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SCIENCE PARKS, ELECTRONICS ACTIVITIES AND REGIONAL DEVELOPMENT: THE CASE OF MANITOBA

BY

FUNG KWAN WONG CHAN

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FUNG KWAN WONG CHAN

A Thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

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Abstract

The objective of this thesis is to identify the key factors underpinning the operations of effective science parks. Electronics activities are taken as the yardstick for inferring the nature and degree of science park development. This is done by placing the determinants of electronics industries within a theoretical framework drawn from the industry life-cycle concept of the behavioural paradigm. Abstracting from that theory, the following two hypotheses are derived:

(1) the survival of the early-stage firms, namely, the small innovative firms, is dependent upon the presence of external learning economies; and

(2) their survival is also a result of the presence of entrepreneurial learning economies.

A logit model that covers Western Canada as a whole and a multiple regression model that focuses on Manitoba are established for empirical verification of these hypotheses. The firm-level data are collected through questionnaire surveys and in-person interviews.

The econometric results of both models confirm that the two types of learning economies contribute significantly both to the agglomeration of the early-stage electronics firms in the first place and to their subsequent expansion in the second place. All in all, both models suggest that the successfulness of a science park depends on the coordination of key players both within electronics industries and government agencies, universities, research institutions, and financial agencies, all of which are lubricated by a proactive park management team led by an official who knows and guides the processes of industrial agglomeration within his or her jurisdiction. However, one must note that these economies alone are insufficient to generate desirable results; rather, it is the whole-hearted long-term commitment by the local authorities to the provision of infrastructure that is the overwhelming determinant of science-park effectiveness.

For dad, mom and Joseph

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Chapter One

The Electronics Industry and Regional Development with Reference to Canada and Manitoba

1.1 Introduction

In recent decades, high-technology industries[1] have become the targets of economic development. They have been considered as the cure-all for the economic grievances of various industrialized nations and their peripheral regions.[2] The theoretical arguments maintaining that high-technology industries impact positively on national and regional economies have received considerable support for the advanced world. Some singular instances of these achievements have been widely documented in the literature of industrial development. Indeed, Markusen et al. (1986) boasted that high-technology industries have become *"the economic Holy Grail"* in many advanced countries, a goal to which they should all aspire.

Apart from the academic fulfilment arising from mating of theories to the actual environment, a high-technology approach to national and regional development for industrialized countries can be justified for practical, pressing reasons. For one, the traditional smokestack activities (such as textiles and steel) embedded in the 19th and early 20th centuries in industrialized countries, have shown an inability to cope with the keen competition emanating from the newly-industrialized and export-oriented Third World countries. In order to stay amongst the leaders of industrialization, advanced countries are compelled both to stimulate and assist high-technology industries and help them bring about innovations.[3] Hence

[1] *High-technology industries refer to a wide variety of sectors of production. In general, they include biotechnology (that is, pharmaceutical), advanced metallurgical and electronics industries. The term "high-technology industries" has a bewildering array of names from "sunrise industries" and "emerging-technology industries" to "knowledge/science-based industries". They are set in contrast to traditional sectors which are often named as "obsolete" or "sunset" industries (Scott and Storper, 1987).*

[2] *The peripheral regions of a country denote the geographical territories which exhibit poorer economic performances either in their industrial mix, employment or income level than the nation as a whole. As far as this thesis is concerned, the terms "peripheral", "problematic", "lagged", "depressed" and "less-developed" regions will not be differentiated and will be used interchangeably.*

[3] *Innovations, commonly known as "new products", can be classified into three major types: (1) basic innovations, namely, "radical innovations", "technological breakthroughs" are products which are completely new and which have general economic impacts on all industries, affecting the well-being of regional, national and global economies; (2) primary innovations, commodities which are developed from basic innovations and*

advanced lines of production prevail in their economies in lieu of the declining industries. At the same time, traditional activities would be rebuilt or revitalized as well, the result of the application of high-technology innovations to their formerly mature production processes. This kind of industrial strategy has become the cornerstone of post-industrialization economic development in the advanced world (Steed and DeGenova, 1983; Markusen et al., 1986; Scott and Storper, 1987).

With respect to regional advancement, Thomas (1985, p.17) concluded that "... in contemporary America, ... the panacea for revitalizing depressed economies at subnational ... levels appears to be the high-technology industry 'quick fix' ". Moreover, the term "regional development" carries a deeper meaning than its apparent face value. It is construed more particularly as the improvement or diversification of industrial structure or mix of subnational economies in a way aimed at regional employment generation or income growth for regions. The hope of diminishing regional disparities within the nation is also attached to this strategy (Maillat and Vasserot, 1988). Of all the high-technology industries that have recently commanded the attention of government officials and academics, it is the electronics industries that are identified as having the most promise for regional development in advanced countries (Organization of Economic Cooperation and Development (OECD), 1988). Meanwhile, apart from traditional tax incentives and other financial assistance to promote this strategy, some scientific infrastructures have been developed as means to attract these industries as well. In particular, science park infrastructures have been singled out by advanced countries as the centrepieces of their industrial strategies (Eul, 1985). Since 1980, 81 science parks have been established in the U.S.A., 21 in France, and at least nine in Canada (Association of University Related Research Parks (AURRP) and the International Association of Science Parks (IASP), 1991): just one indication of the popularity of this form of infrastructure.

There have been many efforts directed to high-technology strategies of industrial and economic development, and these yield mixed results (Schamp, 1987). Many regions in advanced-industrialized countries remain wedded to obsolescent industrial structure and, hence, have continued to suffer from high unemployment during the most recent decade

are novel to the world; (3) secondary innovations, new commodities which are not new to the world but only new to the country where firms are located and; (4) tertiary innovations or new commodities which are adaptations or improvement of secondary innovation products (Hirsch, 1967; Kok and Pellenbarg, 1987).

(Savoie, 1992). What seems to be the crux of their problems is the lack of an adequate understanding of the mechanisms underlying the agglomeration of industries.[4] Hence, there is a need to understand systematically the factors affecting the well-being of high-technology industries in general and electronics industries in particular before science park strategy can hope to become meaningful and effective. In other words, failure to understand the merits of science park infrastructures pertaining to generation of a "critical mass" of economic development in inducing industrial restructuring, income or employment growth runs the risk of missing the full benefits that could flow from it. Therefore, the objective of this thesis is to identify the key factors underpinning operations of effective science parks. Electronics acts as the yardstick for science parks. Thus, it goes about this task by placing the determinants of electronics industries within a theoretical framework drawn from the industry life-cycle concept of the behavioural paradigm of location theory. In other words, through such a study, it is hoped that the major factors contributing to the agglomeration of electronics industries can be revealed. As a consequence, effective measures can be recommended for promoting a high-technology industrial strategy; that is, one directed to science-park development. With the creation of a critical mass of high-technology industries in electronics, the alleviation of regional problems such as unemployment will be made possible. The province of Manitoba, one of the typical peripheral regions of Canada,[5] has singled out high-technology industries, in particular electronics industries as the motor for regional development, is selected as the focus of this study. However, owing to the fact that only a small sample could be collected from the initial survey in the province of Manitoba, the scope of inquiry has been extended to cover Western Canada. Finally, since it has been well-documented that it is the small firms[6] that constitute the largest proportion of establishments and the fastest growing component of the high-technology industries and, hence, the major impetus for regional growth, the

[4] *The agglomeration of an industry refers to the increase in the number of firms of the industry at a fixed location, or the increase in the number of employees, sales and revenues of firms of the industry at a fixed location. Other terms such as the clustering, concentration, mass or growth of industrial activities can be used interchangeably.*

[5] *In this study, the peripheral regions of Canada refer to all the provinces and territories of the country except Ontario and Quebec of Central Canada, the nation's economic and industrial cores. The peripheral regions of Canada, therefore, include British Columbia, Alberta, Saskatchewan and Manitoba, or also known as Western Canada in general; Newfoundland, Prince Edward Island, Nova Scotia, and New Brunswick, or known as Atlantic Canada in general; and Yukon and the North West Territories.*

[6] *The small firms refer to the companies which are in their early phase of development. According to Oakey (1985), they are firms which are predominantly engaged in the production and sales of the "indigenously designed finished or semi-finished products". They are also known as the "start-up", "new", "young" and "early-stage" firms. In the high-technology sector, they are commonly known as the "innovative activities".*

small firms of the electronics industries have been earmarked as the prime study elements (Rothwell and Zegveld, 1982; Oakey, 1985; Keeble, 1988) (for a countering view of the roles of small firms in economic development, see Harrison, 1994).

This study will proceed as follows. The background is given substance by a brief review of the regional problems and industrial restructuring strategies of Canada. In particular, Manitoba's structural crises and the governments' acknowledgment of the ensuing problems will be carefully scrutinized. To further corroborate the approach adopted by this study, a definition of electronics industries needs to be carefully amended. Therefore, a third section of Chapter One has been devoted to defining electronics industries. The characteristics of electronics industries that have been defined therein will be meaningless if they are not elaborated further with respect to their implications for regional development in the section following. Hence, supporting evidence for these characteristics will be traced around the advanced world, to reinforce the argument that electronics industries are incontestably turbines of regional advancement. Above all, Chapter One has identified the need for the advancement of industrial structure as the "problem" to be handled. What is more, electronics industries have been pinpointed as the propulsive industries leading to such structural changes. Such structural changes are fostered by the application of science park infrastructures. In this connection, Chapter Two has to start with the definition and nature of science park infrastructures. Following this, its theoretical significance to industrial development will be discussed. Theoretical significance remains just that - conjectural - unless corroborated by empirical examples. A portion of the chapter, then, is dedicated to examining actual examples of its usage. Turning to Chapter Three, the theoretical background of this thesis will be fully covered. There, it is argued that the neoclassical paradigm of location theory is inadequate to explain the industrial phenomenon in question. Instead, the industry life-cycle concept of the behavioural paradigm is advocated. Indeed, an "information"[7] perspective informs the whole study. Towards the end of Chapter Three, two main hypotheses are derived from the foregoing theoretical arguments. Their resolution, by way of the most appropriate type of modelling, constitutes the main theme of Chapter Four. Its outcome

[7] *Information is defined as the (un)organized data ((un)related facts or figures) and as knowledge (the combination of instincts, ideas, rules, and procedures) which are appropriate for reducing the uncertainty of entrepreneurs in the decision-making process (Meltzer, 1981; Federico, 1985). It is an intellectual construct that is weightless, indestructible, inexhaustible, and transmittable. Moreover, it is not used up by use. In this thesis, information, data, knowledge, skills or technology (practical know-how) will be used interchangeably.*

is a "general" model of logit regression and a "specific" model of multiple regression. Considerable attention is directed to justifying the proxies for the testing of the hypotheses. Chapter Five will reveal the methods used for collecting appropriate data for modelling. To obtain a general feeling for the empirical environment, a review of some of the preliminary findings in the data is presented. The regression results of the two models are reported and explained in Chapter Six. Finally, in Chapter Seven, problems of the development of science park infrastructures as revealed by the two models will be discussed. Some solutions to these problems will be proffered. Before embarking on that exercise, however, it is necessary to begin with a review of Canada's situations on industrial restructuring. This is necessary because such a review can provide a sufficient background to explain the recent emergence of electronics industries as constituents of the major regional development strategies of Canada and Manitoba in particular.

1.2 A Brief Review of Canadian Efforts at Industrial Restructuring

1.2.1 Canada in General

The peripheral regions of Canada are plagued by the deep-rooted problems associated with poor industrial structures. Essentially, they are characterized by a "monolithic" industrial base dominated by resource-based industries. For instance, Western Canada is dominated by forestry, mining, and, or, agricultural activities. The provinces of Atlantic Canada have a common heritage in their involvement in natural resource exploitation for exports, beginning with cod fisheries and forestry, and more recently, relying on mining activities (Phillips, 1982). In a way, the capacity for expansion in the operations of these resource-based activities is limited by the physical quantities endowed by nature. These activities are conceived as, and have been proven to be, of little or no impetus in generating timely new employment opportunities whenever conditions forment sluggish economies. This means that they persistently lack an engine for generating self-sustaining employment opportunities. Many government efforts at all levels have been made to address the problem. Yet, hitherto, results have been singularly disappointing. Serious efforts to overhaul peripheral economies began in the 1960s when emphasis was given to diversification. Tax incentives and financial assistance programmes were resorted to in order both to attract new establishments into regions, and to encourage the expansion of existing operations in traditional manufacturing sectors such as textiles, clothing, food and beverage processing, and wood product industries. As intimated, however, these measures failed to bring about the required significant realignment of regional economic activity mix. This was because they simply encouraged further engagement in traditional sectors that are known to be neither capable of generating new or innovative production lines or products nor able to create new sub-sectors underwriting industrial diversification (George, 1983). At best, since they are focusing on the production of standardized or even out-of-fashion products with saturated markets, these traditional sectors might be able to maintain a stable or slow rate of growth in output and in employment. Any expectation for rapid employment growth would be more unreasonable. As an economic buffer to weather regional cyclical periods of regional unemployment, traditional sectors would fail the acid test. Consequently, the peripheral character of the lagged regions of Canada persisted as government efforts of industrial mix realignment in these one-and-an-half decades proved ineffectual.

With the onset of a severe global recession in the mid-1970s, and like other regional counterparts of the advanced world, the peripheral regions of Canada were subjected to intense economic dislocation. For instance, there was a dramatic increase in unemployment by 1976, especially in the Atlantic provinces and British Columbia (Savoie, 1992). With a rise in social disaffection, increased pressure was felt by different levels of government and they responded by taking a harder look at the problems. The effectiveness of traditional instruments of regional development and growth was called into question, along with the mature economic sectors that they had championed. The authorities were compelled to seek more auspicious sectors to constitute the core of industrial restructuring strategy. By chance and then by choice, the Canadian federal and provincial governments showed special favour for high-technology industries such as electronics, biotechnology, and advanced materials manufacturing, regarding them as possible panaceas for regional industrial restructuring.

The conviction in favour of these novel propulsive sectors is evinced in different government documents. In particular, the Sector Task Force on the Canadian Electronics Industry enunciated that "... the electronics industry (can) be seen as a vehicle for specialized regional development ..." (*Canada Department of Industry, Trade and Commerce* (ITC), the predecessor to the *Industry, Science and Technology Department of Canada* (IST), 1978, p.19). Meanwhile, the federal Department of Regional Industrial Expansion (DRIE) noted that "... companies in all regions have benefited from the commitment on the part of all levels of government to the expansion of the electronics." (DRIE, 1986, p.6).

Among the electronics activities, those bearing on the "telecommunications", "microelectronics", "computer-aided design" (CAD), and "computer-aided manufacturing" (CAM) have been singled out as the magic wands for regional revitalization in Canada for the decades to come (DRIE, 1986; OECD, 1988). The DRIE emphasized telecommunication industry as an important instrument of regional development. It maintained that "... the governments of Canada, the ten provinces and two territories have identified the overall mandate of regional economic development policy as ... the improvement ... for all Canadians. This can be achieved by creating an economy which is both efficient in the context of the world market place and equitable as a whole. Canada's telecommunication industry has a vital role to play in this endeavour." (DRIE, 1986, p.6).

Putting these ideas into practice required nurturing of science-based electronics industries and different levels of government have extended their incentive programmes in consequence. Fiscal incentive programmes provide financial assistance for the industries either in the form of direct subsides, such as grants and loans, or indirect subsidies, such as tax incentives and procurement activities (activities in which the government deliberately purchases items from companies or contracts out services to them). Prominent among the incentive programmes are (1) the Defence Industries Productivity Programme (DIPP), (2) the Industrial Research Assistance Programme (IRAP), (3) the Programme for Export Market Development (PEMD), (4) the Western Diversification Fund, and (5) the Federal Government Income-Tax Base Incentive Package. The DIPP was administrated by the then ITC, but is now under the aegis of IST. It provides grants in the forms of cost-sharing, usually on a 50/50 percent basis between firms and the government, for the acquisition of new advanced equipment for plant modernization of the electronics sectors, specifically the aerospace and other defence-related industries (Wilson, 1973). Meanwhile, the IRAP is administrated by the National Research Council (NRC) which provides grants to cover the skilled labour costs associated with new projects undertaken by companies. The federal government agrees to share the cost of a project on the basis that salaries and wages are paid out by the NRC, while the overhead and equipment costs are met by firms (Ibid.). The PEMD scheme is administrated by the federal Department External Affairs, which provides 50 percent of costs incurred by the company in its penetration of new markets. These contributions are repayable if sales are made to these markets (Canada IST, 1989). For its part, the Western Diversification Fund, administrated by the Western Economic Diversification of Canada, provides assistance to the industries through provision of "contributions": interest-free loans for new product development or commercialization, plant establishments, new market development, industry-wide productivity improvement and feasibility studies examining the market potential of new facilities and new products or the like. Lastly, the Federal Government Income-Tax Base Incentives Package, as its name implies, is a tax incentive scheme permitting companies operating in Canada to deduct a portion of their expenditures for "scientific research" from their taxable income. The eligible portion is subject to variation from time to time but could reach 100 percent of current and capital expenditures (OECD, 1988).

Apart from these incentive programmes, governments have also endowed scientific infrastructures in the form of research or operation centres to support the establishment and expansion of electronics firms. One variant is that of government laboratories that provide equipment or expertise to electronics firms. The other form of infrastructure is known as incubator centres in general, although sometimes they are further distinguished as either "innovation centres" or "science parks". For the most part, these incubator centres provide accommodation as well as various facilities and supporting services for tenant firms. However, the "starter/nursery units" of small incubator centres are known as "innovation centres". They may occupy a unit in a building or a group of buildings where accommodation and completed services and supports for small new electronics companies are provided (Dekker, 1985; Laffaitte, 1985). To be more specific, they provide technical facilities, office services, information, contacts, public relations and marketing services through a qualified centre management team (Krist, 1985). In contrast, "science park" infrastructures are recognized as either "research parks" or "technology parks" that occupy fairly extensive areas of land, accommodating and providing the full range of services and supports for the nurturing of particularly small electronics firms. By and large, since the 1980s, nine science parks have been developed in Canada. They are the British Columbia Institute of Technology Discovery Park, the Simon Fraser University Discovery Park and the University of British Columbia Discovery Park in British Columbia; the Edmonton Research Park in Alberta; the

University of Manitoba Research Park in Manitoba; the University of Guelph Research Park in Ontario; and the Laval Scientific and High-Technology Research Park, the Quebec Metro High-Tech Park and the Technoparc Montreal, all in Quebec (Humble, 1984; AURRP and ISAP, 1991). Five of them are located in Western Canada, three in Quebec, and one in Ontario. As we shall see, these instruments will play a leading part in the rest of the thesis. At this juncture, though, it is necessary to stress the regional focus.

1.2.2 The Problem Region: The Province of Manitoba

Apart from the general efforts initiated by different levels of government in Canada to realign peripheral industrial structures, particular efforts have been initiated by the Province of Manitoba, the primary study region (though it is compelled to extend to Western Canada later on) of the thesis. The province of Manitoba has been one of the peripheral regions of Canada well-known for suffering from an unfavourable industrial structure, but, at the same time, the province is very eager to promote electronics industries for regional economic revitalization. The traditional industrial structure of Manitoba has been dominated by resource-based industries. Its industrial base is disproportionately represented by mining, forestry, fishing, fur production, and agricultural activities (Committee on Manitoba's Economic Future (COMEF), 1963; Manitoba Targets for Economic Development (TED), 1969). It is estimated that, in 1946, the net value of agriculture production was $163 million, representing 45 percent of provincial output. By 1959, it still constituted 23 percent of provincial output as compared with the industry's 10 percent of total production nationwide (COMEF, 1969). The agricultural section is characterized by having stable growth rates at best. It is conceived as having little or no impetus in generating new employment opportunities. The advent of automation and mechanization, the displacement of human labour in the farmsteads by machines, have further impaired the capacity of this economic base for net new jobs (COMEF, 1963).

The deficiency in job opportunities in Manitoba is strongly suggested by persistent plight of net outmigration, a plight which became grave in the 1960s. For instance, for the period of 1961-66, it is estimated that Manitoba lost about 23,400 people through interprovincial outmigration (Savoie, 1992). To stem this selective labour-force net outmigration, the provincial government, in conjunction with the federal government, took measures to create employment opportunities for Manitoba. The early incentive programmes of the 1960s mostly involved the utilization of subsidies for attracting new establishments and for encouraging expansion of existing operations in the traditional sectors such as food and beverages, iron and steel, transportation equipment, textiles , printing and publishing and wood products (COMEF, 1963; TED, 1986; Jenkin, 1983).

The results of these initiatives were less than impressive, for the main problem still prevailed. Under such circumstances, the needs to curtail the province's net outmigration remained compelling. For the period 1971-75, Manitoba was second to Saskatchewan in net interprovincial outmigration, registering −2.29 percent of its population base in comparison with the −5.11 percent applying to Saskatchewan. In absolute terms, Manitoba lost as many as 22,589 people to other provinces. This contrasts sharply with the net gainers: British Columbia (highest winner, with a gain of 4.43 percent to its population base), Alberta (a gain of 2.09 percent of its population base), Prince Edward Island (a gain of 2.78 percent), New Brunswick (a gain of 1.61 percent), and Nova Scotia (a gain of 0.94 percent) (Statistics Canada, 1977).

With the onset of a severe global recession in the mid-1970s, Manitoba suffered much from industrial decline. The traditional sectors showed their weaknesses in having the largest decline in employment; this was especially the case in the machinery and transportation-equipment industries (Sitwell and Seifried, 1984). Hence, during the recession years of late-1970s, Manitoba's net outmigration topped all other provinces. Its population base went down by 4.13 percent for the period 1976-81 (Statistics Canada, 1986). Even during the recovery period 1981-85, it underwent a slight reduction of 0.26 percent of its population base. When the national economy experienced another economic down-turn in the period 1986-90, Manitoba's loss in population base reverted to being the highest among all provinces, exhibiting 3.17 percent shrinkage in its population base (Statistics Canada, 1991).

By the mid-1970s, the governments of Canada had begun to search for the means to save its economy. The "sunrise" industries, essentially the electronics industries, were singled out as the engine of regional development in Manitoba at about that time (Jenkin, 1983). With these in mind, a number of new programmes were initiated, most of which survive to this day. For instance, the Health Industry Development Initiative, administrated by the provincial Department of Industry, Trade and Tourism (ITT), is an incentive programme that involves cost-shared feasibility studies and provides financial assistance for commercializing technology for manufacturing of electronics equipment in the health-care sector (Manitoba ITT, 1990). Apart from that, new infrastructures such as the Industry and Technology Centre, the Canadian Institute of Industry and Technology (CIIT) and, the Institute of Technology Development (ITD) were established.

Established in 1979, the Industry and Technology Centre is administered by the Economic Innovation and Technology Council (EITC, the former Manitoba Research Council (MRC)). [8] Located in southeast Winnipeg, the centre offers technical supports such as testing and evaluation of products, and furnishing of technical information and advisory services to electronics activities (in most cases, at no costs to clients). Aided by the field services staff of the collocated NRC, the centre also attempts to find alternative funding sources for and to defray costs of enterprises (*Trade and Commerce Magazine*, September, 1983). Meanwhile, the CIIT was established in 1985 (and terminated in 1992). It was an innovation centre controlled by the federal NRC. It once occupied a $41 million modernized building, of 17,000 m^2 in size, sited in downtown Winnipeg. Through provision of office space, facilities and services, the CIIT intended to foster research-intensive electronics firms such as those involved in artificial intelligence and expert systems, computer-integrated manufacturing (CIM) and sensor-based robotics manufacturing. With a core staff of 25, the CIIT was equipped with numerous pieces of advanced equipment such as a cluster of VAX8530 and 8520 computers. It also housed the Robotics and Automation Section of the NRC's Division of Electrical Engineering, and the Division of Mechanical Engineering. These research branches focused their research interests in the fields of robotic applications, industrial automation and artificial intelligence. It also accommodated the Electronics Industry Association of Manitoba (EIAM). The EIAM is a non-profit-making organization established in 1983. Its intent is to bring together people with an interest in developing electronics industries in Manitoba. It keeps its member firms informed about environmental changes that affect the development

[8] *The EITC, established in 1992, is administered by the provincial ITT. Its aim is to encourage and facilitate scientific research and technological development of various industries in the province. The council's focus has been largely on promoting biotechnology industries and, to a much lesser extent, electronics activities. Of its 50 scientific staff, 20 possess expertise in the pharmaceutical, microbiology or chemistry fields. Only two are electronics technical personnel.*

of the industries that concern them. To fulfil this task, the EIAM holds regular meetings featuring presentations by leading industrial experts, and also publishes newsletters and an industry directory. To address specific issues, it organizes special conferences.

Established in 1986, the ITD is located in the Engineering Building of the University of Manitoba. It was jointly established by the provincial and federal governments, the administration of the University of Manitoba and its Faculty of Engineering. Initiated with the purpose of facilitating technology transfer,[9] in particular, the delivering of technical information from the university to industries, it serves as the focal point of contacts for industrial people who want to gain access to specialized expertise, capabilities and facilities available in the university's Engineering Faculty or, for that matter, any kind of technology-related assistance that the university can offer. To facilitate the accessibility to the university's technical resources to industries, the ITD acts as an agent between the university and clientele firms. It helps firms to locate appropriate resources available in the university and also helps firms to obtain a local source of high-tech spare parts, product supplies and specialized products or processes and university students for employment. Moreover, with the assistance of the IRAP of the NRC, the ITD initiates and coordinates Research and Development(R&D)[10] projects for local industries. With the support of the provincial department, the ITT, this institution has established the Technology Networking Programme (TECHNET) that involves the publication of a newsletter, *Connection*, and helps academics to commercialize their technological developments, and furnishes a resource centre of business and technological entrepreneurship-oriented materials.

Besides these small-scale developments in infrastructure, a larger-scale infrastructure, known as the University of Manitoba Research Park, was also established in 1982 for promotion of high-technology activities. Initiated by the Board of Governors of the University of Manitoba, it covers an area of 1.08 hectares within the university's Fort Garry Campus

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[9] *In this study, technology transfer and information flow will be used interchangeably.*

[10] *"Research" refers to the process of investigation and experimentation in discovering, interpreting or improving new facts and relationships. "Development" indicates the phase of design seeking beyond the current state of the art. In the phase of "development", novel design concepts are evaluated and improved through experimentation, and are usually guided and evaluated by analysis (Gannon, 1976). In this context, R&D projects are defined as the investigation or experimental work carried out to acquire new and the state-of-the-art scientific and technological knowledge, to devise and develop new products and processes, or to apply newly-acquired knowledge in making technically-significant improvements to existing products and processes.*

(AURRP and IASP, 1991). With a mandate to nurture research-intensive activities, the park only grants leases to firms that are involved in activities of "research and, or products or process development". Manufacturing enterprises are tolerated so long as they limit their production activities to prototypes and demonstration models for market testing. Leases are granted on a "ground only basis" enabling potential tenant firms to design and construct their own buildings on site. Furthermore, only long-term leases, with a minimum of 20 years, are available. It was hoped that this type of arrangement would foster industrial growth within the province. Since its establishment in the early 1980s, the park has attracted only one high-technology firm to the site — the RH Pharmaceutical Incorporated (Secretary of Senate, University of Manitoba, 1988) — not an auspicious start!

1.2.3 Section Recapitulation

To sum up, troubled by the problems stemming from constrained industrial bases in their peripheral regions, different levels of government in Canada began to shift their industrial strategies from an obsession with bolstering "traditional" sectors to a concern for "new" activities. Hence, ever since the mid-1970s, electronics industries, together with other high-technology industries such as biotechnology and advanced materials, have been singled out as the most promising instruments for accomplishing the goal of economic diversification. Various measures have been taken to give substance to these high technology-oriented industrial strategies. Measures advocating science park infrastructure have received perhaps the most attention for reasons that will be made clear later. First, however, it is necessary to clarify what is meant by electronics industries.

1.3 A Definition of Electronics Industries

Ironically, apart from their recognition as being efficacious tools for regional development, electronics industries do not have a generally-accepted definition. Different people define electronics industries differently so as to serve their particular objectives. Some people are simply business-oriented without seriously screening for member industries. Others attempt to classify electronics industries narrowly by their physical products or components. Yet others would lay down criteria to isolate these industries on the basis of their special behaviours in terms of industrial organization or structure.

Probably for the purpose of recruiting as many manufacturing firms as possible to their membership list, the Electronics Industry Association (EIA), the industry's main trade association in the U.S.A. today, has defined electronics industries broadly including food and kindred products, textiles mill products, chemicals and allied products, rubber and miscellaneous plastics products, stone, clay and glass products, primary metal industry, fabricated metal products, machinery, transport equipment, professional, scientific and controlling instruments, miscellaneous manufacturing industries, and finally, the communication service industry (Table 1.1) (Skinner and Rogers, 1968).

Table 1.1

EIA's Definition of Electronics Industry

SIC	Code	Industry Description
20		Food and kindred products
22		Textiles mill products
28		Chemicals and allied products
30		Rubber and miscellaneous plastics products
32		Stone, clay and glass products
33		Primary metal industry
34		Fabricated metal products
35		Machinery, except electrical
	357	Office computing and accounting machines
36		Electrical machinery
	361	Electrical transmission and distribution
	362	Electrical industrial apparatus
	364	Electrical lighting and wiring
	365	Radio and TV sets and phonography records
	366	Communications equipment
	367	Electronics components and accessories
	369	Miscellaneous electrical machinery
37		Transportation equipment
	371	Motor vehicles and equipment
	372	Aircraft and parts
38		Professional, scientific and controlling instruments
	382	Instruments for measuring and controlling
	386	Photographic equipment and supplies
39		Miscellaneous manufacturing industries
48		Communications service industry

Source: Skinner and Rogers (1968, p.2).

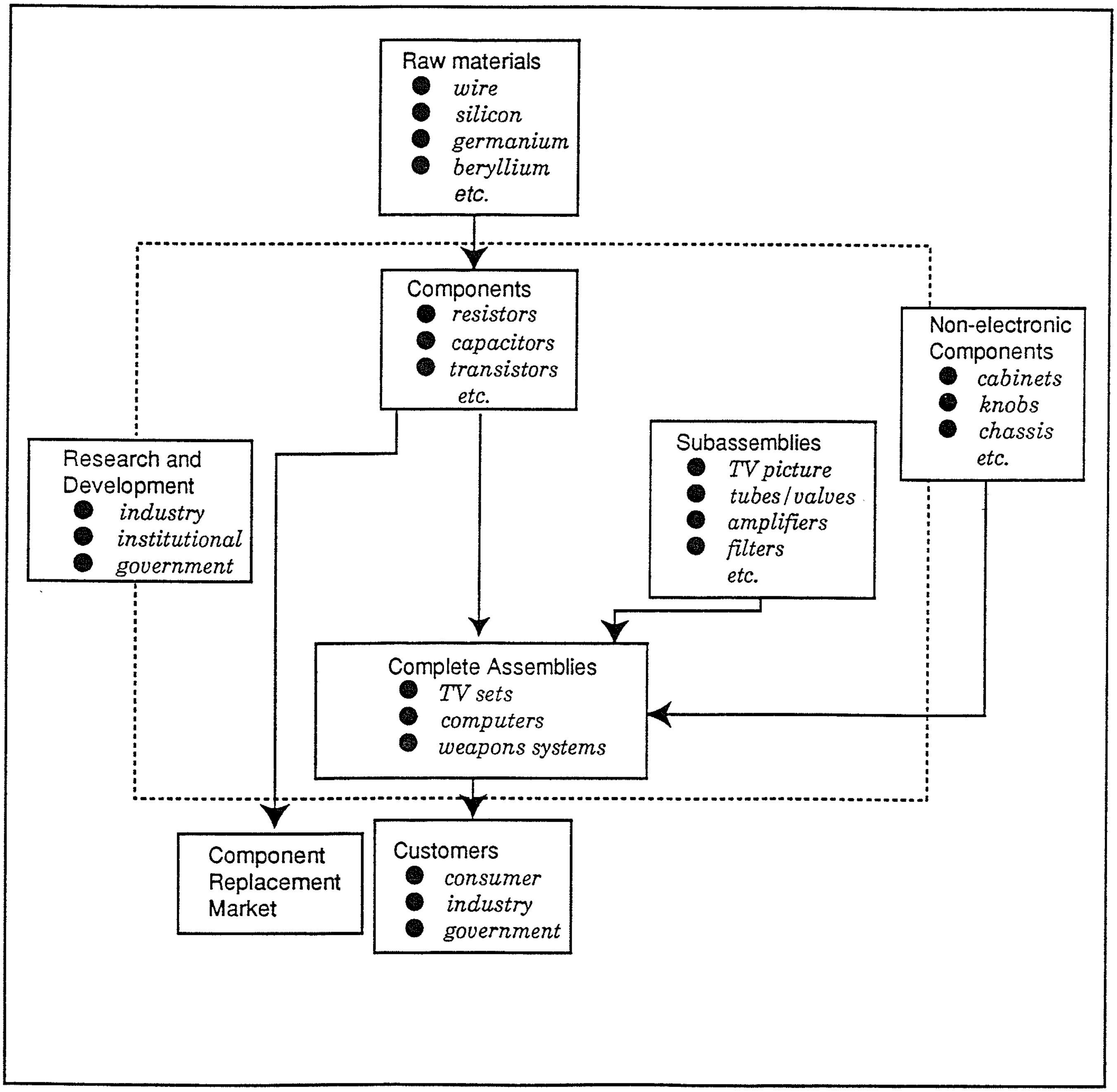
The major advantage of the EIA definition is its ease of application since all these industries can be easily found from the Standard Industrial Classification (SIC) System. By and large, it defines electronics industries from the perspective of "producers' goods"; that is, as inputs to all kinds of production activities. By this standard, any industrial sector that utilizes electronics devices in its production processes will be qualified as "electronics industries". As a consequence, it embraces an inordinately wide spectrum of activities and shows itself to lack any focus at all. Numerous traditional sectors such as textile manufacturing and metal industries are recognized as "electronics industries" in a manner which stretches the bounds of credibility. If a classification system is to be used to depict an industry, it ought to take into account the major component parts of its principal finished goods or end products. Anyway, the EIA definition also fails to highlight electronics industries as newly-emerged economic activities. Therefore, this definition cannot be considered seriously for research purposes. One has no choice but to search further for an acceptable definition.

In order to highlight the physical nature of the products of the industries, some authors insist that electronics industries are those that manufacture devices that turn on electron movement in a vacuum, gas, liquid, or solid-state materials (Skinner and Rogers, 1968; Keeble, 1976). Electronics industries, as a consequence, are essentially confined to the making of component electronics products such as integrated circuits (ICs) and other semiconductors. Similar to the EIA definition, the advantage of this definition is its ease of application. However, in reality, this physical-nature-based definition is overly narrow and restrictive. By its lights, electronics industries are limited to manufacturing of extremely small electronic component products capable of altering or modifying the rate of flow of electrons. The yardstick, then, really limits production of electronics producers' goods or input components to the downstream production processes. Therefore, it does not account for the finished goods that are heavily composed of electronic components. Accordingly, this definition is incomplete in excluding activities such as manufacturing of "computers", "industrial electronics controls", and "electronic measuring equipment".

To continue the search for an acceptable definition for electronics industries, Skinner and Rogers (1968) suggest a definition that highlights the production or process characteristics of electronics industries. They classify electronics industries into three major categories, namely, electronic component production, sub-assembly and complete assembly sectors (Figure 1.1). In this schema, the electronic component sector produces the electronic components;

Figure 1.1

A Definition of Electronics Industries Based on Skinner and Rogers



Source: Skinner and Rogers (1968, p.3) that is to say, the discrete parts that are used to manufacture sub-assemblies and complete units such as transistors, vacuum tubes, resistors, capacitors and so forth. The sub-assembly activities manufacture the immediate products to be assembled with other parts, not necessarily of an electronic nature, before delivering to the consumers, such as television picture tubes, amplifiers, waveguides, and so on. The complete assembly sector produces the operational devices and systems in the form to be used by consumers such as television sets, radios and radar systems. Accordingly, a great range of widely recognized electronics sectors or products are included. However, the main difficulty with this schema lies with identification. For instance, it is difficult to categorize the production of ICs into the component supplier- or sub-assembly-producing groups, but it is far more testing to categorize the sub-assemblies which may contain the equivalent of several hundred discrete components into these groups.

