SAMPLE

The questionnaire survey administered on the two sampling frames (science park and off-park firms) yielded a response rates of 21.78% for the science park firms and 18.75 % for off-park firms. Thus of the total number of firms approached on-park and off-park, 52 were accessible for investigation, including 21 science park firms and 31 off-park firms. Quantitative and qualitative data, reflecting firm characteristics and R&D, innovation and business performance, were elicited from firms in these two sample groups. The profile of firms in terms of industrial characteristic, legal status and age are shown in Tables 8.1, 8.2 and 8.3 respectively. The innovation and business performance of the firms are shown in Table 8.4 and are discussed further in section 8.4. of this chapter.

8.2.1 Technology Sector of Firms

As can be oberved from Table 8.1, 42.23 % of all the firms from both science park and off-park locations are involved in the information and communication technology (ICT) business. Within the science park group, 45.45 % percent are involved in ICT and software businesses. This pattern appears to be common to most science parks throughout the world - a phenomenon deriving from the explosive growth of ICT business and knowledge-based economy in the last two decades.[150] The percentage of off-park firms involved in ICT ventures is 40.0%, confirming the attractiveness and growing importance of ICT-related businesses in Malaysia since the mid-1990s.

Table 8.1: Industrial Sectors of Firms

Type of Activity	Science Park Firms		Off Park Firms		All Firms	
	No.	%	No.	%	No.	%
Information & Communication	10	45.45	12	40.00	22	42.30
Telecommunication & Electronics	3	13.63	3	0.00	6	11.53
Biotechnology	1	4.55	2	6.67	3	5.77
Engineering	3	13.63	2	6.67	5	9.62
Environmental Technology	2	9.09	4	13.33	6	11.53
Design and Development	2	9.09	3	10.00	5	9.62
Others	1	4.55	4	13.33	5	9.62
	n = 22	100.0	n = 30	100 %	n =52	100.0

The preponderance of ICT-based companies among firms in the science park sample is due to the Technology Park Malaysia's (TPM) enthusiastic response to the government's emphasis on the ICT sector. Although the TPM was originally planned to facilitate R&D in both the private and the public sectors through partnership initiatives, this role has been somewhat diluted consequent upon the government's focus since mid-1990s on technological leapfrogging as a strategy for the development of knowedge-based economy. This strategy involved the implementation of a massive project called the Multimedia Super Corridor (MSC) in the Klang Valley to promote business ventures in multimedia and information and communication technologies (ICTs). TPM was subsequently brought under the MSC corridor and became a major location for ICT-based businesses. Companies locating in the TPM are eligible to apply for the MSC status which grants a number of incentives such as freedom to employ skilled workers from foreign countries without restriction and with tax break benefits. Off-park companies locating within the corridor are also eligible for the MSC status which explains why 40 % of the off-park sample firms are involved in the ICT sector.

8.2.2 Legal Status of Firms

Table 8.2 shows that a vast majority of the firms operating in science parks are single independent private companies with previous address (36.4%) and independent private company with branches (27.3 %). Together they make up 63.6 % of all science park firms. This compares with 57.7% of firms for the off-park sample. There is no single independent private company with no previous address in the science park group, indicating that the science park has not resulted to any new firm formation. This is not, however, surprising considering the fact that the park began operation only in 1996 and tenants attracted to the park were already operating elsewhere. However, in the off-park sample there are nine firms that have the status of single independent private company with no previous address. These constitute 30 % of all firms in the sample. In the off-park sample, single independent private companies with previous address constitute 36.67 % of the sample population, which is similar to the science park sample.

[150] More details can be obtained by accessing the website of the International Association of Science Parks (IASP).

Table 8.2: Legal Status of Business of Science Park and Off-Park Firms

Legal Status	Science Park Firms No.	%	Off Park Firms No.	%	All Firms No.	%
single independent private company, no previous address	0	0.00	9	30.00	9	17.31
single independent private company, with previous address	8	36.36	11	36.67	19	36.54
independent government company	1	4.55	0	0.00	1	1.92
independent private company with branches	6	27.27	5	16.67	11	2 1.15
subsidiary of local company	5	22.73	4	13.33	9	17.31
subsidiary of foreign company	2	9.09	1	3.33	3	5.77
	n = 22		n = 30	100%	n=52	100%

8.2.3 Age Profile of Firms

Table 8.3 Age Profile of Science Park and Off-Park Firms

Age Range (years)	Science Park Firms No.	%	Off Park Firms No.	%	All Firms No.	%
1-4	5	22.73	5	16.67	10	19.24
5-8	15	68.18	13	43.33	28	53.85
9-12	2	9.09	4	13.33	6	11.54
13-16	0	0.00	1	3.33	1	1.92
17 and above	0	0.00	7	23.33	7	13.46
Total	n=22	100%	n=30	100%	n=52	100%
MEAN	5.77		9.17		7.74	
STD. DEV.	2.29		5.69		5.43	
MEDIAN	5.50		7.0		6.0	

t= - 2.64, d.f=50, statistical difference at the 0.05 level of significance (one-tailed test)

Companies operating in science parks are mostly new technology-based firms (NTBFs) with average age of less than twenty-five years, and were formed to exploit innovation potential tthrough R&D (see Little 1977). This is also the case in the age profile of science park firms in the present study. In fact, 91% of the science park firms are less than 8 years old compared to 60% of the off-park firms in this age cohort.

Overall science park firms are younger than off-park firms with the mean age of 5.77 years compared to the mean age of 9.17 years for the off-park firms. A t-test showed the difference between the two means to be statistically significant at the 5% level. This pattern is similar to the study by Westhead and Storey (1994) in which the science park firms are younger with a mean age of 9.6 years compared to off-park firms whose mean age is 12.4 years. Similar findings were also reported by Ferguson (1999) in his study of Swedish science park firms.

8.3 DESCRIPTIVE STATISTICS

The means and standard deviations of the fifteeen variables for science park and off-park firms were calculated using the statistical techniques discussed in section 7.6.2 in the last chapter and are shown in Table 8.4.

Table 8.4: Descriptive Statistics

Variable	Science-park Firms		Off-park Firms		All Firms	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Rdexp	21.4791	29.1237	19.7924	29.9626	20.5060	29.3335
QSE	33.0430	17.3012	22.3926	19.7088	28.2218	20.5324
RD Thrust	1.3636	2.2792	1.3333	2.2489	1.3462	2.2394
RDCoop	0.7273	0.4558	0.4667	0.5074	0.5769	0.4989
Univlinks	1.5909	2.3837	1.5000	2.3305	1.5385	2.3302
Vcapital	0.2727	0.4558	0.1667	0.3790	0.2115	0.4123
Govtgrants	0.4091	0.5032	0.3000	0.4661	0.3462	0.4804
International RD	0.3636	0.4924	0.4000	0.4983	0.3846	0.4910
Exports	0.5909	0.5032	0.5333	0.5074	0.5577	0.5015

Patents	1.3182	2.1687	1.0667	1.6802	1.1731	1.8862
Copyrights	1.0455	1.6177	0.5333	1.0417	0.7500	1.3266
Newprods	0.3618	2.6074	1.8667	1.8889	2.6346	2.3766
Sales Growth	0.7307	1.4260	0.4105	0.6868	0.5459	1.0635
Profit ratio Growth	4.6232	13.6065	3.2233	5.8619	3.8156	9.8112
Employment Growth	0.4779	0.6770	0.2137	0.2049	0.3255	0.4795

8.4 TESTING THE HYPOTHESES

Based on the descriptive statistics presented in Table 8.4 above, one-tailed t-tests were performed to determine if there were any significant statistical differences between the means at the 5% level of significance.[151] If the significance level obtained exceeded 0.05 (i.e. $p<0.05$), the alternative hypothesis (study hypothesis) concerned will be accepted (confirmed) and the null hypothesis will be rejected. The reverse was done if $p>0.05$. Similar analysis was undertaken as a supplementary exercise using the chi-square for the seven categorical variables from the above fifteen variables, where the response was in the form of 'Yes' and 'No'. The results of the all the statistical tests are reported in Section 8.3.1 to Section 8.3.6 below.

8.4.1 R&D inputs

H1: Science park firms record higher levels of R&D spending than off-park firms.

8.4.1.1 R&D Intensity

The longitudinal data on R&D expenditure were analysed to get two types of group mean values, namely the average annual R&D expenditure and the average annual R&D intensity. For purpose of tabulation, the mean values obtained were categorised into a number of cohorts (R&D expenditure range in Ringgit Malaysia-RM) and the

[151] These tests are guided by previous studies on science parks, especially by Westhead and Storey (1994), Westhead (1997) and Ferguson and Oloffson (2004).

frequency of firms in each cohort is obtained. The results of these descriptive statistics and the means, standard deviations and the median of average annual R&D expenditure and the average annual R&D intensity are shown in Table 8.5 and Table 8.6 respectively.

Table 8.5: Average Annual R&D Expenditures of Science Park and Off-Park Firms

R&D Expenditure (in RM-Ringgit Malaysia)	Science Park Firms No.	%	Off Park Firms No.	%	All Firms No.	%
0	2	9.09	7	23.33	9	17.31
Less than 250,000	11	50.00	9	30.00	20	38.46
250,001 - 500,000	1	4.54	5	16.67	6	11.54
500,001 - 1,000,000	0	0.00	2	6.67	2	3.85
1,000,001 - 2,500,000	3	13.64	7	23.33	10	19.23
2,500,001 -5,000,000	5	22.73	0	0.00	5	9.62
Total	n=22	100.0	n=30	100.00	n=52	100.0
MEAN	0.9056		0.5613		0.7070	
STD. DEV.	1.2479		0.7450		0.9931	
MEDIAN	0.3176		0.2302		0.241	

Overall, the number of science park firms involved in R&D is greater than off-park companies. Table 8.5 shows that 20 (or 90.91%) of the 22 science park firms, spend on research and development compared to 21 (or 82.69 %) of the 30 off-park firms. The mean R&D expenditures (in RM) for science park firms is RM0.9056 compared to a mean of RM0.5613 (ditto) for off-park firms. A t-test of these means showed that there was no significant statistical difference between science park and off-park firms with regard to R&D expenditures. In terms of R&D intensity, science park firms again perform better with a mean of 21.4791% compared to a mean of 19.7924 % for off-park firms. A t-test was conducted with the result that there was no significant statistical difference between science park and off-park firms with regard to R&D intensity. Based on this test, Hypothesis 1 cannot be confirmed.

Table 8.6: Average Annual R&D Intensity of Science Park and Off-Park Firms

R&D Exp. % of turnover.	Science Park Firms No.	%	Off Park Firms No.	%	All Firms No.	%
0	2	9.09	7	23.33	9	17.31
1 - 10	8	36.36	10	33.33	18	34.62
11 - 20	7	31.82	6	20.00	13	25.00
21 - 30	0	0.00	0	0.00	0	0.00
31 - 40	2	9.09	1	3.33	3	5.77
> 40	3	13.63	6	20.00	9	17.31
Total	n=22	100.0	n=30	100.0	n=52	100.0
MEAN	21.4791		19.7924		20.5060	
STD. DEV.	29.1237		29.9626		29.3335	
MEDIAN	10.4614		6.3811		9.9465	

t= 0.20, d.f=50, no statistical difference at the 0.05 level of significance (one-tailed test)

8.4.1.2 Qualified scientists and engineers (QSEs)

H2: Science park firms employ more qualified scientists and engineers (QSEs) than off-park firms.

Based on the longitudinal data on employment of qualified scientists and engineers (QSEs) for the period 1997-2001, the mean annual QSE and the mean annual QSE intensity of science park and off-park firms and all the firms covered in the two sample groups were calculated. The results of the exercise are shown in Tables 8.7 and 8.8.

Table 8.7: Number of qualified scientists and engineers (QSEs) employed by Science Park and Off-Park Firms

Number of QSE employed	Science Park Firms No.	%	Off Park Firms No.	%	All Firms No.	%
0	0	0.00	3	10.00	3	5.77
1 - 5	7	31.82	17	56.67	24	46.15
6 - 10	4	18.18	5	16.67	9	17.31
11 - 15	8	36.36	4	13.33	12	23.08
16 - 20	2	9.09	1	3.33	3	5.77
> 20	1	4.55	0	0.00	1	1.92
Total	n=22	100.0	n=30	100.0	n=52	100.0
MEAN	10.3311		4.955		7.2295	
STD. DEV.	6.0866		4.6416		5.8905	
MEDIAN	10.7		3.2		5.2	

Table 8.8: Percentage of Qualified Scientists and Engineers (QSE) Employed by Science Park and Off-Park Firms

Percentage of QSEs	Science Park Firms No.	%	Off Park Firms No.	%	Total Firms No.	%
0						
1 - 9.99	0	0.00	3	10.00	3	5.77
10 - 19.99	2	9.09	6	20.00	8	15.38
20 - 29.99	1	4.55	7	23.33	8	15.38
30 - 39.99	7	31.82	4	13.33	11	21.15
40 - 49.99	5	22.73	6	20.00	11	21.15
> 50	2	9.09	1	3.33	3	5.77
	5	22.73	3	10.00	8	15.38
Total	n = 22	100.0	n = 30	100.00	n=52	100.0
MEAN	33.0473		22.3926		28.2218	
STD. DEVI	17.3012		19.7088		20.5324	
MEDIAN	29.4817		18.8556		25.7995	

t=2.03 d.f=50, statistical difference at the 0.05 level of significance (one-tailed test)

Overall, 94.23 % of all firms (both science park and off-park firms combined) employ qualified scientists and engineers (QSE). All (100%) science firms employ QSE compared to 90 % of the off-park firms. The mean QSE of science park firms is 10.3311 compared to a mean score of 4.955 for off-park firms. A t-test on the mean scores for both groups revealed that there is a significant statistical difference between science park and off-park firms with regard to the employment of QSE. There was also a significant statistical difference with regard to the QSE intensity between the two groups firms based on a mean value of 33.0473 for the former and 22.3926 for the latter. Therefore Hypothesis H2 is confirmed.

8.4.1.3 R&D Thrust (Direction of R&D)

H3: Science park firms are more inclined to conduct radically new research compared to off-park firms

Multiple responses were obtained from respondents when asked to report on the five types of R&D thrust. These five types of responses were given scores of 0 to 5 as explained in section 5.6.2 of the last chapter. The results of these responses are shown in Table 8.9, with the number of science park firms responding to each category, reflected in Row 2 while Row 4 indicates the number of off-park firms for each category. Overall, off-park firms have slightly greater focus on R&D than science park firms. This conclusion is based on a mean score of 6.9333 for off–park firms and 6.0909 for off-park firms.

Table 8.9: Thrust or Direction of R&D in Science Park and Off–Park Firms

R&D Thrust	Science Park Firms		Off Park Firms		All Firms	
	No.	%	No.	%	No.	%
Product improvement	22	100.00	20	66.67	42	80.76
Extension of existing range of products	10	45.45	18	60.00	28	53.85
Development of complementary products	8	36.36	18	60.00	26	50.00
Radical new research	6	27.27	8	26.67	14	26.92
No particular focus	0	0.00	7	23.33	7	13.46
Mean	6.9009		7.1667		6.7115	
Standard Deviation	3.7150		4.4418		4.1460	

Table 8.10: Radical Research by Science Park and Off-Park Firms

Type of Response	Science Park Firms No.	%	Off- Park Firms No.	%	All Firms No.	%
Yes	6	27.27	8	26.67	14	26.92
No	16	72.27	22	73.33	38	73.08
Total	n=22	100.00	n=30	100.0	n=52	100.00
Mean	1.3636		1.3333		1.3462	
Std. Dev.	2.2792		2.2489		2.2394	

t=0.05 d.f.=50, statistical difference at the 0.05 level of significance (one-tailed test)
x^2=0.002 significance level= 0.4806 no statistical significance at 0.05 level of significance

However, when the analysis was narrowed down to radical research to test the study's hypothesis, science park firms scored a mean of 1.3636 compared to 1.3333 for off-park firms as shown in Table 8.10. Based on a t-test on these means and the corresponding standard deviations, it was found that the there was no significant statistical difference between the two groups of firms with regard to radical research. Similar results were obtained when chi-square tests were conducted based on the number of the 'Yes' and 'No' answers for this indicator from both science park and off-parks (p>0.05). Therefore Hypothesis 3 is not confirmed.

8.4.2. R&D collaboration and co-operation

H4: Science park firms engage in greater R&D co-operation than off-park firms.

8.4.2.1 Interfirm R&D and Innovation Co-operation

In order to find out inter-firm R&D and innovation co-operation, respondents were asked to state the number of co-operative arrangements with regard to the innovation activities they have with other entities which include competitors, clients/customers, consultant firms, suppliers universities and strategic alliance partners. Respondents can give more than one response to each type of co-operative arrangement. The number and percentage of firms in each of these innovation and co-operative arrangements are shown in Table 8.11. The most important type of co-operative arrangement for innovation for both science park and off-park firms is strategic alliances followed by clients/customers.

Table 8.11: Percentage of Firms Having Co-operative Arrangement on Innovation Activities

Type of Partners	Science Park Firms No.	%	Off Park Firms No.	%	Total No.	%
a. Competitor	3	13.63	5	16.67	8	15.38
b. Clients/customers	9	40.91	13	43.33	22	42.31
c. Consultant firms	2	9.09	7	23.33	9	17.31
d. Suppliers	6	27.27	10	33.33	16	30.77
e. Universities/HEIs	7	31.82	9	30.00	16	30.77
f. Govt. RIs	5	22.73	7	23.33	12	23.00
g. Strategic Alliances	16	72.73	14	46.66	30	57.69

Further analysis was done to determine whether science park firms as a group differ from off-park firms with regard to the strategic alliances forged. The results of the analysis for both group of firms are shown in Table 8.12. A t-test on the means and standard deviations showed that the difference between science park and off-park firms with regard strategic alliances for innovation is statistically significant ($p<0.05$). Chi-square tests also confirmed the significance of the association of this indicator. ($p<0.05$). In view of this Hypothesis 4 is confirmed.

Table 8.12: Number of Strategic Alliances forged by Science Park and Off-Park Firms

R&D Collaboration	Science Park Firms No.	%	Off- Park Firms No.	%	All Firms No.	%
Strategic Alliances	16	72.73	14	46.66	30	57.69
Mean Std. Dev.	0.7273 0.4558		0.4667 0.5074		0.5769 0.4989	

t=1.91, d.f=50, statistical difference at the 0.05 level of significance (one-tailed test)
x^2=3.532 significance level= 0.0301 statistical significance at 0.05 level of significance

8.4.3.2 Links to Universities

H5: Science park firms have greater links with universities than off-park firms.

Multiple responses were received on the types of links science park firms and off-park firms forge with local universities. The number and the percentage of the firms involved in each of these relationships are shown in Table 8.13. Overall, 59.1 % of science park firms have links with universities compared to 50% of science parks firms. In terms of joint research collaboration, only 7 (31.81%) science park firms have such collaboration compared to 9 (30 %) off-park firms.

The six categories of university links were given scores of 1 to 5 as explained in section 5.6.2 of the last chapter. These scores were totalled and analysed for mean and standard deviations and the results are presented in Table 8.14. Based on a t-test of the means of 4.5 for science park firms and 4.3667 for off-park firms, it was found that there is no statistically significant difference between the two groups of firms with regard to links with universities. The analysis was extended to determine how both group of firms perform with regard to joint research collaboration with universities. A t-test on the respective means and standard deviations found that there is no significant difference between science park and off-park firms in joint research collaboration. Further test using the chi-square method on both groups of firms with and without joint research collaboration showed no evidence that would give credence the veracity of the hypothesis. Hypothesis 5 is therefore rejected.

Table 8.13: Number and Types of University Links Between Science Park and Off-Park Firms

Type of link with Universities	Science Park Firms		Off Park Firms		All Firms	
	No.	%	No.	%	No.	%
Informal contact with academics	4	18.18	11	36.67	15	28.85
Employment of academics on a part time consultancy basis	5	22.28	9	30.00	14	26.92
Conducting joint/ collaborative research	7	31.81	9	30.00	16	30.77
Sponsorship of research trials/projects	4	18.18	5	16.67	9	17.31
Access to equipment and other facilities	7	22.28	8	26.67	15	28.85
University/HEI as a customer	9	40.91	6	20.00	18	34.42
Total no. of links	36					
Total no. of firms	22		30		52	
No. of firms having links	13		15		28	
Percentage of firms	59.1%		50.0%		53.85	

.chi square tests on conducting joint/ collaborative research:
x^2=0.020 significance level= 0.4442 no statistical significance at 0.05 level of significance

Table 8.14: Types of University Links Between Science Park and Off-Park Firms (Means and Standard Deviations)

Type of link with Universities	Science Park Firms		Off Park Firms		All Firms	
	Mean	SD	Mean	SD	Mean	SD
Informal contact with academics	0.1818	0.3948	0.3667	0.4901	2.885	0.4575
Employment of academics on a part time consultancy basis	0.6818	1.2868	0.9	1.3983	0.8076	1.3437
Conducting joint/collaborative research	1.5909	2.3837	1.5	2.3305	1.5387	2.3302
Sponsorship of research trials/projects	0.3637	0.7895	0.3333	0.7581	0.3462	0.7640
Access to equipment and other facilities	1.2727	1.9069	1.667	1.7991	1.1538	1.8297
University/HEI as a customer	0.4091	0.5032	0.2	0.4068	0.2885	0.4577
Mean	4.5		4.3667		4.4231	
Standard Deviation	5.8125		5.4360		5.5425	

t=0.08 d.f=50, no statistical difference at the 0.05 level of significance (one-tailed test)

8.4.3 Access to Finance

Respondents were asked about sources of finance for promoting their innovation and R&D activities, and also about the accessibility of these sources, namely, company own finances, borrowing from financial institutions, venture capital and government R&D grants. The results of our analysis in this respect are presented below.

8.4.3.1 Access to Venture Capital

H6: Science Parks firm utilise more venture capital than off-park firms.

In terms of access to venture capital, Table 8.15 shows that 6 science park firms (27.27%) reported use of venture capital to finance R&D activities compared to 5 off-park firms (16.67 %). A score of 1 was given to firms using venture capital and a score of 0 to firms, which indicated that they did not use venture capital. The means and standard deviations of these scores are shown in Table 8.15. A t-test on these values confirmed that there is no significant difference between science park and off-park firms with regard to access to venture capital. Hypothesis 6 is, therefore, rejected. Similar results were also obtained when chi-square tests were conducted based on the response for this indicator from both science park and off-parks ($p>0.05$).

Table 8.15: Sources of Finance for Innovation and R&D Activities

Sources of Finance	Science Park Firms No.	Science Park Firms %	Off Park Firms No.	Off Park Firms %	All Firms No.	All Firms %
Company own finances	22	100.00	30	100.00	52	100.00
Borrowing from financial institutions	8	36.36	8	26.67	16	30.76
Venture capital	6	27.27	5	16.67	11	21.15
Government grants	9	40.91	9	30.00	18	34.62
i. Venture Capital						
Mean	0.2727		0.1667		0.2115	
Std Dev	0.4558		0.3790		0.4123	
ii. Govt Grants						
Mean	0.4091		0.3		0.3462	
Std Dev	0.5032		0.4661		0.4804	

i. $t=0.91$ d.f=50, no statistical difference at the 0.05 level of significance (one-tailed test)
ii. $t=0.81$ d.f=50, no statistical difference at the 0.05 level of significance (one-tailed test)
i. $x^2=0.856$ significance level=0.1774 no statistical significance at 0.05 level of significance
ii. $x^2= 0.667$ significance level= 0.2070 no statistical significance at 0.05 level of significance

8.4.3.2 Access to Government R&D Grants

H7: Science Park firms have easier access to government research funds than off-park firms.

Table 8.15 shows the sources of finance for innovation and R&D activities accessed by science park and off-park firms. It is apparent that 41 % of science park firms and 30% of off-park firms have succeeded in obtaining the grants. A score of one (1) was given to firms that have obtained the grants and a score of zero (0) to firms, which indicate that they did not get such grants. The means and standard deviations of these scores are also shown in Table 8.15. A t-test on these values found that there is no significant difference between science park and off-park firms with regard to access to government R&D grants. Similar results were obtained when chi-square tests were conducted based on the number of the 'Yes' and 'No' answers for this indicator from both science park and off-parks (p>0.05). Therefore Hypothesis 7 is not confirmed.

8.4.4 Internationalisation

H8: Science park firms have more international joint research collaboration than off-park firms

H9: Science park firms are more export-active than off-park firms.

Table 8.16: Internationalisation of Science Park firms and Off-Park Firms

Type of International Link	Science Park		Off Park		Total	
	No.	%	No.	%	No.	%
Foreign market for goods and services	13	59.09	16	53.33	29	55.75
Foreign sources for raw material and other inputs	16	72.73	21	70.00	37	71.15
Use of foreign consultants and technical expertise	9	40.91	14	46.67	23	44.23
Use of foreign technology – equipment and other hardware	19	86.36	26	86.67	45	86.54
Collaborative research projects with foreign partners	8	36.36	12	40.00	20	38.46
Business links with foreign MNCs	15	68.18	16	53.33	31	59.61

Respondents were asked to report on their internationalisation activities, categorised as export of goods and services, foreign sources for raw material and other inputs, use of foreign consultants and technical expertise, use of foreign technology/equipment and other hardware, collaborative research projects with foreign partners and business links with foreign MNCs. As the categories are not mutually exclusive, respondents can indicate to be in more than one of the specified international activities. The number and the percentage of firms involved in each of these international activities are shown in Table 8.16.

Two hypotheses of the study with regard of internationalisation, is about international research collaboration and exporting activity involving both science park and off-park firms. Table 8.16 shows that 36.36% of science park firms and 40% of off-park firms are involved in international research collaboration. In the case of exporting, the percentage for science park firms is 59% compared to 53% for off-park firms. Firms involved with each of these activities were given a score of one (1) and those not involved were given a score of zero (0). Results of the means and standard deviations based on the total scores achieved by both group of firms are shown in Table 8.17. A t-test on these values found that there is no significant difference between science park firms and off-park firms with regard to international research collaboration and exporting activity. Chi-square tests also confirmed that the association with regard to these two indicators was not significant. This means that Hypotheses 8 and 9 cannot be empirically sustained.

Table 8.17: International R&D Collaboration and Exports

Type of international link	Science Park Firms		Off Park Firms		All Firms	
	Mean	SD	Mean	SD	Mean	SD
i. Collaborative research projects with foreign partners	0.3636	0.4924	0.4	0.4983	0.3846	0.4913
ii. Foreign market for goods and services	0.5909	0.5032	0.5333	0.5074	0.5577	0.5015
	n = 22		n = 30		n = 52	

i. t=-0.26 d.f=50, no statistical difference at the 0.05 level of significance (one-tailed test)
ii. t=0.41 d.f=50, no statistical difference at the 0.05 level of significance (one-tailed test)
i. x^2= 0.071 significance level= 0.3950 no statistical significance at 0.05 level of significance
ii. x^2= 0.171 significance level= 0.3398 no statistical significance at 0.05 level of significance

8.4.5 Innovation and R&D Output

Data on total number of new products/processes launched, patents and copyrights for the period 1997 were obtained from both the science park and off-park firms to examine their relative innovation performance. These data were then analysed to determine their average growth rates. The results of this analysis in terms of mean, and standard deviation are presented in Table 8.18, Table 8.19 and Table 8.20 respectively.

8.4.5.1 Launch of new products/processes

H10: Science park firms record higher number of new products/processes than off-park firms.

Table 8.18 shows that 25% of all firms (science park and off-park firms), did not launch any new product/process during the period 1997-2001. The total number of new products/processes launched by science park firms is 81 giving a mean value of 3.6818 and standard deviation of 2.6074. Off-park firms launched a total of 56 new products/processes with a mean value of 1.8667 and standard deviation of 1.8889. A t-test on these means and standard deviations showed that there is a statistically significant difference between the science park and off-park firms with regard to the number of new products/processes launched, thus giving credence to the veracity of Hypothesis 10.

Table 8.18: Number of New Products/Processes Launched by Science Park and Off-Park Firms for Period 1997-2001

Number of new product/process	Science Park Firms		Off Park Firms		All Firms	
	No.	%.	No.	%.	No.	%.
0	2	9.09	11	36.67	13	25.00
1	3	13.63	4	13.33	7	13.46
2	3	13.63	4	13.33	7	13.46
3	2	9.09	5	16.67	7	13.46
4	5	22.73	2	6.67	7	13.46
> 4	7	31.82	4	13.33	11	21.15
Total	n =22	100.0	n=30	100.0	n=52	100.0
Total No. of New Products/Processes	81		56		137	
Mean	3.6818		1.8667		2.6346	
Std Dev.	2.6074		1.8889		2.3766	

t= 2.91, df.=50, statistical difference at the 0.05 level of significance (one-tailed test)

8.4.5.2 Patents Applied or Granted

H11: Science park firms record higher number of patents granted than off- park firms.

Table 8.19 shows that 30% of all firms (science park and off-park firms), did not obtain patents, and did not apply for patents registration between the years 1997 and 2001. The total number of patents applied/granted by science park firms is 29 giving a mean value of 1.3182 and standard deviation of 2.1687. Off-park firms applied for/or granted a total of 32 patents with a mean value of 1.0667 and standard deviation of 1.6802. A t-test on these means and standard deviations showed that there is no statistically significant difference between the science park and off-park firms with regard to the number of patents applied/granted. Hypothesis 11 is therefore not confirmed.

Table 8.19: Number of Patents or Applications that have been taken out by Science Park and Off-Park Firms during 1997-2001

Number of Patents	Science Park Firms No.	%.	Off Park Firms No.	%.	All Firms No.	%.
0	12	54.55	18	60.00	30	57.69
1	4	18.18	4	13.33	8	15.38
2	2	9.09	2	6.67	4	7.69
3	1	4.55	3	10.00	4	7.69
4	1	4.55	1	3.33	2	3.85
>4	2	9.09	2	6.67	4	7.69
Total	n =22	100.0	n=30	100.0	n=52	100.0
Total No. of Patents	29		32		61	
Mean	1.3182		1.0667		1.1731	
Std Dev.	2.1687		1.6802		1.8862	

t= 0.47, d.f=50, no statistical difference at the 0.05 level of significance (one-tailed test)

8.4.5.3 Copyrights Applied or Granted

H12: Science park firms record higher number of copyrights granted or applied than off- park firms.

Table 8.20 shows that 69.23% of all firms (science park and off-park firms) did not obtain copyrights or applied for copyright registration between the years 1997 and 2001. The total number of copyright applied/granted by science park firms is 23 giving a mean value of 1.0455 and standard deviation of 1.6177. Off-park firms applied/granted a total of 16 copyrights with a mean value of 0.5333 and a standard deviation of 1.0417. Actually, only 12 science park and 12 off-park firms are involved in software production. The means and standard deviation for science park firms with total number of 14 is 1.1667 and 1.8007 respectively. Off park firms recorded a mean of 0.9167 and standard deviation of 1.2401. A t-test on these means and standard deviations showed that there is no statistical difference between the science park software firms and off-park software firms with regard to the number of copyrights applied/granted. There is therefore no basis for confirming Hypothesis 12.

Table 8.20: Number of Copyrights or Applications Registered by Science Park and Off-Park Firms for Period 1977- 2001

Number of Copyrights	Science Park Firms No.	Science Park Firms %.	Off Park Firms No.	Off Park Firms %.	All Firms No.	All Firms %.
0	13	59.09	23	76.67	36	69.23
1	4	18.18	1	3.33	5	9.62
2	0	0.00	3	10.00	3	5.77
3	2	9.09	3	10.00	5	9.62
4	2	9.09	0	0.00	2	3.85
> 4	1	4.55	0	0.00	1	1.92
Total	n =22	100.0	n=30	100.0	n=52	100.0
Total No. of Copyrights	23		16		39	
Mean	1.0455		0.5333		0.75	
Std Dev.	1.6177		1.0417		1.3266	

t= 1.39, d.f=50, no statistical difference at the 0.05 level of significance (one-tailed test)

8.4.6 Business Performance and Growth

Longitudinal data (1997- 2001) on sales, profits and employment were obtained from both sample groups to examine their relative business performance and growth of on-park and off-park firms. The results of this analysis in terms of mean, standard deviation and median for the three performance indicators are presented Tables 8.21, 8.22 and 8.23 respectively.