Because of such concerns, this precedent has not been taken up by governmental bodies. Instead, they opt for product-oriented classes. The then ITC classified electronics industries as those that involved the manufacturing of the following six major products: (1) "components",[11] (2) "consumer electronics",[12] (3) "telecommunications and other communications equipment",[13] (4) "computers and other electronic office equipment",[14] (5) "control and

[11] *The term "components" includes a wide variety of products ranging in complexity from large-scale integrated circuits to simple diodes. This group of products, however, can be categorized into two major types: active and passive component subgroups. The active component subgroup includes the production of ICs, other semiconductor (SC) devices and the making of electron tubes (valves). An IC is a SC die holding many mutually-interacting elements which together constitute a circuit. Examples of IC products include logic devices (so called from their coding to respond to the "either/or" kind of instruction), memory devices (called, as implied, from their storage function) and microprocessors (which are combinations of logic and memory devices lodged in a single SC chip. The non-IC SC devices are the circuits which depend on SC (the material acting both as a conductor and insulator) to regulate the flow of electron charges. Examples of these SC devices include diodes, transistors and rectifiers. Diodes are devices containing only two electrodes and appear in the SC form or as valves. They are generally fashioned as integral parts of rectifiers. By way of contrast, transistors accommodate multiple electrodes and are solid-state devices used to amplify electric current. Rectifiers are more specialized in that they pass current in just one direction and are pressed into service as AC to DC converters. As for the passive component subgroup, the major products include oscillators (that is, the devices capable of converting DC power into AC power) and microwave circuit parts and other circuit parts (Todd, 1990).*

[12] *These are electronics goods directly consumed by household consumers. Examples of these goods include manufacturing of television sets, videos, recorders, amplifiers, hi-fi equipment, radios, gramophones, alarm systems, etc.*

[13] *This refers to manufacturing of devices for transmission of information from one point to another by wire, radio, optical or other electro-magnetic systems. Examples of these devices include telephones, telegraphs, microwave transmitting and related equipment.*

[14] *This sector includes manufacturing of mainframe computers, personal computers, electronics typewriters, word processors, cash registers and scales.*

instrumentation equipment" [15] and, (6) "system electronics".[16]

This ITC definition has overcome the difficulties encountered by the Skinner-Rogers definition in identification. It can be easily picked up from any conventional SIC format. It has looked into not only the physical nature of electronic components but also their related finished goods. The intrinsic characteristics of the industries have then been taken care of. It also excludes odd traditional sectors but includes newly-emerging uprising "electronics" sectors. Hence, the old and declining manufacturing sectors are differentiated from the truly electronics production activities. In the light of these advantages, the ITC definition is selected to be one applied in this thesis.

Once electronics industries have been delimited from other activities, the next stage is to put their intrinsic characteristics on a firm footing.

1.4 The Intrinsic Characteristics of Electronics Activities

There are four commonly-held views about the intrinsic characteristics of electronics industries in the advanced world. Electronics industries are (1) highly spatially concentrated; (2) fast growing; (3) very high in advanced technical inputs either in terms of technical expertise or of R&D expenditures and finally; (4) they possess numerous technologically active, new and small establishments. The veracity of these views is now examined.

1.4.1 Highly-spatially Concentrated

Electronics industries in industrialized countries are characterized by their high spatial

[15] *This is a broad electronics sector. The products include all kinds of control devices used in every facet of industrial activities from resources exploration to the most sophisticated manufacturing processes and industrial analytical equipment used in testing and measuring purposes. Examples of these devices include digital temperature/pressure indicators and regulators.*

[16] *This refers to the industrial sector which integrates a variety of electronics equipment into a system, usually designed to monitor an activity or process and to initiate corrective and control functions if necessary. Specifically, they refer to the computer-based activities such as CAD, CAM and CIM. CAD is the generation of computer automated design for display on cathode-ray tubes (tubes in which a stream of electrons, such as that emitted by a heated filament in a tube, or that emitted by the cathode of a gas-discharge tube when the cathode is bombarded by positive ions). CAM is concerned with the application of programmable automation technologies in the production process. CIM involves integration and coordination of design, manufacturing and management using a computer-based system. These systems, however, are still in the process of development and there is some uncertainty regarding their final configuration. Examples of these computer-based activities include the designing or developing of air traffic control systems, industrial process control systems, and aircraft and guided missile manufacturing.*

concentration. Essentially, they have a strong spatial bias towards some areas within a nation. For instance, it is well known that a large number of electronics activities exists in the U.S. states of California and Massachusetts. There, they are particularly represented by computer and SC industries. But electronics activities are also not evenly distributed within the region. Instead, they are highly concentrated in a few selected areas of the region which become the "core-of-the-core" of electronics activities. Most dramatically, in California, such concentrations can be sighted in the vicinity of the Stanford Industrial Park in Palo Alto, the core of Silicon Valley [17] (Bollinger, et al., 1983; Malecki, 1986) (Figure 1.2). Similar development is also found in Massachusetts, where the top leaders of defence electronics are located. In this case, electronics activities are concentrated within the vicinity of the Massachusetts Institute of Technology (MIT) in the Route 128 area of Boston[18] (Malecki, 1986) (Figure 1.3). Upon examination of the 1977 distribution pattern of high-technology industries (which enclosed a number of electronics sectors such as "office computing machinery", "communications equipment", "electronic components and accessories", "aircraft and parts", "guided missiles" and "space vehicles and parts" manufacturing) in the U.S.A., Markusen et al. (1986) determined that California and Massachusetts achieved much higher scores in their concentration of such activities than the nation as a whole; they scored employment Location Quotients (LQ) of 1.49 and 1.43 respectively. These authors asserted that this finding "confirms popular portrayals of Route 128 and Silicon Valley as the nation's top high tech (electronics) centres. California and Massachusetts are at the hub of high tech (electronics) agglomeration in their regions at least in terms of total number of jobs" (Markusen et al, 1986, p.100).

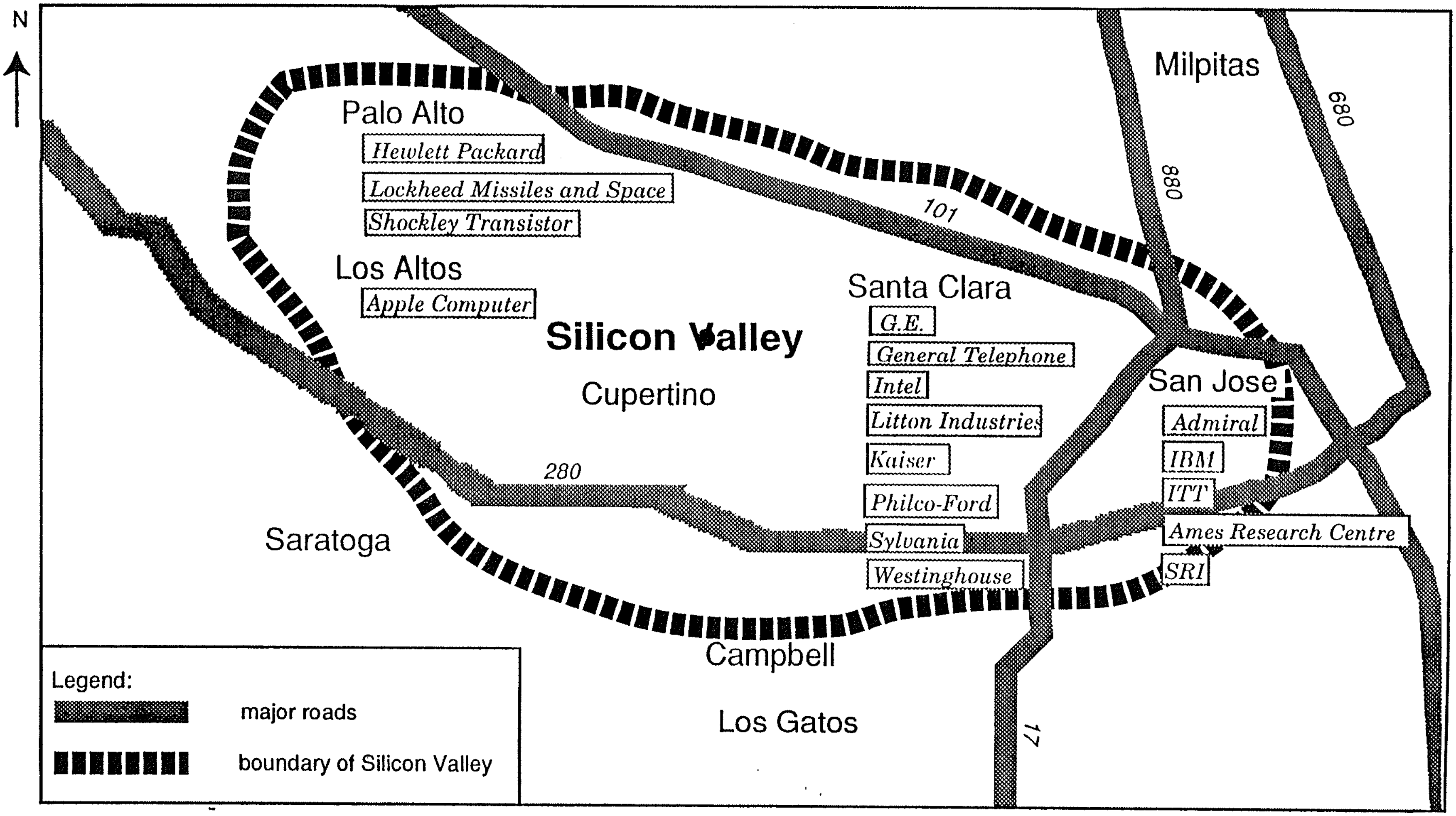
In turning the spotlight to Europe, the electronics industries in the U.S.A. presented a strong spatial bias in a manner similar to those of the U.S.A. The electronics industries are basically concentrated in a few fortunate areas such as the South-East and central Scotland. Massey (1984) evinced that since 1959, the earliest date for which precise figures were available, the South-East of the U.K. had been the largest electronics centre of the country. It accounted for roughly 60 percent of the employment of the electronics industries of the entire

[17] *Silicon Valley, located in northern California, is a very compact industrial complex, measuring approximately 20 kilometres north-west-south-east by 10 kilometres north-east-south-west. This industrial complex has developed south-eastwards along Route 101 from Palo Alto in the north, continuing through Mountain View and Sunnyvale towards the older settlement of San Jose (Oakey, 1984).*

[18] *Originally, Route 128 denoted an eight-line highway that was built during the 1950s as a semicircle around Boston at a radius of 16 km from Boston. Nowadays, its name is the designation for the entire electronics complex in the Boston area (Malecki, 1986).*

Figure 1.2

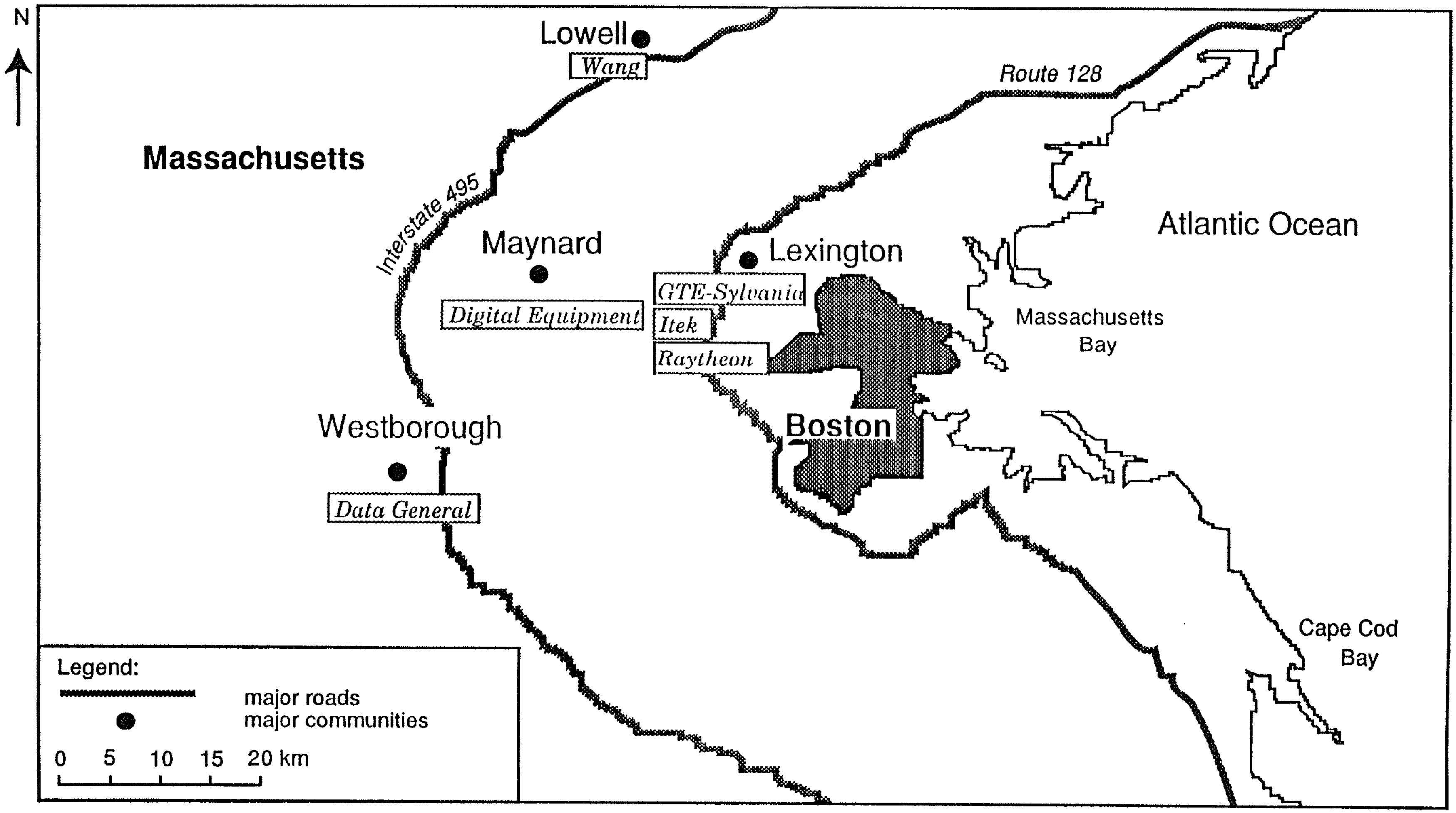
Silicon Valley and its Major Electronics Firms



Source: Modified from Rogers and Larsen (1984)

Figure 1.3

Route 128 and its Major Electronics Firms



country. Meanwhile, Begg and Cameron (1988) analysed the spatial pattern of the electronics sector (for example, the "telephone and telephone equipment", "active components" and "aerospace and telecommunications" activities) and other high-technology industries (such as "synthetic resins and plastics materials", "synthetic rubber" and "pharmaceuticals" productions) in the U.K. They discovered that the South-East secured an employment location index of 129.9; an index which is much higher than the national score of 100. Apart from this, this study also pointed out that Scotland recorded a fairly impressive index of 137.7 in the active electronic component sector.

Looking closer into the South-East concentration, electronics industries are largely concentrated in Greater London (the largest metropolitan city of the U.K.) and within and around the Cambridge Science Park that is located some 80 km north of London (Haug, 1986; MacGregor, et al., 1986). Indeed, Begg and Cameron's (1988) study showed that Greater London registered employment location indices of 195.2 and 109.1 in the "telecommunications" and "telephone/telephone equipment" industries respectively.

1.4.2 Fast Rates of Growth

Another remarkable phenomenon of electronics industries is their fast rates of growth. For instance, Scott (1986), examined the electronics sectors of California for the period 1970-81. Included were electronics equipment (SIC 36), machinery (SIC 35), transportation equipment (SIC 37), and instruments and related products (SIC 38). He found that the employment growth rates of these electronics sectors were as high as 10.6 percent whereas the national manufacturing growth rates was only 3.73 percent. In absolute terms, these sectors under scrutiny grew from 77,161 to 167,102 employees in this period. At about the same period, Dorfman (1983) studied electronics activities associated with Route 128 for the period of 1977-79. She examined electronic components and computers activities and found that they had employment growth rates of 64 and 90 percent respectively. Meanwhile, Armington (1986) examined the performances of high-technology industries, of which electronics equipment (SIC 36) was one, for those regions of the U.S.A. known as the Middle Atlantic, the East North Central, New England, the East South Central, the South Atlantic, the West North Central, the Pacific, the West South Central and Mountain area. The period under study was 1976-80. This author found that high-technology activities experienced an increase of 19.4 percent in their employment for the studied period as compared with 11.7 percent pertaining to non-high-technology activities. Apart from having high rates of employment growth, the electronics industries also secure impressive rates of growth in the number of establishments. This latter phenomenon is of vital concern because the sector stands out as a generator of new, necessarily small enterprises which constitute the basis of regional "seed-bed" development. Since this thesis regards the engendering of high-technology firms, in particular electronics firms, as critical both to efficient science-park operations and to the promotion of local well-being, the concern with establishment numbers is readily apparent. Lending support to the argument that electronics industries exhibited fast growth rates in their number of establishments, Miller and Cote (1987) discovered that in the U.K., the rates of new business formation within the electronics sector (such as "office computing machinery", "communication equipment", "electronic components" and "defence industries") and the other high-technology industries were 50 percent higher than the low-technology activities.

Across the Atlantic Ocean, electronics industries in the U.K. enjoyed fast growth in employment as well. I have analyzed the data provided by Smith's (1991) study of the determinants associated with the location of advanced-technology industries for the period of 1979-87 and found that the electronics sectors of the Oxfordshire region had the most impressive employment rates of growth as compared with other non-electronics sectors of the same region. Specifically, within the electronics data-processing equipment sector, for instance, the computer manufacturing subsector showed an employment growth rate of 1,979.50 percent; the component and other electronics equipment recorded a growth of 1,050 percent; the telegraph and telephone equipment class registered 260 percent; and the radio and electronic capital goods group managed 200.50 percent. In contrast, the other high-technology activities of a non-electronics nature experienced relatively low or even negative employment rates of growth. Non-electronics activities included biotechnology, engineering, electrical equipment, racing-car manufacturing, vehicle components, scientific and precision instruments as well as computer software. Their employment rates of growth ranged from −21.40 to 51.50 percent; except for the electrical installation and control, and computer software activities that dramatically grew by 227.3 percent and 91.1 percent respectively.

1.4.3 High Advanced Technology Contents

Another common attribute of electronics activities is that they are intensive users of advanced technology. They are identified on the basis of their relatively high R&D expenditures or high proportion of scientists and engineers in their labour inputs (Markusen, et al., 1986; Thomas, 1985). Sometimes, they also stand out by virtue of strong technical training or education backgrounds of their establishment founders. MacGregor et al. (1986), in surveying the 85 firms in the Newbury District (west of London, U.K.) during the early 1980s, found that the manufacturing high-technology undertakings which were involved in manufacturing of electronic goods such as computer hardware and broadcasting equipment had a higher proportion of managerial, professional and technical (MPT) staff than the overall firm population. No less than 33 percent of the labour force of these high-technology manufacturing firms were in the category of MPT. In contrast, for the overall manufacturing establishments, only 19 percent conformed to the MPT category. Henderson (1989) studied four American SC plants in Scotland in the year 1985, and discovered that they all showed a higher than usual proportion of technical workers. To be precise, 33 percent of General Instruments' work-force was of this category, while the proportions for Hughes Aircraft, National Semiconductor and Motorola were 30, 25 and 23 percent respectively. Overall, according to McCalman (1988), there were over three hundred electronics firms operating in Scotland with a total employment of around 45,000 people in 1985. Of this total, 20 percent consisted of "scientists, engineers and technicians".

1.4.4 Small Electronics Firms as the Most Active Electronics Organizations

Finally, small electronics firms have a particular role to play in the well-being of electronics industries. For instance, Armington (1986) found that smaller electronics firms have experienced much higher employment growth rates than their larger counterparts. This author found that employment in high-technology firms with less than 100 employees increased by nearly 50 percent for the period of 1976-80; while, those over 100 employees increased by 15 percent only. From a Canadian perspective, de Melto et al. (1980) studied 198 Canadian-controlled firms in electronics industries that included telecommunication equipment and component product sectors, and contrasted them with non-electronics activities that included electrical industrial equipment, plastics compounds and synthetic resins, smelting and refining and crude petroleum production. They concluded that smaller establishments contained much higher percentages of R&D expenditures than their larger counterparts. Upon re-examining their data, I found that firms with less than 50 employees had the highest R&D expenditures to sales ratios, while larger firms with employees over 500 had the lower ratios.

In brief, electronics industries in industrialized countries are in general characterized by their strong spatial bias. They tend to cluster around metropolitan areas, universities or science park settings. The prominence of Stanford, MIT and Cambridge (England) bears witness to the university-science park connection. Furthermore, they have enjoyed remarkably higher growth rates in the number of employees and in the number of establishments than either overall manufacturing, the non-electronics sectors or the low-technology industries. The industries are also known for their high technical content. The proportion of technical workers in their labour forces ranged round 20 and 33 percent in the 1970s and 1980s respectively. Finally, it is also small electronics firms that uphold the best traditions of dynamism. Essentially, it is small firms that hold the records of having the highest employment growth rates, and the highest R&D expenditures per sales dollar.

1.5 The Implications of Electronics Industries to Regional Development

1.5.1 Introduction

Electronics industries have a multitude of significant implications for the advancement of the well-being of the regions which contain them. Hopes have been attached to those characteristics, highlighted above, which promise to alleviate unemployment problems in the short and long run.

As fast-growing sectors in regional economies, electronics industries are lauded for their across-the-board impact on a host of markets. More importantly, they are acclaimed for their ability to engender both employment and small firms. In this respect, they are immediate prolific creators of new jobs (Bollinger, et al., 1983). This will translate into being an important buffer in regional economies, one fully capable of countering concurrent down-cycles and contemporary recessions and their attendant bouts of employment dislocation.

Meanwhile, a high level of concentration of electronics activities may act as a "retention force" for existing firms and, at the same time, constitutes the "critical mass" that attracts firms from outside the region or the country. Such a clustering pattern of electronics activities is believed to be able to bring in linkage effects that, in turn, induce non-electronics manufacturing activities into the region. For example, an agglomeration of CAD or CAM activities may be able to attract into the locality a wide range of non-electronics corporations such as the electrical, mechanical or hydraulic firms which utilize computer-controlled machines in their production process. With the increase in the number of non-electronics manufacturing establishments and, hence, employees, the consumption base of the localities would be enlarged. As a consequence, other service activities will be attracted into the area to serve the expanded population. Eventually, the economic bases of the areas are thoroughly diversified as well as being decidedly larger. Hence, when the whole mechanism begins to unfold, the economic structure of regions will lean towards self-sustainable growth and development. This will consign the initially vulnerable resource-based or "primitive" regional economics to historical oblivion. When this desirable state is realized, employment opportunities will not simply come from electronics industries but from all other induced economic activities in the long run.

The competence of electronics agglomeration in inducing non-electronics activities into the locality has been extensively manifested in the current literature. Segal and Quince (1985), for example, observed that a mass of some 350 firms which are in the electronics sector (such as "telecommunications" and "computer hardware" manufacturing) and other scientific-based activities (such as "computer software" and "biotechnology" industries and "scientific consultancy") had drawn a number of national and international financial and business service firms and activities to Cambridge, a town some 80 km north-east of London. Following from their higher-than-average high-tech content in the course of innovativeness and development, electronics industries are prone to conceive and to commercialize new products. Hence, there is a great onus on electronics industries to harness scientific expertise to the required financial resources for rapid generation of innovative products. By nature, new products are not standardized in shape, size or in their functional forms. This means that electronics industries themselves are subject to rapid transformation in their means of production and in the kind of end products. Consequently, the creative entrepreneurship-minded practitioners of electronics industries are likely to be of an unconventional mould. Not surprisingly, this mindset is inclined to generate many spin-off firms.[19] These new and

[19] *A spin-off firm is a new venture formed by the entrepreneur who previously worked at an existing high-*

usually small electronics establishments become the suppliers of the larger corporations that formerly employed the entrepreneurs. Their supporting services provided to large corporation are usually of a novel kind or of such a nature as not to tempt large corporations into inhouse development. Many new products are likely to spring from this process. For instance, the component electronic sectors, specifically, those engaged in SC manufacturing, have created numerous new electronics sectors: computer manufacturing, electronics industrial control and instrumentation production. With the rapid springing up of new sectors, it is reasonable to suppose that rapid employment opportunities are going to increase in the longer run. Of course, it is one thing to advocate electronics as a regional saviour; it is quite another to find corroborating evidence for its efficacy. Nonetheless, the following sub-section will muster evidence from the advanced country context to underscore the value of electronics.

1.5.2 Supporting Experience

The development of Silicon Valley is one of the most successful tales that can be regaled concerning the manner whereby electronics stimulates regional economic restructuring, and, hence, alleviates the prevailing unemployment problem. In retrospect, Silicon Valley was largely a lagged region plagued by poor economic performance. In the 1940s, its industrial base was dominated by agricultural-related activities (Saxenian, 1985). As Miller and Cote (1987, p.3) clearly pointed out, "Right after World War II, there was hardly anything but agricultural land around Stanford University (in Palo Alto) and to the south towards San Jose". In 1950, Santa Clara County, located in the western portion of Silicon Valley, boasted a mere 800 manufacturing employees and half of them worked in canneries and food-processing plants (Rogers and Larsen, 1984; Miller and Cote, 1987). However, advancing into the 1950s, as the local government enthusiastically participated in the promotion of defence industries, electronics activities began to agglomerate in the area. Since then, the region's industrial structure has undergone rapid transformation. Captivated by massive public research spending for aerospace and defence, a number of fully-fledged defence electronics companies such as Lockheed Missiles and Space, General Electric (GE), General Telephone (GTE), Litton Industries, Kaiser, Philco-Ford, Sylvania and Westinghouse were drawn into Palo Alto. Besides, myriad electronics-related research centres and laboratories

technology organization (Glasmeier, 1988).

were also lured into the region. These research institutions included Shockley Transistor Company, International Business Machines (IBM), International Telephone and Telegraph (IT&T), Admiral, Scientific Research Institute (SRI) and Ames Research Centre of the National Aeronautics and Space Administration (NASA) (Figure 1.2) (Rothwell and Zegveld, 1982; Aydalot, 1988). These electronics enterprises and research institutions were fertile breeding grounds for electronics and other high-technology spin-offs (Rothwell and Zegveld, 1982; Monck et al., 1988). Saxenian (1985) noted that in the single year of 1968, thirteen new high-technology enterprises were spun off from within Silicon Valley. Shockley Transistor Laboratory, established by William Shockley at Palo Alto, for example, was most famous for its procreating of large numbers of new electronics enterprises. This laboratory, founded in 1955, gave birth to Fairchild Semiconductor, which in turn became the spawning ground for scores of spin-offs. Numerous electronics companies in the region were formed by physicists and engineers formerly employed by, or associated with, Fairchild. As Mason (1979) described:

> "...The first spin-off was 1959, when Baldwin, not from the original Shockley team, left Fairchild to form Rheem Semiconductor, collecting on the way people from Hughes Aircraft. In 1961, four of the originals left to form Amelco, and one of these, Hoerni, left in 1964 to form Union Carbide Electronics; moving on in 1967 to form Intersil. Of particular interest ...was another event in 1961, when Signetics was formed. This was formed by four people, who were a significant part of the Fairchild Conductor team ...They managed to get venture capital backing from the Dow-Corning group for this move." (op. cited in Rothwell and Zegveld, 1982, p.28).

Between 1959 and 1979, Fairchild Semiconductor spawned an amazing total of fifty new companies (Saxenian, 1985). The many spin-offs from Fairchild indisputably laid the groundwork for an agglomeration of electronics activities in Palo Alto and its surrounding areas to which the name Silicon Valley was given. This accounted for the takeoff of the valley in the 1960s (Rogers and Larsen, 1984). In the early 1980s, at least one-third of Silicon Valley's labour force was employed in the approximately 700 electronics-related companies (Saxenian, 1985). Apart from the electronics firms, numerous complementary facilities such as universities, laboratories, consultancy firms, professional and trade associations, libraries and newspaper agencies furnishing the stock of technical or business knowledge required for electronics production were also crowded within this rectangular area of no more than 20 by 10 kilometres (Rothwell and Zegveld, 1982). This high level of local information sourcing further bears witness to the tight-knit and huge electronics concentration within the region.

Owing to its heavy mass of electronics activities and electronics-related activities, Silicon Valley was no longer a backward region preoccupied by traditional industrial sectors. Rather, it had become the largest and most widely known high-technology complex in the world. Over 5,000 different high-technology companies were located within the region in 1980 (Miller and Cote, 1987). In effect, it has become the world's electronics centre for microelectronics,[20] computers, computer peripheral and telecommunications industries (Rogers and Larsen, 1984). In the late 1980s, about 3,000 microelectronics manufacturing firms swarmed into this area (Rogers and Chen, 1990). Sixty percent of all semiconductor start-ups since 1987 were located in Silicon Valley (Ibid.). In total, this region contained 25 percent of all the U.S.A's semiconductor employment (Aydalot and Keeble, 1988). Some of the great names of these industries — Hewlett-Packard and Intel, and the brightest star of them all, Apple Corporation — were born and grew up in this flat, sun-soaked valley (Miller and Cote, 1987). Moreover, Silicon Valley has become the birthplace of many new consumer electronics sectors such as those engaged in the manufacturing of pocket calculators, video games, home computers, cordless telephones and digital watches (Rogers and Larsen, 1984). In turn, the reputation of Silicon Valley as a high-technology complex has continued to attract firms from outside and led to the development of other economic sectors, not least of which was a strong venture capital business base. As estimated by William Hambredcht, a cofounder of one of the largest venture capital firms in Silicon Valley, over 18 percent of all venture capital financing in the U.S.A. in 1981 were located in Santa Clara County; by 1983, this proportion went up to 40 percent (Malecki, 1986). On account of the county's greatly diversified electronics industrial structure, employment opportunities grew rapidly. Between 1960 and 1975, the county's employment increased by 156 percent, over three times

[20] *These are the devices constituted from extremely small electronics parts (Todd, 1990).*

as much as the national rate of 46 percent, and more than double that of California's 64 percent increase. Meanwhile, between 1970 and 1975, its growth rate in manufacturing jobs surpassed that of the traditional growth leaders such as Houston and Orange County, not to mention the national average. Over 600,000 jobs were created in manufacturing sectors alone (Saxenian, 1985). The tremendous growth of employment opportunities of the county can also be directly reflected in the rapid increase of its total population. In absolute terms, between 1950 and 1975, the population of Santa Clara County increased by over one million people (Ibid.).

Another notable instance of the part played by electronics industries in regional development is that of Massachusetts, especially the Route 128 area of Boston. In the first half of this century, Massachusetts was dominated by traditional manufacturing sectors such as leather, textiles, apparel, furniture, machinery and shipbuilding. Its unemployment rate had always been among the highest in the nation (Steven, 1985; Harrison and Kluver, 1989). With the advent of the nation's military and space programmes during, and immediately after, World War II, a few well-established military-related electronics firms began to spawn around MIT and the Route 128 area of Boston (Harrison and Kluver, 1989). Among their number were Raytheon and GTE-Sylvania (Figure 1.3). Both had tentative beginnings in lamp and vacuum tube manufacturing, and were generally military-related even prior to World War II (Ibid.). Their presence and growth in the region served as well-springs for the training of numerous engineers, many of whom latterly elected to branch out on their own with classic start-up microelectronics enterprises. As a consequence, the region acquired a reputation for its "seed-bed" capability, a reputation overshadowed only by the more spectacular record of Silicon Valley (Steven, 1985). Other businesses are lured into the region and, in like manner to Silicon Valley, a sophisticated venture capital sector was created in the region (Monck et al., 1988). By now, it has become one of the major electronics industrial areas of the nation with the clustering of numerous prominent electronics firms. Many of them are found along Interstate 495, another circumferential highway 16 to 24 kilometres further out from Boston than Route 128. They include Wang Laboratories, Digital Equipment Corporation (DEC), and the Data General (DG), word-processing and minicomputer firms that rose to prominence in the 1970s and 1980s. Along Route 128, the older military electronics firms such as Raytheon and Itek, built in the earlier era of the 1950s and 1960s, are still there (Rogers and Larsen, 1984). Nowadays, Route 128 has gained the reputation of being the second largest microelectronics heartland in the world, second only to Silicon Valley. The major microelectronics product manufactured in this region is integrated circuits (Dorfman, 1983). Massachusetts is also ranked second in the nation in the number of employees in the computer industry (Malecki, 1985). Essentially, its computer industries take a leading role in the miniaturization of computer equipment, especially in the product areas of minicomputers and office machines (Steven, 1985). It is also well known for its production of industrial controls and instruments, communications equipment, and defence electronics such as radar, sonar and guidance controls for missiles (Dorfman, 1983; Steven, 1985; Haug, 1986; Harrison and Kluver, 1989).

The magnitude of electronics-related activities and the induced employment opportunities deriving from them are extraordinary. It is estimated that, in the 1980s, DEC alone accounted for more than 10 percent of all high-technology employment in the state, and indirectly provided up to 20 percent of all other employment opportunities there (Monck et al., 1988). Moreover, between 1979 and the first quarter of 1988, more than 440,000 net new jobs were created in Massachusetts. After 1985, the unemployment rate of Massachusetts fell to 4 percent, placing the state's performance at or near the best of all the industrial states in the U.S.A. (Harrison and Kluver, 1989).

In sum, worldwide electronics industries, for example, those in the U.S.A., have a very important role to play in the advancement of regional economies. They are promising tools for alleviating short- and long-term employment problems of the regions. They demonstrate their potential to engender rapid increase of employment opportunities well beyond their own activity proper. In other words, they promote strong multiplier-direct, indirect and induced-effects. In the longer run, they serve as catalysts for industrial restructuring. They can quite conceivably transform traditional resource-based economies into high(er)-technology, information economies. To be sure, the foregoing discussion of the intrinsic characteristics of electronics industries draws heavily on American experience because these have been richly documented by researchers. It is appropriate now to address the Canadian situation. As the Canadian experience is less well documented, justifications of the intrinsic characteristics of the Canadian electronics industries have to be elicited from the data resources of Statistics Canada. Some preliminary findings both for Canada and Manitoba are presented below.

1.6 Electronics Industries in Canada

The electronics experience of other advanced countries has direct relevance to the regions of Canada in general and to the Province of Manitoba, in particular. All the aforementioned intrinsic characteristics of electronics industries have been replicated in the regions of Canada, and not least in Manitoba. Consistent with the generally recognized features of electronics industries, the Canadian version maintains that (1) they are also spatially concentrated in certain regions of the country and within the regions as well; (2) they have relatively high rates of growth in terms of employment; (3) they are remarkable for the spawning of new firms; (4) they inevitably input high technical contents, such as high R&D expenditures in their production process, and finally, (5) they are remarkable for the spawning of new small firms. Clarification of these points is the purview of the following section.

1.6.1 The General Case

1.6.1.1 Spatial Concentration

As far as the locational concentration of electronics industries is concerned, by the late 1970s, at least 80 percent of these activities were located in Ontario and Quebec (Canada ITC, 1976). This tendency has persisted. For instance, for the year 1989, Table 1.2 indicates that these two jointly accounted for 82.2 percent of the employment in electronics industries in the country.[21] Quebec accounted for 26.1 percent and Ontario for 56.1 percent. On the other hand, Table 1.3 indicates that both provinces concurrently accounted for 70 percent of the electronics establishments in the nation. Evidently, the typical establishment in Ontario and Quebec employs more workers than the typical establishment outside those provinces. The fact remains, nevertheless, that these two provinces contain by far the lion's share of

[21] *Owing to the sensitivity of their activities, the electronics industries' provincial employment data are not released by Statistics Canada. Only gross national totals are available under the national tables of Statistics Canada's publications. Missing data at the provincial level are commonplace. Establishments of industrial activities are expressed in terms of nine different employment categories: 1-5, 6-10, 11-25, 26-50, 51-100, 101-299, 300-499, 500-999, and above 1000 employees. Hence, at least three different ways can be used to estimate the employment size of each industrial activity. The total employment of any industrial activity may be estimated by adding the products of the number of firms in the categories multiplied by either (1) the lowest boundary of the category, or (2) the mid-point of the category, or (3) the upper boundary of the category. These three methods have been tried accordingly. The best results come from the last method. It gives a very close estimation to the known national totals across provinces. They can represent the "true" national totals by as close as 96.82 percent, 97.83 percent and 100.02 percent for the years of 1983, 1985, and 1989, respectively, as per Table 1.4. (1989 is the latest date for which electronics employment figures are available).*

Canada's electronics industries.

Meanwhile, as observed by the DRIE in 1986, different regions have their own electronics emphasis. To the Atlantic provinces, electronics firms are involved in the development of the sophisticated instrumentation and equipment that are required for the harvesting and managing of the natural resources located along the continental shelf. Lately, these activities

Table 1.2

Regional (Employment) Concentration of the Electronics Industries[22] of Canada by Province, 1989

Province	Electronics Employment (Xi)	Manufacturing Employment (Yi)	(Xi/Yi)%	Location Quotient (LQ)
Newfoundland	72	18646	0.39	0.06
P.E.I.	68	3742	1.82	0.28
Nova Scotia	2725	40276	6.77	1.02
New Brunswick	336	36139	0.93	0.14
Quebec	33715	524016	6.43	0.97
Ontario	73840	1018177	7.25	1.09
Manitoba	7580	56746	13.36	2.01
Saskatchewan	909	21350	4.26	0.64
Alberta	5250	91785	5.72	0.86
British Columbia	6590	158952	4.15	0.62
Total	131085	1969820	6.65	

Source: Calculated from Statistics Canada. **Manufacturing Industries of Canada: National & Provincial Areas.** CS31-203.

have been urged not just to restrict themselves to the traditional sectors such as fisheries but also to become involved in the rapidly developing petroleum industry. In Central Canada, electronics firms are heavily involved in the R&D activities whose products and services are essential to keep the industrial manufacturing heartland of the country competitive in world markets. They emphasize advanced "telecommunications", "factory and office automation", "CAD/CAM", "artificial intelligence applications" and "software development". As far as

[22] *From Table 1.2 to Table 1.9, electronics industries refer to the sum of SIC 3211 (aircraft and aircraft parts industry), SIC 3341 (record players, radios and television receivers industry), SIC 3351 (telecommunications equipment industry), SIC 3352 (electronic parts and components industry), SIC 3361 (electronic computers and peripherals industry) and SIC 3368 (other electronic office, business machines industry).*

Table 1.3

Regional (No. of Establishments) Concentration of Electronics Industries of Canada by Province, 1989

Province	Electronics Establishments (Xi)	Manufacturing Establishments (Yi)	(Xi/Yi)%	Location Quotient (LQ)
Newfoundland	3	355	0.85	0.34
P.E.I.	2	163	1.23	0.49
Nova Scotia	20	820	2.44	0.97
New Brunswick	9	778	1.16	0.46
Quebec	192	11362	1.69	0.67
Ontario	505	16103	3.14	1.25
Manitoba	32	1258	2.54	1.01
Saskatchewan	21	903	2.33	0.93
Alberta	70	3032	2.31	0.92
British Columbia	130	4332	3.00	1.19
Total	984	39106	2.52	

Source: Calculated from Statistics Canada. **Manufacturing Industries of Canada: National & Provincial Areas.** CS31-203.

Western Canada is concerned, the electronics firms in the Prairies have developed in response to the three fields endemic to the region: communications, resource development and agriculture. Looking at the west coast of Canada, the electronics firms of British Columbia mainly involve themselves in telecommunications, with ongoing research in the areas of mining and forestry applications and oceanography.

In order to highlight the relative picture of the distributions of electronic activities, the location quotient (LQ) index is used. [23] For the purpose of this study, the LQs are

[23] *Location quotient is a measure of spatial concentration or specialization of a particular industry. It demonstrates the spatial shares of, for example, employment, or establishments, or shipments, of the concerned industry of a particular region in comparison with the region's share of all national industry. In general, it is calculated by:*

$$LQLW = \frac{X_i/Y_i}{\Sigma X_i/\Sigma Y_i}$$

where,

LQ = *Location quotient;*
X_i = *Employment (establishments) belonging to X activity (electronics industries) in region i;*
Y_i = *Employment (establishments) of Y activity (total manufacturing) in region i;*
ΣX_i = *Employment (establishments) of X activity (electronics industries) of the base area (nation);*
ΣY_i = *Employment (establishments) of Y activity (total manufacturing) of the base area (nation).*

The greater the value of the LQ, the greater the degree of specialization of the activity in question in the region. A value of 1 means that the region has exactly the same proportion of the activity in question as the base area (the nation). A value of less than 1 shows that the activity is under-represented in the region as calculated in terms of (1) the number of employees and (2) the number of establishments of electronics industries in each province.

With respect to employment concentration, Table 1.2 shows that the national electronics activities accounted for 6.65 percent of the total national manufacturing activities in the year 1989. There were three provinces with electronics activities accounting for employment proportions which were very close to the national proportion, namely, Ontario (7.25 percent), Nova Scotia (6.77 percent) and Quebec (6.43 percent). As to be expected, their LQs bordered on one; that is, Ontario scored 1.09, Nova Scotia scored 1.02, and Quebec scored 0.97. For its parts, Manitoba registered an LQ of 2.01; the highest in the country. Its electronics activities accounted for 13.36 percent of provincial manufacturing employment, a proportion substantially higher than other provinces. Of course, Ontario and Quebec set the tone for calculation of all provincial LQs on account of their much larger work-forces. Manitoba's manufacturing employment size was roughly 5.6 percent of that of Ontario; and its electronics employment size was roughly 10 percent of that of Ontario. In relative terms, Alberta performed a touch poorer than the norm, with an LQ reading of 0.86. The lowest LQ was for Newfoundland (0.06), then New Brunswick (0.14) and Prince Edward Island (0.28). At 0.64 and 0.62, Saskatchewan and British Columbia were between the very poor scoring Atlantic provinces and the better, though still under-represented, Alberta.

With respect to establishment concentration, Table 1.3 demonstrates that the regional scene was slightly altered. The total number of electronics establishments in 1989 accounted for 2.52 percent of all manufacturing establishments in Canada. Ontario and Quebec claimed title to the largest number, thus setting the tone for the calculation of the provincial LQs. Accordingly, there were only three provinces with LQs above the magic number of one: then, Ontario led with an LQ of 1.25, followed by British Columbia with 1.19, and the Manitoba with 1.01. The other provinces displayed LQs of less than one. The provinces with LQs closest to one, albeit below it, were Nova Scotia (LQ=0.97), and Alberta and Saskatchewan (LQ=0.93 in both cases). The lowest outright was Newfoundland, with an LQ of 0.34; New Brunswick registered 0.46, Prince Edward Island 0.49 and Quebec 0.67.

In brief, within the nation, the electronics industries in Canada conform to a strong spatially-biased pattern. In terms of the sheer size of the electronics industries, they are

against the norm, implying that the region has a low level of specialization. When the LQ is greater than 1, the region has a higher level of specialization in the activity than the base area (the nation) (Goodall, 1987).

mainly localized in Ontario and Quebec. These two provinces procured an overwhelmingly large proportion of the nation's electronics industries. They also commanded a high percentage of electronics employees in their manufacturing sector, a proportion very close to the national average. In comparison with other provinces, Ontario possessed the highest percentage of electronics employees in its manufacturing sector, while Quebec registered the third highest (just after Nova Scotia). However, in terms of the LQ index, a more sophisticated and precise measure for industrial agglomeration, the electronics industries are disproportionately concentrated in Manitoba and in Ontario. Both provinces gained the above-one employment and establishment LQs for their electronics activities. Indeed, Manitoba attained the highest employment LQ of all provinces; meanwhile, Ontario scored the topmost establishment LQ in the nation. Such data, in effect, indicate that Manitoba is closer to the "east" than to the "west" of Canada in terms of electronics development. Apart from this, Nova Scotia and British Columbia are the secondary electronics centres in Canada. Both provinces had either their employment or establishment LQ above the national standard of one. Finally, electronics industries are least concentrated in the three Atlantic provinces: Newfoundland, Prince Edward Island and New Brunswick. All these provinces displayed employment and establishment LQs of less than 0.5.

Probing into the within-region spatial distribution of electronics industries, existing data showed that the Canadian electronics industries exhibited a similar pattern to those of the rest of the advanced world. To be precise, electronics activities were, for the most part, crowded into the metropolitan areas of the regions. An investigation of the 1986 sub-national electronics/electrical data provided by Statistics Canada (1990) for seven provinces (Nova Scotia, New Brunswick, Quebec, Ontario, Manitoba, Saskatchewan, Alberta and British Columbia) indicated that the industries were mostly sited in their largest population centres.[24] This fact was most noticeable in Manitoba, British Columbia and Quebec; over half of the provinces' electronics (and electrical) establishments and employees were localized in their largest urban centres such as Winnipeg, Greater Vancouver and Montreal. In Manitoba, Winnipeg possessed 32 (88.89 percent) of all the 36 electronics (and electrical)

[24] *In most cases, SIC 33 (electrical and electronics products) pertaining to various sub-provincial areas of Canada has not been broken down into the three- or four-digit industrial sectors. The employment and establishment data for the electronics activities (identified as SIC 3211, SIC 3341, SIC 3351, SIC 3352, SIC 3359, SIC 3361 and SIC 3368) for the major metropolitan areas of the provinces) are, therefore, unavailable. In the absence of "pure" electronics data, the use of the "less-pure" electronics figures of SIC 33 for the illustration of the within-province spatial distribution of electronics industries in Canada is unavoidable.*

establishments of the province. This city also accounted for 2,413 (87.81 percent) of the province's 2,748 electronics (and electrical) workers. Meanwhile, in British Columbia, 112 (81.75 percent) of the province's 137 electronics (and electrical) establishments and 3,991 (84.52 percent) of the region's 4,722 electronics (and electrical) employees were congregated in Greater Vancouver. In Quebec, 261 of the province's 355 electronics (and electrical) establishments (73.52 percent of the provincial total) were found in Montreal. In total, this city had 22,391 (65.04 percent) of the province's 34,429 electronics (and electrical) workers. In the provinces of Ontario, Nova Scotia and Saskatchewan, the concentration of electronics (and electrical) activities in the metropolitan areas was also discernible. The proportions of electronics (and electrical) establishments in their largest urban centres of Toronto, Halifax and Saskatoon respectively ranged from 61.12 to 47.37 percent while those of electronics (and electrical) employment stretched between 77.28 and 47.80 percent. Although most provinces had evinced perceptibly high concentrations of electronics (and electrical) activities in their most populated areas, Alberta presented a somewhat "mixed" picture in this matter. The electronics (and electrical) industries were highly concentrated in its metropolitan area only in their number of establishments but not in their employment size. Edmonton contained 24 (40 percent) of the province's 60 electronics (and electrical) firms. However, this city merely accounted for 416 (12.8 percent) of the province's 3,249 electronics (and electrical) employees.

1.6.1.2 Fast Rates of Growth in the Number of Employees

Electronics industries in Canada have been known for their fast rates of growth in the number of employees.

For the 1983-89 period, when the average employment growth rate of all manufacturing sectors was only 19.72 percent (Table 1.4), electronics industries grew by 36.84 percent according to the "true" national total, or even more, 44.60 percent according to the estimated total (Table 1.5).[25] Nevertheless, in real terms, while overall manufacturing gained 299,378 jobs, electronics activities accounted for 34,495 of them. In other words, electronics was responsible for roughly 11 percent of the new jobs created in the period.

Furthermore, electronics industries were consistently growing faster than the overall

[25] *See footnote 21 for the explanation of "true" national total and "estimated" total.*

manufacturing rates for the periods of 1983-85 and 1985-89. When the overall manufacturing activities grew by 5.74 percent in the period of 1983-85 (Table 1.4), electronics increased by 14.49 percent (Table 1.5). Put otherwise, while the overall manufacturing activities gained 107,614 new jobs, electronics activities took care of 14,215 jobs, or roughly 14 percent of the overall manufacturing gains. For the period of 1985-89, when the total manufacturing grew

Table 1.4

Provincial Manufacturing Employment for the Years 1983, 1985 and 1989 with Growth Rates for the Periods 1983-85, 1985-89 and 1983-89

Province	Est Employment			Percentage Change		
	1983	1985	1989	1983-85	1985-89	1983-89
Newfoundland	15836	16201	18646	2.30	15.09	17.74
P.E.I.	3061	3388	3742	10.68	10.45	22.25
Nova Scotia	34223	35149	40276	2.71	14.59	17.69
New Brunswick	28429	29456	36130	3.61	22.66	27.09
Quebec	474820	490742	524016	3.35	6.78	10.36
Ontario	838490	911418	1018177	8.70	11.71	21.43
Manitoba	51359	51461	56746	0.20	10.27	10.49
Saskatchewan	18866	19245	21350	2.01	10.94	13.17
Alberta	72292	74692	91785	3.31	22.88	26.96
British Columbia	133150	134724	158952	1.18	17.98	19.38
Yukon & NWT	355	295	439	−16.90	48.81	23.66
Total	1670881	1766762	1970259	5.74	11.52	19.72

Source: Calculated from Statistics Canada. **Manufacturing Industries of Canada: National & Provincial Areas.** CS31-203.

by 11.52 percent, electronics rose by 19.53 percent. This meant that the share of electronics activities amounted to 26,219 new jobs out of 95,882 in the manufacturing sector as a whole, or roughly 25 percent of the new jobs created for the period of 1985-89. From a regional perspective, Ontario and Quebec exhibited a moderate rate of growth, 39.61 percent and 32.13 percent respectively, in electronics employment for the period of 1983-89. The Atlantic provinces were mixed in their electronics employment growth rates for the same period. On the one hand, Nova Scotia and New Brunswick enjoyed employment growth that more than doubled their base figures; that is, 111.57 percent and 175.41 percent respectively. On the other hand, Prince Edward Island suffered from an overall decline of 42.37 percent for the same period, equivalent to cutting its base figure by nearly three-quarters. Meanwhile, Newfoundland could maintain a higher-than-average rate of growth, some 46.94 percent, for the same period. In Western Canada, all four provinces experienced higher-than-average rates of growth for the same period; that is, 40.14 percent for Manitoba, 72.16 percent for Saskatchewan, 133.61 percent for British Columbia, and emphatically, 176.61 percent, the highest growth rate in the nation, for Alberta.

Table 1.5
Estimated Electronics Industry Provincial Employment for the Years 1983, 1985 and 1989 with Growth Rates for the Periods 1983-85, 1985-89 and 1983-89

Province	Est Employment			Percentage Change		
	1983	1985	1989	1983-85	1985-89	1983-89
Newfoundland	49	49	72	0.00	46.94	46.94
P.E.I.	118	38	68	–67.80	78.95	–42.37
Nova Scotia	1288	2081	2725	61.57	30.95	111.57
New Brunswick	122	321	336	163.11	4.67	175.41
Quebec	25517	28035	33715	9.87	20.26	32.13
Ontario	52892	60908	73840	15.16	21.23	39.61
Manitoba	5409	5890	7580	8.89	28.69	40.14
Saskatchewan	528	981	909	85.80	7.34	72.16
Alberta	1898	2655	5250	39.88	97.74	176.61
British Columbia	2821	3904	6590	38.39	68.80	133.61
Yukon & NWT	9	4	0	–55.56	–100.00	–100.00
Est Total	90651	104866	131085	15.68	25.00	44.60
Actual Cdn	93632	107195	128127	14.49	19.53	36.84
Est Rep	96.82	97.83	100.02			

Source: Calculated from Statistics Canada. **Manufacturing Industries of Canada: National & Provincial Areas.** CS31-203.

Delving into the electronics subsectors employment growth, Table 1.6 shows that the biggest single contributor to that growth in the period of 1983-89 was "component products". Its corresponding growth rate was 100.01 percent, sufficient to bring about an increase of 12,327 new jobs. The other main contributors were "industrial control and instrumentation" and "system electronics (aerospace)", with values of 59.2 percent and 44.5 percent respectively attaching to them. The poorest growth sector was "telecommunications equipment", which grew by 3.5 percent only. On a provincial basis, the "component product" activities prospered dramatically in Manitoba, New Brunswick and Prince Edward Island.

With the exception of Nova Scotia, Newfoundland and the two Canadian territories, other provinces evinced positive growth in "component product" activities as well for the 1983-89 period. Meanwhile, the "industrial control and instrumentation" activities were doing exceedingly well in Alberta, Saskatchewan, New Brunswick, British Columbia, Nova Scotia and Manitoba. In contrast, Prince Edward Island and the two Canadian territories registered no gains at all. The "system electronics" activities recorded positive rates of

Table 1.6

Electronics Industry Employment Growth for the Period 1983-89 by Sectors

Province	Component % change	Consumer % change	Telecomm % change	Computer % change	Control % change	System % change
Newfoundland	0.0	0.0	0.0	0.0	59.2	1900.0
P.E.I.	1900.0	0.0	-100.0	4900.0	0.0	−100.0
Nova Scotia	-15.0	0.0	0.0	0.0	108.2	209.8
New Brunswick	3050.0	0.0	49.49	400.0	900.0	157.9
Quebec	173.9	98.3	−17.7	0.7	14.6	26.9
Ontario	60.5	6.1	8.7	50.9	44.8	42.6
Manitoba	3663.0	0.0	50.3	−32.4	100.0	40.9
Saskatchewan	188.9	0.0	−92.3	35.3	1580.6	72.7
Alberta	616.4	0.0	124.5	971.4	1757.1	104.8
British Columbia	298.5	0.0	−91.8	190.4	563.3	253.7
Yukon & NWT	0.0	0.0	0.0	0.0	0.0	-100.0
Total	100.1	11.1	3.5	36.9	59.2	44.5

Source: Calculated from Statistics Canada. **Manufacturing Industries of Canada: National & Provincial Areas.** CS31-203

growth for all regions with the exception of Prince Edward Island and the two territories. This branch of electronics grew very rapidly in Newfoundland, British Columbia, Nova Scotia, New Brunswick and Alberta. The performance of "telecommunications equipment and other communications" activities was patchy at the provincial level. Stability prevailed in Newfoundland, Nova Scotia and the two territories, but, sharp reductions occurred in Prince Edward Island, Saskatchewan, British Columbia and Quebec. The highest positive growth came from Alberta, then New Brunswick and Manitoba. Ontario experienced moderate growth in telecommunications employment. Only Quebec and Ontario recorded positive growth in "consumer products" activities, while the others were either uninvolved in this branch or incapable of expanding it. As for "computer" activities, they grew fastest in Prince Edward Island, Alberta, New Brunswick and British Columbia. They declined dramatically in Manitoba. Stability obtained in Newfoundland, Nova Scotia and the two territories; but discernible growth occurred in Quebec and more substantial growth occurred in Saskatchewan.

1.6.1.3 Fast Growth in the Number of Establishments

Not only do electronics industries have fast growth rates in terms of employment, they also register fast growth in the number of establishments.

Between 1983 and 1989, the number of electronics establishments showed a strong growth of 36.67 percent (Table 1.7) as against the 10.95 percent average rates of growth for the number of manufacturing establishments in general (Table 1.8). Put otherwise, when 3,864 new establishments were added to the total stock of manufacturing establishments (Table 1.8), 264 of them were electronics manufacturers. Hence, the new electronics manufacturers accounted for 6.83 percent of new establishments of all manufacturing activities.

As a matter of fact, the growth rates of electronics new establishments were consistently higher than the average manufacturing growth as a whole for the periods of 1983-85 and of 1985-89. In the former period, the tally of new electronics establishments grew by 17.64 percent while those for overall manufacturing grew by 4.44 percent. Consistently, in the latter period, when the number of electronics establishments grew by 16.17 percent, the stock of overall manufacturing establishments rose by a modest one percent. From a regional perspective, for the period of 1983-89, the Atlantic provinces should be quite satisfied with their growth rates in the number of establishments in electronics activities. Two of their provinces, Newfoundland and New Brunswick, had the highest growth rates in the country; 200 percent and 125 percent respectively (Table 1.7). While Prince Edward Island was stable, Nova Scotia grew in this respect by 66.67 percent. It must be conceded, however, that these dramatic rates of growth rose from very small absolute totals. Moreover, these figures look more significant because the overall rates of growth of the new manufacturing firms in these provinces were low. Their inventory of overall manufacturing new firms grew no more than 25 percent for the period of 1983-89. The highest growth rates of new manufacturing firms came in New Brunswick (23.30 percent), Prince Edward Island (16.43 percent), Newfoundland (6.61 percent), and Nova Scotia (1.86 percent) (Table 1.8).

Table 1.7

Estimated Provincial Electronics Industry Establishments for the Years 1983, 1985 and 1989 with Growth Rates of the Periods 1983-85, 1985-89 and 1983-89

Province	**No. of Establishments**			**Percentage Change**		
	1983	1985	1989	1983-85	1985-89	1983-89
Newfoundland	1	1	3	0.00	200.00	200.00
P.E.I.	2	2	2	0.00	0.00	0.00
Nova Scotia	12	19	20	58.33	5.26	66.67
New Brunswick	3	4	9	33.33	125.00	200.00
Quebec	164	181	192	10.37	6.08	17.07
Ontario	392	468	505	19.39	7.91	28.83
Manitoba	22	21	32	−4.55	52.38	45.45
Saskatchewan	12	19	21	58.33	10.53	75.00
Alberta	32	35	70	9.38	100.00	118.75
British Columbia	79	96	130	21.52	35.42	64.56
Yukon & NWT	1	1	0	0.00	−100.00	−100.00
Total	720	847	984	17.64	16.17	36.67

Source: Calculated from Statistics Canada. **Manufacturing Industries of Canada: National & Provincial Areas.** CS31-203.

As far as Central Canada is concerned, Ontario and Quebec began with relatively strong electronics activities bases. However, their rates of electronics establishment growth were less satisfactory in comparison with the national average. The electronics activities in these two provinces grew by 17.07 and 28.83 percent respectively. These rates were well below the national average of 36.67 percent (Table 1.7). However, their rates of electronics establishment growth were more impressive than their rates of establishment growth in their manufacturing sectors. Of all their manufacturing activities, the new firms in Ontario only grew by 9.08 percent and Quebec, 9.98 percent (Table 1.8). All of the Western provinces had above-average rates of growth. The highest growth rate of new electronics firms was 118.75 percent for Alberta. It was followed by Saskatchewan, a 75 percent growth; then, British Columbia with a rate of 64.56 percent (Table 1.7). These growth rates stood out in comparison with those pertaining to all manufacturing which grew by a rate of 24.42 percent for Alberta, 22.03 percent for Saskatchewan, and 13.40 percent for British Columbia (Table 1.8). Manitoba was especially noteworthy in this respect, enjoying a growth rate of 45.45 percent in its new electronics establishments (Table 1.7), but only 0.08 percent for all manufacturing establishments (Table 1.8). Therefore, whether viewed from a national or regional perspective, the stock of electronics firms grew fast, very much faster in some cases, than the stock of all manufacturing firms.

Table 1.8

Provincial Manufacturing Establishments for the Years 1983, 1985 and 1989 with Growth Rates for the Periods 1983-85, 1985-89 and 1983-89

Province	No. of Establishments			Percentage Change		
	1983	1985	1989	1983-85	1985-89	1983-89
Newfoundland	333	321	355	–3.60	10.59	6.61
P.E.I.	140	141	163	0.71	15.60	16.43
Nova Scotia	805	820	820	1.86	0.00	1.86
New Brunswick	631	665	778	5.39	16.99	23.30
Quebec	10331	10653	11362	3.12	6.66	9.98
Ontario	14763	15570	16103	5.47	3.42	9.08
Manitoba	1257	1267	1258	0.80	–0.71	0.08
Saskatchewan	740	791	903	6.89	14.16	22.03
Alberta	2437	2536	3032	4.06	19.56	24.42
British Columbia	3820	4062	4332	6.34	6.65	13.40
Yukon & NWT	29	28	44	–3.45	57.14	51.72
Total	35286	36854	39150	4.44	6.23	10.95

Source: Calculated from Statistics Canada. **Manufacturing Industries of Canada: National & Provincial Areas.** CS31-203.

The aggregate trends disguise intraindustry variations. Consequently, it is necessary to uncover greater detail. The highest number of new establishments among the electronics industries came from "computers and other office equipment" activities (Table 1.9). This branch had an impressive 118.9 percent growth in the number of establishments for the 1983-89 period. The other main contributors were "component products" and "consumer products". They grew by 53.7 percent and 31.3 percent respectively. The worst performance was recorded by the "telecommunications equipment" branch, which declined by 8.8 percent. The "industrial control and instrumentation" and "system electronics" activities grew moderately; that is, by 13.1 percent and 10.9 percent respectively. The two highest growth industries, namely, the "computers and other office equipment" and "component product" activities grew remarkably fast in a number of provinces : Alberta, Prince Edward Island, New Brunswick, Saskatchewan and British Columbia. Their number of establishments more than doubled in this 1983-89 period. However, the growth of these two sectors stalled in the province of Newfoundland and in the two territories. In other provinces, these sectors accelerated moderately. New firms devoted to "consumer products" sprang up only in Quebec and Ontario. New "telecommunication" firms, for their part, emerged only in New Brunswick and Quebec, while other provinces registered reduced numbers or showed no change at all.

Table 1.9

Electronics Industry Establishment Growth for the Period 1983-89 by Sectors

Province	**Component** % change	**Consumer** % change	**Telecomm** % change	**Computer** % change	**Control** % change	**System** % change
Newfoundland	0.0	0.0	0.0	0.0	100.0	100.0
P.E.I.	100.0	0.0	−100.0	100.0	0.00	−100.0
Nova Scotia	25.0	0.0	0.0	0.0	40.0	250.0
New Brunswick	300.0	0.0	100.0	100.0	100.0	0.0
Quebec	67.86	50.0	9.1	77.3	−2.0	−20.0
Ontario	28.8	25.0	−4.8	94.2	1.0	13.6
Manitoba	33.3	0.0	0.0	33.3	100.0	62.5
Saskatchewan	100.0	0.0	−50.0	150.0	0.0	133.3
Alberta	400.0	0.0	−12.5	1400.0	275.0	12.5
British Columbia	180.0	0.0	−50.0	266.6	25.9	18.5
Yukon & NWT	0.0	0.0	0.0	0.0	0.0	−100.0
Total	53.7	31.3	−8.8	118.9	13.1	10.9

Source: Calculated from Statistics Canada. **Manufacturing Industries of Canada: National & Provincial Areas.** CS31-203

The performances of "system electronics" and "control and instrumentation" activities were rather mixed. For the former, whereas Nova Scotia, Saskatchewan and Newfoundland expanded their numbers by at least 100 percent for the period, the two territories and Prince Edward Island closed down 100 percent of their establishments. Meanwhile, Quebec recorded a 20 percent decline in the number of firms in "system" activities. By the same token, while Alberta, Manitoba, New Brunswick and Newfoundland received at least 100 percent more new "control and instrumentation" firms, Quebec lost two percent of its original number, leaving Prince Edward Island, Saskatchewan, and the two territories to register no change whatever.

1.6.1.4 High Technical Contents

The requirement of "high technical contents" is one of the main features distinguishing electronics from other industries. The writer of this thesis desired to verify this characteristic as applying to Canadian electronics firms. Unfortunately, Statistics Canada provides no data on this subject at the provincial level. One must have recourse to circumstantial evidence for Canada as a whole to remedy this defect. In this regard, the Robertson Nickerson Limited Report (Robertson Nickerson Limited, 1984) was examined. This report indicated that electronics industries spent more on R&D than any other industrial sector. Roughly 25 percent of industrial R&D expenditures was accounted for by electronics industries. They spend on the average four to five percent of their sales revenues on R&D as compared with the one percent usual in other industries. The R&D expenditures of the new start-ups or firms at their "early growth phase" of electronics industries can easily exceed 10 percent of sales (Ibid., 1984).

1.6.2 The Special Case: The Province of Manitoba

In view of the thesis topic, it is desirable to underscore Manitoba's position with respect to the various attributes belonging to the industry. This involves interpreting the data already furnished. As mentioned previously, the 1986 electronics (electrical) data of Statistics Canada (1990) indicated that Winnipeg accounted for 32 (88.89 percent) of the 36 electronics (electrical) firms in the province. At the same time, the city also possessed 2,413 (87.81 percent) of the province's 2,748 electronics (electrical) employees. Indeed, upon examination of the information provided by the EIAM (EIAM, 1984/5), it was discovered that 47 (92.16 percent) of 51 of the association's electronics (electrical) manufacturing members were located in Winnipeg.

Looking into the growth of the industries, Manitoba's electronics industries recorded an employment growth of 40.14 percent; some 2,171 new jobs for the period of 1983-89 (Table 1.4). This meant that electronics activities grew very much faster than the province's overall manufacturing employment growth, which, at 10.49 percent (Table 1.5), produced 5,387 new jobs. Electronics activities, therefore, accounted for as much as 40 percent of the new jobs created in the manufacturing sector. This pattern is also true for the two sub-periods of 1983-85 and 1985-89. When overall manufacturing employment grew by only 0.20 percent (Table 1.5) for the period of 1983-85, electronics employment was up by 8.89 percent (Table 1.4). For the later sub-period, when the former was 10.27 percent (Table 1.6), the latter was 28.69 percent (Table 1.4). With regard to branches of electronics, the main contributor to the 1983-89 employment growth was "component products", a branch that grew by a rate of 3,663 percent (Table 1.6). Not surprisingly, this was the highest growth rate among all provinces for the period. It created 989 new jobs for Manitoba. The "telecommunications equipment", "control and instrumentation equipment" and "system electronics" branches grew fairly well for the period also. They grew by the rates of 50.31 percent, 100 percent and 40.95 percent, respectively (Table 1.6). The poorest performance was registered by the "computers and other office equipment" branch which declined by 32.37 percent for the period (Table 1.6); or, more tangibly, by 491 jobs.

Apart from employment, electronics industries in Manitoba experienced very fast growth rates in terms of the number of new establishments appearing as well. For the entire 1983-89 period, they grew by 45.45 percent (Table 1.7), a far cry from the 0.08 percent rate applying to all manufacturing activities (Table 1.8). The main contributor was the "industrial control and instrumentation equipment" branch. It grew by 100 percent in this period (Table 1.9). The other significant contributors were "system electronics", "component electronics" and "computers and other office equipment". They grew by 62.50 percent, 33.33 percent, and 33.33 percent respectively. The worst performance arose from "telecommunications equipment", which had no growth at all in the number of establishments between 1983 and 1989. Significantly, Manitoba did not experience consistent growth in the number of electronics establishments in these years. In the earlier period of 1983-85, the number of its electronics firms declined by 4.55 percent (Table 1.7), an occurrence, incidentally, which was the only negative growth rate among the provinces. However, in absolute terms, this only meant a loss of one firm. In the later period of 1985-89, numbers jumped by 52.38 percent. Eleven new firms were established during these years.

1.6.3 Conclusion and Summary

To conclude, the basic attributes of electronics industries found in other advanced countries have been replicated in Canada and, not least, in the province of Manitoba. First of all, the distribution pattern of Canadian electronics activities has been highly uneven. Within the nation, they are disproportionately localized in Ontario, Quebec and Manitoba. Within provinces, except for Alberta, they are unequivocally clustered in the metropolitan areas. Secondly, the industries experienced very fast growth rates; indeed, the rates far exceed those applying to the national manufacturing sector. In the 1983-89 period, when the overall manufacturing activities grew at a rate of 17.92 and 10.95 percent in their number of employees and establishments respectively, the national electronics industries increased at an impressive rate of 36.84 and 36.67 percent respectively. Among the electronics activities, it was the "component electronics" branch that had the most impressive employment growth rate, that is, 100.6 percent for the 1983-89 period. With respect to the growth in the number of establishments, the most impressive branch was "computers and other office equipment", recording 118.87 percent in the same period. Finally, electronics industries spend on the average four to five percent of sales revenues on R&D, a figure greatly overshadowing the manufacturing average.

As far as the subject region of this thesis is concerned, the Manitoba electronics industries are mainly located in Winnipeg. To recall, the 1986 electronics (electrical) data of Statistics Canada (1990) suggested that Winnipeg accounted for 32 (88.89 percent) of the 36 electronics (electrical) firms in the province. The city also possessed 2,413 (87.81 percent) of the province's 2,748 electronics (electrical) employees. Furthermore, in the early 1980s, 47 (92.16 percent) of 51 of the EIAM's (electrical) manufacturing members were located in Winnipeg. Provincial electronics activities grew in employment terms at a rate of 40.14 percent, and in the number of establishments at a rate of 45.45 percent over the years from 1983 to 1989. These growth rates were significant when they were compared with the 10.49 percent and 0.08 percent applying to equivalent figures for Manitoba's overall manufacturing activities in the same period. "Component electronics" emerged as the fastest growing branch in employment, with a growth rate of 3,663 percent for the period of 1983-89. In terms of the number of establishments, the "industrial control and other office equipment", "system electronics (aerospace)", "component electronics" and "computers and other office equipment" branches all registered impressive growth rates, namely, 100 percent, 62.50 percent, 33.33

percent and 33.33 percent respectively.

All these observations show that electronics industries have great potential for triggering regional, and by extension, national, development. This potential will be further explored in the chapters to come. Setting the scene, however, is a chapter dealing with science parks, the quintessential policy instrument that sets out to embrace the merits of electronics development.

Chapter Two

Science Parks and Their Roles in Nurturing Small Electronics Firms

2.1 Introduction

Chapter One demonstrated that electronics industries have been widely recognized as a nostrum for the economic pain of many peripheral regions in the advanced world, including Manitoba. This province has long been endowed with a poor industrial structure. Its economic activities are dominated by agriculture and lack employment opportunities, both of which serve to generate net outmigration. With the onset of a global recession in the mid-1970s, the problem of net outmigration became particularly acute. The problem was also persistent. In the period of 1986-90, Manitoba's loss of base population to outmigration was the highest among all Canadian provinces. The electronics industries, characterized by their high spatial concentration, fast growth rates and high technical contents seem to be heaven-sent for the alleviation of this structural problem.

Stamped by fast growth rates in both number of employees and establishments, electronics industries promise enormous employment opportunities for any locality, leading to the immediate relief of the short-run unemployment problem. With high technical contents such as high percentage of technical personnel and R&D expenditures in their production process, the industries are efficient generators of new products and, hence, new industrial activities within the electronics sector. Being spatially concentrated, they accumulate a mass of industrial activities, resulting in the attraction of numerous complementary non-electronics economic activities into the locality. Owing to the capability of the electronics industries to create numerous new industrial activities within and without the electronics sectors, the long-run unemployment difficulty provoked by the poor industrial mix of the region can be overcome. Various parts of the advanced world, in particular Silicon Valley and Route 128 of the U.S.A., have evinced the vital role of the industries in regional development. In Canada, specifically, in the province of Manitoba, the barebones of electronics industries' concentration are already apparent. These putative agglomerations have great potential for regional development, especially in their science park manifestation.

Accordingly, this chapter is dedicated to reviewing science parks and their related infrastructures so that their merits as tools for regional development can be fully appreciated. To begin with, a section will be devoted to a discussion of the attributes of a typical science park. Following this, an attempt will be made to clarify the role played by science parks in the nurturing of high-technology firms in general and innovation activities in particular. Finally, the experiences of worldwide science parks, which have been fairly successful in nurturing innovation high-technology firms drawn from the electronics industries, will be considered.

2.2 The Nature of Science Parks

Of late, science parks have been recognized as the most important instrument for generating a critical mass of high-technology firms that consequently triggers regional development. They provide "a chance to save endangered jobs in large but declining undertakings in traditional sectors by promoting young high-tech firms" (Allesch, 1985, p.60). Besides, "in today's atmosphere of large-scale unemployment many communities are looking enviously at the job creation capabilities offered by high-technology industries, and in searching for the magic wand to solve their employment problems, are trying to create science parks" (Cox, 1985, p.17). What is more, science parks render some "radical restructuring solution" to the "troubled regional economies", which are desperately casting around for means to ameliorate their disadvantages (Todd, 1990). Therefore, they "seem to share three common goals: job creation, business development, economic diversification" (Dekker, 1985). These are powerful arguments in their favour.

Although "science parks" have often be cited in the literature as one of the most promising tools for regional advancement, there is no consensus on a definition of what they are. Some confusion always arises in distinguishing "science parks" from either "business or commercial parks", or "innovation centres", and "high-technology complexes" (Eul, 1985). The confusion is basically caused by different inclinations of researchers in selecting the attributes of the scientific infrastructures that serve as study units of their research. With the inclusion or omission of some of those attributes, such scientific entities are then dubbed by different names. To solve this problem, the basic attributes of these infrastructures ought to be identified. The upshot is an acceptable combination of these attributes which will offer a meaningful definition of science parks.

By and large, the much-mentioned attributes of the scientific infrastructures at issue include the availability of research facilities and related institutions, attributes concerning the physical landscape of the site, the lot size, and, sometimes, the managerial functions of their administration, or, whether their origins are planned or appeared "spontaneously". With the focus on the nurturing of high-technology activities, especially electronics industries, in a locality, a "science park" will be defined with these activities as its cornerstone.