8.4.6.1 Sales Turnover

H13: Science park firms record higher sales turnover than off-park firms.

Table 8.21 : Mean Annual Sales Turnover of Science Park and Off-Park Firms

Annual Turnover	Science Park Firms		Off Park Firms		Total Firms	
	No.	%	No.	%	No.	%
less than 500,000	4	18.18	6	20.00	10	19.23
500,000-999,000	2	9.09	4	13.33	6	11.54
1,000,000-2,499,000	5	22.73	8	26.67	13	25.00
2,500,000-4,999,000	4	18.18	7	23.33	11	21.15
5,000,000-7,499,000	3	13.64	0	0.00	3	5.77
7,500,000-9,999,000	1	4.55	1	3.33	2	3.85
10,000,000-14,999,000	1	4.55	3	10.00	4	7.69
15,000,000 and above	2	9.09	1	3.33	3	5.77
Total	n=22	100.0	n=30	100.0	n=52	100.0
MEAN	4.7508		3.4393		3.9942	
STD. DEV	5.9236		4.6109		5.1928	
MEDIAN	2.576		1.6833		2.345	

The data collected on sales turnover were analysed to get two types of value, namely the mean annual sales (in RM) and mean annual sales growth rate. The analysis on the mean annual sales is presented in Table 18.21, which shows that 50% of the science park firms with a mean annual sales turnover of less than 2.5 million Ringgit compared with 60% of the off-park firms with that mean annual sales. The mean and standard deviations for science park firms are 4.7508 and 5.9236, whereas the values for off-park firms 3.4393 and 4.6109 respectively. A t-test on these values shows that the difference between science park and off-park firms with respect mean annual sales is not statistically significant. The mean annual sales growth rate and the related standard deviation are shown in Table 8.24. A t-test on these values found that the difference between science park and off-park firms with regard to mean annual sales growth rate is statistically not significant. Therefore Hypothesis 13 is rejected on the basis of available evidence.

Table 8.22: Average Annual Sales Growth Rate of Science Park and off-Park Firms

R&D Exp. % of turnover	Science Park Firms No.	%	Off Park Firms No.	%	All Firms No.	%
< 0.5	13	59.09	25	83.33	38	73.08
0.5 – 0.99	2	9.09	2	6.66	4	7.69
1.0 – 1.49	4	18.18	0	0.00	4	7.69
1.5 – 1.99	0	0.00	0	0.00	0	0.00
2 and >	3	13.63	3	10.00	6	11.54
Total	n=22	100.0	n=30	100.0	n=52	100.0
MEAN	0.7307		0.4105		0.5459	
STD. DEV.	1.4259		0.6868		1.0635	

t= 1.07, d.f=50, no statistical difference at the 0.05 level of significance (one-tailed test)

8.4.6.2 Profit Ratio

H14: Science park firms are more likely to record higher profits than off-park firms.

The data on profits were analysed to get two types of group mean values, namely the mean annual profit ratio and the mean annual profit ratio growth rate and these are shown in Table 8.23 and Table 8.24 respectively. Although off-park firms have higher mean profit ratio (12.4310) than science park firms (7.9134), as shown in Table 8.23, science park firms have higher mean annual profit ratio growth rate (4.6232) than off-parks firms (3.2234), as is apparent from Table 8.24. A t-test on the means and the standard deviations of the annual profit ratio growth rate found that there was no statistically significant difference between science park and off-park firms with respect to profit ratio growth rate ($p>0.05$). Therefore Hypothesis 14 cannot be sustained by the weight of available evidence.

Table 8.23: Average Annual Profits of Science Park and Off-Park Firms

Profit as % of Sales	Science Park Firms No.	%	Off Park Firms No.	%	All Firms No.	%
0	9	40.91	6	20.00	15	28.85
1 - 10	5	22.73	9	30.00	14	26.92
11 - 20	7	31.82	10	33.33	17	32.69
21 - 30	0	0.00	2	6.67	2	3.85
> 30	1	4.55	3	10.00	4	7.69
	n=22	100.0	n=30	100.0	n=52	100.0
Mean	7.9134		12.4310		10.5197	
Std Dev	12.3954		13.7505		13.2617	
Median	1.1665		10.116		8.2221	

Table 8.24: Average Annual Profits Ratio Growth Rate of Science Park and Off-Park Firms

Profit Ratio Growth Rate	Science Park Firms No.	%	Off Park Firms No.	%	All Firms No.	%
< 0.5	14	63.63	14	46.67	28	53.85
0.5 – 0.99	1	4.55	4	13.33	5	9.62
1.0 – 1.49	2	9.09	2	6.67	4	7.69
1.5 – 1.99	0	0.00	1	3.33	1	1.92
2 and >	5	22.73	9	30.00	14	26.92
Total	n=22	100.0	n=30	100.0	n=52	100.0
MEAN	4.6232		3.2234		3.8156	
STD. DEV.	13.6066		5.8619		9.8112	

t= 0.50, d.f=50, no statistical difference at the 0.05 level of significance (one-tailed test)

8.4.6.3 Employment Growth

H15: Science park firms register higher employment growth rate than off-park firms.

The data collected on employment were analysed to get two types of values, namely the mean annual employment (in number of employees) and mean annual employment growth rate. The analysis on the mean annual employment is presented in Table 18.25. Overall, 38.47 % of all firms have mean annual employment size of less than 20 employees with 17.31 % having more than 50 employees. The mean and standard deviations for science park firms are 37.2 and 31.0182 respectively and the corresponding values for off-park firms are 30.79 and 37.2199. A t-test on these values found that the difference between science park and off-park firms with respect mean annual employment is not statistically significant. The mean annual employent growth rate and the standard deviation are shown in Table 8.26. A t-test on these values found that difference between science park and off-park firms with regard to mean annual employment growth rate is significant. Therefore Hypothesis 13 is confirmed.

Table 8.25: Mean Annual Employment Size of Science Park and Off-Park Firms

Mean Number of Employees	Science Park Firms No.	%	Off Park Firms No.	%	Total Firms No.	%
1 – 10	4	18.18	11	36.67	15	28.85
11 – 20	4	18.18	1	3.33	5	9.62
21 – 30	2	9.09	9	30.00	11	21.15
31 – 40	6	27.27	3	10.00	9	17.31
41 – 50	2	9.09	1	3.33	3	5.77
> 50	4	18.18	5	16.67	9	17.31
	N =22	100.00	N=30	100.00	N=52	100.00
Mean	37.2009		30.79		33.5023	
Std. Dev.	31.0182		37.2199		34.5562	
Median	34.5		21.7		25.0	

Table 8.26: Average Annual Employment Growth Rate of Science Park and off-Park Firms

Employment Growth Rate	Science Park Firms No.	%	Off Park Firms No.	%	All Firms No.	%
< 0.5	16	72.73	25	83.33	41	78.85
0.5 – 0.99	3	13.63	5	16.67	8	15.38
1.0 – 1.49	0	0.00	0	0.00	0	0.00
1.5 – 1.99	1	4.55	0	0.00	1	1.92
2 and >	2	9.09	0	0.00	2	3.85
Total	n=22	100.0	n=30	100.0	n=52	100.0
MEAN	0.4779		0.2137		0.3254	
STD. DEV.	0.6770		0.2049		0.4795	

t= 2.02 d.f=50, statistical difference at the 0.05 level of significance (one-tailed test)

8.4.7 Summary of Test Results

A summary of the results of the hypotheses tests based on the fifteen variables are presented in Table 8.27 below. The details of the results of the t-tests in terms of means, standard deviations, value of t-statistics and value of significant level obtained by using Excel and other statistical analysis tools are presented in Appendix VIII.

Table 8.27: Summary of Results

No.	Hypothesis	Study Finding
H1.	Science park firms will record higher levels of R&D spending than off-park firms.	Not Confirmed
H2.	Science park firms will employ greater number of qualified scientists and engineers (QSEs) than off-park firms.	Confirmed
H3	Science park firms are more inclined to conduct radically new research compared to off-park firms.	Not Confirmed
H4.	Science park firms will engage in greater R&D collaboration than off-park firms.	Confirmed
H5.	Science park firms will have greater links with Universities than off-park firms.	Not Confirmed
H6.	Science Parks firm utilise more venture capital than off-park firms.	Not Confirmed
H7.	Science Park firms have easier access to government research funds than off-park firms.	Not Confirmed
H8.	Science park firms will have more international joint research collaboration than off-park firms.	Not Confirmed
H9.	Science park firms have higher export orientation than off-park firms.	Not Confirmed
H10.	Science park firms will record higher number of new products/processes launched than off-park firms.	Confirmed
H11.	Science park firms will record higher number of patents granted than off- park firms.	Not Confirmed
H12.	Science park firms will record higher number of copyrights granted or applied than off- park firms.	Not Confirmed
H13.	Science park firms will record higher sales turnover than off-park firms.	Not Confirmed
H14.	Science park firms will record higher profits than off-park firms.	Not Confirmed
H15.	Science park firms register higher employment growth rate than off-park firms	Confirmed

As shown in Table 8.27, statistically significant differences between science park and off-park firms were found in only four variables namely QSE intensity, interfirm collaboration, number of new products and services launched, and employment growth. Off-park firms performed better than science parks firms only in one variable, namely, international R&D collaboration. The next section will discuss these tests results.

8.5 DISCUSSION

The objective of this study is to find out whether science parks stimulate innovation and enhance business performance of firms located on them. Data from two different sampling frames, one from a science park and the other from off-park locations were used. This procedure has enabled useful comparisons to be made about the two groups of firms in terms of innovation input and output, and corporate performance.

The results of the hypothesis testing presented in section 8.4 showed that science parks firms perform better than off-park firms in all the performance indicators except in international research collaboration. Despite this overall positive outcome, the performance of science park firms compared to off-park firms is found to be significantly higher with regard to only four indicators, namely employment of qualified scientists and engineers (QSE intensity), inter-firm collaboration, launch of new products and processes, and employment growth.

8.5.1 R&D Inputs

Firms need to develop their absorptive capacity to adopt, adapt and assimilate external information and apply it for commercial ends (Cohen and Levinthal 1990). To achieve this, they would need to make sufficient investment in research and development and employ adequate number of qualified scientists and engineers (QSEs). Science park firms are said to be more R&D-intensive, which also requires them to employ more QSEs. The present study examined both these indicators of R&D intensity.

8.5.1.1 R&D Expenditures

The level of R&D spending and intensity does not differ significantly betweeen science park and off-park firms although it varies according to size of company and technology sector. The study found that there is no statistically significant difference between science park firms and off-park firms in terms of R&D intensity (R&D expenditures expressed as a percentage of sales) with the former recording a mean of 21.48% compared to 19.79% recorded by the latter. This finding is consistent with the study on UK science park firms by Westhead (1997) where the respective means are 20.6% and 13.5%. However, these results are disappointing considering the fact that park management follow policy of attracting companies that conduct R&D. Even the advantage of the MSC status granted to TPM companies, which makes them eligible for consideration of MSC R&D grants, is not reflected in the findings, as the park companies record only marginally better performance in the mean R&D intensity compared to off-park firms. Perhaps there are other factors that explain this paradoxical situation.

Companies may show ambitious R&D activities in their business plans, so as to get favourable consideration for admission into the science park. But once admitted, they may not conduct R&D to the level expected of them. Lack of funding is one of the major barriers faced by these SMEs to conduct R&D. Banks in Malaysia are generally risk-averse to R&D activities undertaken by local companies especially SMEs. This is probably because banks lack information and do not possess the expertise to evaluate viable proposals from technology-based SMEs. Besides, many companies do not utilise the R&D funds available either because they are not interested to apply or they are not aware of the existence of such R&D grants.

Nevertheless, the above results should be interpreted with caution for a number of reasons. Firstly, SMEs in Malaysia generally do not keep good accounting records of their R&D activities. In fact, it is the lack of such data that makes it difficult to identify technological intensiveness of a business venture in Malaysia. Secondly, the respondent firms might be involved in innovation and R&D activities without realising that these activities contribute to their technological competency. This is evident when a number of respondents in both the science park and off-park samples reported R&D thrust such as product improvement and extension of existing range of products without any R&D expenditure and employment of QSEs. Thirdly, SMEs may not be willing to reveal their R&D activities in order to maintain the secrecy of such activities to prevent such information from falling into the hands of third parties who could be their rivals. For these three reasons SMEs could be under-reporting their R&D activities as in the case of many studies (see Kleinknecht 1987).

8.5.1.2 Employment of Qualified Scientists and Engineers

There is a wide variation in the employment of QSE within science park firms as well as between the two groups of firms. All science park firms indicate employment of QSE while there are three (3) off-park park firms that do not employ any QSE. Overall science parks firms employ greater number of QSEs than off-park firms with mean value of 33.05% for the former and 22.39% for the latter. These findings are consistent with the study on UK science park firms by Westhead and Storey (1997). The means were 27.6% and 19.0% respectively. However, in the present study, the difference in these means is statistically significant compared to the study by Westhead and Storey, which does not detect such a difference between the two means.

There are two possible reasons for the above positive outcome in the QSE intensity indicator of the present study. The first reason is related to MSC status enjoyed by most of the science park firms' status, which allows them to recruit qualified staff from overseas without restrictions. QSE from low costs countries such as India and China are usually paid wages lower than those local QSEs but can only work in companies that are located within the MSC. Technology Park Malaysia companies enjoy this advantage compared to off-park companies. Another possible reason for the finding is related to the variation in R&D expenditures incurred between the two groups of firms. Companies that score high means in the R&D intensity usually also employ the required number of QSE to undertake the R&D activities. This positive relationship between R&D intensity and QSE intensity is shown in Table 8.31. Thus

TPM companies already registering higher R&D intensity (though not significantly different) and enjoying the MSC status are encouraged to employ more QSE in comparison to off-park companies to carry out their R&D activities. Thus their QSE intensity is significantly higher than that of the off-park companies.

However although overall the employment of QSE by both science park and off-park firms is higher than the findings of other studies as highlighted earlier, the QSE intensity can be further enhanced if more QSEs are attracted to work in SMEs with better working conditions and terms including better wages. Generally QSEs in Malaysia would prefer to work in established multinational companies where they command higher pay and enjoy better working environment or work in government-owned companies and universities where there is greater job stability rather than in SMEs including new technology-based firms.[152] Many SMEs do not have the financial resources to employ and retain large number of QSE and therefore, depending on their needs, recruit skilled manpower from low-cost countries such as India.

8.5.1.3 R&D Thrust

Although 90.91 % of the science park firms are involved in R&D based on the data for R&D expenditure (Table 8.5), most of them are involved in product improvement, and extension of existing product range as shown in Table 8.9. This is not surprising as 50 % of the science park firms are involved in ICT products, which have shorter product life. Therefore these firms need to improve their products as well as introduce new products to survive in a highly competitive ICT business environment. The R&D is also undertaken to reduce manufacturing time so that the products created are delivered in the shortest possible time to customers locally and abroad. The results show that the technological levels of science parks firms are not statistically different, from that of off-park firms. This finding confirms the results of

[152] The government has been attempting to attract Malaysian scientists working abroad to return home and work in Malaysian companies. The results of this campaign has been rather disappointing due to local working conditions and terms. Local companies are unable to match the salaries currently enjoyed by these scientists although a few large government companies and private companies have managed to recruit them.

the study of science park and off–park firms in the United Kingdom by Westhead and Storey (1994).

Technology-based businesses seeking the Multimedia Super Corridor (MSC) status[153] need to locate in a site within the corridor, which extends from the Petronas Twin Towers in the central business district of Kuala Lumpur to the Kuala Lumpur International Airport (KLIA). Technology Park Malaysia (TPM) is strategically located within this corridor, and thus became a magnet for many companies, seeking the MSC status. Therefore it is this factor coupled with the 'image and the overall prestige of the site' that attracted many firms to locate in TPM. In other words, these firms did not consider access to research facilities nor the prestige being linked to universties and HEIs, as important factors influencing their decision to locate in TPM. Thus it is not surprising to find most of the TPM tenant companies not conducting any significant research as in the case of a study on science park firms in the United Kingdom by Westhead (1997). Another reason is that, with the exception of a few, most of these SMEs do not have the resources in terms of money and technical manpower to conduct internal R&D let alone radical research.

8.5.2 R&D Collaboration and Cooperation

Two indicators used in the present study to measure R&D collaboration and co-operation are inter-firm co-operation and links between firms and local universities.

8.5.2.1 Inter-firm Collaboration

It is apparent from the results of our survey (Table 8.11) that inter-firm collaboration is generally low. The most important form of collaboration is strategic alliances in which 73% of science park parks are involved compared to 47% of off-parks and the difference between them is statistically significant ($p<0.05$). But off-park firms perform better than science park firms in the other types of collaborative initiatives but the difference is only marginal between the two groups of firms.

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[153] Companies granted the MSC status enjoy numerous incentives including tax break and employing QSEs from abroad.

The reason for science park firms having greater number of strategic alliances can be attributed to the type of technology sector, founder characteristics and government policies. As shown in Table 8.1, 59% of science park firms are involved in ICT, telecommunications and electronics sector compared to 50% in the off-park firm group. Science park firms more than off-park firms have greater tendency to launch new products and services forging strategic alliances with other firms. This is confirmed by the findings of the case studies of all the three science park firms whose founders are enthusiastic about the need for such alliances to enhance their innovation and business performance.

8.5.2.2 Links to Universities

The results show a reasonably high level of interactions between on-park and off-park firms and local universties. Overall, science park firms have more links with universities, although the difference is not shown to be statistically significant. Most of the universities in Malaysia are funded by the government and, they provide a lot of opportunities for local businesses in the area of procurement of technology, equipment and services. Local universities do require the products and services of local software and IT firms, thus becoming major customers for local technology-based businesses. Informal contacts still feature high in the study and is consistent with the observation made by World Bank (2005, p.125) which describes the university-industry relationship in Malaysia as one of arm's length, 'where a team of university's professors or reserach scientists is called in on an as-needed basis'.

One notable observation in the above findings is the reasonably high percentage of science park and off-park firms having joint collaborative research with local universities. In fact, the percentage of science park firms (31.81) engaged in joint collaborative research is higher than that found in other studies. For example, in the study by Felsenstein (1994), the percentage is only 13%. There are possibly three reasons for the higher percentage as shown in the present study. The first reason relates to the condition imposed on firms receiving government R&D grants. Two of science park firms (9%) and eight of off-park firms (23%) are recipients of grants provided under the Industrial R&D Grant Scheme (IGS) by the Ministry of Science, Technology and Environment (MOSTE).[154] An important requirement of this grant is the need for the grant recipient firm to collaborate with researchers in universities or research institutes on the particular research project funded by the grant. However, this condition is not strictly imposed in the case of grants under the Multimedia R&D Grant Scheme (MGS) given by Multimedia Development Corporation (MDC) to local ICT and multimedia companies.[155] This partly explains why most of the ICT companies in both the science park and off-park samples do not engage in research collaboration with local universities, although other forms of links are also in evidence, as shown in Table 8.13. The overall finding is also consistent with the study by Mohnen and Hoaraeu (2002), which found that, firms receiving government support for innovation engage in outright collaboration with universities and government laboratories.[156]

The second reason is about the real need of firms to use scientific know-how offered by universities in specific technologies, such as biotechnology and nanotechnology as observed by Veugelers and Cassiman (2005). In fact, the biotechnology firms in both sample groups have links with local universities. The third reason is the deliberate attempts by both the science park management and the technology transfer officials in the universities to link park companies with various university facilities. It should be noted that the CEO of the park is a university professor appointed on secondment by his/her university to head the park management. While some companies do not need such links for reasons stated earlier, others do find it essential to forge links with local and foreign universities. For example, TPM Academy, a subsidiary company of the TPM Corporation (park owner), has forged smart

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[154] The Ministry is now known as the Ministry of Science, Technology and Innovation (MOSTI).

[155] One of the criteria for MGS grants includes linkages to local research institutes and leading companies.

[156] Mohnen and Hoareau (2002) conducted the study of firms in France, Germany, Ireland and Spain using the information contained in the second Community Innovation Survey (CIS). Large firms and those with patents are the ones that mainly forge such links.

partnerships with a number of foreign universties to facilitate exchange of expertise and intelligence in the field of biotechnology, engineering, ICT and business.[157]

However, had it not been for the research grants provided by the government, the level of interaction between the firms and local universities would have been much lower than what it is at present, if not non-existent. In fact, according to a survey by the World Bank (2004), less than 10 % of Malaysian firms collaborate with local universities and research insitutes. One of the main reasons is the perception amongst most SMEs that university research is not relevant to their needs - a fact acknowledged in the Eighth Malaysian Plan document (see GoM 2001). The World Bank (2004) also cites lack of relevance of services offered by research and technology institutions (including universities) to the firms as the primary reason for lack of collaboration between university and industry in Malaysia. Like in the case of R&D input discussed in section 8.3.1 above, most of the firms did not view links to university as an important factor influencing their decision to locate in TPM. Another possible reason is that the universities prefer to deal with more established companies for reasons of bigger research grants, prestige and absorptive capacity, as shown in a study by Mohnen and Hoareau (2002). For example, the Multimedia University in Cyberjaya has collaboration with major foreign companies but not with local companies located in the Multimedia Super Corridor, including those located in Technology Park Malaysia.[158]

8.5.3 Access to Finance

More than 90% of both science park and off-park firms in the present study single out availability of finance as the most important factor hampering their innovation activities. This finding is consistent with studies by Oakey (1984) and Westhead and

[157] TPM Academy was established in 1998 as a subsidiary of TPM and become fully operational in February 2000. As a government company it is owned by the Ministry of Finance Incorporated. It operates under the Ministry of Science, Technology and Innovation (MOSTI).

[158] According to Mohan et al (2004), the Multimedia University has collaboration with 37 companies and 29 universities from all over the world. The collaboration takes the form of scholarships, research grants, setting up of laboratory facilities and sponsorships (equipment, visiting staff).

Storey (1997) on UK science park firms. Finance companies consider technology-based businesses credit risk not, however on the basis of evidence but for lack of knowledge as they lack the expertise required to evaluate businesses plans submitted by firms seeking bank loans and the uncertainty associated with any R&D activity. SMEs are also partly to blame for their inability to communicate their business ideas to the banks (Boocock and Mohd Noor 2001). In view of these financial barriers, firms increasingly turn to government R&D grants and venture capital funds.

Science park management offer support services that include helping tenant companies identify funding sources such as government R&D grants, venture capital, and angel finance.[159] For example, Technology Park Malaysia has established a venture capital fund that can be accessed by its tenant companies. In view of this, science park firms are supposed to have better accessibility to venture capital and government grants.

The present study however found that although overall science park firms have better access to venture capital than off-park firms, the difference between them is not statistically significant. This is surprising considering the fact that TPM has its own venture capital fund that could be utilised by its tenant companies. With the exception of one respondent in the study, all the other twenty-two companies did not access the venture capital provided by TPM. Generally, venture capitalists are too cautious in investing in start-ups and technology-based businesses in Malaysia because like the banks they lack the expertise to evaluate technology ventures as well as lack the knowledge in specific areas, especially those related to ICT, multimedia and Internet. Furthermore, the dot.com burst of the mid-1990s affected the venture capital industry worldwide including Malaysia resulting in venture capitalists being extremely cautious in investing in technology ventures. The finding of the present study is also consistent with the observation made by Billingsley (2004) about lack of access to venture capital being the second most important impediment to the growth of science park firms in the US, especially after the dot.com bubble burst.

Venture capital companies also look for companies, which have the capability to compete locally and globally. Although a large number of science park firms in the study have reported to export their goods and services, not all of them are truly global in nature. Just opening an office in one foreign country to market their products does not make them a truly global company. Another reason is the infant stage of the local venture capital industry resulting in limited funds to finance the explosive growth of technology-based businesses especially within the MSC. As a result, venture capital companies become very selective; and this results in fewer companies qualifying for venture capital funds.

In terms of access to government grants, the finding is similar to that of access to venture capital, with 41% of science parks have successfully obtained the grants compared to 30% of off-park firms. The higher percentage for science park firms is due to their greater awareness of the availability of government grants compared to off-park firms. This is partly due to the fact that officials from MOSTI organise talks at TPM to explain the details of such grants to the tenant companies. This advantage enjoyed by firms in a managed science park, like the TPM, is not available to off-park firms, which are dispersed in off-park locations. Despite this, the difference in the percentage of science park firms that have obtained government R&D grants is not statistically significant from that of off-park firms due to the reasons elaborated earlier.

8.5.4 Internationalisation

The present study examined the internationalisation aspects of the firms from two perspectives: exports and international research collaboration.

Science park firms seemed to rely on opportunities arising from government projects, which are aimed at developing the ICT and multimedia sectors through the Multimedia Super Corridor launched in 1996.[160] For example, government

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[159] This is one of the services offered by the Aberdeen Science and Technology Park in Scotland. Other science parks around the world also offer similar support service.

[160] The government is the single biggest buyer of ICT products and processes due to various projects

departments are major customers of one of the survey respondents located in TPM, accounting for 85% of the company's total sales.[161]

Lack of adventurism and global-level strategies is also reflected by the lack of Malaysian-based global ICT brands (Richter 2002). At the national level, SMEs in Malaysia are still dependent on domestic market. They export only 26 % of their total output (MITI 2004).

To many SMEs engaging in export ventures is a risky and costly activity especially when there is lack of knowledge about foreign markets. Many of the ICT-based companies in TPM have found their niches in domestic market thanks to the explosive growth of the ICT sector as a result of the policy drive in the country towards the development of a knowledge economy. To these companies latched on to the local market, exporting would not be a priority concern possibly until the local ICT market reaches the saturation point. On the other hand, there are some TPM firms and off-park firms who have become 'born global' firms within two years of their formation. They were able to achieve this by engaging in internationalisation as early as possible to overcome size limitations of the domestic market and to gain from 'first mover' advantages in foreign markets. A good example is the success of one respondent involved in software producer who derived 60% of their revenues from exports.

In terms of R&D collaboration with foreign partners, off-park firms (40.0%) seem to have greater collaboration than science park firms (36.36%). But the results of our analysis showed that in this respect, the difference between the two groups of firms is not statistically significant. The main reason behind this is that off-park firms are older and have over the years established international links to develop their technologies compared to most science park firms, which are much younger and

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such as computerisation of the civil service, smart school projects, community call centres, these ventures are not going to continuously provide business opportunities.

[161] In fact, 85 % of Iris Corp's turnover of RM18.86 million in 2001 came from two government flagship projects, namely, the Malaysian Electronic Passport (MEP) and the Government Multipurpose Card (GMPC). This is based on report by New Straits Times on 11 July 2002.

have yet to establish such links. Nevertheless, the fact that 36.36% of the science park firms have R&D collaboration with foreign partners is reasonably high. This can be explained with reference to owners' motivation and the image associated with location in TPM. This is not surprising in view of the exposure of TPM tenants through campaign by MDC and TPM to attract technology–based businesses as well as the efforts by these two organisations to promote joint ventures in these businesses (Malairaja and Zawdie 2004). The case studies of four SMEs have shown that strategic alliances are formed with foreign owners of technology. For example, one of the respondents has forged a link with a company in China to develop fingerprint technology.

Overall, the participation of both science park and off-park firms in international research collaboration is low with 63.66 % of the former and 60.0% of the latter not involved in such collaboration. There are various explanations for these findings. Firstly, both science park and off-park firms do not see the need for such collaboration as most of them are not involved in radically new research or high level R&D activities. Secondly, the majority of science firms and a big percentage of off-park firms are involved in ICT and multimedia businesses, which usually does not require such collaborative efforts. They would rather employ the required skilled manpower from low cost countries like India to work on the research projects locally. Thirdly, international research collaboration is costly, risky and difficult to manage. Most of the local firms do not have the financial resources and the absorptive capacity to undertake such collaborative projects.

8.5.5 Innovation and R&D Output

The three measures of innovation output used in the study are patents, new products/process launch and copyrights. In terms of patents and copyrights, the present study found no significant difference between the performance of science park firms and off-park firms. This finding is consistent with the study of science park firms in Sweden by Lindelof and Lofsten (2003). However, in terms of new product/process launch, the present study found that science park firms perform significantly better than off-park firms. This is not consistent with the study on UK science parks by UKSPA (2003) in which off-park firms launch nearly twice as many new products (not services) on average than science park firms. Similarly, the finding of the present study is also not consistent with the study on Swedish science park firms by Lindelof and Lofsten (2003), which found no significant difference between the two groups of firms.

The low level of patenting amongst both the science park and off-park firms is a manifestation of low level of patenting at national level. For example, the United States Patent and Trademark Office (USPTO) granted only 266 patents to Malaysia for the period 2000-2004 compared to 19,010 granted to South Korea, 1,800 to Singapore and 26,705 to Taiwan.[162] Even amongst companies in the Multimedia Super Corridor (MSC), patenting is dismally low. For example, there were 812 MSC status companies in 2002 but the number of patents registered by the companies was only 39. There are many explanations for low patenting amongst ICT and multimedia companies. One major reason is shorter product life cycle in sectors such information and communication technologies in general, and software in particular. To the companies, speed to market is far more important that spending time and resources on patent application and registration. This is reflected in greater number of new products and processes launched as shown in Table 18.2. Another reason is that firms may prefer secrecy over patents, as a strategy to appropriate returns from their R&D investments. The age of the firms is another major influence on patenting activity. A significant number (90%) of companies are less than eight years old and therefore would not have reached the patenting stage as in the case of a study on UK science park firms by Monck et al (1988). Besides the age factor, quite a number of firms are involved in software production; and in Malaysia software products are not patented. This finding is again consistent with the study by Monck et al (1988). Start-ups cannot afford the legal costs associated with patenting their software innovations and do not have the manpower and time to engage in patenting activity.

[162] See USPTO at URL: http://www.uspto.gov/

8.5.6 Business Performance and Growth

Science park firms perform better than off-parks on the three business performance indicators employed in the study: sales, profit and employment growth. However the performance of science park firms is only marginally better in sales and profit ratio growth because when compared to the growth rates of off-park firms, the differences were not found to be statistically significant. Only in the employment growth rate did the science park firms performed significantly better than off-park firms. Therefore, the marginally higher performance of science park firms in sales and profits raises the fundamental question of the importance of locating in science parks. After all, the science park environment is supposed to provide the resources and opportunities for the tenant firms to be more innovative and generate greater sales, profits and employment opportunities.[163] Ferguson and Olofsson (2004) observed similar pattern with regard to sales and employment growth rates in the study of science park firms in Sweden. Their study found both rates to be not significantly different from the corresponding rates achieved by off-park firms, although science parks firms performed marginally better. Ferguson and Olofsson attribute this to the presence of a few high performing science park firms.

However, there could be genuine reasons for the marginal performance of science park firms in sales and profit ratio in the present study. Most of the science park firms are young firms trying to penetrate local markets. Many of these firms could possibly be motivated by the drive to launch new products and processes rather than by focusing on sales and profits. The fact that these firms have higher R&D intensity (though not significant) and significantly higher QSE intensity, as discussed earlier, is another indication of the other objectives of these firms - that is, focusing on creating innovative products rather than securing market share or generating higher profits. This was also confirmed in the case study of three science park firms, which will be discussed in chapter nine.

[163] According to Parry (2001, p.216), 'the mission of science parks is to help, at a profit, the process of company formation and growth and to assist companies in gaining a competitive advantage'.

In terms of employment growth, science park firms performed significantly higher than off-park firms. This finding is not consistent with studies by Westhead (1994) and Ferguson and Oloffson (2004), which found the employment growth rate of science park firms to be only marginally better than off-park firms. The reasons for this significant higher employment growth in the present study can be explained in terms of the reasoning based on the significant higher QSE intensity recorded by the science park firms, as discussed in section 8.4.1.2 above. Moreover, a number of respondents in the science park sample have invested heavily in R&D; and these firms have recruited a large number of staff over the five-year period to run their non-R&D functions. This, however, does not mean that the science park environment factor was responsible for the R&D plans of the companies concerned. Such companies, which already have good growth prospects, prefer to take advantage of the incentives associated with the MSC status and therefore locate on the park. Similarly, science park management also prefer to support companies, which have sound business and R&D plans and those with good growth prospects. Obviously, these few high growth companies create more employment opportunities that contribute to the significantly higher employment growth rate amongst the sample of science park firms. This pattern could possibly exist amongst similar growth-oriented off-park companies although this is not significantly borne out by the results of the study. In view of this, it is difficult to argue that science park firms are capable of achieving significantly higher employment growth rate of-park firms although difference is statistically significant in present study.