The most commonly-accepted attribute is the availability of research facilities or the presence, on site, of related advanced-education institutions such as universities or technical colleges. Taylor (1985, p.137) has particularized science parks as "the developments which are associated with research facilities such as university research laboratories and ancillaries." To the International Association of Science Parks (IASP) and the U.K. Science Parks Association (UKSPA), a science park is characterized as "a property-based initiative" (that is, the real estate initiative which may include a building, a group of buildings or a parcel of land) which has "formal and operational links" with research institutions such as "a university", or "other higher-education research institutions" or "research centres". So far as Worthington (1982) is concerned, science parks are to be identified by the presence of research facilities such as "laboratory-type structures" on their sites. Similarly, Eul (1985) associates science parks with the presence of "buildings" where accommodation can be "provided on a short, medium- or long-term basis" and where "research inter-change or interaction" is encouraged with the university for "companies engaged in product research and prototype development", and they "land on, or close to, the campus or institution of academic excellence." The issue involved is one concerning the interrelationship of such infrastructures on the one hand and research institutions on the other hand with special emphasis on the importance of "face-to-face contacts" between the parties involved so as to facilitate the transfer of technological information. Nevertheless, all these definitions are still too vague to distinguish "science parks" from "innovation centres". The latter have been recognized as the type of infrastructure that provides an extensive range of research facilities (such as workshops or laboratories) along with other office facilities (such as conference rooms, meeting rooms, secretaries and office equipment) to tenant firms. Therefore, undoubtedly, the availability of advanced facilities or of a close physical relationship with advanced-education institutions or research institutions is a basic attribute of such scientific infrastructures, but, alone, it is not sufficient by itself to separate "science parks" from "innovation centres".

Meanwhile, some writers are very fond of mentioning the design of the landscape of such infrastructures. In addition to the details surrounding the accommodation of one or more buildings on the designated sites, they stress that the parcel of land is to be in "greenfield" or "park-like" settings (Currie, 1985; Worthington, 1982). Nevertheless, the issue that concerns us here is one not so much of the beauty of the industrial setting per se but rather of the financial constraints of the authorities involved. The determination of a spectacular landscape simply depends upon the degree of flexibility inherent in the financial and spatial contraints imposed on the authorities and the locations in question. Hence, over-emphasis on the design of greenfield or park-like settings of such infrastructures is to be avoided.

At the same time, one must avoid the trap of confusing "innovation centres" with "commercial parks" because of the presence of some high-technology industries in the latter. In point of act, "commercial parks" can be easily distinguished by the absence in them of research facilities geared to high-technology tenants, and by the presence in them of representatives of the overwhelmingly traditional manufacturing sector.

It may also be questionable to maintain that "science parks" embrace industrial developments such as those in Silicon Valley and Route 128 in the U.S.A.; Ottawa, Toronto and Montreal in Canada; and parts of South Wales and Central Scotland in the U.K. At best, they should be known as "high-technology complexes" or "high-technology clusters". Although they cover extensive areas and generally accommodate a wide range of facilities and services nurturing high-technology firms, they are simply spontaneous agglomerations of different economic activities that have coalesced through time. Only those scientific infrastructures that are designed by the planners to nurture high-technology activities deserve to be known as "science parks". By comparison, complexes or clusters named above are not generated to abide by the long-term planning designs of the planners. Nor, for that matter, are they confined to restricted spatial boundaries. In contradistinction, science parks are typically a gathering of high-technology firms within the spatial dimension of the parks and the agglomeration of diversified economic activity takes place, as intended, outside the premises of the parks.

Another important attribute of science parks is their "mandated functions". For instance, both the IASP and the UKSPA have stressed the "management function" which is defined as the active management in the activities of technology transfer to encourage the formation and growth of "knowledge-based businesses" that are tenants on site. Unfortunately, this is not sufficient to distinguish science parks from "innovation centres". The latter also involve management teams that are actively involved in the activities of technology transfer, and the latter are also active in initiating conferences, meetings that facilitate interaction and flow of information between residing entrepreneurs on the one hand and research personnel on the other hand. Their management teams may even provide consultation on matters relating to taxation, licensing, marketing and business development (Krist, 1985; Eul, 1985). However, confusion may be caused by the similar administration function of the "commercial parks" which would also offer "office functions" for high-technology tenant firms (Eul, 1985; Taylor, 1985). In other words, the sole presence of management teams to perform administration work pertaining to the infrastructures may not be sufficient to delineate these industrial infrastructures one from the other.

Therefore, in order to derive a meaningful definition of "science parks", the fundamental distinguishing feature must be identified. Primarily, such industrial entities should be able to provide the state-of-the-art research facilities to their tenant firms or should have the means to facilitate technology transfer to high-technology tenant firms from research institutions. To arrive at these ends, the science parks should own management teams that have to go beyond the duties of the physical maintenance of the infrastructures, and yet, more vitally, to provide those services bridging the gap between tenant firms on the one hand and research institutions or researchers on the other hand. Technology transfer and the mediating management efforts are what distinguishes science parks from other forms of industrial arrangements.

To facilitate inter-institution and inter-personal relationships, science parks are preferably to be located at the closest proximity to research institutions as possible. Consequently, more "face-to-face" contacts will become the norm of "science park effects".

This is not to say that the "greenfield" or "park-like" landscape is something of no consequence. Science parks should not consist of a single building but be composed rather of a cluster of buildings. This clustering tendency differentiates them from incubation centres. For such a cluster the "landscaping" aspect assumes significant proportions.

Following these statements, it is evident that the science parks should involve a process of detailed planning from the setting of the landscape, to the selection of tenant firms, to the agenda of in-park services to be provided, and to the incorporation of the "right" kind of advanced facilities either within the parks or in proximity to them. This rules out the spontaneous spawning of "high-technology complexes" or "high-technology clusters" which are better regarded as "science parks" in the restricted sense.

To fix the idea, "science parks" are, therefore, the well-planned industrial infrastructures that take up a parcel of quality land with acceptable green space for nurturing of high-technology industries, especially small start-up firms. To facilitate technology transfer, the park is located at the closest proximity to any universities or research institutions as possible. It also requires a proactive management team to oversee not only the maintenance of the physical well-being of the parks, but, more importantly, the flow of information between tenant firms and research institutions on site and immediately off it. High frequencies of "face-to-face" contacts between the two parties should be arranged by such management teams. A more detailed evaluation of the issues arising from this definition of "science parks" is made in the following section.

2.3 The Implications of This Definition of Science Parks

Science parks, as defined above, have special relevance to the nurturing of small, and/or, new high-technology firms.

In small or new firms, entrepreneurs have to face all kinds of problems from finance and production, to marketing, legal matters and managerial skills. To start with, financial feasibility is the primary concern of all entrepreneurs. Unfortunately, it has been well documented that it is very difficult to convince financial institutions or private capitalists to support companies without established track records for either their products or management (Cooper, 1984; Monck et al., 1985). Such difficulty constitutes a higher burden to small high-technology firms than to the other businesses because of the higher risks and uncertainties involved in the former. Therefore, without sufficient ongoing financial resources it would be difficult for small high-technology firms to rent a premises that suits their purposes at a low cost, and more difficult to hire qualified employees for production (Cooper, 1984).

Another survival requirement of small high-technology firms is the continuous upgrading a wide range of "knowledge". This know-how consists of technical knowledge for the development of new products, commercial knowledge for organizing or managing efficient businesses, financial knowledge for securing equity and long-term debt in their initial years and marketing knowledge such as the needs of their clients (Ibid.; Rexrodt, 1985). Therefore, being denied channels of acquisition of relevant information, small high-technology firms would be literally putting their survival at stake. The mortality rates of high-technology firms appear to be high in the U.S.A. The vast majority of business failures occur within the first ten years of the firms' lives. In the U.K., small high-technology firms also appear to be particularly vulnerable. One study suggested that 69 percent of all business failures occurring in 1965 were of firms less than ten-years' old; 62 percent of them were in fact under five-years' old (Bosewell, 1972, p.57).

Knowing all these problem areas of small high-technology firms, science parks enter into the picture as the vehicles for reducing these hindrances. Records show that the chances of survival rate of these small high-technology firms can be considerably raised by the simple expedient of being locating in science parks. The basic reason for this is that science parks can provide efficient and relevant technology transfer as well as less costly rental fees to tenant firms. Thus, in the light of the foregoing definition of science parks, the vision of the instrument will have much to offer.

On the lighter side, the "greenfield" or "park-like" attribute of the science park has provided an "environmentally-friendly" and relaxing working atmosphere for the work-intensive researchers and entrepreneurs. The literature lends credence to the view that such an environment will enhance informal or leisurely communication among entrepreneurs, academics, industrial researchers or other park participants (Lowe, 1985; Monck et al., 1985, p.128). With increased interaction among all these parties, high-technology entrepreneurs could efficiently acquire technical or managerial (such as financial, marketing, organizational) information deemed vital for their needs. In the longer run, not only the existing tenant firms could survive within the park but the facility also might attract more high-technology enterprises or other economic activities. This explains how the critical mass of industrial agglomeration is formed in time. In the short run, the park will provide ready accessibility to the essential technical facilities of entrepreneurial firms. Material testing, measurement of individual parts, prototypes or products and the evaluation of measurement or testing series, and the like, would also be immediately available at the in-park government or private laboratories and facilities. More efficient relationships will be established between the users and the suppliers of all these services; in a way, the travelling or transportation time will be minimized but the person-to-person contacts will be maximized. More specific requests of the information users will be accurately passed onto the information sources. The designing and fabricating of new products are made much more conveniently than through other forms of contacts. In due course, the costs of production of entrepreneurs would be substantially reduced. These all mean higher gross profits to such entrepreneurial firms.

Nevertheless, such a relationship is not a one-way street. The personnel of the laboratories and facilities are scientists or engineers. They would be kept informed of the market needs by their clients, the high-technology entrepreneurs. In this context, the researchers may come up with new product ideas and may desire to have their innovation tested, developed, and commercialized. Furthermore, when the park is close to a university(ies), the faculty members or the graduate students of the university(ies) may be kept informed of the industrial needs. They may also be interested in launching their own business ventures to profit from their new ideas or they may be prepared to loan their expertise to the existing firms. On both counts, a greater possibility occurs for the creation of spin-off firms from research institutions. As far as labour requirements of high-technology firms are concerned, the university serves as a resource centre for continued training and interaction with the industries in a non-corporate environment, and serves to supply newly-trained researchers to in-park firms (Malecki, 1981). All these within-park interactions conspire to make the park a breeding ground for new ideas and new products that are going to change a world very much larger than the park itself.

However, a caution is in order: the physical attributes of science parks should not be emphasized so much as to overshadow the important roles played by their management teams. All these benefits would not come along by themselves without an effective go-between to operationalize them. Timely meetings and conferences have to be arranged. Matching of users' needs to suppliers' resources requires the referral of a coordinator. Perhaps grievances or complaints have to be heard and mediated by a third party. All these have fallen onto the shoulders of the management team of the park, which must be an active, proactive and enthusiastic.

Rather than being imaginary, this view of the science park can be corroborated by reality. In other words, there are some existing scientific infrastructures in the industrialized countries that fit the definition. Hence, in the following section, some popular examples of science parks which aim at nurturing electronics industries are reviewed.

2.4 Some Experience of "Electronics" Science-Park Development

2.4.1 The Stanford Industrial Park

There are quite a number of successful science parks among the industrialized countries which were implemented for the promotion of new electronics firms. Possibly, the most renowned of these is the Stanford Industrial Park located at Palo Alto, California (Figure 1.1).

In the late 1940s, the bold idea of the Stanford University of hiring "star" professors was handicapped by the university's poor financial situation. To overcome this hurdle, Stanford University elected to sell its underdeveloped campus land to obtain the necessary finances. However, the original Stanford family forbade the sale of any of its 3,564 hectares of the land gift. It was Fred Terman, then vice-president of the university, who hit upon the idea of establishing a high-technology industrial park on the campus land. This project, it was hoped, would not only bring financial returns to the university but also enhance its "academic prestige and excellence" (Rogers and Larsen, 1984). Indeed, the park has been recognized as "Stanford's secret weapon" (Ibid., 1984; Saxenian, 1985).

The park is sited on 267 hectares of land adjoining the Stanford campus on a "genuine greenfield" site furnished with apricot and walnut orchards (Monck et al., 1988). Today, the park insists on maintaining low rental rates for its tenants. It has also become a major recipient of aerospace grants from donors such as Litton Industries, Lockheed, Westinghouse, GTE, Intel, Kaiser Industries, Ford, GE and Precision Equipment. Most important of all, it furnishes numerous state-of-the-art electronics research facilities and R&D laboratories established by SRI, NASA, IBM, IT&T, Admiral and Sylvania. The park has been contributing to the financial well-being of the university since its establishment in the 1950s. The prepaid leases amount to over 18 million US dollars; and by 1981, the annual rental income was about 6 million US dollars (Rogers and Larsen, 1984). Specifically, the Stanford Industrial Park has been very successful in attracting electronics firms into its site. By 1955, seven high-technology firms, largely electronics companies, were located in the park; by 1960, the tally had risen to 32; by 1970, it numbered 70 (Rogers and Larsen, 1984). Although the number has declined to 55 tenant firms in recent years, the park still accommodates a large number of employees — around 25,000 workers (AURRP and IASP, 1991). In the past few decades, the Stanford Industrial Park has served as a model of electronics development in the U.S.A. and around the world.

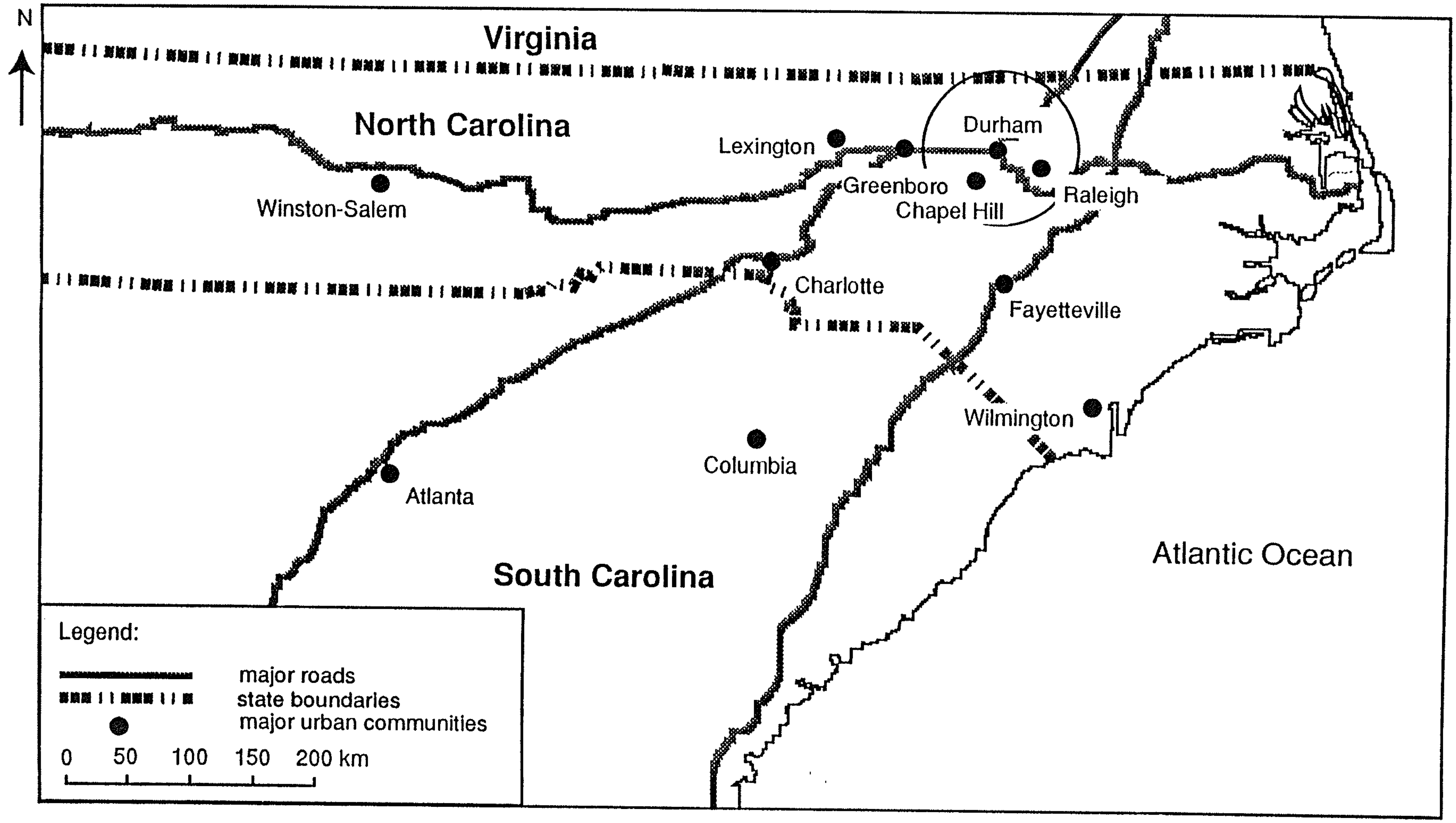
2.4.2 The Research Triangle Park

Apart from the Stanford Industrial Park, the Research Triangle Park of North Carolina is also a well-known science park for fostering innovative electronics firms in the U.S.A. (Figure 2.1).

The park was established in 1956 in order to familiarize industrial and governmental research interests with the scientific resources and cultural advantages of North Carolina and thereby to advance further the research resources of the area. It is sitting on some 2,000 hectares of high-quality landscape with reasonable proximity to three major universities: North Carolina State University (in Raleigh), Duke University (in Durham), and the University of North Carolina (in Chapel Hill). It also embraces an area where numerous

Figure 2.1

Location of Research Triangle Park
(approxmiately as the circumscribed area)



facilities are to be found for servicing high-technology activities (Humble, 1984; Rogers and Chen, 1990). The facilities located within the park that are aimed at the fostering of high-technology firms include the International Business Machines (IBM) Research Centre and the Microelectronics Centre of North Carolina. The former is a private-sector laboratory, the latter is a non-profit institution founded in 1980 at the insistence of the state governor, with the purpose of cementing ties between the university laboratories on the one hand and those of GE and the IBM Research Centre on the other hand. There is a great range of government industrial supporting services as well. Among their numbers are the North Carolina Science and Technology Institute and the North Carolina Science and Technology Research Centre (Rogers and Larsen, 1984; O'Connor, 1985; Todd, 1990).

As a result of these efforts, the Research Triangle Park has been very successful in attracting electronics firms onto its site. By one recent reckoning it accommodates 25 organizations. Most of these organizations concentrate on new-product designing and prototype development, although, to be sure, there is a small number of light manufacturing activities (Miller and Cote, 1985). Together, these organizations provide about 250,000 jobs in the park. The two largest are Northern Telecom and IBM, which combined, account for 15,000 jobs. Six other large corporations contribute another 8,000 jobs to the park (Miller and Cote, 1985).

In recent years, the Research Triangle Park, reminiscent of the Stanford Industrial Park, has been cited as a model of science-park development for the U.S.A., to say nothing of other countries. As Whittington (1985) observed, delegations of government officials and economic development planners from other states of the U.S.A. and from other countries routinely visit the park in the hope of learning how to replicate its heavy concentration of high-technology activities, and, in particular, its great mass of electronics activities.

2.4.3 The Cambridge Science Park

In the U.K., the most prominent science park that is devoted to the nurturing of electronics firms is the Cambridge Science Park. Indeed, this park has become the best known of all such parks, not just in Britain but in Europe as a whole (Segal and Quince, 1985). It was established in 1973 by Trinity College with the mandate of attaining a long-term financial rate of return comparable with that of the college's other commercial investments (Ibid.; Monck et al., 1988). Physically, it was sited on a "greenfield" landscape of 496 hectares on the campus of Trinity College within Cambridge University (Jones and Dickson, 1985; Segal and Quince, 1985; Monck et al., 1988) (Figure 2.2). It provides accommodation in the form of nursery units for small and new start-up electronics firms on short-term leaseholds. Also to be found there are such facilities as a social centre, patent agencies and venture capital companies, all essential to the functioning of start-up electronics enterprises (Segal and Quince, 1985).

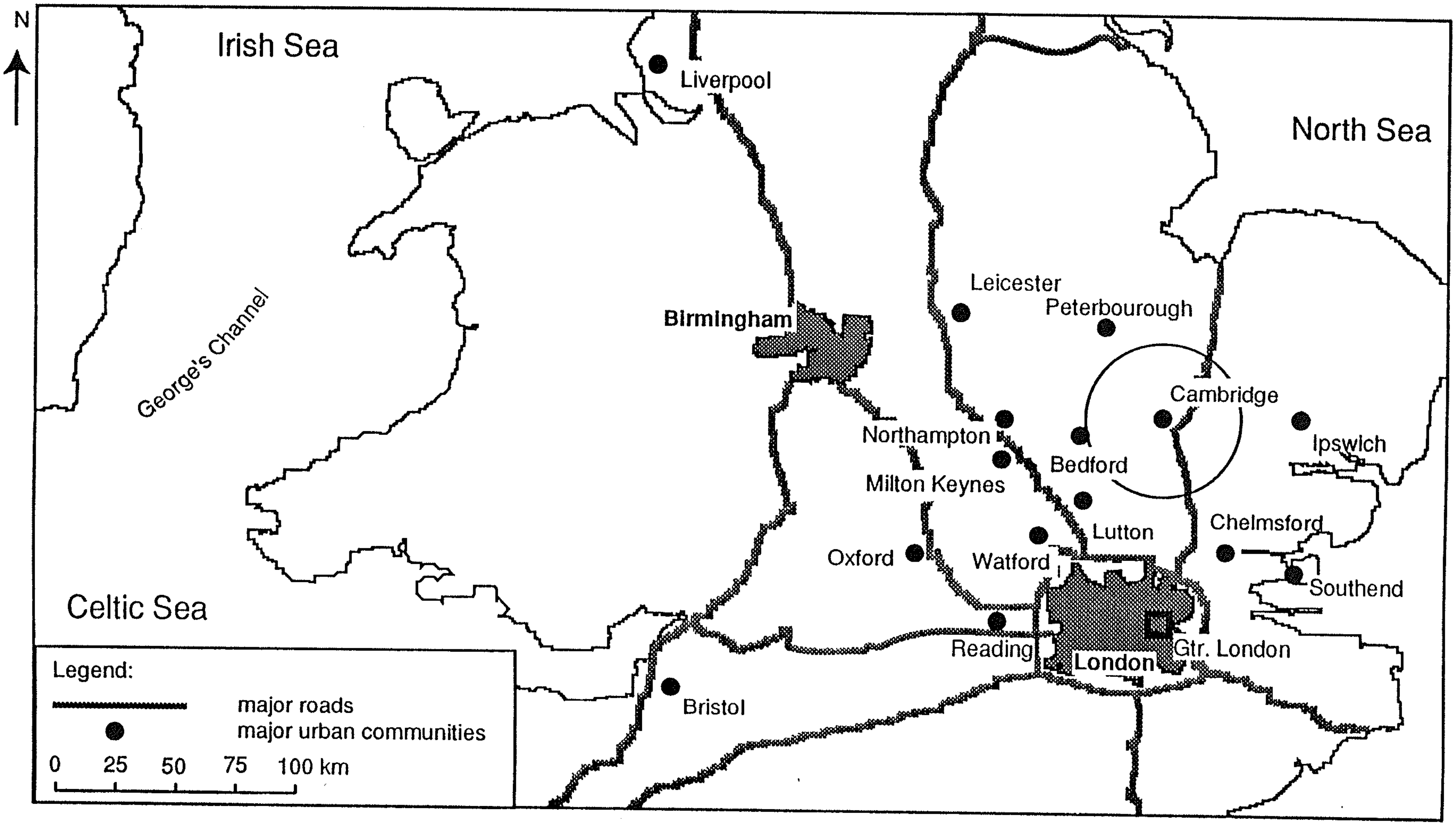
After the first tenant, a spin-off from the Physics Department of Cambridge University, moved in during 1973, the park grew quite slowly for the first five years. By 1978, there were only seven tenants. It is fair to say that for the first phase of its existence, the park played no more than a very minor role in constituting a focal point for electronics industries in the area (Ibid.). The situation changed with the onset of the 1980s. With the provision for the first time of on-the-park nursery units for start-up or very small companies, the rate of occupancies increased very fast. By mid-1984, there were nearly 40 tenant companies which provided 1,000 jobs in the park (Segal and Quince, 1985). By 1986, it boasted 68 firms employing 1,900 people, occupying 214,650m^2 of premises and was the largest science park in the U.K. (Monck et al., 1988). Most of its tenant firms were involved in the production of electronics goods such as microelectronic components, telecommunications devices, scientific instruments and computer hardware (Rothwell and Zegveld, 1982; Miller and Cote, 1985; Saren, 1985; Segal and Quince, 1985). Other activities encompassed computer software and elements of biotechnology. The park has also been effective in bringing economic development to the wider region. In and around the city of Cambridge (which has a total population of some 200,000 people, including those in the surrounding villages and towns), there were approximately 350 high-technology companies by the end of 1984, accounting for nearly 20 percent of the total employment in the area (Segal and Quince, 1985).

2.4.4 The Heriot-Watt Research Park

Another successful case in Britain of science parks designed for the nurturing of

Figure 2.2

Location of Cambridge Science Park
(approxmiately as the circumscribed area)



electronics industries is that of the Heriot-Watt Research Park. Established in 1971, the Heriot-Watt Research Park expressly desires to encourage the conversion of academic research into marketable industrial processes, products and services. In particular, it seeks to create enabling conditions for tenant firms to undertake specific activities in research, development, design, engineering and prototyping with the provision of university facilities (Kirschbaum, 1985). The park is a planned infrastructure that occupies 68 hectares of land within the campus of Heriot-Watt in Edinburgh, Scotland (Figure 2.3). The facilities contained within the park include an active industrial liaison office, called Unilink, which facilitates technology transfer between tenant firms, Heriot-Watt University and the University of Edinburgh. It achieves this through collaborative projects between firms and the universities (Miller and Cote, 1985). By 1985, the park accommodated 23 organizations occupying 23 hectares of land. A number of those firms are either academic spin-off electronics companies (such as Edinburgh Instruments), or are the spin-off firms formed as a result of undertaking applied research work for government laboratories, especially the Science and Engineering Research Council (Monck et al., 1988).

2.4.5 The Sophia Antipolis Park in France

In France, the most prominent representation of a successful science park geared to nurturing small electronics firms is the Sophia Antipolis Park located near Antibes on Côte d'Azur (Figure 2.4). This park was established in 1969. Its name is derived from a Greek expression which means literally "city of wisdom". Its mandate is to regroup research activities, advanced training centres (essentially, the universities) and innovative industries together to create an environment conducive to "cross fertilization" — a process which, in turn, leads to the spawning of new high-technology firms (Dormand, 1988; Hansen, 1990).

It stands out in respect of its establishment on "unspoiled hills" in a region of attractive scenery. It is strictly regulated in terms of architectural planning and protection of the environment of 2,535 hectares. The site was selected because of its close proximity to three higher-education institutions: *Ecole des Mines de Paris* (Paris Institute of Mining Technology), *Ceram* and *Université de Nice*. It features an on-site innovation centre (known as *a pépinière* in French); that is, the Sophia Antipolis Technologies Reception Centre, which covers $1,000m^2$.

Figure 2.3

Location of Heriot-Watt Science Park
(approxmiately as the circumscribed area)

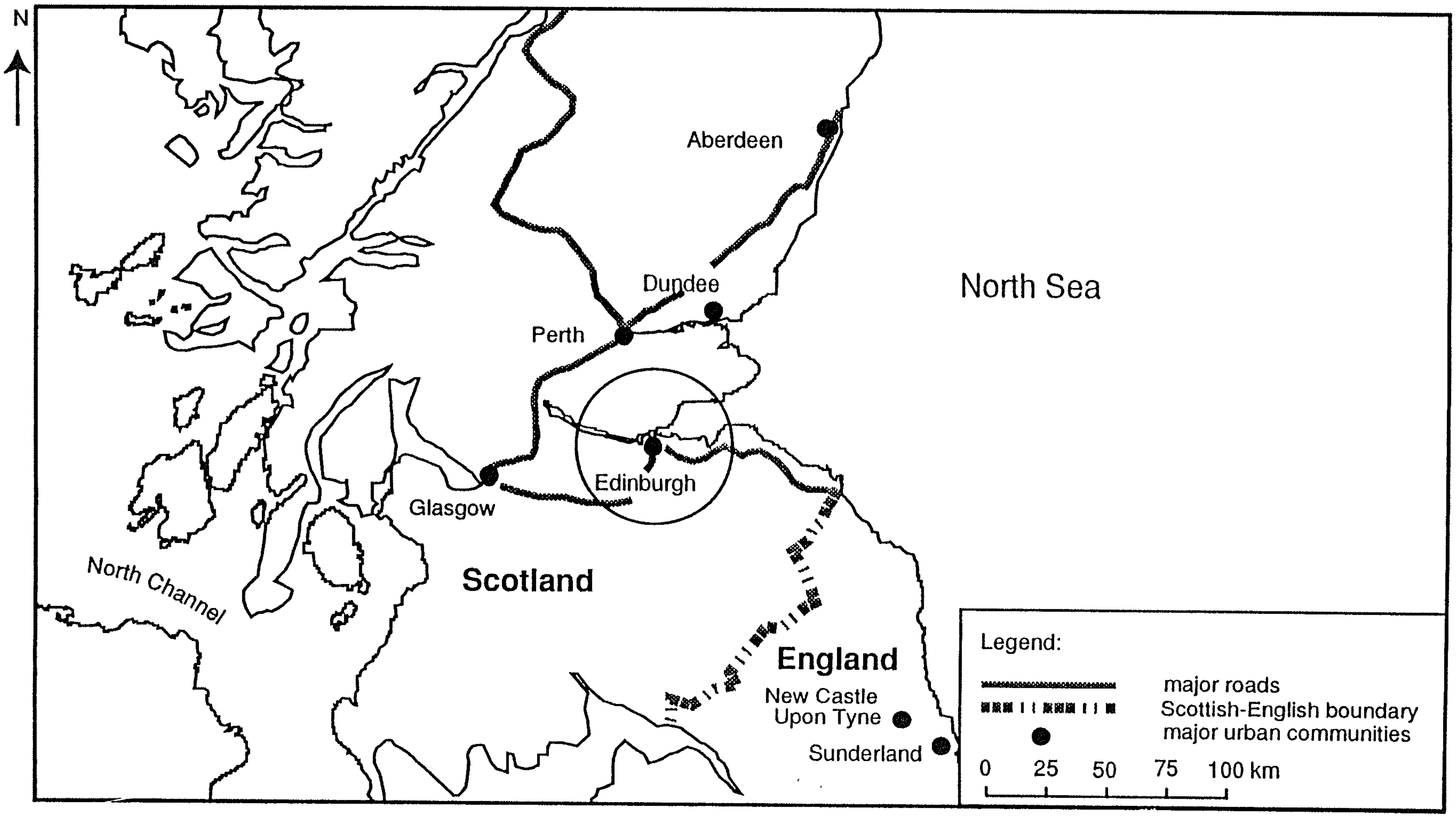
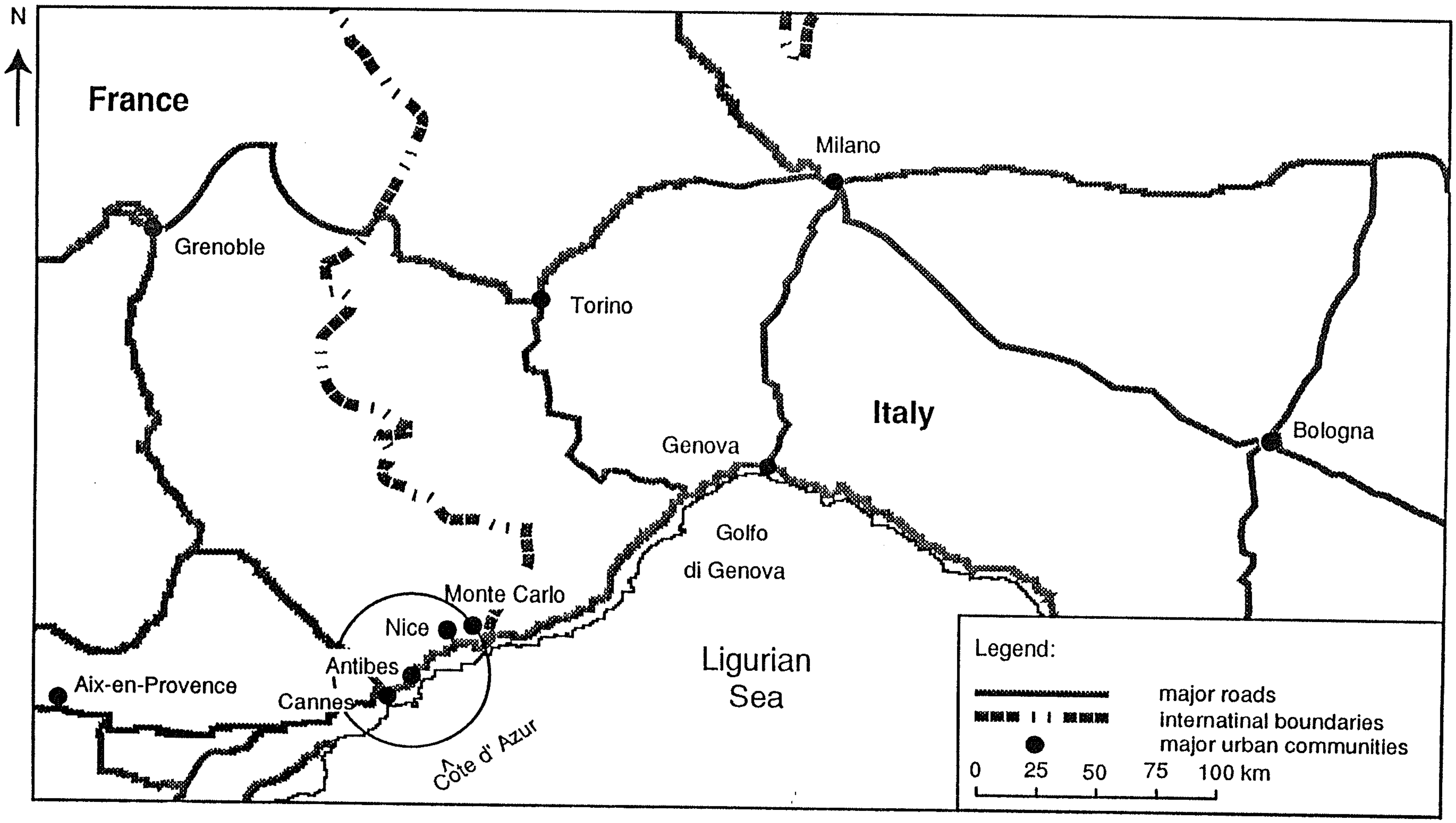


Figure 2.4

Location of Sophia Antipolis
(approxmiately as the circumscribed area)



This releases small lots for accommodating firms at moderate cost and provides services such as administration, and relations with a network of scientific, technical, commercial and administrative specialists for the young entrepreneurs (Laffaitte, 1985; Dormand, 1988).

Within the park, there are some national research institutions such as the *Institut National de la Recherche en Informatique et Automatique* and *Agence Francaise pour la Maîtrise de l'Energie*; a social centre; patent agencies and venture capital companies (Segal and Quince, 1985). It has been very successful in attracting activities dedicated to R&D, software and specialized manufacturing. In 1985, a total of 120 firms, organizations and societies were operational, providing employment for about 5,000 workers (Laffaitte, 1985). In 1991, the tally of firms mounted to 650 employing 12,000 people (AURRP and IASP, 1991). Of special note, it has hosted a unique concentration of electronics companies, essentially telecommunications activities, and has become an increasingly popular site for large multi-national electronics producers seeking a foothold in "Fortress Europe". The in-park multi-nationals include DEC and Texas Instruments (Laffaitte, 1985).