8.6 FURTHER DISCUSSION

8.6.1 Interview-Based Study

Besides the longitudinal study based on questionnaire survey, the results of which were discussed above, the study also conducted an interview-based study in order to get a closer understanding of the impact of the science park environment on the growth and development of technology-based businesses in Malaysia. Three science park firms and one off-park firm who responded to the mail questionnaire survey were selected for this study. These four firms were interviewed via e-mail correspondence. Questions posed to the firms appear in Appendix VII. These four firms obviously do not represent the population under study. However the qualitative information obtained was use to investigate whether location influences firms innovation and R&D activities and thus their growth and perfomance. The four companies chosen for the case study are: Skali, PUC Founder and Ivoli from science park location and Advanced Interconnection Technologies (AIT) from off-park location. The main findings of the four case studies are highlighted in 8.6.2 below.

8.6.2 The Main Findings of the Case Studies

8.6.2.1 Skali – From Ex-Bankers to Successful Technopreneurs

Skali's core business includes provision of software solutions; shared infrastructure business for hosting and e-mail and support and consultancy division None of the company's six founders have background and qualifications in information technology. Four of the founders are ex-bankers and the remaining two come from the telecommunication industry. However they have shown tremendous courage and ability to steer the company on a challenging and unpredictable path from a pioneer to a well known e–business company in Malaysia. They are confident of achieving the corporate target through overall growth and sustainability to be brought about by vigorous expansion plans and commitment to R&D to produce quality products and services. The company chose to locate in a science park (UPM-MTDC incubator) location due to the affordable Internet infrastructure costs, which was ranked as the number one reason for moving into the incubator complex. Besides this, 'access to university facilities' and 'prestige and overall image associated with the location' were also important influencing factors. The company does not have R&D collaboration with any university, although the company itself is located in the incubator complex, which is part of University Putra Malaysia (UPM). In fact, links to universities and research institutes appear to be only slighlty important to the growth of the company. The company cites strategic alliances, in-house R&D, competitors and customers as very important stimuli to its innovations.

Nevertheless, Skali acknowledged that it did benefit by locating in the incubator complex, but the benefit is just confined to the spillover effects from the publicity gained through campaigns conducted by the university about the incubator and its tenants. The company confidently expressed that it would have achieved the same level of success had it been located elsewhere (off-park). This is because the company believes that the most crucial factor for its success is the entrepreneurial spirit of the founders.

Skali is a classic case of a company which has demonstrated that one need not be a technologist to succeed in a technology business. The company has the intention of going for listing on the MESDAQ but not in the near future. The founders would prefer to concentrate on other core objectives, especially enhancing their R&D capabilities to create quality products to ensure overall growth and sustainability of the company.

8.6.2.2 PUC Founder – Success in Niche Market

PUC Founder started as an IT provider to local publishing companies in Malaysia. The company's core business include software and e-business solutions and commercialising biometrics technology. Its main products are electronic publishing systems (EPS), electronics management systems (EMS) as well as providing front-to-back end solutions to the publishing sector. The company has emerged as the largest provider of the EPS, securing 80% of the local Chinese language press industry in Malaysia. Based on the impressive revenue growth for period 1998-2001, Respondent B was ranked 23rd on the list of the 500 fastest-growing technology companies in the Asia Pacific region for the year 2002.[164] Following the impressive record in sales and profits for the period 1997-2001, the company was succesfully listed on MESDAQ market of the KLSE in April 2002.

The company chose to locate in Technology Park Malaysia (TPM) because of its Multimedia Super Corridor (MSC) status which requires its premise to be sited in

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[164] This report called the Technology Fast 500 Asia Pacific Ranking is prepared annually by Deloitte Touche Tohmatsu which offers audit, consulting, financial advisory and tax services thorough member companies distributed across the world. For details visit Deloitte website at www.deloitte.com

one of the designated areas within the corridor and in this respect, TPM appeared to be the best choice. The company ranked 'prestige and overall image associated with a science park address' as the number one reason for choosing TPM, followed by 'availability of support services in the park'. Access to government incentives, grants and venture capital and availability of skilled labour were ranked third and fourth respectively.

Despite ranking availability of support services as the second most important reason reason for moving into the park, the company only uses the IT infrastructure offered by the park. In fact, the company claimed that location in the science park had little impact on the its impressive growth rate during the period 1997-2001. The success of the company was due mainly to its R&D and business strategies which were well in place before it moved into TPM. The circumstances underlying the operation of the company suggest that the success achieved could have obtained even if the company were located in an off-park site.

The case study of PUC Founder shows that a company with a good technology product created with the assistance of government R&D grants and backed by a strong management team can scale up a niche market and achieve impressive growth. Location in a science park environment may enhance the company's image but will only play a small role on its overall growth and development.

8.6.2.3 Ivoli – Pioneer in E - Business

The third case study is about Ivoli, which is involved in developing software, hardware and services. The company grew from a RM60,000 paid-up company to more than RM10 million within four years of formation. The success of the company is partly attributed to strategic partnerships with both off-park large multinational companies and with SMEs. The reason for locating in TPM is the same as Skali. Apart from the convenient location of TPM, reasonable rental rate was the other factor that influenced the company's decision to locate in TPM. Other benefits include Internet access, affordable auditorium rentals for training and sports centre for its staff. The respondent acknowledged that it was very satisfied with the support given by the management of TPM. However, it was confident that it would have achieved the same level of success if located elsewhere (off-park location).

This case study shows that a company need not be R&D intensive to succeed in technology-based business although certain level of R&D is necessary for product improvement. The company's experience also shows that certain benefits can be derived from location in a science park although these benefits may not directly contribute to R&D or overall growth and development.

8.6.2.4 AIT – Adaptation of Imported Technology

Advanced Interconnection Technologies (AIT) began as an assembler of electronic devices and products. In 1997, the company entered into collaboration with a research-based company in the US to design and develop anti car theft system based on Radio Frequency Identification (RFID) technology.[165] The company then set up a plant at special designated industrial zone to produce the technology product for local as well as international market. But the Asian Financial Crisis which seriously impacted the Malaysian economy dealt a severe blow to the ambition and vision of the company. But the company was determined to carry on its R&D with a scale down in its manufacturing operations. However lack of financial resources continued to affect its operations especially its marketing efforts.

Location of the firm in a special designated industrial zone was never an issue. Management felt that there was no need for them to locate in a science partk setting. AIT had a good product and government support for its R&D. What the company lacked was an effective management team to plan and implement its sales and marketing strategies. This is a good case of a company which developed a technology that has tremendous market potential, albeit hampered by market shocks

[165] RFID technology is sometimes referred to as contact-less technology made up of three components: tags, reader and the host computer system. Basically the technology transmits the identity (in the form of a unique serial number) of an object wirelessly, using radio waves. It is extensively used in retail supply chain management, logistics, health and pharmaceuticals. For details visit the website of the Independent European Centre for RFID at www.rfidc.com.

of regional order. The case study shows that innovation goes beyond successful introduction of new products into the market.

8.6.3 Does Science Park Location Matter?

The four case studies highlighted above have demonstrated that producing and patenting new products and processes do not necessarily result in innovation success. The success will ultimately depend on the effective co-ordination of innovation strategies with other business strategies, such as human resource development, production, marketing and finance (Baldwin and Johnson 2001). These case studies have also shown that entrepreneurial and management factors, including attributes relating to the company founders can also influence the scope for innovation and business performance. Skali is a classic case of a company, which owes its phenomenal success to the entrepreneurial spirit of its founders despite facing initial financial setbacks. In the case of PUC Founder, success in innovation was achieved by scaling up the niche market.[166] Ivoli succeeded by forging strategic partnership with local SMEs and large international companies. In the case of AIT, although the company has a good technological product the company still needs to focus on its marketing activities. The company will not make much headway, even with a promising product, if it fails to enhance its marketing capabilities, which are crucial for success in high technology markets (Dutta et.al 1999).

None of the three science park companies in the above case studies owe their performance growth to the location in a park environment. They maintained that they would have attained the same level of success if located elsewhere. However, two of them, did acknowledge that the park location has benefited them, although not directly in terms of their R&D and innovation activities. For example, Skali was attracted to the low cost of rental offered by the incubation complex whereas Ivoli succeeded in getting venture capital from Technology Park Malaysia (TPM). With respect to other advantages supposedly deriving from being located in the park (especially prospects for enhancing R&D and innovation capabilities, winning

[166] Markides and Geroski (2000) have pointed out the need technology-based companies to scale up niche market.

markets and generating profit), the points raised in the case studies suggest that, location in science park would hardly make any significant difference to the performance of on-park companies.

So can we say that the park has failed to support the growth of its tenant companies? Or is it too early to come to such a conclusion since the park is less than ten years old? Whatever the verdict, respondents in this case study have generally expressed the view that they have not gained much from being located in the park, other than certain pecuniary benefits such as low rental and the benefit of image. The case studies also show the extensive role played by the government in terms of providing grants and other incentives.

8.7 CONCLUSION

The rationale behind the establishment of science parks as a public policy instrument is to promote the growth of technology-based businesses and enhance commercialisation of research. However, it is clear from the summary of the results shown in Table 8.27 that science park firms do not significantly differ from off-park firms with regard to most of the indicators. The disappointing results especially with respect to the level and the type of R&D and university links involving science park firms raise one fundamental question: is science park an effective policy instrument to enhance innovation and technological capabilities of technology-based businesses? This begs a further question: did the park management make it easier for the tenant companies to have access to financial and non-financial resources, access to university resources or assist in their R&D activities?

Substantial investments have been made to develop science parks in Malaysia, so that these parks can support the growth of local technology-based businesses; but the results so far leave much to be desired. What then is wrong with the science park strategy? It can be argued that there is nothing wrong in the strategy – the problem is not so much with the strategy as with the implementation of it. If the science park strategy has failed to achieve the desired outcome in local technology development, this could be attributed to a number of factors other than location. For instance, one respondent selected for the case-study expressed that although, his company benefited from its location in TPM, it would have still achieved the same level of success if located outside the park. To this respondent the crucial factor for success is entrepreneurial spirit and focus regardless of firm location. Similar views were also expressed by other respondents in the case studies as discussed above. But there are some who did acknowledge the benefits of science park location especially in terms of publicity spill-over and enhanced image and prestige associated with science park address. The results of the study presented in this chapter have serious policy implications, which will be discussed in the next chapter.

SUMMARY AND CONCLUSIONS

9.1 INTRODUCTION

The science park strategy has emerged over the last couple of decades as an important instrument of technology policy in many countries aimed at promoting the growth of technology-based, small and medium-sized enterprises (SMEs). This trend is predicated on the understanding that the science park strategy provide a value added environment in terms of resources, opportunities and capabilities that would enable tenant firms to engage in R&D and innovation activities and enhance their growth and competitive performance. The present study tested this hypothesis by evaluating the characteristics and performance of technology-based SMEs located in Malaysian science parks vis-a-vis a comparable group of off-park firms. Specifically, the study attempted to investigate whether science park firms, compared to off-park firms:

- (i) use more research and development (R&D) inputs;
- (ii) engage in greater R&D co-operation and collaboration;
- (iii) have better access to venture capital and government R&D grants;
- (iv) show higher international orientation in terms of exports and international research collaboration;
- (v) produce greater innovation output; and
- (vi) show better business performance.

These provided the six dimensions for the empirical aspect of the study. Two independent but comparable samples of firms were used to test a set of fifteen hypotheses formulated from the above six study dimensions. The science park sample contained 22 firms drawn entirely from Technology Park Malaysia (TPM), while the off-park sample contained 30 firms drawn from locations outside the park. Data obtained from the sampled firms were analysed using statistical techniques such as t-tests and chi-square to determine whether there are significant statistical differences between the two groups of firms with regard to the fifteen indicators. The main longitudinal study was supplemented by an interview-based study (case study) involving three science park firms and an off-park firm, in order to get better insight of innovation at enterprise level. The next section provides a summary the findings of the longitudinal study.

9.2 SUMMARY OF FINDINGS

Science park firms appear to perform better than off-park firms in all the fifteen indicators employed in the study, except in the area of international research collaboration. However, the study found no statistically significant difference between science park and off-park firms with regard to ten of the fifteen indicators. These ten indicators on which the two groups of firms cannot be distinguished on the basis of statistical evidence are: R&D expenditure, R&D thrust, collaboration with universities, exports, access to venture capital, access to government R&D grants, patents, copyrights, sales growth and profit ratio growth. Science park firms perform significantly higher only in employment qualified scientists and engineers (QSE), inter-firm R&D collaboration, launch of new products and processes, and employment growth. Off-park firms perform better only in international research collaboration but the difference is not statistically significant. The study findings are summarised as follows:

9.2.1 R&D Inputs

Overall, although science park firms score higher in the mean R&D intensity and mean QSE intensity than off-park firms, significant statistical difference between the two means was found only in the QSE intensity. The comparatively higher mean R&D intensity recorded by science park firms is mainly due to the higher percentage of these firms (90%) compared to off-park firms (67 %) conducting R&D, and the presence of a few R&D intensive science park firms rather than higher R&D intensity across the board. The significantly higher QSE intensity recorded by science park firms is attributed to the greater number of science park firms conducting R&D as well as the MSC status enjoyed by them which allows them to employ QSEs from low-cost countries. Similarly, although more science park firms

(27.3%) conduct radical research compared to off-park firms (26.6%), the difference is not statistically significant.

9.2.2 R&D Collaboration and Co-operation

The study found that there was statistically significant difference between science park and off-park firms with regard to inter-firm collaboration. This significant difference is found only in strategic alliances whereas in the other types of collaboration, off-park firms perform marginally better. However there was no statistically significant difference between the two groups of firms with regard to collaboration with universities. Had it not been for the condition imposed on firms that receive government R&D grants to collaborate with universities' researchers, the number of science park firms having university-industry links would have been much even weaker.

9.2.3 Access to Finance

There were no statistically significant differences between the two groups of firms with regard to access to venture capital and access to government R&D grants. Access to venture capital is still a problem for the majority of science park and off-park firms. Only 27 % of the science park firms and 17 % of the off-park firms have managed to get venture capital support including government venture capital funds. The study also has shown the important role played by the government in providing various types of research grants to stimulate SME innovation. This is apparent from the fairly large percentage of both science park (40%) and off-park (30%) firms being recipients of such R&D grants. Without these grants, many of the science park and off-park firms would not have been able to conduct R&D.

9.2.4 Internationalisation

The study showed that 59 % of science park, and 53 % of off-park firms were involved in export business. However, there is no statistically significant difference between the two groups of firms with respect to exports. The study revealed that science park firms tend to rely too much on domestic market, exerting little or no internationalisation effort. However, in international research collaboration, the percentage of off-park firms (40%) was found to be higher than science park firms (30%) and it is in only in this indicator that off-park firms perform better than science park firms, with the difference between the two being not statistically significant.

9.2.5 Innovation and R&D Output

With the exception of new products and processes launched, science park firms do not differ significantly from off-park firms, with regard to the other two innovation output indicators namely, patents and copyrights. The significantly higher performance of science park firms with respect to new products and processes launched is attributed partly to the park being a popular location for ICT based firms, particularly due to the MSC status, and partly to the fact that ICT companies usually produce more new products and processes than non-ICT firms.

9.2.6 Business Performance and Growth

In the area of business growth, science park firms perform significantly better than off-parks firms, albeit only, with regard to employment growth. The significantly higher employment growth rate is due to the advantages enjoyed by science park firms in terms of freedom to recruit skilled manpower from low cost countries and also due to the need to employ more QSE and supporting management staff to complete R&D projects funded by government R&D grants and own funds. With respect to the other two indicators - sales and profit ratio growth - although science park firms appear to perform better than off-park firms, on close examination, the two do not differ significantly from one another on this score.

9.3 IMPLICATIONS

Overall the results of the study indicate that science parks in Malaysia are not producing the desired output in terms of enhancing the innovation and technological capabilities of tenant firms. The marginal edge science park firms have over off-park firms – and that, despite being located on a value added environment in terms of facilities, access to venture capital and other incentives should be a major point of concern to advocates of the science park strategy. The findings of the study therefore have important implications for many actors in the Malaysian national innovation system, particularly technology-based firms located on science parks and elsewhere, policy makers, science park management, universities, financial institutions, trade associations and the government, as is apparent from the discussion from sections 9.3.1 to 9.3.5 below.

9.3.1 Science Park and Off-Park Firms

Overall, lack of R&D amongst science park firms is at odds with the rationale for setting up such parks, which are supposed to attract knowledge and R&D intensive companies. Both science park and off-park firms need to invest in R&D and employ qualified scientist and engineers (QSE) to enhance their absorptive capacity to acquire and assimilate technology. 'Otherwise dealing with new technology, even more sophisticated technology, could be like catching the tiger by the tail' (UNIDO 2004, p.11). This absorptive capacity is necessary to enable them to benefit from imported technology brought in by FDI and to link up with the global supply chain. Firms cannot expect to achieve success overnight because technological learning is a painstaking and cumulative process (Hobday 1995). Lessons can be learned from the technological learning experience of firms in Japan, Korea and Taiwan to master new and sophisticated technologies.

Lack of inter-firm collaboration amongst science park firms and with other firms also has implications for technology development. The firms covered in this study may have some good reasons for not collaborating and networking. For instance, the nature of business may be such that it does not call for collaboration. Alternatively, firms may be constrained by resources (time, money and staff) to engage in collaborative projects; or do not wish to share the secrecy or confidentiality of their business operations, especially their innovation and R&D activities. But in doing so, these firms overlook the importance of innovation networks in providing them access to information and resources, new markets and technologies. They thus fail to see how these networks can be used to achieve strategic objectives, such as sharing risks and outsourcing from learning, scale, and scope economies (Dittrich 2002).

Science park firms would be expected to expand into international markets rather than relying too much on domestic market opportunities.[167] For example, one tenant located on Technology Park Malaysia derived 85 % of its turnover in 2001 from two government flagship projects. There is nothing wrong in securing legitimate business deals regardless of who the buyer is. Many companies in the Silicon Valley exploited the opportunities arising from defense contracts offered by the US government (Malairaja 2003). A good example worth emulating is the success of one local software producer in the science park sample, which derives 60% of its revenue from exports.

Technology-based SMEs should also avoid focusing on a narrow subset of innovation strategies. Implementation of innovation strategies should be coordinated with other business strategies especially those related to human resource development, production, marketing and finance (Baldwin and Johnson 1995). For companies to succeed in innovation, they should be taught how to scale up the niche market (Markides and Geroski 2005). The case study of one respondent, which is involved in the design and manufacture of car immobilisers based on adaptation of imported technology, is a clear example of lack of linkages between R&D efforts and marketing strategies. The firm has failed to develop its marketing capability, which is crucial for it to succeed in high-technology markets.

9.3.2 Science Park Management

Technology Park Malaysia (TPM) should focus on assisting the SMEs to acquire the necessary skills, knowledge and capabilities to engage in R&D and innovation activities. There are various issues that need to be addressed by the park management.

[167] For example although the government is also the single biggest buyer of ICT products and processes due to various projects such as computerisation of the civil service, smart school projects, community call centres, these ventures are not going to continuously provide business opportunities. Therefore for long run sustainability, technology-based businesses need to go global as the domestic market is limited, and the increasing global nature of technological market niche.

The first issue is about the preponderance of ICT-based companies in TPM. This situation has to be reviewed in order to ensure that TPM does not eventually become an IT park and deviate from its original mission to assist technology-based companies involved in a variety of technology sectors. TPM management should attempt to attract more companies from other technology sectors, especially biotechnology, which has greater potential of establishing links with local universities for R&D collaboration.

The second issue is about attracting too many MNCs to operate in science parks. This practice should be reviewed because although it helps to bring in capital and management know-how, it has been found ineffective in generating technological spillovers.[168] Despite this, the Kulim High-Technology Park (KHTP) in the state of Kedah houses mainly MNCs.[169] Similarly, a number of MNCs are also found in TPM. If the rationale for attracting MNCs to locate in science parks is to encourage collaboration with local firms, has this been achieved? More importantly has it contributed to the attainment of deep integration (technology and production-based) or has it been limited to shallow integration (market-based)?[170] Lessons could be learned from the bad experiences of some science parks in Finland where large telecommunication firms like Nokia and Sonera in these parks relied more on international collaboration rather than fostering links with local SMEs except for business support services (Sadowski et al 2003).

The third issue is about TPM itself being involved in technology ventures. For example, TPM is involved in operating biodiversity centers in Raub in the state of Pahang and Belum in Perak. It is perfectly legitimate for TPM as a corporatised body to be engaged in businesses to generate income, apart from managing the park. However, the issue is, to what extent is the involvement of TPM in such businesses

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[168] Even in Europe lack of spillover to small firms is due to the dominance of large corporations in R&D (Soete 1999).

[169] Of the twenty-two tenants in KHTP, only two are local SMEs and the rest are mainly foreign MNCs, among which include Intel, Fuji Electronics, Silterra and Celestica.

[170] UNCTAD (2001) urges governments to put in place mechanisms that enable the achievement of deep integration to reap the full benefit of technology transfer and technology development.

affecting its entrusted role as outlined in the park's mission statement? Is the management spending too much resources (time, money and manpower), on its other businesses, to the detriment of its mission and vision? TPM should instead focus on creating opportunities for tenant firms and new firm formation because the 'critical condition for entrepreneurial enterprise is opportunity' (Feldman et al 2005, p.139). A good model to emulate is the University of Warwick Science Park (WSP) in the UK, which offers services tailored to suit individual tenant companies. In fact, the strategy adopted by WSP provides a useful guide for sustainable approach to science park development (Harper 2003). TPM should build on the marginally better performance of its tenant firms in ten of the fifteen variables to assist them to become more innovative and competitive.

The fourth issue is about having managers with the right expertise and skills to achieve the park's mission. Technology transfer is a difficult and complex process with many hurdles to overcome. In view of this, science park managers need to have good networking and communication skills as well as technology transfer experience in industrial or academic setting transfer.[171] They must focus on developing and implementing mechanisms that link tenant firms to facilities and resources provided by universities and research institutes. They must recognize the fact that the relations with tenants companies begin the day the companies enter the park (Sanz 2003).

9.3.3 Universities and Research Institutes

The findings of the current study indicate that overall, local R&D institutions in Malaysia have been ineffective in assisting local firms to upgrade their technological capabilities.[172] Therefore, there is a need to strengthen university-industry collaboration to enhance commercialisation of research results.[173] This may require

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[171] Rowe and Webster (2000) cited in Parry (2001).

[172] Similar observation has been made by Capannelli (1997).

[173] Lessons could be learned from Finland where networks have been successfully developed to promote university-industry links and R&D co-operation (Vestergaard 2003). Similarly Mitra (2000) explains how the Graduates Enterprise programmes of the University of Adelaide that not only addresse the issues related to university-industry links but also promote entrepreneurship (Mitra 2000).

policy initiatives to remove the constraints that impede the development of the "triple helix culture" (Saad and Zawdie 2005). Officials from local universities need to visit science parks to explain the type of research and other facilities available to tenant firms. Industry leaders including those from foreign firms in Malaysia and especially those with expertise in the area of research and technology development should be invited to sit on university boards. Technology transfer offices (TTOs) in universities also need to recruit individuals with expertise not only in patent law, licensing or technical expertise but also those with marketing skills and entrepreneurial experience (Siegel et al 2003). Besides commercialisation of research results, universities can also organise programmes aimed at assisting science park firms to internationalise their operations. Lessons can be learned from the programme run by the University of Oulu to assist science parks firms involved in the software sector in Finland to expand their business into the U.S market. [174]

9.3.4 Financial Institutions

Financial institutions in Malaysia like elsewhere consider technology-based businesses in general to be credit risk mainly because they do not have the competence to evaluate such technology ventures. The government can help by way of implementing appropriate policies to encourage financial institutions and venture capitalists to play a more effective role in financing technology-based businesses. In this regard, the setting up of a specialised SME unit within Bank Negara Malaysia in 2002 to address issues related to SME financing is a step in the right direction.

9.3.5 Government

The Malaysian government would need to look into the broad institutional context to promote innovation and technological development amongst SMEs. There is no point setting up science parks and then expect SMEs to enhance their innovation capabilities, if these SMEs lack the absorptive capacity to master new technologies. For this purpose, it is important that the bureaucratic culture gave way to the

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[174] For more details see Bengtsson and Lowegren (2000) about the success of the Global Software program conducted by the University of Oulu in Finland. The focus of the programme is on business and management practices and not on technology.

development of an interactive network of institutional and organisational links in which SMEs could find themselves active rather than passive players. This calls for policy initiatives to develop and strengthen the national innovation system in Malaysia, which, at present is diffused and fragmented. Within the NIS framework, policy should seek to promote interaction between researchers in public and private organisations and provide the right level of protection in the form of intellectual property rights (IPR). In other words, the focus of policy should be on promoting the culture of innovation amongst local entrepreneurs rather than on real estate aspects of science park development.[175]

Large companies in a technology park should be encouraged to share their knowledge and expertise. Perhaps the management of TPM should experiment with the idea of attracting a large anchor company and implement a planned programme to foster collaboration between this company and tenants in the park. However, this policy should be implemented cautiously because anchor companies cannot be expected to be knowledge gatekeepers (Morrison 2004). For a start, therefore, TPM could invite local large companies with established R&D divisions, such as Proton (automotive) or Sapura (telecommunications), to set up research facilities in the park. This, however, does not preclude the possibility of inviting a foreign MNC as an anchor tenant if the MNC is willing to collaborate with local SMEs. For example, Siemens played a collective role together with innovative SMEs and research institutes in the development of high-tech cluster in Munich in Germany (Sternberg and Tamasy 1999).

There are also lessons to be learned from experience elsewhere that for the park to focus on a narrow range of sectors could be a risky strategy. A case in point here is the story of the Silicon Valley dot.com, which before its collapse in 2000-2001,

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[175] Lessons could be learned from the way the Hsinchu Science-based Industrial Park in Taiwan provided effective co-ordination resulting in identification of proven local firms' participation (UNCTAD 2003).

thrived on one technology.[176]. Policy makers must also realise that knowledge intensity is not just confined to IT and biotechnology alone and can also emerge in other (traditional) sectors (Bell et al 2004).

A major factor militating against the effectiveness of the science park strategy is the shortfall in the supply of QSEs (qualified scientists and engineers). The Malaysian government has sought to address the issue by recruiting talents from abroad through the "Second Home" programme launched in 2001. The Hsinchu Science-based Industrial Park in Taiwan is a good example of a science park that succeeded in attracting Taiwanese working overseas, especially in the Silicon Valley, to return and work in the park.[177]

The government should also review the MSC status granted to companies, which is currently benefiting only companies located within the MSC. Technology-based companies located in science parks outside the MSC as well as those located in other off-park locations should be considered for the status. There must be good reasons such as high rental and other costs that make it prohibitive for some companies with the right technology and business plan to locate within the MSC..

It is also time that policy set the basis for identifying SMEs with high technology and knowledge content. This can be achieved if SMEs reflect in their financial reports their expenditures on R&D inputs, such as costs of equipment and materials for R&D, wages paid to scientists, researchers and technicians involved in the R&D activities and costs of patenting. Similarly, the financial reports should also reflect R&D output in terms of the values of new products and processes introduced into the market during the accounting period concerned.

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[176] The Malaysian government has been for long emphasising a number of emerging technologies such as aerospace, advanced materials, advanced manufacturing, and biotechnology. But this hype fizzled out with the launching of the Multimedia Super Corridor (MSC) in 1996 with the focus shifting to multimedia and ICTs businesses. The government only recently announced the National Biotechnology Policy to encourage the development of biotechnology sector.

9.4 LIMITATIONS OF RESEARCH

The study focused on only one science park in Malaysia. Other science parks were not included because, as explained earlier, only Technology Park Malaysia met the requirements of study in terms of type of firms and number of years in operation. Moreover, TPM is the largest science park with more than 100 firms involved in a variety of technology businesses. This sample represents 65% of technology-based SMEs in all the science parks in Malaysia. The sample is big enough to give a fair representation of high-tech SMEs in Malaysia. Despite this the sample size is not big enough for the use of more robust statistical techniques such as cluster analysis and discriminant analysis.

However, the study is not without limitations. One area of limitation relates to the reliability of the data obtained thorough the questionnaire survey. The study had to make do with data gaps arising from confidentiality of information pertaining to the performance of science park and off-park firms and the technology strategy they employ.

Another problem relates to the indicators used to measure innovation at firm level. It is not easy to measure innovation of firms, although R&D expenditure, new products and processes and patents, are often used for this purpose. Measurement of innovation poses both conceptual and practical problems. Input indicators like R&D expenditures do not necessarily show the occurrence of innovation. Nor do output indicators like patents cover all innovations as most incremental innovations are often neither documented nor patented. Research has also shown that small firms under-report their R&D efforts (Kleinknecht 1987). There is, as a result, a certain degree of arbitrariness as to where to draw the line between what is innovation and what is not.

Identifying technology-based SMEs in off-park locations was a difficult task. This problem was compounded by somewhat loose definitions of technology-based firms.

[177] According to O'Neil (2003), in 2000, 4,108 returned migrants worked in the park. 113 of the tenant companies were started by US educated returnees. 478 of the returnees hold Ph.D. Their presence facilitated overseas connections with 70 of the companies having offices in the Silicon Valley.

Since TPM attracts only firms that intend to undertake research, it was assumed that all the firms in the science park (except those involved in support services like catering and finance) were included in the survey. For the survey of technology-based businesses in off-park locations, the database of Technopreneurial portal of the MDC was extensively used apart from accessing websites of SMIDEC, MTDC, and FMM. There was, however, no way of verifying the commitment of all these firms to research and development, even if they said they were as they did in their response to the questionnaire administered. An obvious way round this problem would be to conduct in-depth studies of individual firms. This, however, falls beyond the scope of this study.

9.5 FUTURE RESEARCH

As noted above, detailed case studies involving more science park and off-park companies should be undertaken to complement longitudinal quantitative studies. As pointed out by Freeman (1989), the case study approach can enhance understanding of the innovation process as well as helping one to trace the origin of the technological phenomena involved. The current study managed to conduct such studies (as supplementary to main survey study) on four firms only due to time and resource constraint. Also, since growth of a firm is dependent on internal and external factors, it would be worthwhile for future studies to examine how other factors such as management attributes, founders' characteristics and globalisation impact science park firms in relation to off-park firms.

A comparative study involving science park firms in different countries is also worth the exercise, as it would enable a better understanding of the science park phenomenon under different technological and policy environments. There are no such studies to date comparing science parks in industrially advanced countries with their counterparts in developing countries like Malaysia.

9.6 CONCLUSION

Science parks would be expected to evolve into clusters. This metamorphosis of science parks would enable tenant firms to enhance their innovative capabilities and also stimulate the formation of new technology-based firms. Failure to achieve this will result in science parks functioning as high-tech islands without synergies and interaction with other actors in the national innovation system (Massey et al 1992). Science parks have the potential to emerge as effective mechanisms for development of technological capabilities by reducing the dependence on conventional North-South technology transfer system, which for the most part, has failed to produce the desired effect for long-term sustainable development.

Building science parks is not about real estate development, but about creating businesses, jobs and wealth for the local and national economy. More importantly, it is about creating a culture of innovation, new technologies, entrepreneurship and competitiveness. Malaysian science parks, in general, and TPM, in particular, have the potential to emerge as effective mechanisms to support technology-based SMEs and facilitate commercialisation of local university research. In order to achieve this, the park management must focus on creating opportunities for tenant firms and stimulate the emergence of new firms so as to avoid the pitfalls that led the failure of science parks in many parts of the world. The government has also to play a crucial role in addressing numerous implementation issues to ensure the success of policies and programmes aimed at building local technological capabilities, especially that of SMEs. This requires strong political will to make sure that social capital including leadership and governance are nurtured and developed within government, academia and industry. Implementation of innovation strategies and programmes at various levels require leadership that upholds governance, responsibility, accountability and transparency.