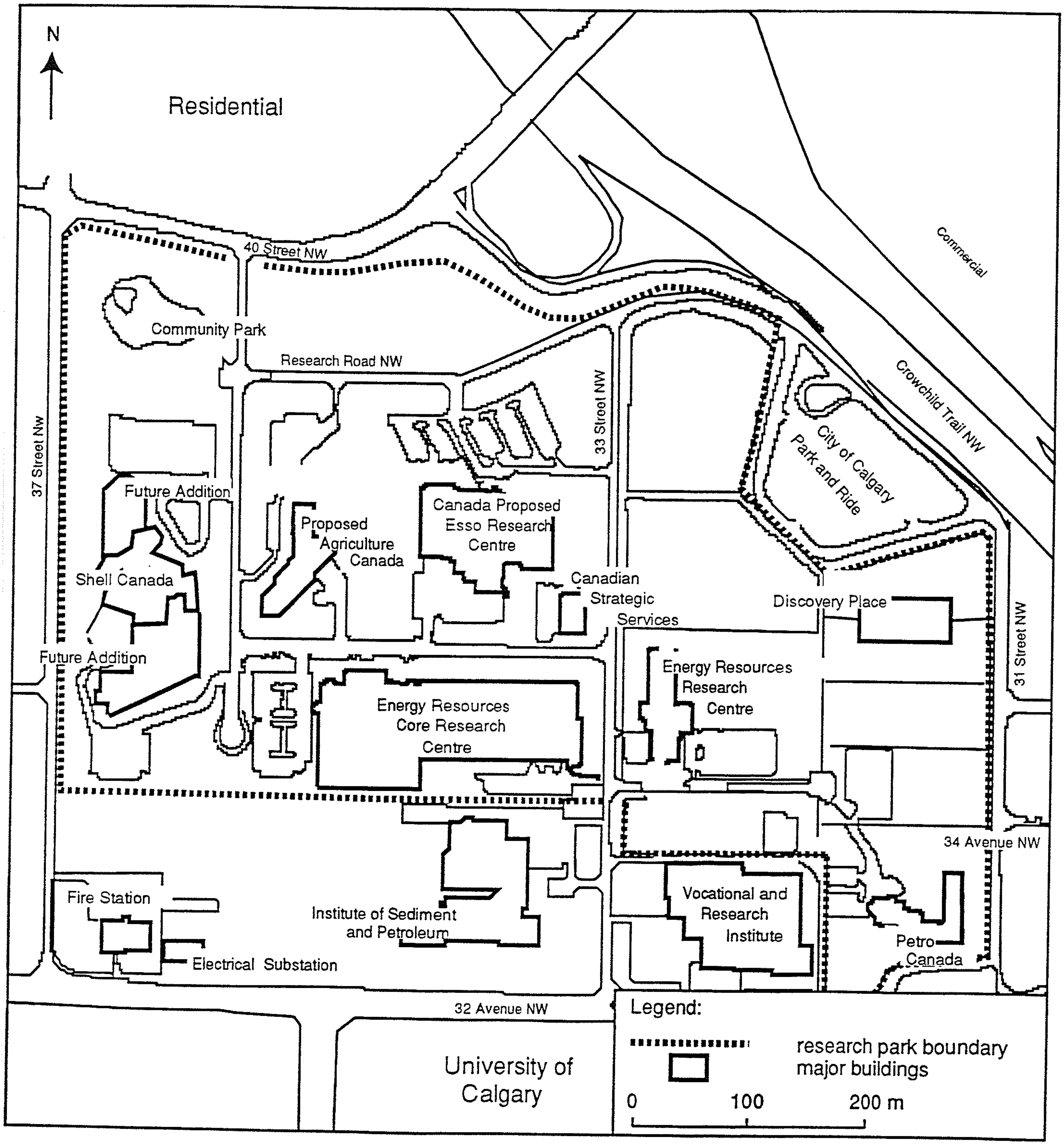
2.4.6 The University of Calgary Research Park

Like other industrialized countries, Canada has also adopted science-park infrastructures in its industrial strategies. The most prominent of them in promoting electronics industries are the University of Calgary Research Park in Alberta and the Innovation Place of Saskatchewan.

The University of Calgary Research Park was established in 1966, and is the oldest science park in Canada. Situated on a planned site of 51 hectares, immediately north of the complex of buildings which houses the Science and Engineering Faculties of the University of Calgary (Figure 2.5), it provides supporting facilities for high-technology firms. The major facilities in the park comprise an innovation centre, namely, the Technology Enterprises Centre, and other research organizations. The Technology Enterprises Centre occupies two buildings: the Discovery Place and the Digital Building. They occupy some $2{,}880m^2$, with room for up to 50 enterprises in units from 14 to $180m^2$ each. The main function of the

Figure 2.5

The University of Calgary Research Park



Centre is to provide affordable space with office services, access to funding and technology, and on-site business counselling geared to the wants of the start-up or research-intensive firms. On-site services are augmented with seminars and services provided by consultants, legal firms and "friends" of the Technology Enterprise Centre, often at no cost to the tenants. The major research institution for the support of electronics firms is the Alberta Microelectronics Centre.[26] The park also hosts the Canadian Institute for Advanced Research to serve as a link to facilitate technology transfer between private firms and research organizations.

Currently, the park houses some 30 firms. More than 900 individuals, mainly professionals, work in the park (AURRP and IASP, 1991).

2.4.7 The Innovation Place of Saskatoon

Established in 1977, the Innovation Place is the second oldest science park in Canada. Initiated as a cooperative project between the Saskatchewan Economic Development Corporation (SEDCO)[27] and the University of Saskatchewan, the Innovation Place is mandated to foster on-site high-technology firms, essentially electronics and biotechnology activities, through the encouraging of more interactions among companies, universities and government research organizations. The facilities and the land of the park are operated on a commercial basis, but plans are subject to the approval of the University of Saskatchewan.

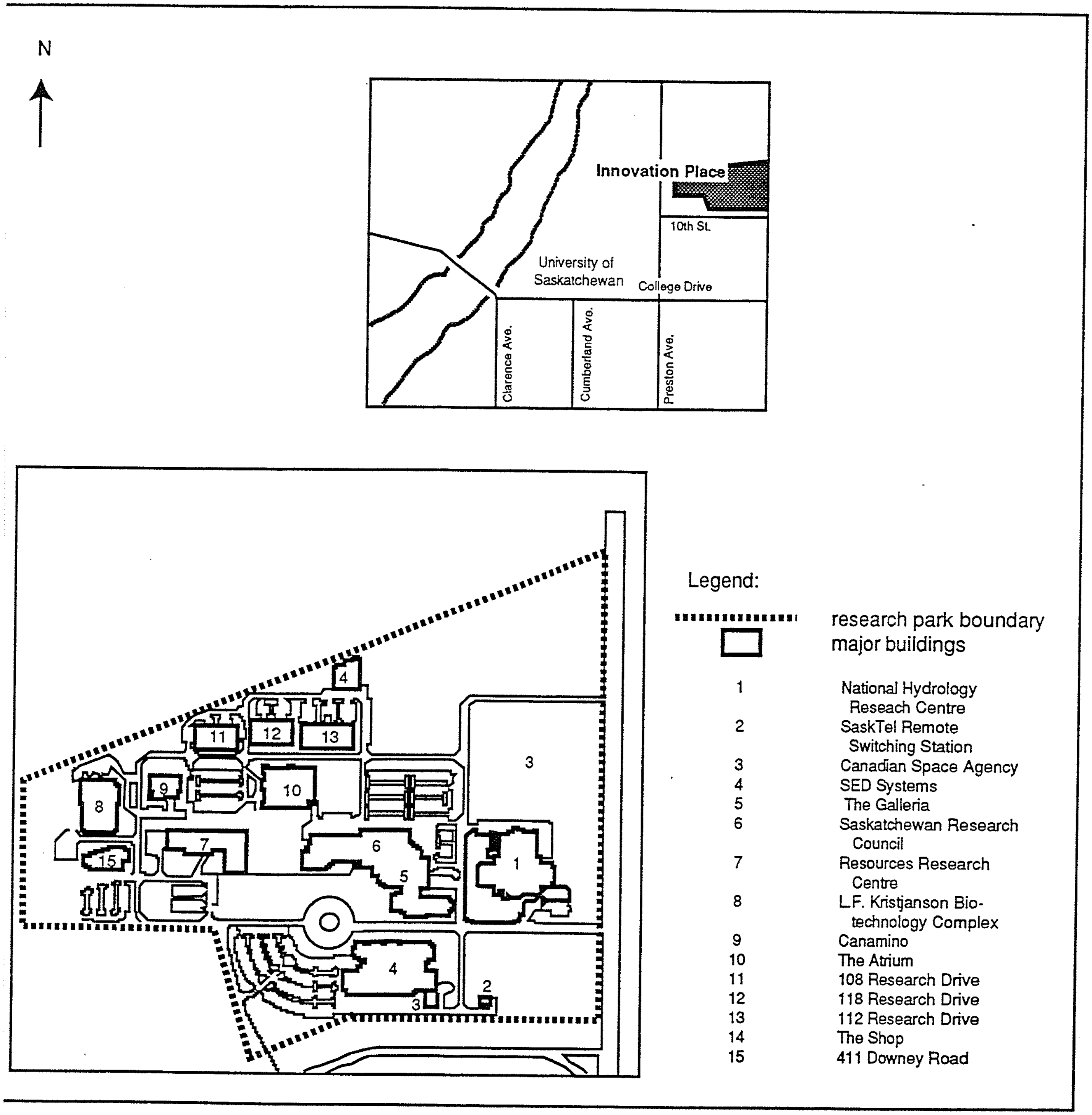
The Innovation Place sits on a planned site of 49 hectares, adjoining the University of Saskatchewan (Figure 2.6). The supporting facilities include a number of research agencies such as the Saskatchewan Research Council, a government research organization dedicated to the application of science and technology to the province's industrial development. There is also an innovation centre, namely, the Atrium, a three-storey, 9,630m^2 modern building, providing office and laboratory space for research companies. There are also private

[26] *The Alberta Microelectronics Centre is a government research centre. Equipped with 10 staff, and computer equipment valued at 150,000 Canadian dollars, it provides education and consulting assistance in the areas of design of semi-custom very large-scale integration (VLSI) chips, sensors and controllers and other semi-custom micro-systems for regional companies.*

[27] *The SEDCO is a provincial crown corporation which is also running ten other industrial parks in the province. SEDCO has a long-term lease of land (some 32 hectares) in the Innovation Place from the University of Saskatchewan. It is totally responsible for the planning development, construction, marketing, operations and maintenance of the land and buildings of the Innovation Place.*

Figure 2.6

The Innovation Place



and government agencies which provide business consulting services for the start-up electronics firms on site. Such agencies include the Centre for International Business Studies, the Innovation Place Business Centre, and the Saskatchewan Business Consulting Services. In 1991, this science park hosted some 51 firms, employing 1,160 people on site (AURRP and IASP, 1991).

2.5 Summary

Although a number of science parks are operating reasonably satisfactorily in a number of countries, some authors are still quite sceptical about the abilities of science parks to promote high-technology enterprises. Schamp (1987), for instance, found that 50 percent of the science parks in the U.S.A. have attracted only very few enterprises on site. He concluded that those parks "do not seem to be an appropriate instrument" for a rational regional policy. This kind of conclusion will immediately invite outbursts of counter-arguments. Apparently, the other side of the observation is that the number of successful cases has been as many as the failure cases in terms of tenant growth rates of the parks. Furthermore, the successful half have strongly displayed the possible agglomeration impacts that they can bring about. The second-half fail because they simply lack the ability of drawing more tenants into the parks. The principal concern here is the capability of the management teams to meet the mandated functions of the parks rather than the stock of the physical inventories of the parks. The performances of the parks simply mirror the qualities of the management teams involved. Understandably, the inability of most science parks to attract tenant firms may be occasioned by an inadequate conceptual understanding of these scientific infrastructures by their management teams, and/or regional planners. Besides, very often, these scientific entities are superficially defined on the basis of their physical appearance, simply on account of their possession of good quality landscape or numerous research facilities such as universities. In this respect, the neglect of the functional roles of science parks as nursery beds for start-up firms in the high-technology sectors is a common phenomenon. It suggests that failure to recognize science parks as agglomerations of innovative activities is widespread even in planning circles. In the absence of such a conceptual understanding, identification of the major elements contributing to the clustering of innovative activities within the science parks is not possible, not to mention the implementation of effective measures by regional planners to attract tenant firms on site. It follows, then, that if science parks are to be successfully developed, it is absolutely crucial that the park management acquires an understanding of the agglomeration of industrial activities, particularly the innovative activities. Above all, this chapter helps to clarify the confusing images and perceptions of science park infrastructures. Though some successful cases have borne witness to the possible industrial benefits which they may engender, the exact agglomeration processes have received little attention. This kind of negligence cannot be excused if the science park is to be upheld as an instrument of regional development. In order to grasp such an understanding, it is necessary to examine many of the tenets fundamental to industrial location theory, and that leads us into the next chapter in which the theoretical underpinning of this thesis will be explicitly spelt out.

Chapter Three

The Behavioural Paradigm of Location Theory and Concepts Relevant to the Agglomeration of Innovation Activities

3.1 Introduction

Location theory is a well-established body of principles developed for the explanation and prediction of the clustering of economic activities (Markusen et al., 1986; Goodall, 1987). In particular, its behavioural paradigm, first developed in the mid-1960s, has emerged as the most popular framework for the explanation of industrial agglomeration, and, by extension, the growth of innovation activities in recent decades (Walker, 1975; Massey, 1978; McDermott and Taylor, 1982; Wood, 1987; Thomas, 1987). This chapter will look into the evolution of location theory since it progressed from the traditional, normative paradigm to the contemporary behavioural paradigm. To start with, a section briefly reviewing the normative paradigm and its pitfalls will explain the reasons for turning to the behavioural paradigm where frameworks covering innovation activities are required. Within the behavioural paradigm, however, there are several contenders vying for pride of place. Accordingly, it is necessary to devote multiple sections to reviewing such concepts as the Marxism perception, business-cycle theory, the product life-cycle perspective and, eventually, the industry life-cycle notion. In due course, critical evaluations of each of these contesting conceptions with respect to innovation activities have led to the conclusion that the industry life-cycle is the most appropriate framework for handling the phenomenon in question. The end product of this chapter is the production of some hypotheses based on the industry life-cycle conception for empirical verification.

3.2 The Normative Theorem

3.2.1 A Review of the Normative Paradigm of Location Theory

The normative perspective, widely known as neoclassical or least-cost location theory, the earliest principles of location theory, is what the capitalist world accepts as mainstream industrial analysis (Webber, 1972; Smith, 1987). The generally recognized founder of normative industrial location theory was Alfred Weber (Smith, 1987). His work was originally published in Germany in 1909 and translated into English in 1929 (Chapman and Walker, 1987). In the late nineteenth and early twentieth centuries, the gravitational "centre" of the Weberian school of research was located in Europe and expressed mainly in the works of Palander (1935). By the mid-twentieth century, the idea was diffused to North America where it underwent extension and refinement and became a well-established conceptual framework through the writings of Hoover (1948), Greenhut (1952; 1956) and Isard (1956).

Fundamentally, the normative paradigm is built on an overwhelmingly important assumption: perfect competition. Under conditions of perfect competition, the prices of outputs and the costs of production or inputs are static with no variation over space so that firms can freely compete against each other (Goodall, 1987). By the same token, there exists a homogeneous production environment and perfectly-informed decision-makers. By homogeneous environment, it is meant that there exists an isotropic plain with insignificant spatial variation in the political, economic, technological or cultural systems (Hamilton, 1978). Meanwhile, the perfectly-informed decision-makers are equipped with all relevant knowledge and, hence, with full assurance in their decision-making process[28] concerning the production of firms (McDermott and Taylor, 1982; Smith, 1987). Given these *perfect information conditions*, the normative paradigm suggests that the achieving of the goal of cost minimization is the major issue concerning managerial personnel decision-making process and the key to industrial growth (Smith, 1987; Chapman and Walker, 1987).

Accordingly, the goal of cost minimization can be achieved through three major strategies, namely, internal economies of scale, economies of scope, and external scale economics. Internal economies of scale, commonly referred to as "increasing returns to scale", "economies of mass production" or "bulk economies", is the achieving of cost minimization through mass production which, in turn, rests on the process of organizational restructuring, itself based

[28] *The decision-making process can be envisaged as a conscious, ordered human process through which problems or goals are identified or the optimum alternatives are chosen for solving unique problems or for moving towards a desired state of affairs; more simply, for achieving particular goals (Cyert and March, 1963; Shull et al., 1970; Tosi, et al., 1986). It is often used as a synonym for other terms such as problem-solving, goal-achieving or strategy-selecting or implementing procedure.*

on the labour process[29] (Weber, 1929; Samuelson, 1976; Chapman and Walker, 1987). It is incumbent on the employing of staff with specific skills such as in engineering, finance or marketing. Only by employing these professional workers is mass production or efficient production possible. In such cases, the costs of production will be lowered (Reekie and Allen, 1983).

Economies of scope is the process procuring minimization of costs through the combination of production lines of corporations which arise from organizational restructuring such as that involved in vertical integration[30] (Panzar and Willig, 1981; Goldstein and Gronberg, 1984). In vertical integration, for instance, involving the acquiring of sales firms or the integration of sales agencies into the manufacturing corporations, the transaction costs of going to the market such as those concerning the searching for prices, closing contracts, collecting payments, communicating work specifications, and so on can be avoided (Clarkson and Miller, 1982). Vertical integration also involves the utilization of slack resources (the underutilized production inputs) in the production process. Very often, the inputs for the production of one commodity are very specialized with varied competencies and, hence, are indivisible or non-transferable to other tasks. For instance, an accountant can rarely be transferred to a market research man's desk and perform his job with the same competence as a marketing specialist (Reekie and Allen, 1983). These types of specialist resources are often hired with, or built onto a larger productive capacity that exceeds the needs of production for the purpose of preparing for expansion of outputs in the immediate future of firms. When such indivisibility and under-utilization of production capacity occurs, inefficiency of production will result. Clearly, it is inefficient to use a highly-qualified accountant or market research specialist for two and a half days out of five and, because inadequate work is available, to employ them as a bookkeeper or delivery man respectively on the remaining two and half days (Ibid.). In such cases, these specialists, being underutilized, become the

[29] *The labour process, also known as division or specialization of labour, is defined as the fine-tuning of labour tasks through the formation of specialized sections or units within firms.*

[30] *Vertical integration refers to the linear consolidation of formerly independent firms operating in the entire spectrum of production and distribution stages of a certain product under one single firm through merging or acquisition (Clark, 1985; Shepherd, 1985). Merging is the absorbing or the buying out of other firms to form a new larger firm (in some cases the uniting of more than two firms at once). Acquisition, also known as the taking over procedure, on the other hand, is a more aggressive buying-out behaviour in which one firm seizes another against its managers' will. In such taking-over circumstances, the acquiring firm makes a sudden "tender offer" to buy the target firm's stock at a price well above the going price. If it gains 51 percent of the stock, the target firm is taken over and absorbed into the acquiring firm (Shepherd, 1985).*

slack resources of the corporation. Involving them in more production processes, however, means that these slack inputs can be utilized to a fuller capacity, resulting in efficiency and cost saving (for more examples, see Keyyey and Brooks, 1991; Isaksen, 1994; Nonaka and Takenchi, 1995).

External economies of scale, commonly denoted as agglomeration economies, is the achieving of cost minimization through the locating of firms within or adjacent to a large cluster of supporting activities (Toyne, 1974; Goodall, 1987). External economies of scale can be broken down into two major types: localization economies and urbanization economies (Hoover, 1948). Localization economies, also known as the benefits of industrial linkage, are the minimization of costs through the locating of firms in close proximity to their market participants such as their suppliers, customers and competitors (including firms in similar activities) (Richardson, 1971; Keeble, 1976; Chapman and Walker, 1987). Urbanization economies, also known as regionalization economies, are the minimization of costs occasioned by locating firms alongside the more general supporting activities which are potentially available to any firms irrespective of the industry to which they belong (Scott, 1980; Smith, 1981). In doing so, the physical distance between the industry and its supporting activities is lowered. In turn, the costs of production will be reduced as well. For instance, because of its close proximity to suppliers, the industry can swiftly obtain the required inputs for production. By the same token, closeness to academic institutions allows industries to quickly obtain the type of labour that they want (Goldstein and Gronberg, 1984).

3.2.2 A Critique of the Normative Paradigm

There is no question that normative theory has been a useful conceptual instrument for understanding the agglomeration of industrial activities (Bale, 1976). However, its framework is not without flaws and recognition of its shortcomings has been commonplace since 1960 (Walker, 1975).

Criticism of normative theory tends to centre on its assumption of perfect information. In accord with this thinking, entrepreneurs are rational individuals equipped with complete information in their decision-making process concerning the well-being of the corporations.

This implies that the availability of knowledge or skills to entrepreneurs is, in effect, a constant rather than a major explanatory variable accounting for the growth of industry. On this account, normative theory has been criticized in that it is totally unrealistic to assume that all entrepreneurs possess superhuman feats of knowledge in their decision-making process and that the availability of information is completely insignificant in affecting industrial survival. In reality, it is the situation of imperfect information rather than perfect information that forms the actual environment governing the mechanisms of industrial clustering. Chapman and Walker (1987, p.18), in recognizing the prevailing conditions of imperfect information, claim that "no individual can, in reality, possess such ominiscient powers." Far from being all-knowing, as the normative point of view assumes, entrepreneurs are, indeed, individuals with bounded rationality or who act with uncertainty or hesitations caused by the absence of perfect knowledge; that is, knowledge of all relevant circumstances in carrying out all their decision-making process concerning the well-being of the production process and, hence, the agglomeration of economic activities (Dicken, 1971; Riley, 1973; Hamilton, 1974; Szilagyi and Wallace, 1980). Entrepreneurs, for instance, often are deficient in grasping real market situations; instead, they have to predict the level of demand for their products. Obviously, this means that entrepreneurs have to adjust their market expectations through their decision-making processes from time to time. In the case of big deviations between their predictions and realities, their production process will be jeopardized and, hence, the survival of the firms will be at stake. In this respect, Hirsch (1967) states a truism that "all decisions are made with imperfect information" (op. cited in Federico, 1985, p.66). Waterson (1984), in corroboration, observes that even the "peak coordinator", that is, the decision-maker within a large joint-stock company who is in a position from which he or she can control important aspects of the external environment of the firm, including the price of inputs such as materials, or costs of labour, does not possess perfect knowledge.

The assumption of perfect information conspires to deny the importance of the availability of information in the decision-making process that ultimately determines the survival of firms. The availability of information will shrink entrepreneurs' uncertainty in the course of planning, development and production. "Without the proper flow of information, it is impossible to ... plan an organization's future objectives in a rational way" (Federico, 1985, p.141). Put bluntly, "information is a prerequisite for innovation ... " (Dieperink and Nijkamp, 1987, p.67). When Ellwein and Bruder (1982) studied Western Germany, they noted that innovation problems turned out to be information problems (cited in Kok and Pellenbarg, 1987). In view of these reservations, researchers have recognized that the availability of information is particularly important to the performances of innovation activities.

In sum, the normative paradigm has been severely criticized on account of its unrealistic assumption of perfect information. It has been downplayed by critics as being too "abstract" and "desk-bound" (Smith, 1971). Others argue that it produces an "outdated view of the industrial world" and has become increasingly unconvincing and has limited value in explaining modern industrial development, specifically the agglomeration of high-technology industries (Malecki, 1985; Vaughan and Pollard, 1986). Responding to such inadequacy, the behavioural approach has surfaced. This approach rejects the assumption of perfect information. Instead, it focuses on the maximization of information flow that reduces uncertainty of the decision-making process of entrepreneurs. The reduction in production costs becomes a consequence of the degree of mobility of information flow. As a matter of fact, this approach has become a major framework in the explanation of industrial clustering in recent decades, as the following section will explain.

3.3 The Behavioural Paradigm on Industrial Agglomeration

In contrast with the normative paradigm, the behavioural paradigm is built on the assumption of imperfect information. In this case, entrepreneurs are individuals who possess partial knowledge of most of the information relevant to the operations of firms and they actually face a great deal of uncertainty in their decision-making process. Given this condition, if uncertainty and, hence, riskiness in the decision-making process of entrepreneurs are to be reduced and corporations to prosper, effective and efficient acquisition of information become imperative and, hence, the achieving of learning economies is important (Tornqvist, 1968, 1970; Pred, 1974; Westaway, 1974). As opposed to the normative paradigm, then, the behavioural approach emphasizes the importance of the availability and application of all kinds of information. The success of entrepreneurs then depends upon the manner in which they gather or interpret the information known to them. Different kinds of information gathered or interpreted will mean different types of behaviour of entrepreneurs and different locational outcomes.

Formally, learning economies are then recognized as either internal, external, or entrepreneurial learning economies. Internal learning economies, also known as organizational learning economies, are the efficiency gained through systematic acquisition of knowledge by organizational restructuring of firms from within (Harrington, 1987; Morphet, 1987). For their part, the type of efficiency derived from regular acquisition of information from local institutions is labelled as external learning economies, while, entrepreneurial learning economies are the benefits induced by the fast and precise collection of information by the decision-makers or the top management within firms.

Internal learning economies can be achieved by processes such as those focusing on the division of labour. From the behavioural perspective, the labour process involves a hierarchy of authorities. Managerial officials of each specialized unit are accountable to their immediate superiors, or top management, such as presidents, owner-entrepreneurs, or general managers; in turn, these superiors are responsible for their subordinates' decisions and actions as well as their own (Zaltman et al., 1973). Within such a hierarchy, mid-level managerial personnel, as part of their routine operations, have the responsibility of presenting a full account of all relevant knowledge acquired by themselves or their subordinates to top management (Dicken, 1971). For instance, the manager of the R&D division should be actively involved in analyzing data, accessing new facts or knowledge learned from external sources, such as government agencies, other companies, and university institutions for the improvement or development of new products or processes, and in reporting the results to those higher up in the hierarchy (Katz and Kahn, 1966). Likewise, the manager of the marketing unit should be obliged to report regularly to his or her boss what he or she has done, what those under him or her have done, what his and her peers have done, what he or she thinks needs to be done, his or her problems and the problems of his or her unit, and about matters of organizational practice and policy on the promotional campaigns of the products (Scott, 1981). Furthermore, managerial personnel of different divisions may be compelled to keep records of performance or to retain records of alternative solutions and report these to top management on a regular basis.

For instance, managerial personnel of the production division should calculate and keep summary figures for all the lower units reporting to them; to say nothing of providing a summary for the echelons above them, most notably, the general managers of the organization. These reporting formats may be in simple written form such as the daily operation schedule indicating the timing of the operating process, or in more complex written layout such as the annual summary of the operation units and the occasional research studies of particular projects relating to the functioning of companies or, even in the form of verbal presentation in various boards, conferences, councils, committees, and staff meeting within corporations (Katz and Kahn, 1966).

At least three major advantages can be inferred for such a system of reporting with respect to acquisition of information. First of all, since these reporting processes are operated on a regular basis, new information has to be acquired constantly. Such information becomes more readily and quickly available to owner-entrepreneurs or top management. Secondly, the reports are usually prepared by specialist staff members who have expertise in appropriate divisions. For instance, firms may have economists and political experts in their staff team who are skilful in conducting detailed and in-depth marketing analyses and who are capable of exploring and identifying relevant information in relation to the changing political and social and economic forces in the external environment that may have immediate or long-range impacts on the marketing strategies of firms. Equipped with sophisticated logistic management techniques such as econometric modelling and statistical analysis methodologies, these specialists are able to seek precise information and to provide advice to counter the doubts that plague decision-makers (Meltzer, 1981). Manipulated by the distinctive competence of these specialists in the information acquisition process, the information gathered by them is much more objective and less inclined to conform to the idiosyncratic perceptions or personal biases of decision-makers. Lastly, and most important of all, the reporting system may serve as a mechanism supplying entrepreneurs with feedback information.[31] Through use of the system, entrepreneurs apply the new information supplied from below to update the original information and then to determine new operational policies or strategies. The cycle continues as new feedbacks are passed to entrepreneurs from below from time to time. Such feedback loops supply entrepreneurs with new information in a continuous and unbroken manner (Dicken, 1971). Consequently, the extent of uncertainty will shrink as entrepreneurs learn more and more from the new, feedback information. It follows that lengthy and haphaz-

[31] *Feedback information is the amount of information that an individual receives about the results of his or her job. Specifically, it refers to the knowledge that an entrepreneur obtains from the performance of his or her previous decision-making processes (Szilagyi and Wallace, 1980; Tosi et al., 1986).*

ard information searches will take less time and internal learning economies will materialize. In other words, the feedback loop helps to improve the way that information is collected as well as the quality of information being gathered.

Apart from adjusting the labour process, vertical integration is another major organizational restructuring process that internalizes information that once existed outside the firm. Through acquisition or merging procedures, firms are able to extend their internal control over related upstream or downstream activities. Under such control, these former competitors or supplier firms have, in effect, become the branch plants of the newly-reorganized corporations. In consequence, a hierarchy of authority and a reporting system is formalized between the predator and the acquired or merged firms. In brief, the extended reporting system has created a new "contact system"[32] that allows the now enlarged internal operations to be run efficiently through a more sophisticated reporting hierarchy.

Regarding external learning economies, they can be procured by locating industries in the closest proximity to their market players and other specialized facilities or services directly or indirectly related to the operations of firms. Because of the distance-decay effect,[33] close proximity to all these will encourage constant interactions; that is to say, face-to-face contacts between entrepreneurs on the one hand and specialists outside firms on the other. By being sensitive to their facial expressions, seating positions and emotional intent gestures of the specialists or the display of visual materials (e.g., diagrams and documents), entrepreneurs during these face-to-face meetings may detect the reliability of the message received (Goddard, 1970; Szilagyi and Wallace, 1980). At the same time, it is often possible to solicit questions of clarification from the specialists to avoid misunderstanding and ensure

[32] *A contact is the transmission or exchange of information between two parties (Katz and Kahn, 1968; Goddard, 1970; Szilagyi and Wallace, 1980). Contacts can be classified into three major groups, namely, face-to-face contacts, technical-device contacts and correspondence contacts. The channels for face-to-face contacts include informal meetings such as visits and social gatherings such as luncheon meetings, drinking and golf playing. They can take the form of formal meetings such as conferences and seminars. The channels of technical-device contacts include electronic communications such as "telephones", "confra-phones" (the telecommunications devices enabling the linking up of several telephone calls onto one circuit), and "Confra-Visions" (the electronic devices which use closed-circuit television for relaying vision between meetings and video-phones already incorporate a small picture into the conventional telephone) (Goddard, 1970; Fernie, 1977). The channels for correspondence contacts are letter and magazine posting. A contact system, then, refers to a network or a formulation of such channels through which transmission or exchange of information between two parties are possible.*

[33] *The distance-decay effect is a fundamental concept in Geography. It is the effect that distance imposes on the degree of interaction between two points in space. It suggests that as the distance between two points increases, the intensities of interaction between them will decrease and vice versa (Goodall, 1987).*

that information gathered is geared to the proclivity of entrepreneurs. In this respect, these face-to-face contacts make the process of information acquisition a two-way channel or a feedback mechanism through which entrepreneurs can check the accuracy and reliability of information delivered to them. Such a learning process is "organic" rather than "mechanical" in interpreting the information intercepted.

As far as the economies of entrepreneurial learning are concerned, the existence of entrepreneurship is the crux of the whole concept. Leibenstein (1987) has broadly defined entrepreneurship as the capacity of individuals to put forth ideas for the sake of product innovation or improvement. To Thomas (1987), entrepreneurship is conceived as the behaviour of an entrepreneur which results in the commercial production of a product and/or process of innovation. The entrepreneur may be a single person or a specific group of persons responsible for making the crucial investment and long-range strategy decisions. Entrepreneurship takes into account the personal traits of decision-makers such as experience, educational backgrounds, family backgrounds and mental or psychological state (such as enthusiasm, motivation and creativity), traits which allow them to take effective initiatives to acquire information essential for production.

Some writers have emphasized the importance of experience in entrepreneurial learning economies. As Miller and Cote (1985) see this, the experienced entrepreneurs have usually established good friendship ties with other industrial participants such as external advisors (for example, academics, lawyers, and bankers), suppliers and potential buyers of their commodities, business acquaintances, friends, previous employers, accountants, and government officials. Because of good friendship ties, a broad network or contact system of information arises which promises numerous communication channels such as golf clubs, seminars or conferences allowing frequent contacts between entrepreneurs and other industrial participants. As such contacts increase, different types of information required for production innovativeness are there to be tapped by the experienced entrepreneurs.

In sum, the behavioural paradigm, by rejecting the assumption of perfect information known to entrepreneurs, claims that entrepreneurs are imperfectly informed. Owing to their lack of full information, they constantly face uncertainty throughout their decision-making process. In order to reduce all those uncertainties in the decision-making process and, hence, the riskiness of business operations, entrepreneurs seek various means of collecting and intercepting essential information. The whole procedure is to reap the benefits of learning economics. The restructuring of organizations, the locating of firms with respect to their markets and other supporting facilities, and the quality of decision-makers will all make the acquisition process more efficient and precise. By organizational restructuring, such as that associated with the division of labour and vertical integration, a hierarchied contact system or reporting system is established to facilitate the mobility of information flow within corporations. By means of close proximity to markets, the physical distance between entrepreneurs and other professionals will be minimized. Face-to-face contacts between the two parties are made much more convenient. In due course, entrepreneurs will gain their experience through all these contacts, both within and without their firms. Accurate information permits them to run their businesses more efficiently and effectively than ever. If entrepreneurs of industries act in concert, then they would also reap the benefits of the agglomeration of the industries, namely, external learning economies. By then the costs of production will be lowered, not simply because of the lowering of input costs but more importantly because of the efficiency gained from the speedy mobility of information within firms and among firms. In all these respects, the behavioural paradigm is favoured by many writers as a more appropriate approach to depict the mechanisms governing modern industrial activities.

3.4 The Contestants for the Behavioural Paradigm

Recently, numerous behavioural theories have emerged to explain the agglomeration of innovation activities. The Marxist view and the business-cycle concept are the two most popular claimants (Kingston, 1984).

3.4.1 The Marxism Conception

The Marxist approach is known as the political or radical industrial perspective. It has its origins in the powerful socialist thinkings embodied in the writings of the German economist Karl Marx. His *Das Kapital* and *Communist Manifesto*, to say nothing of his disciple Lenin's *Imperialism: The Highest Stage of Capitalism*, constitute the core of the concept (Hamilton, 1978; Smith, 1981). Notwithstanding their long existence, these writings were ignored by mainstream industrial economists of the capitalist world until fairly recently. For instance, Weber, the founder of industrial location theory, did not incorporate even a mention of Marxist notions in his writings. Ironically, the writings of Karl Marx and Frederich Engels, and many of the published sources used by Lenin, were available in Weber's native German language before 1909, the year in which Weber's work, the *Theory of Industrial Location*, was published (Hamilton, 1978). In the view of many authors, political and ideological conflicts are the two main obstacles to the diffusion of Marxist-Leninist ideas in the capitalist world (Ibid.). The introduction of Marxist-Leninist thinking is perceived to be unacceptable because (1) "it conflicts with their (conventional) conservative views, vested interests or acclaimed national ideals", and (2) "they identify the translation of Marxist-Leninism into practice with the "siege situation" of the Soviet Union during its phase of socialism in one country" (Hamilton, 1978, p.3). Hence, the lone "socialism" of the time was erected by military seizure and was disparaged in consequence by democrats. Such political, and to a greater extent, belligerent overtones of Marxist-Leninist thinking may then be interpreted as a movement to end capitalism by violent means.

However, in the face of massive closures of factories and the skyrocketing of unemployment rates in Europe and North America in the 1960s, many writers became aware of the Marxists' prediction of the downfall of capitalism. They began to take note of the precepts underlying Marxist thinking. At the same time, many behavioural theorists were beginning to accept the idea that the political system in general predetermines the market system and social systems. Hence, the Marxist political notion of industrial growth gained ground in the behavioural paradigm at this time. In effect, this represents a radical shift in philosophy in the study of industrial growth (Massey, 1977; Storper, 1981; Massey, 1985; Atkinson and Coleman, 1989).

In general, the Marxist framework sees the key factor governing the agglomeration of innovation activities as the capitalist political system itself. Capitalism is recognized as the political system in which general production of commodities of societies is based upon private enterprises. Most important of all, the whole system is driven by the bourgeois group, the selfish and greedy individuals who share the ultimate goal of profit-seeking, or, in Marx's term, the "accumulation of capital" (Goodall, 1987). In the light of the Marxist theorists, the bourgeoisie account for the spawning as well as the downfall of innovation activities. Under the pressures of capital accumulation, the bourgeoisie would participate tirelessly and endlessly in any activity that promotes production efficiency. Marx (1848) has claimed notably that "the bourgeoisie cannot exist without constantly revolutionizing instruments of production ..." (cited in Hamilton, 1978, p.3). In this regard, multitudinous appearances of novel means of production or new technologies and, hence, new firms would indisputably be a prevalence rather than a rarity in every capitalist economy.

The bourgeoisie, as stated, are responsible for the outburst of innovation activities. Paradoxically, however, they may also lead to the collapse of these activities. To bring the goal of capital accumulation into fruition requires constant innovating of production means. On the other hand, it also demands continual expansion of market share and, hence, the achievement of a monopolistic market. In *Das Kapital*, Marx states that "The need of a constant expanding market for its products chases the bourgeoisie over the whole face of the globe. It must nestle everywhere, settle everywhere, establish connections everywhere. The bourgeoisie have, through its exploitations of the world market, given a cosmopolitan character to the production and consumption in every country ... industries no longer work with indigenous raw material but draw material from the remotest regions, industries whose products are consumed not only at home, but in every quarter of the globe .... In place of the old ... national self-sufficiency we have ... a universal interdependence of nations." (cited in Hamilton, 1978, p.3).

The ultimate weapon utilized by the bourgeoisie for the maintaining of their monopolistic power in the marketplace is the establishing of multi-national or transnational firms. Lenin adduced innumerable examples drawn from official, statistical, corporate or other published sources to demonstrate the emergence of multi-nationals in the then contemporary capitalist economies. He claimed that American and German capitalists had created "two 'Great Powers' ... GEC [34] and AEG (German General Electric Company), from which no other electrical firm in the world is completely independent ... and spawning subsidiaries in 'new' countries and in other branches of industry" (cited in Hamilton, 1978, p.4). This observation was extended to other industrial activities such as oil, steel, mining and automobile activities (Ibid.).

[34] *For GEC, Lenin meant GE. GEC is a separate UK firm.*

Multi-national firms originally surfaced in nineteenth-century England at a time when the civilians of the country were suffering from hunger and unemployment induced by catastrophic downturns in the trade cycle. Under this situation multi-national firms became a solution to pressing economic problems. The political bourgeoisie were encouraged to expand the domestic market to overseas. Lenin quoted Cecil Rhodes (whom he described as a somewhat more honest social-chauvinist) as saying " ... after attending a meeting of the starving unemployed in London's East End, in 1895 that ' ... to save the U.K. from a bloody civil war, we colonial statesmen must acquire new lands for settling surplus population, to provide new markets for the goods produced in the factories and mines ... '" (cited in Hamilton, 1978, p.5). These multi-nationals were nurtured on public grants and privileges by the governments of the day to solve the economic crisis of the country (Ibid.). Therefore, they had the economic and political muscle to appear almost everywhere and constantly expanded their markets for selling their products. They established numerous subsidiaries and marketing channels, reaching not only to domestic markets but to those overseas. By the same token, fast growing multi-nationals found it easier to develop monopolistic markets for their products. In their monopolistic markets, the multi-nationals may have exclusive control over the provision of their products, especially through price manipulation. Huge amounts of capital would be accumulated and repatariated to the home country. The wealth of the nation would be safeguarded and the exigent national economic problems then solved.

Without doubt, multi-nationals can engender widespread capital accumulation for the bourgeoisie. It has been often cited by researchers that the sales of these corporations are so great that they often have annual revenues equivalent to or larger than the yearly GNPs of some of the industrialized nations. The annual sales of IBM, for instance, have been as large as the GNPs of countries such as Norway and Portugal (Fatemi and Williams, 1975). Sheer size makes these firms destabilizing agents in the economy. Their constant expansion and huge sales suggest an important source of power which rivals nations. With their strong financial muscle, these corporations often undergo organizational restructuring processes so as to control their external environment, maintaining their monopolistic power in the marketplace. In essence, Marxist economists tend to treat the variety of complex intra-organization arrangements, ranging from specialization of labour to vertical integration of production, as a theoretically unproblematic process carried out by multi-nationals to ensure their success. Through the process of backward or forward integration, such as acquisition of supplier or sales companies, these giant corporations may extend their authority or control to ever larger sections of their market areas, creating an extremely hostile environment for their competitors. On all counts, the smaller firms which are less advantageous in their financial or management strength than their counterparts have to face very keen competition in the marketplace. In *Das Kapital,* Marx (1867) vividly portrays how these sturdier and bigger enterprises, in pursuing efficiency, sharpen competition, acquire smaller, "available" or less efficient firms, put smaller capitalists out of business, concentrate businesses even more and create periodic over-production crises (cited in Hamilton, 1978).

Therefore, in order to impose control over multi-national firms and to lubricate the nurturing of innovative activities, the Marxists maintain that the whole crux of the problem depends on the role of governments as "arbiters", "entrepreneurs" or, simply, decision-makers among the industrialists (Hamilton, 1978; Massey, 1984; Onimode, 1985). For instance, governments may enact regulations such as the antitrust laws or legal restrictions, preventing the giant enterprises from engaging in the acquisition or the merger of activities. The control of these firms over the supply of technologies can, therefore, be reduced or eliminated. Moreover, government may assist innovation activities by means of incentives such as grants, loans or other fiscal privileges for the purchase of advanced technologies for production (Uri, 1982). Alternatively, they may develop or strengthen various infrastructures such as research laboratories or universities and facilitate the flow of on-the-edge scientific information to entrepreneurs. In this respect, innovation activities are given the opportunity to stand firmly against the possible exploitation of multi-national firms in market areas. In a way, the wealth of the nation would be maintained in the hands of the majority rather than the minority business elites.

In short, putting the foregoing assertions into context, Marxist theory highlights the dyfunctionalities of the capitalist political system as the major contraints impinging on knowledge-based activities. The economic-oriented bourgeoisie and their money-pursuing apparatus, multi-national firms, are the principal stumbling blocks to the perpetual advancement of innovative activities. Their yearning for market expansion and capital accumulation compels the bourgeoisie to establish giant companies for the tapping of monopolistic profits. Indisputably, survival of the innovative activities then acutely relies upon the well-defined roles of governments as regulators in the sustaining of a less antagonistic marketplace from which information resources can be secured without hindrance.

3.4.2 The Business Cycle Concept

3.4.2.1 The Emergence of the Business Cycle Concept

The business cycle concept has been labelled as long-wave theory, Kondratiev-wave theory, the Schumpeter approach, or trade cycle theory. It has its intellectual roots in the work of the Dutch economist van Gelderen in 1913 (Dicken, 1986). However, it is the Russian economist, N.D. Kondratiev's monumental labour – a paper titled "*The Long Waves in Economic Life*" of 1926, together with the work of Kuznets (1930) which present the definitive early scholarship on the notion of business cycle (Kondratiev, 1928, 1935, 1984; van Duijn, 1983; Dicken, 1986; Hall and Preston, 1988). It has been observed that aspects of business such as employment, production, wages, prices and profit levels of an area, nation or larger segment of the world appear to develop in cycles or repetitive oscillations, proceeding in a series of long waves and experience alternating periods of industrial boom and slump (Dicken, 1986). While all industries are affected, fluctuations are most marked in capital goods' production sectors (Goodall, 1987).

As far as Kuznets (1930) is concerned, in studying secular movements in production by various industries, he perceptively observed that over time there is a conspicuous slackening in the rate of increase in an industry's rate of growth. Kuznets (1930) notes that:

> "As we observe various industries within a given national economy, we see that the lead in development shifts from one branch to another. A rapidly developing industry does not retain this vigorous growth forever but slackens and is overtaken by others whose period of rapid development is beginning. Within one country we can observe a succession of different branches of activity in the vanguard of the country's economic development,

> and within each industry we can notice a conspicuous slackening in the rate of increase" (cited in Thomas, 1981).

In similar vein, Burns (1934) studied 104 continuous series of production trends of American industries beginning between 1870 and 1885 and ending in 1929. This study led to the formulation of his law of industrial growth: *"An industry tends to grow at a declining rate, its rise eventually followed by a decline"* (Burns, 1934, p.173).

Despite these general observations, the notion of the business cycle was still not yet fully conceptualized and was devoid of satisfactory explanations. Although Kondratiev (1928) had successfully identified innovation swarms as one feature of economic upswing in the cycles, he failed to see that this would provide the explanatory mechanisms that he was searching for. It was Schumpeter, after spending a lifetime accumulating the materials for his monumental, two-volume *Business Cycles*, of 1939, who christened these observations and put them into perspective (Hall and Preston, 1988). Schumpeter (1939) proposed that these business cycles were occasioned by a variety of exogeneous events such as wars, gold discoveries, harvest failures and, most important of all, the upsurge of "innovations" penetrating all segments of the economy. To verify his proposal, he identified three cycles of accelerated and decelerated growth between the 1700s and the 1930s. The first cycle, known as the "Industrial Revolution Kondratiev", which stretched approximately from 1785 to 1842, was brought about by developments in cotton textile manufacturing, smelting and refining of iron, and early applications of steam engines. The second cycle in this series, known as the "Bourgeois (or Railway) Kondratiev", occurring between 1842 and 1897, was induced by the diffusion of railways and the Bessemer process of steel-making. Finally, the chemical, electrical and motor vehicle industries brought forth the third cycle, known as the "Neo-mercantilist Kondratiev", which started in 1897 and was stilling running its course when Schumpeter wrote in the 1930s and 1940s.

Since the time of Schumpeter's (1939; 1942) writing, a very considerable amount of literature commenting on business cycles has appeared. The more recent contributions include those of Galbraith (1967), Mensch (1979), Mandel (1980) and Freeman and Soete (1982). These works have been largely devoted to authenticating Schumpeter's assertions.

For example, Galbraith (1967) contends that entrepreneurs are no longer vital, and that the force of innovation has become the principal motion for shaping modern economies. This force takes the form of new products and innovation production systems which are initiated, grow and eventually fall into obsolescence over the course of the product life-cycle. Mensch (1979), for his part, presented lists of innovations for various periods in the nineteenth and twentieth centuries and showed that innovations were clustered at the lowest troughs of long wave depressions. Freeman and Soete (1982), on the other hand, pinpointed as most significant the fourth (postwar) Kondratiev cycle associated with the upsurge of innovation products such as "electronics", "synthetic materials", "drugs", "oil and petrochemicals", and (especially in Europe and Japan) "consumer durables" and "vehicles" products. More recently, some authors have contended that the 1980s mark the beginning of the fifth Kondratiev cycle, which involves the emergence of microelectronics and associated information technologies (Hall and Preston, 1988).

3.4.2.2 Technological Changes and Innovation Activities

As far as the exact mechanism leading to the agglomeration of innovation activities is concerned, Schumpeter (1939) was the popularist laying blueprints for others to follow.

In his view, by offering super monopolistic profits, radical innovation commodities generate a strong "bandwagon effect", the attraction of a "swarm" of imitators or modifiers to exploit new openings in market areas. In a rolling wave of new entrants jockeying for a finite market, the level of growth in sales and profitability of new commodities of firms have become highly unpredictable. This will mean dangers to the survival of these corporations. Accordingly, the main concern of entrepreneurs has become one that resorts to rapid generation of new or improved products by advancing their production processes. As a result, it is hoped that barriers have been set to prevent the wholesale entry of competitors. Eventually, the firm is able to maintain sole control over its marketplace and can continue to reap monopolistic profits. Hence, the managerial emphasis of corporations has been shifted from traditional and routine operations to one that anticipates developments. As a matter of fact, during the first phase of the monopoly power over their innovative products, such firms will enjoy a very large profit margin. Needless to say, entrepreneurs are capable of exercising organizational restructuring such as specialization of labour or vertical integration. They are eager to employ specialists or to buy out other independent R&D activities so as to acquire or develop on-the-edge technologies for efficient production. In this regard, massive entry of competitors is blocked. The monopolistic profits and survival of corporations are maintained and guaranteed. Most noteworthy, the flare-up of innovation activities spawned by new technologies of existing industrial activities will follow. Hence, to Schumpeter (1939), the tenor of technological change dictates the decline and birth of innovation activities. The possible great profit margins of radical products will attract numerous combative imitators into the marketplace. In a way, these imitators cripple sales, profits and, hence, viability of existing innovation industries. At the same time, the fear of entrepreneurs being outclassed by imitators has driven them to launch barrier-to-entry tactics; that is, the development of innovative technologies and thereby the rapid generation of new commodities to bar potential or actual competitors from the marketplace. Schumpeter (1939) coined the expression "destructive creation" to describe this process.

3.4.3 Sectional Summary

To sum up, both Marxist theory and business-cycle theory have highlighted environmental conditions as the major constraints to innovation activities. Marxist theory emphasizes the nature of capitalism, its dominance by multi-national corporations, and the monopolistic competitive market structure which they create as the hostile environment in which small firms with, perhaps, their new products have to contend with in order to survive. Hence, efficient new product production would be the key to the survival game of these enterprises. Governments may play an active role in protecting new firms and the development of innovation activities. They could act as arbiters to issue regulations or implement incentives or infrastructures enpowering innovation activities against multi-nationals so as to attain learning economies.

On the other hand, business-cycle theory sees the environment facing the newly-emerged activities as one composed of plenty of predatory competitors and imitators of their new products. To protect their ongoing interests, firms not only have to conceive but they must do so at a rapid rate. In turn, the continuous production of "on-the-edge" products has imposed high barriers of entry to potential entrants and may also defeat sluggish competitors. Eventually, learning economies would have been attained by firms through organizational restructuring.

Above all, these two schools of thought have the merit of attempting to go beyond the general unrealistic assumption of homogeneous industrial space. They regard the performance of industries as manifestations of the environmental context of corporations. Putting this otherwise, rather than normalizing the differences in the environmental space or treating them as merely deviations from a tendency, these two schools elucidate the fact that the space economy is an unsystemic "mosaic of unevenness" and that microeconomic decisions (decision-makings of individual firms) are always made in the context of macroeconomic circumstances (exogeneous forces). As Smith (1981, p.142) observes, "the chief merit of the Marxist approach ... is its breadth which permits industrial location to be analyzed as an integral part of the totality of ... the political process."

The main flaw of these two theorems is their failure of recognizing the demand side of the market; that is, the needs of customers on the decision-making process of corporations. Numerous authors have pinpointed the fact that preferences of patrons rather than the presence of competitors has been the primary influence on innovations. As Gilpin (1975, p.65) notes,

> "Everything that we know about technological innovation points to the fact that user or market demand is the primary determinant of successful innovation. What is important is what customers or producers need or want rather than the availability of technological options. Technological advance may be the necessary condition for technological innovation and on occasion new technology may create its own demand but in general and in the short-run, the sufficient condition for success is the structure or nature of demand."

Similarly, Rothwell and Zegveld (1982, p.102) also assert that:

> "Between 70 and 80 percent of successful technological innovations arise in response to the recognition of a need of one sort or another. Where the innovation arises as the result of new-technology, the successful innovator determines that a need exists before he or she proceeds with the development, and, he or she establishes that the need is sufficiently widely diffused (that is, that the market is sufficiently large) for the innovation to be viable. The successful innovator mounts a comprehensive after-sales technical support service where appropriate. The successful innovator is aware of changing market conditions ... ."

In response to such inadequacy of the Marxist and the business cycle theories, the industry life-cycle concept featuring the demand side of the market; that is, the preference of customers, has emerged as the more appropriate and relevant theoretical framework to explore innovation activities.

3.5 The Industry Life-cycle Concept

3.5.1 The Industry Life-cycle and its Product Life-cycle Predecessor

The industry life-cycle concept has its origin in the product life-cycle notion. Hence, a brief review of the latter may help to throw light on the formation of the former.

The product life-cycle concept is a construct developed by Vernon and his students in the first instance to explain the trading patterns of various production activities of the U.S.A. in the 1960s (Norton and Rees, 1979; Dicken, 1986; Taylor, 1987).

The basic premise of this theorem is that a product will evolve through three distinct stages in its life cycle, namely, the "new product", "maturing product" and "standardized product" stages (Vernon, 1966). At the "new product" stage, an innovation product is manufactured in customerized or batch forms. At its "maturing" stage, the product is manufactured in mass production and it is during this stage that foreign sales expand in response to rising demand. At its "standardized" stage, the product will become obsolescent but it may continue to be produced in large volume.

The process that changes the degree of novelty of products, also known as changes of technical sophistication, has been recognized as the key to the distribution or location of various types of production activities among nations. At each stage, the product's technical sophistication varies in degree and has different technical and managerial requirements. By the same token, different stages of production of the product can be carried out at different places. This constitutes its character of global division of labour. Hence, the "new product" phase is mostly associated with the advanced countries such as the U.S.A., where engineering and scientific inputs are more readily available, and associated with knowledge-intensive production. In the second stage, the volume of outputs increases rapidly, necessitating greater managerial ability and access to capital for growth. High technical skill requirements begin to lessen. and the product can be produced either in the advanced or developing countries. On the other hand, in its "standardized" stage, the product has become standardized and its rate of growth also "stabilizes" or even declines (Park and Wheeler, 1983). With little concern for the need for higher technical skills in the whole process of mass production, this third phase is mostly associated with offshore manufacturing, in particular in the developing countries where pools of unskilled and low-wage labour are accessible.

The product life-cycle concept has the advantage of providing possible explanations for the growth of a firm. It lends credence to the idea that firms may also evolve from one stage into another. Thus, firms will require striking variations in the technical or managerial inputs at different stages of production. Nevertheless, this concept has been criticized as being too "simple". First of all, it only concerns the time path of only one firm which produces one single product or one industry but not the overall industrial activities (Krumme and Hayter, 1975). Secondly, it lacks the detailed descriptions of various possible phases. It has oversimplified the early stage of industries. It fails to incorporate a "precommercialized" stage in the early stage of industries. This is a serious omission because this "precommercialized" stage is the stage where firms are involved in the development of new ideas, and in the designing and fabrication of potentially commercialized products. Finally, it fails to incorporate the "rejuvenation" stage in the later phases. These observations may hamper the operationalization of the concept, along with its potential for empirical verification, leading to inconsistent results (Suarez-Villa, 1984). These limitations, especially those arising in the context of firm formation, severely hamper its use in studies of industrial agglomeration.

3.5.2 The Industry Life-cycle Concept

The product life-cycle concept is full of conceptual flaws which, in combination, prevent it from identifying the constituent components contributing to the agglomeration of industrial activities. This renders its uselessness for the explanation of industrial growth. Hence, recently, Todd (1990) has expanded the theoretical base of the industry life-cycle concept with detailed descriptions of various possible phases of industrial growth as an alternative to the product life-cycle view. Looking from an industrial perspective, Todd defines the life-cycle of industries into seven stages, namely, the "conception", "birth", "childhood", "adolescent", "maturity", "senescence" and "rebirth" stages. In the "conception" stage, the major activity involves "the congealing of the idea in the innovator's brain that is transformed into the makings of a new product." The making of a prototype, an example or a model of the new products in the form of a piece of hardware, constitutes the "birth" stage of the industry. The "childhood" stage is then defined as "the period when the budding enterprise is preoccupied with devising a range of prototypes." The industry comes to its "adolescent" stage when "it has narrowed the choice of product specifications and effectively marketed a limited number of products adhering to hard-and-fast design attributes." In essence, new products are commercialized. Industries which successfully negotiate adolescence are poised to reach full bloom in maturity. The "mature" firm is concentrated on mass production of a standard product. In the "senescence" stage, the industry is concentrated on the manufacturing of the increasingly standardized obsolesent products in which all technological characteristics are eroded away. In the "rebirth" stage, the industry is not only concentrated on the production of obsolescent products but also emphasizes the generation of new or modified products.

The industry life-cycle concept utilized in this study is a modified version of Todd's approach. In this modified version, Todd's first four stages have been collapsed into one single stage called the "early stage" of the cycle. This is not just because one wishes to maintain the consistency of the title of the stages that denote different "ages" of industries or firms in time. Most importantly, this version can pinpoint the types of activities that distinguish "small" from "large" firms enlisted in high-technology sectors. According to Oakey (1985), "small firms" are firms which are mainly engaged in the production and sales of "indigenously designed finished or semi-finished products." In this context, the activities undertaken by these "small firms" have embraced those described in the "conceptualization", "birth", "childhood" and "adolescence" stages of Todd's version of industry life-cycle. Hence, in essence, these four stages could be collapsed into one entitled "early-stage" of the industry life-cycle and, for the purpose of this study, it is particularly relevant to "small firms" belonging to high-technology activities.

Such a small-firm-is-early-stage-firm equivalence helps to clarify some misconceptions of high-technology industries in the industry life-cycle context. In the first place, it is misleading to regard high-technology industries as emerging "earlier" than any other industrial activities. In no sense are the high-technology industries the forerunners or predecessors of "mature" or "declining" industries. In a historical sense, many of the "mature" or "declining" industries existed long before the advent of the present "high-tech" industries. The "innovative" image of high-technology industries denotes nothing more than their impacts leading to the restructuring of the production processes of other activities. Such an image conveys no sense of being the "early stage" of other activities. Besides, an activity that has been restructured by high technologies has little need to claim itself as high-technology industry. More realistically, the high-technology industries occupy the "advance stage" or "on-the-edge stage" of all other production processes rather than of that being the "early stage" of any other existing production activities. Secondly, the well-known high-technology industries are not free from the problem facing other industrial activities; that is, the problem of "aging". Markusen et al. (1986) carried out a cross-sectional review of twenty-nine high-technology industries and found that they contain as many stages of development as other industries. There are high-technology industries that bear the character of "innovativeness" and are growing rapidly; those that grow modestly and are still endeavouring to penetrate the market; those that experience volatile growth through "defence dependence"; those that become "mature" and face the problem of "market saturation"; and, finally, those that are declining and have to resort to "rationalization" for the extension of their business life. In this context, high-technology industries do not seem to live up to their popular image as being the "early stage" of all other activities when they are not immune from aging themselves. Thirdly, looking from the perspective of firm sizes, the principal activities of the large and small high-technology firms vary greatly from those of their smaller counterparts. The large firms are those that have established themselves over time. They are now mainly engaged in mass production of some standardized products. The innovative impulse is incorporated into their giant entities as a means of keeping up their leading positions in the industries under the pressure of selective market conditions. Failure to attend to innovation would have dire consequences. Hence, innovation is given institutional recognition, becoming a corporate bureaucracy. In contrast, the small firms are the truly "innovative" firms that live on nothing but the production of new ideas and new products. Only when their hope of commercializing one or more of their new products materializes would they be able to launch into relatively large-scale production. This means take-off and growth to them. Unlike their larger counterparts, small firms depend for their survival on the acceptance of their new product or products and not on standardized products. Accordingly, the managerial behaviour of large and small firms differ. In an empirical sense, any modelling of the behaviour of high-technology firms has to take into account these differences. In introducing firm size into the picture, the industry life-cycle comes back into play.

In short, the stages of development of industries or firms have been aligned such that "innovative firms" are "small firms" that engage in the "early-stage" activities of the industry life-cycle, while large firms occupy the later stages of the industry cycle.

This approach to industrial studies is useful because it has circumvented the difficulties of the product life-cycle concept which derive from the focus on single-product firms. Most importantly, advantage is also gained in easily identifying the special needs of different stages of industries. Industrial strategies can be more accurately formulated; not being too general but instead being specific to the stage of the industrial groups under investigation.

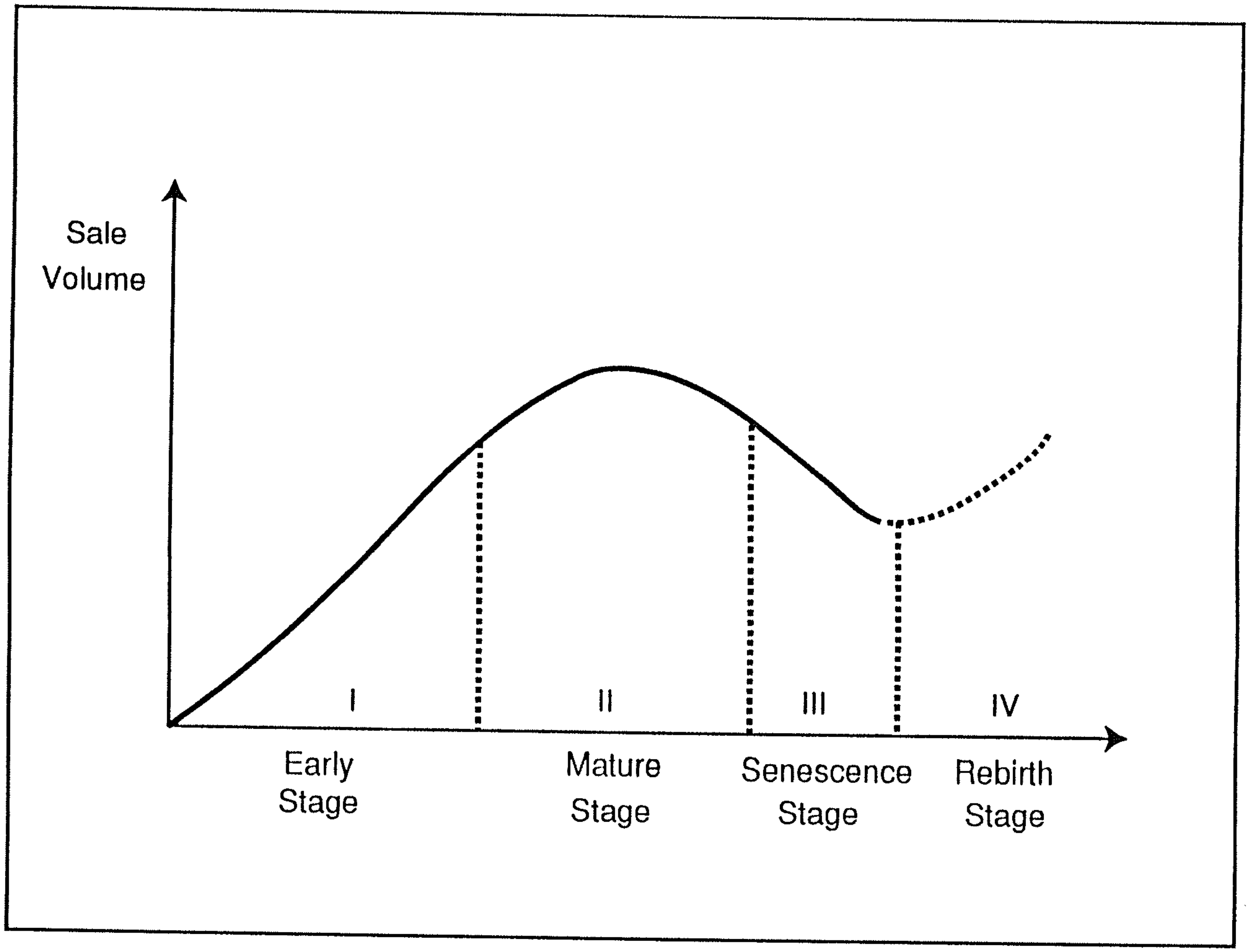
To be sure, similarities between product and industrial cycles exist. For instance, the industrial profile may resemble that of the product life-cycle, namely, an S-shaped curve expressed in terms of, say, sales volume in time. Accordingly, the early-stage industries are marked by an unpredictable sales volume as the acceptability of the "idea" or "new" product is still unsettled. Only when their new products have been tested and proven to be generally accepted by consumers would they begin to gain ground in the marketplace and the business. Hence, some of them will be outcompeted by their counterparts. Those industries or firms that are able to penetrate the threshold level of acceptance of their products begin to "take-off". Understandably, mass production for their products becomes their principal mode of production. As markets open to their products, they grow in "sizes" as well. They are said to have attained the "mature" stage of the industry life-cycle. In this "mature" stage, their sales volumes begin to stabilize and persist at a high level for quite a while. Yet their future is precarious because the market is saturated. When market saturation turns into rejection, their sales will begin to subside. This condition marks their transition into the "senescence" stage of their industry life cycle. Under such a circumstance, industries and their constituent firms may have to generate new, or else, modified products to prolong their industrial life. Should their new or modified products gain acceptance in the market they are given the chance of "rebirth". With the upturn of their sales, they are truly in the "rebirth" stage of the cycle. The profile of all levels of market acceptance and firm sizes over time is depicted in Figure 3.1. The following sections will describe and explain the market mechanism of each stage in detail.

3.5.2.1 The Early Stage

The early stage of an industry involves activities where new product ideas are generated and fabricated into prototypes as well as being introduced into the marketplace. The preferences or tastes of potential consumers are crucial to the early-stage firms in developing their innovative products. As a product new to the market, the preferences of the customers are not really collectively well-defined. Under such a circumstance, the early-stage firms will have to customize their products rather than to manufacture the on-the-shelf type of "standard" products. It is then understandable that the market sizes of new products are

Figure 3.1

The Industry Life-Cycle Profile



very vague. Therefore, to cope with all these uncertainties, innovation firms have to be very flexible in their processes of production so as to meet the ever-changing requirements of customers' tastes. As these firms are initially lacking in information, they ought to be both fast and efficient in making good that defect. Only then will they be able to formulate rational production plannings and assessments for their further innovative endeavour.

For instance, the swift acquisition of applied engineering knowledge allows new technical problems for which solutions do not already exist to be solved quickly, enabling new product ideas to be specified or prototypes to be refined, extended and converted quickly to the new expectation of customers (Gannon et al., 1976).

Likewise, apt managerial information[35] such as market condition reviewed by, among other sources, the proactive marketing research companies are crucial for conceiving the extent of acceptance of their new products by potential customers. In gathering and analyzing the data regarding customers' attitudes towards the existing competitive products, the marketing researchers may be able to predict the probabilities of gaining a place for their new products in the marketplace. Suggestions would have been made for the improvement or modification of this new product, ensuring a higher rate of success. In incorporating these proactive research activities at the very early stage of product development, the possibilities of market failures at the other stages are likely to be reduced as well (Miller and Cote, 1987). Eloquent testimony to the efficacy of these marketing studies in contributing to successful product development can be seen in such disparate market successes as the Ford Mustang and Maverick automobile introductions, the original launching of sculptured Wilton rugs and the "snorkel" writing pens (Wasson, 1971). These three successful stories demonstrate the fact that acquisition of precise market information concerning the requirements of consumers gathered through such means as marketing research is key to effective development of new product ideas.

Meanwhile, these early-stage entities that are about to launch new products onto the markets have to face a wide variety of legal hazards or risks. There is always the potential of being sued by their consumers who would have been injured or harmed accidentally or

[35] *This term refers to the knowledge and skills concerning market conditions (such as the customers' preferences, levels of demand, and so on), office operations (such as accounting and administrative routines), purchasing and marketing affairs (product promotion or advertising procedures).*

unintentionally in the course of using the products carelessly. There is also the possibility that new products may not be fully protected against partial or complete copying (outright adoption) by competitors or even their own employees; hence, the loss of their monopolistic profits over their markets (Karger and Murdick, 1972). All these legal hazards will heavily jeopardize their financial well-being. At one extreme, this could mean immediate bankruptcy of firms. To a moderate extent, their research activities references for further development or modification of the second or third generation of new products will be hampered. Therefore, acquisition of legal knowledge on patents, copyrights or trade secret protections are indispensable to managerial information required for the agglomeration of early-stage industries.

Notwithstanding the general appreciation of the vital role of technical, managerial and legal knowledge, more often than not, they may not be readily available to the early-stage firms. It is common knowledge that industries at this stage are subject to immense financial constraints, as the markets of their new products are unidentified and their outputs may be small. Such financial situations render difficult the hiring of specialists such as scientists, engineers, marketing or financial analysts. As a result, the exercises of organizational restructuring and fine-tuning of labour tasks within firms become virtually impossible. Immersed in this "monetary hot water" and with great difficulties to internalize all kinds of information, the early-stage firms are characterized by their dependence on external connections in satisfying and supporting their quests for information.

Perhaps by locating firms at close proximity to research facilities such as universities, government and private laboratories, firms will find an outlet for tapping technical information from external sources. Close proximity to such facilities enhances contacts, essentially face-to-face contacts, between the early-stage firms and the institutional specialists. By means of frequent visits to research agencies, entrepreneurs of the early-stage firms may quickly obtain technical skills or knowledge that they otherwise would have to finance by themselves. Flexibility in product development, therefore, is increased; and, rapid adaptation of new products to the changing market needs is made possible. There is much evidence supporting the possible benefits gained from close proximity to technical resource centres. For one thing, collocation could constitute the critical mass needed for industrial agglomeration. Many writers argue that the concentration of "sunrise" activities and industries in both the Route 128 area near Boston and the Silicon Valley complex south of San Francisco owes much to the stimulation of local technical-oriented universities (Haug, 1986; Oakey, 1985). Dorfman (1983) suggests that these local academic institutions are steeped in the tradition of research at the frontiers of development in electronics, computer science and instrumentations. *Aviation Week and Space Technology* (November, 1988), drawing its observations from Florida, concludes that successful operations of high-technology firms (such as X-Ray and electromedical equipment, aerospace, pharmaceuticals and computer manufacturing) there are basically a result of the availability of continuing-education programmes delivered by the nine state universities. Continuing initiatives, such as the Florida Engineering Delivery System, a programme with more than 2,500 participants, allow Florida technical entrepreneurs to obtain advanced academic degrees. It enables the technical entrepreneurs to keep abreast of current developments in the field through tutored, videotaped television courses and electronic blackboard instructions. Meanwhile, Monck et al. (1988) and Bullock (1983) voice the opinion that university consultancy, in many cases, may have led to new design and new product development that usually become the basis of an embryo business. They drew their observations from the Boston area where MIT encouraged its faculty staff to provide consultancy to high-technology businesses in the region one day per week.

On the other hand, the locating of firms at close proximity to financial agencies is another means of seeking external information supports. Through frequent meetings with government and private financial agencies such as venture capital companies and powerful fundraisers from sources such as wealthy individuals, pension funds, special investment arms of banks and insurance companies, the early-stage firms may be able to acquire vital monetary support as well as advice essential to their overall well-being. It is well-known that venture capitalists are skilful monetary advisors. In fact, many of them do much more. Very often, they provide administrative assistance, marketing strategies and technical know-how throughout the early phases of firms in the risky high-technology businesses. They are ready to get involved in any difficulties and unpleasant managerial circumstances when warranted (Rogers and Larsen, 1984; Miller and Cote, 1985; Miller and Cote, 1987). With close connections to venture capitalists, the early-stage firms gain frequent and timely external managerial, financial, administrative and marketing assistance. These are the functions where venture capitalists excel (Morphet, 1987). Acknowledging the expertise of these venture capitalists, Rogers and Larsen (1984) consider them to be the "powerful gatekeepers" governing the fate of innovative activities. To fix the idea, Dorfman (1983) recounts the spawning of high-technology start-ups in Boston with the First National Bank of Boston beginning to suppor companies emerging from MIT in 1943. In 1958, it was the first bank in the U.K. to set up to assist small business corporations. Also, in 1946, Boston was the location of the establishment of American Research and Development (ARD), which was specifically set up to finance "high-tech" companies and make crucial investment in DEC. Recent research on the role of venture capitalists has shown that mere financial support is often less important than the overall business package that venture capitalists provide. Recognizing that entrepreneurs may have little experience in running their newly-established companies, venture capitalists can provide the whole range of business supports in areas such as personnel and marketing until companies are firmly established. Meanwhile, as far as the public purse is concerned, Oakey (1985) conducted a postal-and-interview survey of the 174 small firms belonging to the instruments and electronics industry (that is, MLH 354 and 364 respectively) in the Scottish development region, the San Francisco Bay Area of California (including Silicon Valley), and the South East of England. He found that the small firms of the Scottish development region were highly dependent upon the financial, and presumably, the overall managerial supports, provided by government agencies. Roughly 75 percent of the Scottish small firms used government incentives in the five-year period prior to being interviewed. Finally, the locating of firms at close proximity to local specialists of market research companies, sales agencies, repairing companies and government procurement agencies for the tapping of market information is another way to gain supports from external resources.

Wasson (1971, p.130) noted that salesmen, to say nothing of service personnel, are in the key positions to discover the weakness of the firms' own products or those of their competitors, as well as other needs for product improvements or for product flexibility. On the other hand, through their first-hand contacts with the buyers and users, the repairing and servicing personnel and distributors are in an excellent position to learn of the defects in the firms' products and also in those of their competitors, as well as product attributes being sought but not available in any of the competitive offerings. In effect, the ITT of Manitoba (1983) asserts that the existence of local vendors has been the major reason for innovation firms flocking to Silicon Valley or Route 128 or Kanata near Ottawa. Moreover, it is well recognized that spawning of new high-technology firms along Route 128 was basically owing to government aerospace and defence procurement programmes which opened up a direction for new product development that the early-stage firms could follow and foster. More importantly, in the longer run, it is also observed that after a period of four to five years, 40 percent of the turnover of this kind of new spin-off firms was generated in the commercial non-government markets (Rothwell and Zegveld, 1982; Bollinger et al., 1983). All in all, firms at this stage are extremely dependent upon the support offered by local facilities and institutions. They require not merely close proximity to research institutions and financial agencies in government or the private sector but also to other marketing and consultation services. Past studies have shown that innovation firms at this stage are in all probability inclined to locate themselves in either innovation centres, science parks or large metropolitan centres where the facilities or services are spatially clustered and where frequent face-to-face contacts between entrepreneurs and specialists are permitted.[36]

Apart from the importance of the availability and accessibility to local resources, the entire preoccupation of the early-stage firms concerns entrepreneurship; that is, the quality of innovativeness of the person or personnel running the business. Experience of entrepreneurs in industries is by and large very important to the early-stage firms. Prior industrial experience of entrepreneurs usually implies the existence of a close relationship or connections with their external resources. The literature in this respect also emphasizes the relationship between entrepreneurs and consumers or the users as well. Entrepreneurs have to practice their understanding of their consumers or users. Effective entrepreneurship will help them ignore the tales and rumours prevailing in the marketplace and makes them capable of picking the appropriate know-how required for commercializing their new products or ideas. They should also be capable of discerning precise data or facts concerning users' preferences and the changes in preferences. All these presuppose close contact of entrepreneurs with their customers.