The findings of this study show that difference between science park and off-park firms is not statistically significant on 11 of the 15 performance indicators considered. This casts doubt not only on the effectiveness of the management of the science park in terms of the provision of services to tenant firms, but possibly also on the plausibility of science parks in general as a strategy of promoting innovation in developing countries. For developing countries, in general, science parks would be a high cost development strategy, particularly if they were promoted as a top-down planning initiative and independent of the holistic framework of the national innovation system. In such cases, science parks tend to be driven not so much by innovation objectives as by real estate objectives.

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Definitions of Science Parks

1. UKSPA Definition

The United Kingdom Science Park Association (UKSPA) defines a science park as a business support and technology transfer initiative that:

- encourages and supports the start up, incubation and development of innovation led, high growth, knowledge based businesses;
- provides an environment where larger and international businesses can develop specific and close interactions with a particular centre of knowledge creation for their mutual benefit; and
- has formal and operational links with centres of knowledge creation such as universities, higher education institutes and research organisations.

2. IASP Definition

The International Association of Science Parks (IASP) based at Malaga, Spain defines a science as:

An organisation managed by specialised professionals, whose main aim is to increase wealth of its community by promoting the culture of innovation and the competitiveness of its associated businesses and knowledge-based businesses. To enable these goals to be met, a Science Park stimulates and manages the flow of knowledge and technology amongst universities, R&D institutions, companies and markets; It facilitates the creation and growth of innovation through incubation and spin-of processes; and provides other value-added services together with high quality space and facilities (IASP International Board, 6 February 2002). This definition encompasses other terms and expressions such as "Science Park", "Technology Park", "Technopolis", "Technology Precint" or "Research Park".

3. AURRP Definition

The Association of University Related Research Parks (AURRP) defines research park or science park as a property-based venture which has: (1) existing or planned land or buildings designed primarily for private and public R&D facilities, high-technology and science-based companies, and support services; (2) a contractual and/or formal ownership or operational relationship with one or more universities or other institutions of higher education, and science research; (3) a role in promoting R&D by the university in partnership with industry, assisting in the growth of new ventures, and promoting economic development; and (4) a role in aiding the transfer of technology and business skills between the university and industry.

APPENDIX II

Definitions of Innovation and National Innovation System

Innovation

"innovation concerns the search for, and the discovery, experimentation, development, imitation, adoption of new products, new processes and new organisational set-ups (Dosi 1988, p.22)

"innovation consists of various forms of knowledge when responding to market-articulated demands and other social needs" (OECD 1999, p.15)

innovation is the search for, and discovery, development, improvement, adoption and commercialisation, of new processes, products, organisational structures and procedures" (Jorde and Teece 1999)

innovation is the creative process of applying knowledge and the outcome of that process (GoV of Canada 2001, p.4).

innovation is at once the creator and destroyer of industries and corporations (Utterback 1996, p.xiv)

innovation has become the industrial religion of the late 20th century (The Economist 18 February 1999).

National Innovation System

"a set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provide the framework within which governments form and implement policies to influence the innovation process. As such it is a system of *interconnected institutions* to create, store and transfer the knowledge, skills and artefacts, which define new technologies (Metcalfe 1995, p.462-463).

"a national innovation system comprises firms, universities, non-profit entities, and public agencies that produce or support the production of science and technology within national borders" (Keller and Samuels 2002, p.7).

"all important economic, social, political, organisational, and other factors that influence the development, diffusion, and the use of innovations" (Edquist 1997, p.14).

"composed of specialize institutions combining and interacting in the production, diffusion and application of specialised knowledge" (Pavitt 2002, p.8).

Public Research Institutes in Malaysia

No.	Name of Institute
1	Applied Research Institute
2	Department of Drainage and Irrigation
3	Forestry Department Peninsular
4	Forest Research Institute of Malaysia (FRIM)
5	Forest Research Institute Malaysia (FRIM)
6	Institute for Medical Research (IMR)
7	Malaysian University of Science and Technology (MUST)
8	Malaysian Palm Oil Board (MPOB)
9	Malaysian Cocoa Board
10	Malaysian Agricultural Research and Development Institute (MARDI)
11	Malaysia Institute for Nuclear Technology Research (MINT)
12	MIMOS Berhad
13	Malaysian Center for Remote Sensing MACRES)
14	National Hydraulic Research Institute of Malaysia (NAHRIM)
15	Palm Oil Research Institute of Malaysia (PORIM)
16	Standards and Industrial Research Institute of Malaysia (SIRIM)
17	Sabah Fisheries Department
18	Sarawak Forestry Department
19	Science and Technology Research Insitute for Defence (STRIDE)
20	Technology Park Malaysia (TPM)
21	Universiti Tun Abdul Razak (UNITAR)
22	Universiti Pendidikan Sultan Idris (UPSI)
23	Universiti Kebangsaan Malaysia (UKM)
24	Universiti Malaya (UM)
25	Universiti Malaysia Sarawak (UNIMAS)
26	Universiti Malaysia Sabah (UMS)
27	Universiti Putra Malaysia (UPM)
28	Universiti Sains Malaysia (USM)
29	Universiti Teknologi Malaysia (UTM)
30	Universiti Tenaga Nasional (UNITEN)
31	Universiti Utara Malaysia (UUM)
32	Universiti Teknologi Petronas (UTP)
33	Rubber Research Institute of Malaysia (RRI)
34	Veterinary Research Institute
35	Fisheries Research Institute
36	Universiti Islam Antarabangsa

APPENDIX IV

SCIENCE PARK FIRMS

1	Advanced Virtual Information Services	37	iSi-Dentsu (Malaysia) Sdn Bhd
2	AIG-Software International JV S/B	38	ITForces.com Sdn Bhd
3	Airocom Technology Sdn Bhd	39	Ivanex Sdn Bhd
4	Alcatel Internetworking Inc.	40*	Ivoli Sdn Bhd
5	Aptitude Malaysia Sdn Bhd	41	iZapper Technology Sdn Bhd
6	Asia Pacific Inst. of InfoTech (APIIT)	42	Kilostream Resources Sdn Bhd
7	Asiatravelmart Sdn Bhd	43	Konsortium Multimedia Swasta
8	British American Tobacco Asia Pac	44	LK Solutions Asia Pacific Sdn Bhd
9	Comptel Communications Sdn Bhd	45*	Mastek MSC Sdn Bhd
10*	Computer Infobase System Sdn Bhd	46	Multi Media Synergy Corporation
11	Creative Advances Technology S/B	47	MyBiz Malaysia Sdn. Bhd.
12	Creative System Consultant Sdn Bhd	48*	MyeERP Solutions Sdn Bhd
13	CSA MSC Sdn Bhd	49	mySpeed.com Sdn Bhd
14	CT Solution Sdn Bhd	50	Net Space Learning Sdn Bhd
15	Custommedia Sdn Bhd	51	Netlink Ranve Infotech Sdn Bhd
16*	Cyber Village Sdn Bhd	52	Nsys Consulting Sdn Bhd
17*	Cybertowers Sdn Bhd	53	OBM Software Sdn Bhd
18	Dagang Net Commerce Sdn Bhd	54*	Tropbio
19*	DAG Consult Sdn Bhd	55*	Pentamaster Technology
20	De La Rue (M) Sdn Bhd	56	Pernec Multimedia R&D Sdn Bhd
21*	Malaysian Optronics	57	PDX Infoworld Sdn Bhd
22	Digicert Sdn Bhd	58*	Photronix
23	DynaFront Systems Sdn Bhd	59*	PUC Founder (MSC) Berhad
24	Cybercom Resources	60	Rockwell Automation (M) Sdn Bhd
25	Ecompazz.com Sdn Bhd	61	Sapura Advanced System Sdn Bhd
26	e-Cop.net Surveillance Sdn Bhd	62*	Scientific Atlanta Malaysia
27	Educational Trend Sdn Bhd	63	Scope International (M) Sdn Bhd
28	e-Komoditi Sdn Bhd	64	Software Online Sdn Bhd
29	Electric Angels (MSC) Sdn Bhd	65	STS Offshore Services (M) Sdn Bhd
30	Eutech Cybernetics Sdn Bhd	66	Synergy Log-In Systems Sdn Bhd
31	FCS Computer System Sdn Bhd	67	Team Vantage Sdn Bhd
32	Genting Information Knowledge Ent	68	Tekla (M) Sdn Bhd
33*	GHL Systems Sdn Bhd	69	Teras Teknologi Sdn Bhd
34	HeiTech Padu Sdn Bhd	70	Tri Excel Systems Sdn Bhd
35*	IFCA (Software Online)	71	UMM Synergy Corporation Sdn Bhd
36	IHM Sdn Bhd	72	Systems@Work
37*	Intelligent Edge Technologies Berhad	73	VIA Communication Network Sdn
38*	Iris Technologies Sdn Bhd	74	Wannastation.com (M) Sdn Bhd
73*	TMediaShoppe	75*	Willowglen MSC Bhd
74	Kawalan Cecair Sdn Bhd		

Note: Respondents to survey questionnaire are marked with superscript *

76	Articulate Online Sdn Bhd	83	Multimedia Tech Enhancement Op
77	Ashpool Systems (M) Sdn Bhd	84	MYlink Communication Sdn. Bhd
78*	Nesmart	85*	Skali
79	BarcoNet Sdn Bhd	86	Sapura Nokia Software Sdn Bhd
80	Jurudata Services Sdn Bhd	87	Telekom Malaysia Berhad
81	Measat Digicast Sdn Bhd	88*	Redtone Technology Sdn Bhd
82	Web Commerce Communications	89	Meteor Sdn Bhd
89	Amada (M) Sdn Bhd	94	Rapid Technology Solutions Sdn Bhd
90	Astronautic Technology (M) Sdn Bhd	95	Shapeshifters Inc. Sdn Bhd
91	Bridgestone Global Engineering Cons	96	Solution Engineering Sdn Bhd
92	Lotus Engineering Malaysia Sdn Bhd	97	Taramedic Corporation Sdn Bhd
93	Polytron Resources Sdn. Bhd.	98	Zetro Technology Sdn Bhd
99	CCM Pharma Sdn Bhd	101	Sartorius (Malaysia) Sdn Bhd
100	Novozymes Malaysia Sdn Bhd	102	Patimas Computers Berhad

Note: Respondents to survey questionnaire are marked with superscript * to respective number.
Three of the respondents Skali, Netsmart and Malaysian Optronics are located at UPM-MTDC incubator but are included in the science park sampling frame as the incubator is a managed facility and conforms to IASP definition of a science park.

APPENDIX V

OFF-PARK FIRMS

No.	Name of Company	No.	Name of Company
1	Basis Bay Sdn Bhd	45	Ramgate MSC S/B
2	Scrint Technology	46	Win Tech Solution
3*	EBuku Sdn Bhd.	47	Vhq Post S/B
4	Express Audio Industry	48	Biztone.cpm
5	Ezcal Software Distribution	49	Leapfrog Technologies
6	Galaxy Communications & Office	50*	Technology Innovation Resources
7	HenBen Resources	51	DapanNet S/B
8*	Concept Engineering	52	Translatent Technologies
9	Morphexus Sdn Bhd	53	The Asaitic Technology
10	MRCB Multimedia Consortium S/B	54	Power Innovations S/B
11*	Napera Softawre Sdn Bhd	55	RNC Technology S/B
12	Pernec Advanced Network Sdn Bhd	56	Team Data S/B
13	Q&S Pressparts Sdn Bhd	57	OIS Sdn Bhd
14	Rescomm Technologies Sdn Bhd	58	WinAccat.com S/B
15	RF Communication Sdn Bhd	59	BCM Electronics Corp
16	Rk Komputer Sdn Bhd	60	Bellcorp Technology
17*	Karensoft Technology	61	CS Metal Industries
18	Luster Precision Engineering	62	Gallant Electronic
19	MDEC Electronics	63	IFS Malaysia R&D
20	Mega High-Tech Corp	64*	Brite Tech
21	Multiple Technology System S/B	65	Latimal Sdn Bhd
22*	Magnus HRM	66	Micon –Tech Sdn Bhd
23	E-Pay Sdn Bhd	67	Enviroserve Sdn Vbhd
24	Intertac S/B	68	LHT Kitarsemula S/B
25	Yesmobile S/B	69*	Emanon Sdn Bhd
26	Netcousins.com S/B	70	RES Malaysia S/B
27	Excel.net S/B	71	Presico Sdn Bhd
28	People Associates S/B	72*	Transwaja Pile Testing Sdn Bhd
29*	Multimedia Research Lab Sdn Bhd	73	Sheng Kunag Circuit Board
30	Viztel Solutions	74	SMT Technologies
31	Xybase Sdn Bhd	75	Internexia S/B
32	i-enable S/B	76	Profitera S/B
33	Grand Dynamic Resources	77*	Ftech Sdn Bhd
34	EDE Diamont Tools	78	Bellcorp Technology
35*	Dataran Berlian Sdn Bhd	79	Cosmo Engineering
36	Malaysian Industrial Diamond	80	Tesa Tape Malaysia S/B
37	Grimaud S/B	81	Malaysian Electroplating Techn
38	Datum Technologies	82*	Standard Equipment
39	Phimax Technologies	83	Alloyplass Engineering Sdn Bhd
40	H&L High-Tech Sdn Bhd	84	Aquakimia Sdn Bhd
41	Handmetal Knives	85	CST Engineering
42	LD Technologies	86*	Chain Cycle
43*	Alam Sekitar Sdn Bhd	87	La BoostHelath Beverages
44	MOH Pharmaceutical	88	Mega Senandung S/B

89*	Pollution Engineering Sdn Bhd	125	Success Electronics
90	Merlin Home Automation	126*	TC Auto Tooling Sdn Bhd
91*	Infortech Alliance Berhad	127	Ortech Malaysia S/B
92	Misa Sdn Bhd	128	Alten Sdn Bhd
93	Core Electronics S/B	129	Patline Ergoseat S/B
94	Live ware Technology	130	Tako Astatic Technology
95	Incosmatech	131*	SM Muhibbah Sdn Bhd.
96	DNA-AD Tech S/B	132	Scrint Technology S/B
97	Image FX Ninety Nine	133	Toplink Technologies
98*	Jaya Recycling	134	Orisoft Technlogy
99	Scanpress Sdn Bhd	135*	AKN Messaging
100	Smart-ED Dot Com Asia Sdn Bhd	136	Prime Oleochemical
101	U-Com Consulting Sdn Bhd	137	EXE technologies
102	Biztone.com S/B	138	Alif Technology
103	Unico Communication S/B	139	DBA Industries
104	Asia Information Network	140*	Elocool Technologies Sdn Bhd
105*	Haveaboard	141	Nova Sprint s/B
106	Supercomal Technologies	142	Hovid Sdn Bhd
107	Systronic Industries	143	AsiaEP.com S/B
108	TTE Electronics	144	Decimal Point S/B
109*	Supervitamins Sadn Bhd	145	AT Solutions
110	Mage FX Ninety Nine	146	Tech-line S/B
111	ETS Services	147*	Epsilon Technology (M) Sdn Bhd
112*	Protemp Exhibitions	148	FSBM Ctech S/B
113	Net linx Asia S/B	149*	Dynamite Paper
114	Greene Engineers MSC S/B	150	Paracorp Technology S/B
115*	AIT Interconnection Technologies	151	Pintar Media S/B
116	Ascendsys S/B	152	Artshop S/B
117	Embedded Wireless Labds	153	TOPF MSC S/B
118	Dbix eLabs S/B	154	Mahir Net S/B
119	KISL Technology Centre	155*	Magnus HRM Net Sdn Bhd
120	Plato MSC S/B	156	Axis Systems S/B
121	Intergates Technologies	157	BRG Asia
122	AIMS Technology S/B	158*	Alif Technology Malaysia Sdn Bhd
123	SS Innovations	159	VOL Asia S/B
124	MMM Technology S/B	160	Akisoft MSC S/B

Note: Respondents to survey questionnaire are marked with superscript * to respective number.