Another dimension of an "experienced" entrepreneur is his or her relationship with

[36] *Bergsman et al. (1972), in identifying the industrial pattern in several major cities in the U.S.A., found that high-technology industries were mainly clustered in the metropolitan areas. By employing factor analysis techniques, they showed that many of these cities had fairly high factor loadings, ranging from 0.367 to 0.881, in favour of a concentration pattern for high-technology industries in the metropolitan areas. For instance, in the New York metropolitan area, the communications equipment, medical instruments and chemical products' industries had fairly sizable factor loadings of 0.569, 0.579 and 0.367 respectively. In Chicago, the radio and television receiver industry recorded a loading as high as 0.881. In Los Angeles, transportation equipment, aircraft and communications equipment industries had factor loadings of 0.779, 0.633, and 0.565 respectively. In Boston, the electronic components and scientific equipment instrument sectors registered loadings of 0.511 and 0.544 respectively.*

the external financial resources. It is understandable that these early-stage firms may not have the financial muscle in terms of initial and ongoing capital investment. Therefore, to set up their own firms, entrepreneurs more often than not have to borrow from all possible financial sources. Hence, an "experienced" entrepreneur may have accumulated adequate collateral against which loans, and most important of all, sound business advice, can be secured (Rothwell and Zegveld, 1982; Lloyd and Mason, 1985). Perhaps they have also established a reputation in industries before they take the risk of pursuing their own business ventures.

The literature also tells that a solid academic or technical-education background enjoyed by the individual entrepreneurs is another important attribute of entrepreneurship. Oakey (1984) stresses that high education background is of compelling consequence to the survival of small high-technology companies. Rothwell and Zegveld (1982) also think that strong technical education backgrounds of individuals will mean strong research and analytical skills. These skills allow them to gather or identify precise technical knowledge quickly from scientific journals, conferences or scientific groups or communities for their own applications. In consequence, they are capable of providing precise decisions on the limitations and possibilities of design or production processes, and on the preferred design procedures (e.g., use of standard modules) and the use of certain materials. Their experience and external connections will not only facilitate their overseeing of the manufacturing of the innovation but also will permit them to iron out production bugs before commercial sales. Besides, another dimension of their education backgrounds is that regarding the amount of their management training. Most likely they are very eager to pursue management courses from the accredited education institutions. There, they are formally trained to handle internal information flow as well as to analyze information available within and without their firms.

Another primary attribute of entrepreneurship — which is of great import — is enthusiasm. Without it, the owners of firms would not be true entrepreneurs. This requires an energetic attitude towards their businesses; they have to totally commit themselves to their businesses. This is the drive needed for attaining innovation excellence. It is also this quality that keeps them competitive. With their concerns for all types of information required for a successful business, entrepreneurs will in due course pass along their knowledge and information in the most effective way to their co-workers. A swift flow of information within the firm will mean high sensitivity of its production process to the needs of the market, not just for the perfection of "internal bureaucracy" but also in terms of innovativeness. It is documented, incidentally, that entrepreneurship is more likely to thrive in a family setting, with succeeding generations assuming business initiatives.

To substantiate the foregoing arguments, examples are drawn from some popular cases as follows. It was discovered, for instance, that most of the founders of the new-technology-based companies, essentially the spin-offs of MIT, in the Route 128 area of Boston, tended to have a high level of education, the average being a Masters' degree in engineering (Roberts and Wainer, 1968). Sixty-eight percent of all new computer firm founders in the U.K. possessed degrees or the equivalent technical qualifications; among which 54 percent possessed a Ph.D. or computer or electronics degrees (Kelly, 1987). Firms started by entrepreneurs with a management background, particularly if they had a degree or professional qualification in management, showed the fastest rates of growth (Oakey, 1984; Lloyd and Mason, 1985). Moreover, a study of 200 MIT spin-off companies in the 1960s showed that these entrepreneurs had a strong entrepreneurial heritage. Half of them came from families where the father had been an independent businessman (Roberts and Wainer, 1968). It is also asserted that before starting their own businesses, entrepreneurs who came from the Lincoln Laboratory had spent two and a half years in the industry in order to obtain the necessary commercial experience (Bollinger et al., 1983). Entrepreneurs also are enthusiastic individuals who appear to have a high need to achieve (Ibid.). Lloyd and Mason (1985) examined 122 new independent and founder-based manufacturing firms established during or after 1976 in the electronics sectors together with others in Manchester, Merseyside and South Hamsphire of the U.K. through a postal-and-interview survey for the 1980-82 period, and came to similar conclusions as Roberts and Wainer (1968).

3.5.2.2 The Mature Stage

Industries and their firms at the mature stage of the industry life-cycle are those whose products are fading from their "new" images, and whose technologies begin to adjust to the needs of mass production.

The market accepted the "new" products, transforming them into "household" products. The preferences of consumers are more or less expressed by voting on their purchases. Certain "new" products are apparently more successful than others. The production technologies associated with them are amended to approach standardization. Perhaps simple technical modifications or improvements of the products are all that is required to serve the now expanded markets. In other words, the markets for their products are taking off. R&D activities may not be a priority of firms in this stage. To meet the skyrocketing market demand is their top priority. In these circumstances, all mature-stage firms would rank high production efficiency as the prime means to meet the enormously enlarged market demand. In this regard, applied engineering is immediately utilized for redesigning the manufacturing system in respect of material handling, assembling procedures, quality control or the inspection process, and for upgrading machinery, equipment and utilities. High-volume production with low unit costs compatible with rapid increase in product demand can then be achieved (Carson et al., 1972).

It follows that sound administrative or managerial knowledge is required for better planning of the overall production operation. This type of know-how involves expertise in "facility budgeting"; that is, in co-ordinating conflicting or competitive uses of resources such as machinery and equipment (Ibid.). It also involves "time budgeting" with respect to the finding of alternative input sources; fast responsiveness for competitive pricing; swift delivery or transportation; accurate placement of orders and receiving procedures (such as keeping of records, inspection and stock control). When there is a change in production, the incidence of dumping of all raw materials procured at the beginning of the process can be avoided. In a way, in-house managerial expertise is made possible for the steady growth of markets as products are accepted by more and more people. In-house professionals are expected to manage internal information flow in a secure fashion; that is, in a way that prevents "secrets" from leaking to competitors.

As the mature firms are taking off at this stage, they will anticipate future developments and plan for them. They can exercise specialization of labour and vertical integration to tap production efficiency. As mentioned already, specialization of labour involves a hierarchy of delegation of authority in which the supervisors of each specialized section or unit are responsible for reporting regularly to higher levels of management a full account of the knowledge which has been acquired, either by themselves or from their subordinates and which has direct relevance for achieving the goals of the firm. Such reporting systems are designed for swift delivery and relay of relevant data or facts concerning the maximization of production efficiency to top management of firms. Vertical integration, by putting the distinct operations at different stages together under one common control through merger or acquisition, similarly develops a hierarchy of authority relationship between the predatory firms and the acquired or merged companies. To this end, relevant knowledge can also be collected and delivered regularly and speedily to different levels of management. For instance, acquisition of retailing outlets in the less-developed countries provides a firm with adequate power to warrant a greater control over the supply of reliable knowledge concerning the potential size of the market in very remote areas (to the firm). By such means, the problem of excessive production may be avoided.

Therefore, by contrast with the firms in the early-stage industries, the mature firms depend more on internal learning economies rather than external learning economies, albeit the latter are still indispensable to efficient operations.

3.5.2.3 The Senescence Stage

Senescent industries or firms will have completely standardized their production technologies. Products also will advance from their "standard" images to "obsolete" images in the course of this stage. When they are still "standard" products, their demand will be at their peak plateau of sales. Once they are regarded as "obsolete", their sales will subside. The rates of growth in sales and in profits begin to slacken rapidly when as the senescence stage takes hold (Suarez-Villa, 1984).

Therefore, the principal strategy of senescent firms is to achieve a higher level of operational efficiency in the light of declining markets. However, further division of labour and vertical integration at this stage will thicken the layers of bureaucracy. The problems of controlling and co-ordinating the work of departments will become increasingly difficult, thwarting the goal of higher levels of operational efficiency. Probably, "the right hand does not know what the left hand is doing" (Shepherd, 1985). In that event, reporting of unreliable and delayed essential data to upper management will have become customary practices rather than exceptions within such senescent firms (Ibid.). Learning diseconomies, or inefficiency in information flow in lieu of learning economies, emerge under these circumstances. Transformation of the internal structure of firms through rationalization of the production system and vertical disintegration are the tendencies that come to the fore. The former denotes internal restructuring of the organization by closing down or liquidating some of its production facilities, management, or sales services and the concentration on fewer activities such as production or assembly (Storper, 1981; Suarez-Villa, 1984; Markusen et al., 1986). By vertical disintegration, some production processes are divested or separated from the firm so that these particular processes can be performed by specialist companies outside the firm devoted to subcontracting activities (Clarkson and Miller, 1982; Scott, 1983; Suarez-Villa, 1984).

In essence, then, the survival strategy of the senescent firms is to avoid internal learning diseconomies. They can be partly solved by rationalization of production and vertical disintegration. A more radical alternative is the total realignment of their production technologies.

3.5.2.4 The Rebirth Stage

When firms are prepared to revitalize their production and routine operations through the incorporation of some or all advanced technologies, they are electing to seek "rebirth" through the production of modified, improved, or at best, "new" products.

At this juncture firms face highly-saturated markets for their existing product with limited expansion capacities. Although at the outset of the senescent stage, the sizes of the markets remain large, they have become highly unstable and are shrinking at a rapid rate. In consequence, the sale and profit levels of firms are declining at an ever-accelerating rate. Some firms are compelled to withdraw from their production activities (Suarez-Villa, 1984; Todd, 1990).

Entrusting themselves to spawning of new products rather than mass production of obsolete products often offer the only hope for such firms (Todd, 1990). Because of their sound accumulated earnings from the past, the firms may still have the strength to restructure their internal organization in a fashion which allows technology transfer. They might set up an R&D department to serve as an "in-house" engine for supplying the necessary scientific or marketing know-how for the production or commercialization of their provisional new products (Reekie and Allen, 1983). Aided by their financial clout, they are also capable of acquiring other specialty firms to obtain needed new product-development talent.

In the event that the sizes of companies are extremely large as a result of overspecialization or over-extension in the past, the avoidance of internal learning diseconomies through vertical disintegration may be a promising strategy.

3.6. Justifying Hypotheses

The industry life-cycle theory has demacrated industrial activities into different stages in terms of their technological characteristics filling customers' demands. This has not only helped to identify the problems facing each group of industries, but also has introduced the time dimension into the discussion of industry growth. The theory has also emphasized the primary role of market conditions that gear industries to meet the market demand with efficient production processes. Extrapolating from that precedent, this thesis also attempts to distinguish the type of problems facing firms at various stages of development. Hence, it has been explicitly shown here that for different stages and for different firm-sizes at each stage of the industry life-cycle there should be different industrial strategies to promote industrial and firm growth.

When new technologies and their offspring products are not yet well received by their markets, the early-stage firms face the prime problem of detecting consumers' preferences. It is more likely that different consumers or types of consumers will have different expectations from new products designed to serve their needs. Hence, their preferences will show up as a heterogeneous assemblage. It is the tailor-made type of products that have to be generated from the state-of-the-art technologies, rather than the ready-made type of products, in order to fit well-defined market needs. The market condition at this juncture can then be described as stochastic and the demands issuing from it are unstable; the companies are under great financial stress. To reap external and entrepreneurial learning economies for the benefits of their operations is their only means of survival.

When some of the new ideas and their offspring products have been generally accepted by different groups of consumers, the consumers' preferences are hinted in vehement demands for products. In this sense, those products begin to take-off in their production. The mature-stage firms are gearing their production technologies towards meeting the unveiled market preferences. On the way, only those technologies that are related to the large-volume production processes of those products will be fully elaborated. As a result, some technologies approach "standardization". Yet, the mature-stage firms still enjoy large sales volumes in existing markets. They grow at the expense of extracting themselves from external resource supports. In this stage, those firms and industries gain their production efficiency from internal learning economies rather than from external supports. Much of their production efficiency is gained from organizational restructuring. Their direction of growth will approach division of labour or vertical integration.

As the products have become "household" products or necessities, the firms will face a saturated market condition. The industries of this kind will become "senescent". Their constituent firms are in their senescence stage of the industry life-cycle. Their production technologies have become well standardized in tandem with the appearance of sales plateaus in their markets. Among their worries are the looming prospects of product obsolescence, to say nothing of market saturation or impending decline. As these firms may also have acquired a large organizational bureaucracy, they may begin to experience the first instances of internal learning diseconomies. Hence, to maintain production efficiency, they may have to resort to rationalization of production. Their direction of growth is vertical disintegration.

When the products have come to be regarded by consumers as out-of-fashion or obsolete, the concerned industries have to save themselves by giving themselves another chance. They look for a "rebirth" process. To attain this, they may have to reallocate part of their accumulated capital to set up an R&D department to generate both new products and themselves. Another direction involves "trimming of the fat" that arises from being over-specialized or over-expanded, the "fat" responsible for internal learning diseconomies.

Provided that both or either of these options produce results, the industries and the related firms will undergo "rebirth".

In short, the industry life-cycle concept suggests that firms at different stages, in response to various market demand situations, should make use of particular types of learning economies in their production process in order to be efficient and to survive.

The whole concept asserts that:

(1) efficient early-stage firms have to access external learning economies more than internal learning economies for their survival;

(2) entrepreneurial learning economies are particular attributes of the early-stage firms;

(3) to the mature firms, the accomplishing of internal learning economies through specialization and vertical integration are imperative for their growth;

(4) the avoidance of internal learning diseconomies through rationalization of production and vertical disintegration is vital for the survival of senescence firms; and lastly,

(5) the achieving of internal learning economies, essentially the establishment of R&D departments, and through labour process, vertical integration; or the avoidance of internal learning diseconomies through vertical disintegration are of high priorities for the survival of the "reborn" firms.

Since the objective of this thesis is to find the determinants compelling the electronics firms in general, and the early-stage or small electronics firms in particular, to agglomerate in science parks, only the first two assertions are relevant and addressed henceforth. The hypotheses derived from them for further empirical verification can then be stated as:

(1) the survival of the early-stage firms is dependent upon the presence of external learning economies; and

(2) their survival is also a result of the presence of entrepreneurial learning economies.

The remaining chapters of this thesis are geared to the particulars of the empirical verification of these two hypotheses. These particulars include the choices of modelling, the selection of representative proxies of the determinant variables, the collection of the required data, the estimation of the parameters of the determinants and, eventually, the interpretation of the empirical results as well as the evaluation of their relevance both to academic inquiry and policy determination. The next chapter addresses the modelling issue.

Chapter Four

The Models for Agglomeration of Early-stage Electronics Firms and Activities

4.1 Introduction

This chapter is going to formulate empirical studies of the two hypotheses on the determinant dimensions of early-stage firm growth of the industry life-cycle theory derived from the last chapter. It will focus on external learning economics and entrepreneurial learning economics as the two major dimensions contributing to the agglomeration of early-stage firms. Hence, in this chapter and the chapters to come, some objective procedures for the verification of these assertions will be designed and discussed.

Early-stage electronics firms are synonymous with "small" electronics firms as the basic units of studies. As depicted in Chapter Three, "small" firms are the firms that embrace all of the economic activities of early-stage firms described in the industry life-cycle concept in that their principal intent is to generate new product ideas, fabricate prototypes, and commercialize new products. In this context, the early-stage activities of the industry life-cycle are nothing but the activities of "small" innovation firms. Such a concept conforms well with reality too. As reported in Chapter Four, evidence exists around the advanced world that "small firms" constitute the largest proportion of and are the fastest growing units of the high-technology industries and electronics industries in particular. Therefore, a study of their success will have significant implications for industrial growth and development. Meanwhile, as observed in Chapter Two, many renowned science parks claim their success in terms of their attraction of small tenant firms as "critical masses" to trigger regional growth and development; for instance, the Stanford Industrial Park and the Research Triangle Park of the U.S.A.; and, the Cambridge Science Park, or Heriot-Watt Park of the U.K.; as well as, the Sophia Antipolis of France. Hence, the role played by "small" firms in high-technology activities is affirmative.

As a consequence, any modelling designed to study high-technology activities, and, in this case, electronics activities, has to take into account the S-shape profile of the industry (firms) life-cycle concept, the capability of contrasting early-stage (small) firms against the later-stage (large) firms, and the choice of appropriate variables or proxies to represent the dimensions of agglomeration of high-technology activities. The painstaking search for such mathematical formulation ends up with logit modelling as the most appropriate approach of all other counterparts.

Naturally, the next step followed is to put small electronics firms as against their larger counterparts of Manitoba into testing. Unfortunately, this attempt failed as a result of divergence in the process of estimation of the parameters. Hence, multiple regression modelling techniques have to be resorted to. The more favourable approach has not been given up, however. Instead, aggressively, the study has been extended to cover Western Canada as a whole for logit modelling and turned out to be successful. Therefore, in this chapter, there are two types of models to be evaluated and discussed. There is a "general" model of logit regression that covers Western Canada as a whole and there is a "specific" model of multiple regression that targets Manitoba. Hence, in the following sections, the application of these two types of modelling techniques for this study will be separately justified according to their technical properties. There are also sections devoted to the criteria of selection of proxies, as well as interpretation and expectations of the selected proxies in their own right.

4.2 The General Model

4.2.1 Justification of Logit Modelling

As aforementioned, the objective of the General Model is to test the hypotheses that external learning economies and entrepreneurial learning economies are the major underlying forces explaining the agglomeration of the early-stage electronics firms of Western Canada as a whole. Logit regression modelling is an appropriate candidate to serve the purpose because it depicts the S-shape relationship between the explanatory variables and the dependent variable that is dictated by the industry life-cycle theory. Besides, as a "discrete" model, it explicitly contrasts the characteristics of small firms against the larger counterparts as being formulated on the left-hand side of the model specification, hence, the dependent variable.

Technically, the logit regression model can be specified as follows:

$$E(Y_i) = \frac{1}{1 + e^{-\alpha-\beta_k X_{ik}}}.$$

or,

$$E(Y_i) = \frac{e^{\alpha+\beta_k X_{ik}}}{1 + e^{\alpha+\beta_k X_{ik}}}.$$

As a probability model, the logit S-shaped curve is vertically bounded within the interval (0,1) such that when the explanatory variable (X_{ik}) approaches negative infinitive, the expected value of the dependent variable E(Y_i) will approach 0; likewise, when the explanatory variable X_{ik} approaches positive infinitive, the dependent variable E(Y_i) will approach 1.

Nevertheless, the dependent variable can also be expressed as the probability of having an early-stage or a small firm as π_i, given the characteristics of observation i. In order to see how the regression results of the logit model would look like, we can put E(Y_i) $= \pi_i$ into the above expressions, and solve for $(\alpha + \beta_k X_{ik})$. We thus obtain:

$$log\frac{\pi_i}{1-\pi_i} = \alpha + \beta_k X_{ik}$$

where all logarithms are natural logarithms.

In other words, the parameters estimated by most of the computer packages are going to give a prediction of the *odds* of having π_i, in this case, a small firm, as against $(1 - \pi_i)$, or a large firm. To obtain the probability of having a small firm, the antilogarithm procedure has to be taken; in doing so, this leads us to return to the original specification of the model. Most of the time, we are also interested in finding the effect of a change in the magnitude of one or more independent variables X on the probability that $Y = 1$; that is, the probability π_i, having a small firm itself. This can be calculated from the relevant parameters (β_k) and the respective probabilities π_i and $(1 - \pi_i)$ as follows:

$$\frac{d[\pi_i]}{d[X_{ik}]} = \frac{d[\pi_i]}{d[log\pi_i(1-\pi_i)]} \times \frac{d[log\pi_i(1-\pi_i)]}{d[X_{ik}]}$$
$$= \beta_k \pi_i (1-\pi_i).$$

4.2.2 Logit Assumptions

In general, the logit model assumes that the dependent variable, Y, is of binary scale, taking on the value of 1 or 0. Moreover, the outcomes on Y are assumed to be mutually exclusive and exhaustive; that is, the surveyed firms could only be either a small firm or a large firm but not both.

Y is further assumed to depend on K observable variables X_k, $k = 1, \ldots, K$. These explanatory or exogeneous variables account for the variation in $P(Y_i)$.[37] In this case, the learning economies' variables are going to account for the variations in the probabilities of having a small firm. This is analogous to the standard regression model in which the exogeneous variables account for the variations in the means, or expectation, of Y. But, the main difference from the standard regression modelling is the assumption of the logit model that there is a nonlinear relationship between Y and X.

As in the OLS regression, the logit model assumes that the data are generated from a random sample of size N with a sample point denoted by i, $i = 1, \ldots, N$. Hence, the observations on Y should also be statistically independent of each other, ruling out serial correlation (autocorrelation). The independent variables may be random variables, for example the responses to the survey questions, or they may be fixed, as in an experimental setting. There cannot be any exact linear dependence among the X_{ik}'s. This means $N \geq K$ such that each X_k must have some variations across observations (apart from the constant term), and that no two or more X_k's are perfectly correlated. If near, albeit not exact, linear dependencies

[37] *The relationship can be written as either:*

$$P = P(Y_i|X_i, \ldots, X_k)$$

, or simply,

$$P = P(Y|X).$$

exist, then problems of computational imprecision, unstable estimates, and large sampling error may occur. In other words, the logit model will suffer from the same problems of multicollinearity as the OLS multiple regression if these conditions are infringed. Hence, in selecting the explanatory variables of learning economies, care has been taken to ensure that they are representing different aspects of the studied subject.

4.2.3 Method of Estimation of Logit Models

Logit parameters are typically estimated by Maximum Likelihood Estimation (MLE) in contrast to the Least Square Estimation (LSE) or Ordinary Least Squares Estimation (OLS, when Gauss-Markov assumptions are made) used in standard linear regressions.

The conceptual difference between OLS and MLE is that the former is concerned with the picking of the parameter estimates that yield the smallest sum of squared errors in the fit between the model and data, while MLE is concerned with the picking of the parameter estimates that imply the highest probability or likelihood of having obtained the observed sample Y. Above all, OLS estimation is the best for handling linear models; in comparison, MLE handles non-linear models more effectively. Therefore, MLE complies with the logit specification which is non-linear; this rules out OLS estimation as appropriate.

MLE proceeds to find the parameters (βs) so as to maximize the maximum likelihood function:

$$L(Y|X,\beta) = \sum (\pi_i)^{Y_i} \times (1-\pi_i)^{1-Y_i}$$

which can be further reduced to the equation:[38]

$$logL(Y|X,\beta) = \sum_{i=1}^{N} \Big[Y_i log\pi_i + (1-Y_i)log(1-\pi_i) \Big].$$

The next procedure is to take the first derivatives of the above equation with respect to each of the K coefficients β_k, and then to set them equal to zero. Solutions of these K equations will yield the MLE estimates $\hat{\beta}_s$. The logit likelihood equations take the form of:

$$\sum_{i=1}^{N} \Big[Y_i - \frac{e^{\sum \beta_k X_{ik}}}{1-e^{\sum \beta_k X_{ik}}} \Big] X_{ij} = 0$$

[38] *This asserts that, when β can maximize $L(Y|X,\beta)$, β will also maximize $logL(Y|X,\beta)$.*

where $j = 1, \ldots, K$.

A minor drawback to MLE, thus, is of the nonlinearity in the β_k of the logit likelihood equations. This implies that algebraic solutions cannot be obtained directly but implicitly. Approximations by standard iterative algorithms have to be used to solve for the systems of equations. These algorithms are readily available in computer packages such as SAS, SPSS, BMDP or SHAZAM, and hence, are transparent to the user. The estimates of β_k have the properties of unbiasedness, efficiency and normality. Meanwhile, the MLE on these models is nonlinear and the properties are asymptotic; that is, they conform to large-sample properties.

4.2.4 Statistical Inference from Computer Output

With respect to the statistical significance of individual coefficient estimates, the asymptotic t-statistic is usually used for testing the null hypothesis that a coefficient, say β_k, is 0; that is, variable X_k has no effect on Y. Accounting for $(N - K)$ degrees of freedom, if the computed statistic exceeds the critical value, the null hypothesis will be rejected. But, in the SAS program an alternative is available; that is, the Wald test. The Wald test has a chi-square distribution and is acclaimed for its appropriateness for nonlinear regressions.

In testing the goodness of fit of the likelihood equation, the likelihood ratio statistic is computed as:

$$c = -2(logL0 - logL1)$$

where L1 is the value of the likelihood function for the full model as fitted and L0 is the maximum value of the likelihood function if all coefficients except the intercept are 0. In effect, chi-square is used for testing the hypothesis that all coefficients except the intercept are 0. The test is performed by comparing the computed statistic c to a critical value taken from a table of the chi-square distribution of $(K - 1)$ degrees of freedom and significance level α; that is, $\chi_{(2K-1,\alpha)}$. The c χ^2 statistic is more appropriate than R^2 in this respect.

4.2.5 Variable Selection: Proxies

4.2.5.1 The Procedures of Selection

Owing to the unavailability of published electronics data at the firm level for the study areas, surveys and in-person interviews have been conducted to overcome such requirements. (Details of the proceedings of the surveys and interviews are the subject matters of Chapter Five to follow.)

The selection of the variables was mainly based upon their relevancy to the industry life-cycle concept. This necessitated that the measures had to reflect external learning economies and entrepreneurial learning economies, the major forces contributing to the agglomeration of the early-stage firms. Proxies are also selected in accordance with the following statistical criteria:

(1) whenever possible, proxies with absolute measurement scale (where there were well-defined maxima and minimal) were used (Smith, 1973);

(2) variables should be normative in a way that a value judgment could be associated in one direction of movement along their scales (Knox, 1974);

(3) a relatively balanced number of measures selected to represent the dimensions has to be observed.

The initial trial regressions will consist of the "direct" proxies that show up a close relationship to firm growth rate in the correlation matrix. The alternative variables that may represent the two dimensions, external learning economies and entrepreneurial learning economies, and as asked in the questionnaire of the surveys, are listed in the appendix (see p.235). In other words, those proxies can be distinguished as either "direct" or "indirect" proxies. If the former show up as significant proxies, they, therefore, hint at the "presence" of the type of economies they are representing; by the same token, they are expectedly positively related to the dependent variable. Likewise, if the latter show up as significant proxies, they reflect the "absence" of the type of economies they are representing; which also means that they are directionally negatively related to the dependent variable. In the process of searching for the most appropriate combinations of proxies, the "direct" proxies get higher priorities. Only when they fail to show up statistically significant in the trial regression would the "indirect" proxies get their turn. In other words, numerous trial regressions have been run before comfortably sticking to the final one.

Hence, these practices have helped to pin down the whole empirical study into the following specific proxies for the dependent and explanatory variable s as follows.

4.2.5.2 The Dependent Variables

As far as the dependent variable of the logit model is concerned, it is defined in terms of firm sizes, either small or large firms. A small firm, or early-stage firm, is regarded as one that has less than or equal to 25 employees;[39] likewise, a "large firm" is for the purposes of this thesis taken as one with more than 25 employees. Hence, the dependent variable adopts the mnemonic SMALLOC, and has a binary scale of 1 when referring to a small firm and 0 otherwise.

Nevertheless, to be sure that the surveyed firms are really representing the subjects concerned in this study, the meaningfulness of distinguishing them by stages ("early" versus "later" stages), or by ages (those established before 1980 versus those thereafter), or by both ("early stage, new firms" versus "later stage, older firms") has to be justified. Hence, the parametric Student's t-test and the nonparametric chi-square test of sample independence have been applied to surveyed firms for this purpose.

With respect to the practice of dividing the surveyed firms into "early" (or, "small")

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[39] *There is no consensus on what constitutes a small firm quantitatively. The quantitative aspect of a small firm varies from place to place, and one research to another. In the U.K., the Council for Small Industries in Rural Areas defines a small firm as one with 20 employees or less (Cross, 1983). In Canada, the Small Business Secretariat denotes a small business as the independently owned business with a maximum of 50 employees (d'Amobise, 1991). Meanwhile, the U.S. House of Representatives' Task Force on Small Business of Minnesota defines a small firm as "an enterprise having 20 or less employees" (Leyden, 1983, p.9). However, the state of Florida defines a small business as "any business which is owned or operated independently of any other business entity and which has no more than 25 employees ... " (Ibid.). Accordingly, to find an appropriate cut-off for this study, small firms had been defined as firms having either 20 or less employees, or 50 or less employees. Unfortunately, when the dependent variable was defined as such, the logit models did not converge in either case. However, further examination found that the logit regression converged when the cut-off point for the dependent variable was defined by firms that had employees no more than 25. This last finding becomes the yardstick of defining the surveyed firms into the early and later stage in accordance to the industry life-cycle concept.*

or "later" ("larger") stages, the Student's t-test of sample independence has been set up as to test:

H_o : There is no difference between the means of the populations of which "early" and "later" stage firms are samples.

H_1 : There is a difference between the means of the population of which "early" and "later" stage firms are samples. (Hammond and McCullagh, 1974, p.163).

The number of observations for "early" stage firms is 19; for the "later" stage firms, it is 14. It is found that the calculated t-statistic is (−)3.6378, while the t-table's critical value at 99 percent level of significance with 31 degrees of freedom is 2.75 (and for 99.9 percent level of significance it is 3.65). Therefore, the calculated t-statistic falls outside the critical region; the null hypothesis, H_o, has been rejected. We conclude that there is difference in the means of the populations that the two type of firm stages are samples. As a consequence, the surveyed firms can be meaningfully divided into either "early" or "later" stage firms as they are so different from one another.

Likewise, in terms of firm ages, 21 surveyed firms are qualified as "new" firms; and, 13 as "older" firms. The Student's t-test of sample independence is set up to test:

H_o : There is no difference between the means of the populations of which "new" and "older" firms are samples.

H_1 : There is a difference between the mean of the population of which "new" and "older" firms are samples.

It is found that the calculated t-statistic is (−)6.0013; and, the t-table's critical value at 99.9 percent level of significance with 32 degrees of freedom is 3.65. The null hypothesis is rejected accordingly and it is concluded that there is significant difference in the population means represented by the two types of firms according to ages. This verifies that the surveyed firms can be meaningfully divided into either "new" or "older" firm.

To be sure that the empirical observations are compatible with the industry life-cycle concept the surveyed firms have been tested against the theoretical presumption that the stages of the life cycle are correlated with the ages of the firms involved. A chi-square test of independence has been set up for the justification. The general hypotheses are known to be:

H_o : The event "an observation is in row i" is independent of the event "that the same observation is in column j", for all i and j. Or, P(row i, column j) = P(row

i) × P(column j), for all i and j.

H_1 : P(row i, column j) ≠ P(column j), for some i, j. (Conover, 1980, p.159).

In this context,

H_o : The stage of the firm is independent of its age, for all firms and ages.

H_1 : At least some of the stages of the firms are not independent of their ages.

Let $E_{ij} = R_i C_j / N$, then the T-statistic is given by

$$T = \sum_{i=1}^{r} \sum_{j=1}^{c} \frac{(O_{ij} - E_{ij})^2}{E_{ij}}.$$

Accordingly, the observed firms can be arrayed as follows.

Ages	Early Stage	Later Stages	Row Total
New	15	6	21
Old	4	8	12
Total	19	14	33

And, the array of their expected frequencies is as follows.

Ages	Early Stage	Later Stages
New	12.0909	8.9090
Old	6.9090	5.0909

Accordingly, the calculated T-statistic is 4.5366. From the chi-square table, given $(r-1)(c-1)$, or, 1 degree of freedom, and at 95 percent level of significance, the critical value is 3.841. Hence, the calculated T-statistic is greater than that of the chi-square table value. The null hypothesis is rejected. We conclude that stages of the firms are not independent from firm ages. This further means that the early-stage (small) firms are associated with new firms; likewise, the later-stage firms are related to older firms. In addition, the survey data also show that the new but larger firms are mostly branch plants of some well-established parent corporations, and the older but small firms are at the verge of eradication. Hence, we should be confident that the models will represent what they are intended to measure.

4.2.5.3 The Explanatory Variables

As far as the explanatory variables are concerned, they are going to represent two general dimensions of learning economies: external and entrepreneurial learning economies.

The proxies for the former dimension are: "*USCIENT*", "*TECHNF*", "*SALEINT*", "*MGUSC*", "*VENT*", and "*INCUBATOR*". The later dimension, for its part, is represented by "*MGINH*" and "*AGE*". The definitions of these proxies and their relationships with the dependent variable are delineated as follows.

(1) *USCIENT* (associated with *U*niversity *SCIENT*ists) is a proxy for the measurement of external learning economies especially the availability of local technical information resources such as a university, or universities. This variable is measured as the percentage of scientists or engineers of the firm recruited from the local university(ies). For the derivation of this variable, entrepreneurs were asked in the survey to indicate the percentage of scientists or engineers that they recruited from "within the province", "elsewhere outside the province within Canada", "within the U.S.A.", and "within other countries". It is expected that the higher the percentage of scientists and engineers which firms recruited from local areas (within province), the higher the probability that other small electronics firms will be found in the same community. Drawing technical information locally will mean a close familiarity between firms on the one side and local universities on the other. Their relationships will have been easily established through formal meetings such as classes, seminars or conferences, and informal casual luncheon meetings between the parties. All these forms of face-to-face contacts contribute an accurate and direct flow of technical information that facilitates technological transfer. Hence, the expected sign of the estimated parameter of this proxy is positive. The emergence and survival of small electronics enterprises are likely when such contacts are made frequently.

(2) *TECHNF* (associated with *TECH*nical supports from non-face-to-face contacts) is another proxy measuring the availability of local technical information resources within localities containing small electronics firms. However, it is different from *USCIENT* in that it refers to the overall scope of technical information resources rather than to a narrower reference limited to local universities supports. It is expressed as the percentage of average time of entrepreneurs spent on non-face-to-face contacts through different modes of communication that include "telephone", "telex", "fax", or "correspondence" for the accessibility to overall technical supports. Since all these modes of communication are presumably "long

distance" contacts; that is, outside the localities of where firms are situated, a higher percentage of the time of entrepreneurs spent on them will mean the lower availability of overall technical supports in localities. Putting this into perspective, a higher measurement of this proxy will reflect the ineffectiveness or insufficiency of local overall technical supports; this may hamper the development or fabrication of prototypes of small electronics firms at their localities. Therefore, it is expected that this proxy is inversely related to the emergence of small electronics firms with respect to external learning economies. Its estimated parameter is expected to be negatively related to the dependent variable.

(3) *SALEINT* (associated with *SALE*s to *INT*ernational markets) is a proxy to measure the availability of managerial information with respect to market information from "non-local" resources. It is expressed in terms of the percentage of sales (in monetary terms) in international markets (excluding the U.S.A.). Entrepreneurs were asked in the survey to indicate the percentage of their sales either at local markets ("within province") or markets outside localities ("elsewhere within Canada", or "within the U.S.A.", or "within other countries"). When the direct proxy of "local" market information failed to appear statistically significant in the modelling processes, the level of international sales has been taken as a proxy to reflect the deficiencies of local market information. Hence, when this proxy turns out to be statistically significant, then it may be conclude that the hypothesis is confirmed. Nevertheless, the level of sales is generally recognized as a variable always directly proportional to the growth of firms or industries. Therefore, it is expected that the higher the percentage of sales of the corporations in international markets, the higher the probability of the occurrence of small electronics firms owing to the impact of outside localities. However, from the perspective of external learning economies, a higher percentage of sales in international markets means a lower percentage of sales in the "province" where firms are located. This will mean a lower level of face-to-face tapping of market knowledge from local resources such as sales agencies. These sources are not providing adequate marketing data or facts to local firms. Firms will be insensitive to market needs; they lack the required market intelligence of the changes of preferences of their patrons, not to mention anticipating the craving of new products to meet new demands; the growth of firms is, therefore, hampered. In this regard, it is expected the proxy, *SALEINT* indicating the percentage of sales in international markets, should be negatively correlated with the occurrence of small electronics firms.

(4) *MGUSC* (associated with *M*ana*G*erial consultations from the *US* and elsewhere

outside the province of Canada) is a proxy to measure the availability of managerial information resources in the localities where firms are located. It is expressed as the percentage of expenditures spent on computer programming consultations regarding office procedures from agencies outside the province and from the U.S.A. Entrepreneurs were asked in the survey to indicate the percentage of their expenditures spent on computer programming consultations regarding office procedures from "within the U.S.A.", or "elsewhere in Canada" as against "inhouse", "within province" and "within other countries". It is expected that the higher the percentage of such expenditures spent on the U.S.A. sources and elsewhere in Canada, the lower the probability that small firms will benefit from external learning economies. From this perspective, local agencies are presumably not able to provide the required level of managerial resources to the small local firms. The latter have to look for out-of-the-locality resources to fill the void. In a way, this kind of accessibility to managerial consultations has minimized, if not denied, the possible benefits derived from face-to-face local contacts. Thereupon, the estimated parameter is expected to have a negative sign and negative relationship with the dependent variable or the occurrence of small electronics firms.