COMPANY QUESTIONNAIRE

Survey Purpose
The purpose of this survey is to collect data and information on business activities of companies located in science/technology parks and other parts in Malaysia. This exercise forms part of a **Ph.D. study** currently undertaken by Mr. Chandra Malairaja (researcher) at the University of Strathclyde, Glasgow G1 1XQ, Scotland. The study seeks to examine the *Effectiveness of Science/Technology Parks as a Strategy for the Commercialisation of R&D and Development of High-Tech SMEs in Malaysia.*

Confidentiality
The information you provide will be held in strictest confidence. All the data and qualitative information reported in this questionnaire will be used strictly for statistical purposes in the preparation and submission of the researcher's Ph.D. dissertation to the University of Strathclyde, Glasgow. We will therefore not divulge any of this data and information to any identifiable firm or individual.

How you could assist
Please complete and return the questionnaire before **28 February 2003** to:

Chandra Malairaja
22, Jalan Batu Unjur 4
Taman Bayu Perdana
41200 KLANG
Selangor

Phone Number: 03 - 33243602 E-mail: chandram45@yahoo.co.uk

Your co-operation and assistance is appreciated.

Thank you.

Chandra Malairaja

SECTION I: General Details of Company

1. **In which year was your company established?** ....

2. **Status of company:** Is your company a
   - ☐ single independent private company, no previous address
   - ☐ single independent private company, with previous address
   - ☐ independent government company
   - ☐ independent private company with branches
   - ☐ subsidiary of local company
   - ☐ subsidiary of foreign company

3. **Please indicate in the box(es) below the type of activity your company is involved.**
   - ☐ Manufacturing
   - ☐ Production design/development
   - ☐ Research
   - ☐ Marketing/sales
   - ☐ Warehousing
   - ☐ Servicing/repair
   - ☐ Analysis
   - ☐ Consultancy
   - ☐ Training
   - ☐ Software
   - ☐ Others: Please specify ....

4. **Which type of sector/industry is your company involved?**
   - ☐ Microelectronics
   - ☐ Biotechnology
   - ☐ Pharmaceutical
   - ☐ Software
   - ☐ Instrumentation
   - ☐ Hardware and systems
   - ☐ Analysis and testing
   - ☐ Medical
   - ☐ Mechanical
   - ☐ Environmental
   - ☐ Design and development
   - ☐ Fine chemicals
   - ☐ Other manufacturing
   - ☐ Financial and business services
   - ☐ Other services: Please specify..

5. **What are your company's main products/services?**

(i) ....

(ii) ....

(iii) ....

6. Who are the clients/customers for the products/services of your company? You may give more than one response by ticking in the appropriate box.

- ☐ local open market
- ☐ local companies
- ☐ multi national companies located in Malaysia
- ☐ companies located outside Malaysia
- ☐ universities/higher education institutes/research institutes (RIs)
- ☐ overseas open market

7. Number of company employees/ sales turnover/ exports/profits from 1997 – 2001.

Employees/Sales	1997	1998	1999	2000	2001
No. of employees	....	....	....	....	....
Sales Turnover (Ringgit (RM))	....	....	....	....	....
Sales/Turnover Derived from Exports (RM) or % of turnover	....	....	....	....	....
Profit (RM)	....	....	....	....	....

SECTION II: Technology, R&D and Innovation Activities

(a) Technological Sophistication of Company's Product(s) and/or Service(s)
(Tick in the appropriate box)

8. If your company is producing a product(s), is the product(s):

- ☐ based on 'leading edge' or advanced technology
- ☐ entirely novel
- ☐ contains established technology
- ☐ has little technological content
- ☐ is not particularly novel

9. If your company is supplying a service(s), is the service(s):

☐ based on 'leading edge' knowledge
☐ not unique

(b) Scientific Personnel and R&D Expenditure

10. Please indicate in the table below the inputs into your company's product/process development in terms of qualified scientists and engineers (QSE), research and development (R&D) expenditure.

R & D input	**1997**	**1998**	**1999**	**2000**	**2001**
i. Number of qualified scientists & engineers (QSE) employed	....	....	....	....	....
ii. R&D expenditure per year (in Malaysian Ringgit - RM) (or express as percentage of total revenue)	....	....	....	....	....

(c) Company's R&D Focus

11. Please tick appropriately in the box, the focus of R&D in your company, that is, to what aims is the R&D directed. You may give more than one response.

☐ Product improvement
☐ Extension of existing range of products
☐ Development of complementary products
☐ Radical new research
☐ No particular focus

(d) New products/services and patents as outputs.

12. Indicate in the box, the total number of new products/services introduced and patents applied and granted in the period 1997 - 2001.

New products/new processes/patents	1997 - 2001
a. Number of new products introduced	....
b. Number of new processes introduced	....
c. Number of patents applications made	....
d. Number of patents granted	....

13. If your company is a software house, please indicate the total number of copyright applications made and obtained in the period 1997 – 2001.

Copyrights	**1997 - 2001**
a. Number of copyrights applications made	....
b. Number of copyrights registered	....

(e) Technology Management

14. Does your company have a formal technology strategy? ☐ Yes ☐ No

15. Between 1997-2001, did any of your employees attend training courses in Technology and/or Innovation Management. ☐ Yes ☐ No

16. Is there a specific person in your company responsible for management of technology? ☐ Yes ☐ No

SECTION III: Benefits of Science/Technology Park Location

17. Was your company located elsewhere before moving to present address? If Yes, where was the previous location?

☐ City/town
☐ Industrial Area
☐ Other special designated zones

18. In which year did your company locate in the science/technology park? ....

19. What were the reasons/motivations for locating your company in the science /technology park? Please rank 1 to 10 from the most important to the least important reason. Please write the ranking number in the appropriate box.

- ☐ Access/proximity to facilities of universities, other HEIs and Research Insts.
- ☐ Affordable costs/rental of premise offered by the science/technology park
- ☐ Availability of support services in the science/technology park
- ☐ Prestige and overall image by being located in the park
- ☐ Networking with other companies in the science park
- ☐ Facilitate international links for securing market, expertise and technology
- ☐ Good transportation and communication facilities
- ☐ Access to government incentives, grants and venture capital
- ☐ Availability of skilled labour
- ☐ Access to local markets

20. How important is location in science/technology park/IC to your company, in terms of the following benefits. Please tick in one appropriate box only for each row. Complete all the rows.

	Not Impt.	Fairly Impt.	Impt.	Very Impt.
(i) Access/proximity to facilities of universities, other HEIs and Research Institutes (RIs).	☐	☐	☐	☐
(ii) Affordable costs/rental of premises	☐	☐	☐	☐
(iii) Availability of support services in the park	☐	☐	☐	☐
(iv) Prestige and overall image by being located in the park	☐	☐	☐	☐
(v) Networking with other companies in the park	☐	☐	☐	☐
(vi) Facilitate international links for securing market, expertise and technology	☐	☐	☐	☐
(vii) Good transportation and communication facilities	☐	☐	☐	☐
(viii) Access to government incentives, grants and venture capital	☐	☐	☐	☐
(ix) Availability of skilled labour	☐	☐	☐	☐
(x) Access to local markets	☐	☐	☐	☐

SECTION IV: Links with Universities/Higher education institutes (HEIs)

21. Does your company have links with local universities and/or with other higher education institutes (HEIs) and/or with research institutes?

	Yes	No
University	☐	☐
Higher Education Institutes (HEIs)	☐	☐
Research Institutes (RIs)	☐	☐

22. How important are Universities/HEIs links to your company's growth. You may give more than one response. Then select three most important links with the universities/HEIs and rank them 1-3 in order.

	Tick Where Applicable	Rank Three Most Important Link
(i) Informal contact with academics	☐	☐
(ii) Employment of academics on a part time consultancy basis	☐	☐
(iii) Conducting joint/collaborative research	☐	☐
(iv) Sponsorship of research trials/projects	☐	☐
(v) Access to equipment and other facilities	☐	☐
(vi) Other formal links	☐	☐
(vii) University/HEI as a customer	☐	☐

SECTION V: Government Support Programmes

23. Is your company aware of the following government programmes to assist R&D and innovation activities of companies?

	Aware	Not Aware
(i) Commercialisation of R&D Fund (CRDF)	☐	☐
(ii) Technology Acquisition Fund (TAF)	☐	☐
(iii) Industry R&D Grant Scheme (IGS)	☐	☐
(iv) Multimedia R&D Grant Scheme (MGS)	☐	☐
(v) Demonstrator Application Grant Scheme (DAGS)	☐	☐

(vi) Government venture capital funds	☐	☐
(vii) R&D Tax Relief	☐	☐

24. Has your company made any applications to obtain the above government assistance and what is the status of the application?

	Did not Apply	Application Submitted	Application Rejected	Application Approved
(i) CRDF	☐	☐	☐	☐
(ii) TAF	☐	☐	☐	☐
(iii) IGS	☐	☐	☐	☐
(iv) MGS	☐	☐	☐	☐
(v) DAGS	☐	☐	☐	☐
(vi) Govt.venture capital funds	☐	☐	☐	☐
(vii) R&D Tax Relief	☐	☐	☐	☐

25. How important are the above government programmes to your company's growth?

	Not important	Slightly important	Important	Very Important
(i) CRDF	☐	☐	☐	☐
(ii) TAF	☐	☐	☐	☐
(iii) IGS	☐	☐	☐	☐
(iv) MGS	☐	☐	☐	☐
(v) DAGS	☐	☐	☐	☐
(vi) Govt.venture capital funds	☐	☐	☐	☐
(vii) R&D Tax Relief	☐	☐	☐	☐

Section VI: Innovation: Sources, Co-operative Arrangements, Factors Hampering

26. What are your company's main sources or influences of innovation? Please tick one column only for each row. Complete all the rows.

Sources of innovation	Not relevant	Slightly important	Moderately important	Very important
a. In house R&D				
b. Competitors				
c. Clients or customers				
d. Consultant companies				
e. Suppliers of equipment				
f. Universities/HEIs				
g. Govt. research institutes				
h. Conferences, meetings, journal				
i. Computer based info networks				
j. Fairs, exhibitions				
k. Strategic alliances				
l. Others (please specify)				

27. Did your company have any co-operative arrangements on innovation activities with other companies or institutions in 1997-2001?

Yes ☐ **No** ☐

If yes, please indicate in appropriate row/columns in table below.

Type of Partners	Location of partner				
	Malaysia	Japan	USA	UK	Others
a. Competitor					
b. Clients/customers					
c. Consultant firms					
d. Suppliers					
e. Universities/HEIs					
f. Govt. RIs					
g. Strategic Alliances					
h. Others (please specify)					

28. What are the factors that hampered your company's innovation activities? Please tick one column only for each row. Complete all the rows.

Factors hampering innovation	Not relevant	Slightly important	Moderately important	Very important
a. Market uncertainties/risks				
b. High innovations costs				
c. Lack of financial sources				
d. Lack of access to expertise/facilities in universities / RIs				
e. Lack of info on technology				
f. Lack of market information				
g Stringent regulation/standards requirements				
h. Lack of customer responsiveness to new products				
i. Lack of skilled personnel				
j. Lack of govt. support mechanisms				
k. Lack of private sector co-operation				
l. Others (please specify)				

SECTION VII: Internationalisation Aspects

29. Does your company:

	Yes	No
(i) Export goods/services produced by company	☐	☐
(ii) Source raw materials and other inputs from overseas	☐	☐
(iii) Use foreign consultants/technical expertise	☐	☐
(iv) Use foreign technology - equipment and other hardware	☐	☐
(v) Have collaborative research projects with foreign partners	☐	☐

(vi) Have business links with multi-national companies (MNCs) operating in Malaysia ☐ ☐

30. How important are the foreign links to your company?

	Not Impt	Slightly Impt.	Impt	Very Impt.
(i) Foreign market for goods/services produced by company	☐	☐	☐	☐
(ii) Foreign sources for raw materials and other inputs	☐	☐	☐	☐
(iii) Use of foreign consultants, technical expertise	☐	☐	☐	☐
(iv) Use of foreign technology – equipments/other/ hardware	☐	☐	☐	☐
(v) Collaborative research projects with foreign partners	☐	☐	☐	☐
(vi) Business Links with multi-national companies (MNCs) operating in Malaysia	☐	☐	☐	☐

SECTION VIII: Sources of Finance

31. What are the sources of finance to conduct your company's R&D and innovation activities?

a. Company's own finances ☐

b. Borrowing from financial institutions ☐

c. Venture capital ☐

d. Government grants ☐

e. Others Please specify .... ☐

Details of Respondent

Kindly fill in the details of person responsible for completing the questionnaire.

Name: Telephone Number:

Designation: Facsimile Number:

Date: E-mail:

Company's Name:

Address:

APPENDIX VII

Open-Ended Questions for Interview-Based Study

1. Who are the founders of your company, and what are their academic background?

2. What were the founders' motivations to set up the company?

3. Any specific reason to locate the company in Technology Park Malaysia?

4. Overall does your company benefit from its location in TPM?

5. What kind of services (other than the physical office space) provided by the TPM are used by your company?

6. To what extent is your company's growth and development attributed to the location/environment in TPM?

7. Is your company satisfied with the support given by the management of the TPM for your business operations?

8. Would your company have grown to the current level if it has been located elsewhere (not in a designated area such as a technology park/incubation centre), for example in KL city centre?

9. What are the reasons for using/not using grants/incentives provided by the government?

10. Does your company have any strategic alliance/partnership with local and foreign companies? If yes, what kind of alliance and how effective it is?

11. Is your company planning to go global to expand the business? If yes, what kind of strategy will be adopted?

12. Analysts say Malaysia's climb in the technological ladder is slow despite massive government's support (infrastructure, institutions and incentives) for innovation and technological development. What can be done to improve the situation?

APPENDIX VIII

Summary of Results of the T-Tests and Chi-Square

I. Results of t-tests on means and standard deviations of 15 variables

Hypothesis/Variable	Mean Difference	t statistic	DF	p value (one-tailed)	p value (two-tailed)
1. R&D intensity	1.6867	0.2029	50	0.4211	0.8422
2. QSE intensity	10.6547	2.0260	50	0.0241	0.0481
3. Radical Research	0.2525	0.0477	50	0.4811	0.9621
4. Interfirm collaboration	0.2605	1.9087	50	0.0310	0.0620
5. University link	0.1333	0.0849	50	0.4664	0.9327
6. Venture capital	0.106	0.9148	50	0.1824	0.3647
7. Govt. R&D Grants	0.1091	0.8063	50	0.2120	0.4239
8. International R&D	- 0.0364	0.2613	50	0.3975	0.7949
9. Exporting	0.0576	0.4056	50	0.3434	0.6867
10. New products/process	1.8151	2.9140	50	0.0027	0.0053
11. Patents	0.2515	0.4714	50	0.3197	0.6394
12. Copyrights	0.5122	1.3878	50	0.0857	0.1714
13. Sales growth	0.3202	1.0743	50	0.1439	0.2878
14. Profit Ratio growth	1.3998	0.5046	50	0.6161	0.3081
15. Employment growth	0.2642	2.0215	50	0.0243	0.0486

Note: i. $p<0.05$ for hypothesis No. 2, 4, 10 and 15 and therefore are accepted.
ii. $p>0.05$ for hypotheses 8 and therefore not confirmed (negative mean difference)
iii. $p>0.05$ for the rest 10 hypotheses and therefore not confirmed.

II. Results of chi square tests on 7 categorical variables (of the total 15)

Hypothesis/Variable	chi square	DF	p value (one-tailed)	p value (two-tailed)
1 Radical Research	0.002	1	0.4806	0.9612
2. Interfirm collaboration	3.532	1	0.0301	0.0602
3. University link	0.020	1	0.4442	0.8884
4. Venture capital	0.856	1	0.1774	0.3549
5. Govt. R&D Grants	0.667	1	0.2070	0.4140
6. International R&D	0.071	1	0.3950	0.7900
7. Exporting	0.171	1	0.3398	0.6796

Note: i. $p<0.05$ for hypothesis No. 2 only
ii. $p>0.05$ for the rest of the hypotheses