(5) *VENT* (associated with *VENT*ure capital institutions) is a proxy to measure the availability of venture capital to small electronics firms. Entrepreneurs were asked in the survey to show the percentage of financial supports (in monetary terms) received from venture capitalists from within the province as against those from "elsewhere within Canada", "within the U.S.A.", or "within other countries". It is expected that the higher the percentage of their financial supports from venture capitalists within localities, the higher the probability of the locality spawning more small electronics firms. As mentioned in Chapter Three, more often than not, venture capitalists not only provide financial assistance to their client firms but also, more importantly, provide management and technical assistance to the firms from their start-up to the point where they can go public. They may then help entrepreneurs to seek high-growth market opportunities and crystallize the often incomplete but technically brilliant ideas of entrepreneurs. They can also assist in identifying and attracting additional key players capable of supplying all kinds of supports to the entrepreneurial teams. Capitalizing on these, small electronics firms will reap the benefits that are called external learning economies. This proxy, thus, is expected to yield a positive sign in the model.

(6) *INCUBATOR* (associated with *INCUBATOR* centres) is a proxy for the avail-

ability of innovation centres within the localities of small electronics firms. It is a dummy variable that takes the value of 1 when the firm is located within an innovation centre and the value of 0 if otherwise. It is expected to have a positive impact on the dependent variable. The locating of a firm within an innovation centre means that there is a high level of contacts, essentially face-to-face contacts, among entrepreneurs and specialists of the facilities or agencies such as the government or private laboratories, venture capital companies or law firms, located within the scientific infrastructure. As a result, quick and precise acquisition of either technical, or managerial, or legal knowledge, or all of these, is made possible. New product development or its commercialization is well within the capabilities of the resources available in the scientific infrastructure. Hence, this proxy is expected to be positively related to the dependent variable; that is, the emergence of small electronics firms.

(7) *MGINH* (associated with *M*ana*G*erial consultations from *INH*ouse) is a proxy of the availability of entrepreneurial learning economies. It is measured by the percentage of expenditures on managerial consultations, particularly on the computerization of office procedures. It is hypothesized that the higher the percentage of such expenditures, the higher the probability of engendering a new electronics firm. As reviewed in Chapter Three, on account of their limited resources, small high-technology firms are in general incapable of exercising the process of division of labour, or, simply, the hiring of expertise for the performance of specialty tasks within firms. Nevertheless, if entrepreneurs are prepared to experience and to learn those managerial skills and knowledge within their jurisdictions, then there is a higher propensity of such individuals undertaking to start their own firms. In this context, entrepreneurs are most likely capable of learning from the "do-it-yourself" mode of practices from their own experience within firms. Therefore, the estimated parameter of this proxy is expected to have a positive sign, a plus attribute to the propensity of starting one's own firms.

(8) *AGE* is another proxy to measure the propensity of entrepreneurship. It is expressed as the calendar year of the establishment of firms. Therefore, the most recent calendar years will appear as a larger numerical value in the data set. It is hypothesized that the lately established firms are more likely to possess the enthusiastic and ambitious entrepreneurship. Endowed with these entrepreneurs, information can be easily and precisely acquired for the corporations. Therefore, it is expected that its estimated parameter will bear a positive sign in relation to the dependent variable. That means, the more recently

established are the firms, the more likely they will possess entrepreneurs who are enthusiastic and self-motivated. The affirmation of this relationship in the empirical study will confirm the theoretical benefits derived from entrepreneurial learning economies.

So far, there are three proxies that represent the requirements of acquiring out-of-locality information such as overall technical supports (*TECHNF*), office procedures managerial information (*MGUSC*), and market information (*SALEINT*). Since the first two involve the quality of the available information, then they are not necessarily implying that rising quantitative magnitudes are better. Instead, according to agglomeration theories, they are eccentric forces rather than centralizing forces. Therefore, they are undoubtedly expected to have a "negative" impact on the agglomeration of electronics activities. Nevertheless, as quality market information is reflected in sales revenues, then these proxies must be directly proportional to firm growth. Given this reality, we have to expect that they will be positively related to industrial agglomeration. As long as these proxies are statistically significant, we may conclude that they represent a shortcoming of local agencies in providing the required market information; hence, they point to a deficiency in external learning economies.

4.3 The Specific Model

4.3.1 Justification of Multiple Regression Modelling

For the sake of consistency, logit modelling should have been applied to the Manitoba case study as well. As mentioned earlier, logit modelling of small electronics firms in Manitoba conforms with the theoretical underpinning of the whole study; that is, the agglomeration of small firms as against large firms. Unfortunately, in practice, the data available do not allow a straight application of logit regression to Manitoba. An attempt to marry logit analysis with Manitoba firm-specific data proved inadequate because the equation failed to converge in its estimation. Therefore, to remedy this defect, it is necessary to resort to multiple regression.

Nevertheless, when the hypotheses defined earlier are conceived from another perspective, multiple regression modelling is as compatible as logit modelling to this study. Fundamentally, this thesis is concerned with the agglomeration of early-stage firms in the context of the industry life-cycle concept. Yet, at the same time, the intrinsic or structural characteristics of the industrial groups of each stage of the industry life-cycle are very different from one another. Therefore, in a way, they can be perceived as four different linear regression models, each targeted to a particular stage. The growth pattern of the early-stage firms can be approximated by a linear regression equation of its own, and that is what concerns us here. Since small firms are very different from large firms in their structural characteristics, the latter could be considered as outliers in the study of the former type of firms. Hence, to comply with the hypotheses defined earlier, the empirical study is narrowed down to the study of the growth of small firms; albeit no longer in relation to large firms but with the same explanatory dimensions as the logit model has suggested. It follows that there is not much, if any, information lost on applying multiple regression modelling rather than logit modelling to the Manitoba case. As far as the significance of the explanatory proxies to the variation of the dependent variable is concerned, when the same set of proxies shows up as statistically significant in both regression contexts, then we may confidently declare that these proxies are reliable factors in explaining, in this case, the growth of small electronics firms. In short, on applying multiple regression modelling to Manitoba, we are still able to test the hypotheses defined earlier in this thesis. In this context, we are explaining the growth of small electronics firms in Manitoba with the same dimensions defined by the industry life-cycle concept with respect to learning economies.

4.3.2 Multiple Regression Modelling in Brief

The general form of a multiple regression model can be expressed as:

$$Y_i = \beta_1 + \beta_2 X_{21} + \beta_3 X_{31} + \ldots + \beta_k X_{ki} + \ldots + \epsilon_i$$

where Y is the dependent variable, X_s are the independent variables, and ϵ the stochastic disturbances or error term, and i denotes the ith observation. Hence, X_{2i} represents, for example, the ith observation on explanatory variable X_2. β_1 is the constant term or regression intercept of the equation.

Of the case in hand, it is the agglomeration effects (the growth) of small firms that are to be explained by the variables generated from the concepts of external and entrepreneurial learning economies. Hence, Y_i has the value representing the agglomeration effects pertaining to observation i . Then, X_{ki} represents the determinants of agglomeration effects as explained by the variable X_k for the same observation i . The estimated coefficients or parameters, say, β_i, are the estimated magnitude that the clustering effect will be influenced by any change in the respective explanatory variable X_{ki}.

For the estimates of a multiple regression model to be trustworthy, the model itself has to meet all the basic assumptions underlying Classical Linear Normal Regression (CLNR) modelling. These basis assumptions are normality, zero mean of the disturbance, homoscedasticity, non-autocorrelation and uncorrelatedness of the regressors and the disturbances. Technically, these are expressed in the fashion shown.

(1) Normality:

— μ_i — $N\left[0, \sigma^2\right]$.

(2) Zero mean of the disturbances:

$E(\mu_i) = 0$ for all i.

(3) Homoscedasticity:

— $Var(\mu_i) = \sigma^2$, a constant, for all i.

(4) Non-autocorrelation:

— $Cov(\mu_i, \mu_j) = 0$, if $i \neq j$.

(5) Uncorrelatedness of the regressors and the disturbances:

— $Cov(X_i, \mu_i) = 0$, for all i and j.

The multiple regression parameters are conventionally estimated by the Least Square estimators (LSE) or Ordinary Least Squares (OLS) estimators on account of their ease of application. OLS estimators give "the best fit line" relating the dependent and the explanatory variables (perhaps one at a time). Technically, it means to minimize the sum of the squares of the deviations of the observed points (actual value) from the line (estimated value):

$$Min \sum (Y_i - \hat{Y}_i)^2$$

where Y_i refers to the actual observations, and the $\hat{Y}_i$ refers to the corresponding fitted values, so that $Y_i - \hat{Y}_i = e_i$ is the residual or deviation value of the corresponding observations.

The statistical significance of the overall regression is estimated by the R^2 statistic or the adjusted $\overline{R}^2$ statistic which is then justified by the F-ratio. The statistical significance of the individual variables is estimated by their own t-statistics which are then justified by their standard errors.

4.3.3 Proxies of The Multiple Regression Model

With the use of multiple regression modelling to discern the impact of external and entrepreneurial learning economies upon the growth of small electronic firms in Manitoba, the dependent variable, in this case, represented by the mnemonic "EM8990", is defined as the percentage change of the number of employees of the firm for the period of 1989-90. Although the use of a two-year average change may seem very restrictive, it still enables the model to reflect the significant changes occurring between those two years. This is because of the fact that, as noticed earlier, most of the subject firms are of very small size; therefore, a subtraction or an addition of one position to their firm will be very consequential in terms of both their employment size and payroll. It is a very sensitive variable representing the intensity of clustering of small firms in question for the study period. As a matter of fact, the number of observations will decrease when the average change is extended further to three years or more, as the missing data become much acute.

As far as the explanatory variables are concerned, a set of proxies similar to that of the logit model is made use of. In brief, these are proxies used to represent technical external learning economies, namely, *USCIENT* and *TECHNF*; and the managerial external learning economies of *SALEINT*, and *MGUSC*, and *INCUBATOR*; and the entrepreneurial learning economies of *AGE*. They are also postulated to have signs and relationships compatible with those as suggested in the logit model. Differences arising between the two models in the use of proxies occur in the dropping of *VENT* of the external learning economies and *MHINH* of the entrepreneurial learning economies from the multiple regression. They are deleted because of the problem of missing data. However, *VENT* has been replaced by another proxy mnemonic *SUBSID* in the multiple regression model, albeit no appropriate substitute for *MGINH* could be discovered. *SUBSID* (associated with the government agencies with *SUBSID*ies programmes) is a proxy to estimate the availability of local financial agencies providing overall information of operations to firms. It is measured as the percentage of financial supports received from these local government agencies. It is hypothesized as a positive proxy such that the higher the percentage of such support available from local government agencies, the more likely the firm will grow (in terms of employment, in this case). Hence, local government agencies have replaced venture capitalists in the multiple regression model in providing not only monetary assistance to small electronics firms in Manitoba but also technical information and business counselling services as well. In the course of proving their intelligent use of government subsidies, entrepreneurs are involved in many face-to-face contacts with government representatives. In those meetings, government representatives will proceed to pass along other important information relating to the viability of the entire operations of firms. Hence, this proxy succeeds in retaining the rationale for *VENT* without losing much information, if any.

The procedures undertaken to collect the relevant data for fitting into the models will be discussed in Chapter Five. The results of these models will be reported and explained in Chapter Six. Based on the analyses of these results, some suggestions for and observations on the success of science parks in Western Canada in general, and in Manitoba in particular, will be covered in the succeeding chapter, Chapter Seven. It is to the procedures of data collection that we turn first, however.

Chapter Five

Data Collection and Description

5.1 Introduction

In the previous chapter, discussion was mainly centred on the theoretical justification and specification of the logit and multiple regression modellings for the testing of the industry life-cycle hypotheses determined earlier. This chapter carries the study further to the discussion of the manner in which the required data were collected and to the review of the characteristics of the data.

The beginning section will spell out the whole process of data collection; a process which involves identification and location of the study units, conducting a pilot survey, mailing of finalized questionnaires and, where appropriate, carrying out in-person interviews. Exercising prudent designs for these procedures, it is hoped that quality data will be the outcome. Some of the difficulties encountered in the process will be mentioned at this juncture.

Another, and the larger, part of this chapter deals with the description of the collected data. In addition to the elucidation of the mean behaviours of the variables or proxies, the respective data are also justified for their compatibility with respect to (1) the intrinsic characteristics of the electronics firms asserted earlier in Chapter One; (2) the regional subdivision differentiation with regard to Manitoba on the one hand and the other Western provinces on the other; and (3) the behaviours of small (early stage) and large (later stage) electronics firms depicted by the industry life-cycle concept. Discussion of these issues will focus on the efficiency of the variables or proxies in relation to those intrinsic characteristics and to different dimensions of learning economies used for modelling.

Subsequently, a section is devoted to the justification of the surveyed firms as representative electronics enterprises. Characteristic symptoms include: high rates of growth, either in terms of sales or employment; high proportion of high-tech input content, either in terms of a high percentage of scientists or engineers in their work-force, or a high rate of

R&D expenditures relative to their sales revenues. To acknowledge the dynamic role played by small electronics firms, the surveyed small firms are compared and contrasted with their counterparts in these respects. Such variations of small- and large-firm behaviours are objectively assessed by the statistical Student-t-test analysis.

The portrayal of the mean behaviours of the surveyed firms in Manitoba and those in the other Western provinces occupies another major portion of this chapter. The objective of this description is to justify the methodological approach of this study which has revolved around the establishment of two models of different geographical contexts, namely, the general Western Canada model and the specific Manitoba model. The substantiation would be conducted with the help of the Student-t-test analysis in which the variation between the mean behaviour of the Manitoba firms and those in the other Western provinces can be assessed according to each of the "learning economy" proxies. If the Student-t-test analysis confirms that differences in the requirement of learning economies of the Manitoba firms and those in the other Western provinces exist, it follows that the establishment of two models of distinctive geographical contexts is justified.

The final section of this chapter is designed to justify the use of the logit model in practical terms. This has been carried out by establishing the different behaviours of the surveyed small and large firms in their acquiring of learning economies. The Student-t-test analysis is deemed the most suitable to fulfill this purpose. The same "support" proxies exploring the different behaviours between the Manitoba firms and those in the other Western provinces also function as the subjects of this description, albeit now in the context of small versus large firms. If the Student-t-test analysis confirms that there are differences in the acquisition of learning economies between the small and large surveyed firms, then the data can be considered in compliance with the logit model. Subsequently, the logit model can be taken to be of sufficient credibility to reveal the mechanisms of the industry life-cycle concept in practical terms. To begin with, however, the design and procedures of the data collection process are discussed in the next two sections.

5.2 Survey Design

There are two major sources of data: government general statistical publications and objective surveys. The most convenient and handy source of the two is recourse to government publications. However, these publications have the shortcoming of being collected primarily for general government purposes or for the interest of the general public. Therefore, in many respects, government-generated data do not meet the specific needs of academic researchers. In this case, the data measuring external and entrepreneurial learning economies are simply unavailable from government publications. Hence, though decidedly more costly in terms of time taken and other material expenses than the alternative of government publications, data collected by objective surveys are guaranteed to be of direct relevance to researchers.

By and large, an industrial survey can be conducted in two major ways. It can be conducted either by dispatching postal questionnaires to the respondents or by initiating in-person or face-to-face interviews (Oakey, 1981). Townroe (1971) argues that wherever possible, the in-person interview method of inquiry which involves interviewing the actual decision-makers, should be adopted since it offers major methodological advantages. This method has been looked upon by various industrial researchers as an ideal vehicle for obtaining insightful information for industrial studies. It allows the interviewer to clarify directly any particular questions that the respondent might have difficulties with, and ensures that the questions being asked can be made fully comprehensible, and precise information can therefore be collected (Oakey, 1981). Additionally, a first-hand experience that cannot be revealed by statistical tables or a postal questionnaire can be gained from physical visits to the respondents' sites. In contrast, the attraction of the postal questionnaire approach lies in the fact that it is lower in unit cost of completion, a circumstance which allows for a larger sample size.

Nevertheless, these two methods are not mutually exclusive. Both of them can be employed in the same study in a procedure that combines their joint merits. With this in mind, each of the two methods was utilized in the Manitoba portion of the study. Unfortunately, owing to budgetary constraints, only a postal survey was conducted for the segment dealing with the other Western provinces. Details of the steps taken to accumulate the data follow.

5.3 Survey Procedures

Endeavours to acquire electronics industry data were undertaken in 1991 and 1992 through either postal questionnaires or personal interviews or, whenever possible, both. The first step was to identify and locate the study units, the electronics firms in the Western provinces. The full listing of the electronics firms in Western Canada was compiled from different sources, including (1) *The Manitoba Sourcing Directory,* (Manitoba ITT, 1991), (2) *Directory of Electronics Industry Association of Manitoba* (EIAM, 1984), (3) *Manitoba Trade Directory* (Evans Communication Limited, 1989), (4) *Henderson Directory, 1991,* (Henderson Directories Limited, 1991), (5) *The Manitoba Telephone Book* (Manitoba Telephone System, MTS, 1991) (6) *Saskatchewan Manufacturers' Guide* (Saskatchewan Economic Development and Tourism, 1990), (7) *Saskatchewan Directory: A Directory of Advanced-technology Capabilities in Saskatchewan* (Saskatchewan Economic Diversification and Trade, 1991), (8) *Alberta Manufacturers Index* (Alberta Economic Development and Trade, 1989), (9) *BC Technology Directory* (Discovery Foundation, 1990), and (10) *Vancouver Island Advanced Telephone Directory* (The Business and Industry Development Centre, 1992). A preliminary search through these sources enabled the identification of 193 firms involved in electronics activities, of which 43 were in Manitoba and 150 in the other three Western provinces.

As a preliminary test, a pilot survey was carried out. It targeted parties involved in some way with electronics, such as government officials, academics, bankers, and, particularly, the electronics manufacturers themselves. However, due both to financial constraint and the fact that most players are found in Winnipeg (refer to Chapter One), the pilot survey was limited to this city. Such an initial investigation helped the author gain a real sense of the industry, in particular the industrialists' general feeling about existing government policies. Most importantly, through surveying electronics entrepreneurs, the sensitivity of every question asked in the questionnaire can be assessed. Feedback was elicited for the betterment of the questionnaires, for the estimation of the time required for their completion and for the estimation of the time required for further in-person interviews. For the betterment of the questionnaires, Hoinville and Jowell (1977) assert that five to ten interviews will often be able to reveal wording and layout problems of the actual surveys. In this regard, five out of 43 Winnipeg firms that showed keen interest in this study, as reflected in their responses to earlier telephone inquiries, were invited to participate in this pilot survey. Moreover, the pilot survey revealed the encouraging fact that a reasonable cross-section of entrepreneurs was enthusiastic about participating in the survey in general, and the questionnaire survey in particular, although they expressed some reservations with respect to the business confidentiality which had to be observed. The qualitative questions (dealing with opinions) were relatively better received by the respondents than the quantitative questions. Accordingly, the pilot survey helped to confirm the *a priori* argument of having both the postal questionnaires and the in-person interviews in all surveys whenever possible. On the one hand, the postal questionnaires were weighted towards quantitative questions. The answers or responses to these questions required some checking of the actual figures in the books and involved consideration of disclosure. On the other hand, the in-person interviews were calculated to tap the "missing figures" in the returned questionnaires, and most importantly, to answer the qualitative, opinionated, or open-ended type of questions in which the gestural expressions of the respondents were taken into account for later analysis. Furthermore, it was estimated that the optimum length of time for each interview should be roughly one hour. Such an interview duration would balance the desire for tapping maximum information and the danger of having a low response rate resulting from a long and involved cross-examination.

On the basis of those revelations, two useful guides were established: first, the questionnaires for the actual survey were finalized; secondly, the optimum length of time for future interviews was determined. The actual survey commenced in May 1991.

To start with, a total of 131 electronics manufacturing firms in Manitoba were identified and contacted by telephone. The top managerial personnel of the firms, such as owners, CEOs, directors, senior executives, and general or departmental managers were then invited to participate in the survey. If they showed an interest, the questionnaires were sent to them and an in-person post-questionnaire interview was arranged with them. Initially, 43 of the "self-proclaimed" electronics manufacturing firms showed interest in the survey. Eventually, 69.77 percent (or 30) of them actually returned their questionnaires. Unfortunately, of these, only 16 were "usable", a number which represents 37.21 percent of the total (43) set of electronics manufacturing firms in Manitoba. The other questionnaires not usable either because they were incomplete, or because initially the firms wrongly identified themselves. Some of the latter were actually electronics service companies involved in wholesaling, repairing or installation rather than manufacturing.

For the other Western provinces, survey procedures were initiated by mailing-out the questionnaires to all 150 electronics manufacturing firms (65 in British Columbia, 35 in Saskatchewan, and 50 in Alberta). Only 28 responded, representing an 18.67 percent response rate. Unfortunately, only 18 of these were usable. The remaining 10 were either incomplete or did not fit the purpose for which they were intended.

To sum up, a total of 193 questionnaires were mailed out to electronics firms in all four Western provinces and 71 of them were returned. This represented a 36.79 percent crude response rate, but, in the final analysis, only 34 (or 44.89 percent of the total) were usable. The other 37 (or, 52.11 percent of the total) were either incomplete or inappropriate for the purposes of this study. This, nevertheless, still amounts to a fairly satisfactory response rate of 17.62 percent. Of the 34 usable questionnaires, 19 (or 55.88 percent) were from Manitoba, nine (or 26.47 percent) were from British Columbia, three (or 8.82 percent) were from Saskatchewan, and the remaining three were from Alberta.

5.4 Data Description

The collected data can now be reviewed in three broad sections. The first broad section will describe the general patterns of the surveyed firms in terms of the asserted intrinsic characteristics of electronics activities in general. The second broad section will look into the distinctiveness of Manitoba firms as compared with the firms in the other Western provinces. The last broad section will distinguish between the behaviours of small and large firms.

5.4.1 Intrinsic Characteristics

In retrospect, the asserted intrinsic characteristics of electronics firms include, firstly, their fast rates of growth in terms of sales revenues and employment, secondly, their high technical content in terms of high proportion of R&D expenditures to total sales, and high proportion of technical labour input to total labour of the firms, and, thirdly, that small firms grow faster than large firms. In the following section, the collected data for the surveyed firms will be scrutinized according to these characteristics.

5.4.1.1 Sales Growth Rates

The first attribute of the intrinsic characteristics of the electronics activities is fast rate of growth in sales. As shown in Table 5.1, the surveyed firms sustained a very high

Table 5.1
Intrinsic Characteristics of Surveyed Electronics Firms by Firm Size

Firms	Sales Growth Rate, 1986-90	Employment Growth Rate, 1986-90	% Scientists/ Engineers To Total Employees, 1990	% R&D Expenditure To Total Sales, 1990
Small	261.14	87.07	28.97	4.48
Large	135.13	136.42	23.46	15.72
	(*d.f.*=21)	(*d.f.*=25)	(*d.f.*=30)	(*d.f.*=16)
	(*t*=1.17)	(*t*=-0.70)	(*t*=0.66)	(*t*=-1.73**)
Overall	217.31	109.00	26.56	7.61

Source: Survey by the author.
*Note: The information in parenthesis refer to the degrees of freedom (d.f.) or calculated t-statistic (t) of the Student-t-test analysis. Single * implies that the result is statistically significant at the 0.10 level; double **, 0.05 level; triple ***, 0.01 level.*

growth rate in sales for the period of 1986-90. On average, their sales grew by 217.31 percent during this period of time, or by more than two-fold over the base year.

Investigated further at the firm size level, the surveyed small firms have a higher-than-average growth rate of 261.14 percent for this period of time. This contrasts markedly with the 135.13 percent growth rate displayed by the surveyed large firms.

In order to examine objective differentiation of the mean behaviours of the surveyed small and large firms, the Student-t-test analysis is used.[40] Accordingly, the calculated t-statistic fails to reject the null hypothesis that their mean growth rates are not statistically different from one another; it concludes that they are not statistically different from one another at the 0.10 level of significance with 21 degrees of freedom in the one-tailed test.

These findings are inconsistent with the general concept that small firms should have a faster rate of growth, in this case, sales growth rate, than their larger counterparts. Nevertheless, the data depict small electronics firms as firms that maintain the fast growth image of electronics activities. Small firms grew at least as fast as their larger counterparts in terms of sales growth.

5.4.1.2 Employment Growth Rates

Another intrinsic characteristic is the fast rate of growth in employment. With respect to this, the surveyed firms also showed an impressive overall growth for the period of 1986-90. On the whole, they grew 109 percent, in employment during this period (Table 5.1). Nevertheless, in this case, the surveyed large firms have grown faster than the surveyed small firms. The surveyed large firms grew by 136.42 percent in employment, while their small counterparts grew by only 87.07 percent.

On applying the Student-t-test analysis to the two average growth rates, the calculated t-statistic falls within the acceptance region at the 0.10 level of significance with 25 degrees of freedom in the one-tailed test. Hence, the data affirm that the overall surveyed firms reflect the fast-growing image of electronics activities. Small firms grow at least as fast as the large counterparts in terms of employment.

5.4.1.3 Technical Labour Input

The third intrinsic characteristic is related to the high proportion of technical labour

[40] *There are two small-sample parametric statistical tests that served to analyze the significant levels of differentiation between two populations or samples of data; they are the Student-t-test and the chi-square test. In general, the former is applicable to interval-scale data while the latter is restricted to nominal (frequency) data. Therefore, it is the Student-t-test analysis that is appropriate to this case.*

input. On average, high-tech workers account for 26.56 percent of the labour input of the surveyed firms (Table 5.1). This proportion of high-tech labour is somewhat higher than that in the U.S.A. (around 20 percent) but slightly lower that applying in the U.K. (around 33 percent).

By firm sizes, the surveyed small firms have a relatively higher proportion of high-tech labour than their large counterparts: 28.97 percent to the former and 23.46 percent to the latter (Table 5.1).

The result of the Student-t-test does not establish statistical differences between the average proportions of these two groups of firms at the 0.10 level of significance with 30 degrees of freedom in the one-tailed test.

Above all, the surveyed firms in general comply to the general perception of electronics activities entertaining a high proportion of high-tech labour input in the processes of production. However, this aspect is common to all firms, since different firm sizes are not statistically different from one another.

5.4.1.4 R&D Expenditures to Sales

The last intrinsic characteristic of the electronics activities to be described is that of the ratio of R&D expenditures to sales revenues. The surveyed firms show a moderate proportion of their sales revenues allocated to R&D activities; that is, for every \$100 in sales revenue approximately \$7.61 will be contributed to R&D activities of the firms (Table 5.1).

In this case, the surveyed large firms have allocated 15.72 percent of their sales revenues to their R&D activities, an allocation almost four times the 4.48 percent by the surveyed small counterparts.

The result of the Student-t-test analysis tells us that such proportions of the two types of firms are statistically different from one another at the 0.05 level of significance with 16 degrees of freedom in the one-tailed test.

The data, then, reveal the fact that electronics firms are collectively allocating a moderate amount of their sales revenues to R&D activities. Understandably, the large firms, which can afford a longer-run industrial strategy, have a higher allocation of sales dollars to R&D activities compared to their small counterparts. The Student-t-test analysis confirms the statistical validity of such a difference.

5.4.1.5 Section Summary

In sum, the surveyed electronics firms possess dramatically fast rates of growth in both sales revenues (217.31 percent) and employment (109 percent) for the period 1986-90. They also illustrate the attribute of high level of technical content in their processes of production, a fact which is manifested through roughly 26.56 percent of their labour input being either scientists or engineers. They are also characterized by their high level of expenditures in R&D activities; some 7.61 percent of sales revenues are dedicated to these kinds of activities. In a nutshell, this analysis of the surveyed data indicates that the surveyed firms collectively have the same characteristics as those of other industrial countries. By firm size, the surveyed small firms outgrow their larger counterparts in sales (261.14 percent and 135.13 percent respectively) but not in terms of employment (87.07 percent and 136.42 percent of growth respectively). This impressive position of the surveyed small firms is not paralleled in respect of the ratio of R&D expenditures to sales revenues; their ratio of 4.48 percent is dwarfed by the ratio of 15.72 percent registered by their large counterparts. Nevertheless, the variations between the surveyed small and large firms in growth in sales and employment as well as in technical labour content are simply superficial; the corresponding Student-t-tests indicate that these variations are not meaningful, at least in any statistical sense. In other words, although the surveyed small firms grow faster than the surveyed large firms, the surveyed large firms are actually performing as well as the surveyed small firms. Likewise, when the surveyed large firms grow faster than the surveyed small firms in employment, the latter are equal to them by any statistical measure. Meanwhile, the relatively lower level in technical labour input of the surveyed small firms does not really constitute a significant difference from the higher-level of the surveyed large firms. The only remarkable difference between the two types of firms is in their R&D-expenditures-to-sales-revenues ratios; in this case, the surveyed small firms show a significantly lower ratio than their larger counterparts. Above all, in terms of intrinsic characteristics of electronics activities, the surveyed small firms seem to maintain consistently high rates of growth in sales and in employment and exhibit high levels of technical labour input. Their dynamic image, perhaps, is tarnished by their significantly lower R&D-expenditures-to-shares-revenues ratio than their larger counterparts. In one broad stroke, the surveyed firms have measured up to the overall image of electronics activities.

The geographical differentials of the requirements for firm agglomeration will be discussed in the following section and its subsections.

5.4.2. Differentiation Between the Surveyed Firms in Manitoba and Other Western Provinces

To recall, the general Western Canada model and the specific Manitoba model have been established for testing the industry life-cycle concept that the agglomeration of innovation activities depends upon the availability of external and entrepreneurial learning economies. In this regard, it is necessary to justify the establishment of these two models of different geographical contexts. To do this, the differentiation of the firms in Manitoba and those in Western Canada in their acquiring of these learning economies is necessary. Therefore, attempts are not only made to delineate that the needs of the Manitoba firms are different from firms in the rest of Western Canada but also to test the statistical significance of such differences. The Student-t analysis has been appropriated for the testing. It is a one-tailed test in which the mean magnitude of the accessibility information from local resources and entrepreneurs for Manitoba firms should be greater or smaller than the accessibility available to firms in the other Western provinces. Nevertheless, the main objective of this test is to determine the existence of any variation in the mean requirements of the Manitoba firms on the one side and the firms in the Western provinces on the other. These requirements refer to the selected proxies representing different dimensions of learning economies incorporated for modelling; to recall, the proxies *USCIENT* and *TECHNF* are used for measuring the degree of (in)accessibility of technical external learning economies; *SALEINT* and *MGUSC* measure managerial external learning economies; whereas, *VENT*, *SUBSID* and *INCUBATOR* are for overall external learning economies. Besides, *MGINH* and *AGE* are surrogates for entrepreneurial learning economies. In the Student-t-test analysis, if it is found that there is significant difference between Manitoba firms and firms in the other Western provinces for a particular learning economy proxy, then this proxy may be identified as a "Manitoba-specific" proxy that may only be elaborated within the Manitoba context. The appearance of these proxies, therefore, signifies the distinctiveness of Manitoba firms on their learning economy requirements. Subsequently, if the proxy in question does not reflect any significant variations between those two groups of firms, then this proxy may be known as a "common" proxy that can be elaborated not only in the context of Manitoba, but also for the other Western provinces. The revealing of these proxies, subsequently, denotes the common grounds shared by two groups of firms on the acquiring of learning economies.

5.4.2.1 Technical External Learning Economies

As just stated, the proxies *USCIENT* and *TECHNF* are used for measuring the degree of accessibility of electronics firms to technical external learning economies. The former is defined as "the percentage of scientists or engineers recruited from universities within province"; and the latter is expressed as "the percentage of average time spent on non-face-to-face contacts through telephone, telex, fax or correspondence".

5.4.2.1.1 Local University Supports (*USCIENT*)

First of all, this subsection will look into the degrees of accessibility to technical personnel from various sources. Table 5.2 discloses different categories of technical supports by geographical locations. It depicts a situation in which the surveyed Manitoba firms have a higher-than-Western-Canadian-average level of relationship with local universities for technical personnel supports. The proportions of its technical personnel resources divided between local (hence, *USCIENT*) and outside origins are 80.3 percent and 19.7 percent respectively. The latter can be further broken down into 10.9 percent from "other countries", 7.3 percent from "other Canadian provinces", and 1.5 percent from "the U.S.A.". This array of technical personnel resources not only contrasts with the relatively lower percentage of local resources on average in the firms in the other Western provinces (78.8 percent of their technical personnel), but also differs with respect to the importance of other sources of support. For the surveyed firms in the other Western provinces, their technical personnel resources from "other Canadian provinces" ranked second (15 percent); those coming from "other countries" ranked third (5.5 percent), while "the U.S.A." resources came a distant fourth (0.7 percent).

As far as the variation between the mean requirements of the surveyed Manitoba firms and those in the other Western provinces is concerned, the calculated t-statistic for the Student-t-test analysis cannot reject its null hypothesis at the 0.10 level of significance with 32 degrees of freedom in the one-tailed test. This result suggests that the technical personnel requirements of the surveyed Manitoba firms do not differ in a statistical sense from those in the other Western provinces. In other words, despite the fact that the surveyed Manitoba firms have a greater tendency to tap local technical personnel resources than their counterparts in the other Western provinces, this kind of variation does not constitute a material difference between these two groups of firms. The surveyed firms in the other Western provinces have also exploited their local technical personnel resources as much as

Table 5.2

Technical Information
Percentage of Scientists/Engineers
from University
by Firm Size and Geographical Division

Firms	Within Province (*USCIENT*)	Elsewhere Within Canada	Within U.S.A.	Other Countries
Manitoba	80.3	7.3	1.5	10.9
Other W. Prov.	78.8	15.0	0.7	5.5
	(*d.f.*=32)			
	(*t*=1.02)			
Small	70.9	5.3	1.1	22.7
Large	79.1	14.7	1.2	5.0
	(*d.f.*=32)			
	(*t*=-2.13**)			
Overall	79.7	10.2	1.2	8.9

ource: Survey by the author.
*Note: The information in parenthesis refer to the degrees of freedom (d.f.) or calculated t-statistic (t) of the Student-t-test analysis. Single * implies that the result is statistically significant at the 0.10 level; double **, 0.05 level; triple ***, 0.01 level.*

those in Manitoba. Hence, in general, the surveyed electronics firms in Manitoba do not distinguish themselves from those in the other Western provinces in this aspect. These observations have confirmed that Manitoba firms have a higher absolute level of accessibility to local universities for technical human resources; but, such an absolute level of accessibility is not sufficient to distinguish them from their Western counterparts. Therefore, the impact of this proxy upon Manitoba firms will imply a similar impact in the other Western provinces.

5.4.2.1.2 Non-face-to-face Technical Consultation (*TECHNF*)

Another measurement of technical external learning economies is the means permitting technical consultation to take place; that is to say, either through face-to-face contacts or non-face-to-face contacts. Face-to-face contacts measure the availability of technical external economies, while non-face-to-face contacts, on the contrary, measure the unavailability of technical external learning economies. Table 5.3 has proportioned these two categories of

Table 5.3

Technical Information
Percentage of Time Allocated to
Face-to-Face versus Non-Face-to-Face Contacts
by Firm Size and Geographical Division

Firms	Face-to-Face Contacts	Non-Face-to-Face Contacts (*TECHNF*)
Manitoba	25.8	74.2
Other W. Prov.	37.7	62.3
		(*d.f.*=32)
		(*t*=1.61**)
Small	26.6	73.4
Large	39.6	60.4
		(*d.f.*=32)
		(*t*=1.50*)
Overall	30.7	69.3

ource: Survey by the author.
*Note: The information in parenthesis refer to the degrees of freedom (d.f.) or calculated t-statistic (t) of the Student-t-test analysis. Single * implies that the result is statistically significant at the 0.10 level; double **, 0.05 level; triple ***, 0.01 level.*

communication modes. From the geographical perspective, the surveyed electronics firms of Manitoba have acquired their technical consultation more from outside-locality resources (74.2 percent of such total time) than from local resources (25.8 percent of such total time). The surveyed firms in the other Western provinces vary from Manitoba in the split of weights of these two spatial resources rather than in the order of importance. For these firms, outside-province resources account for 62.3 percent of their time on technical consultation with local resources account for the remaining 37.7 percent of such time. From the data, it can be suggested that local consultation, that is, face-to-face technical consultation, does not serve as the major resource base for firms across Western Canada. This fact is at odds with the earlier perception of Manitoba firms having higher levels of accessibility to local technical consultation compared with firms in the other Western provinces.

Resort to the Student-t-test analysis for the mean variations of *TECHNF* between the surveyed Manitoba firms and those in the other Western provinces is forthcoming with a calculated t-statistic that rejects its null hypothesis at the 0.05 level of significance with 32 degrees of freedom in the one-tailed test. This result has pointed out, first, that the surveyed Manitoba firms have turned more to technical consultation outside the province than their counterparts in the other Western provinces, and, second, that such a higher level of consultation is also statistically significant. In effect, this difference reflects the general weakness of local technical facilities in providing information support for the surveyed electronics firms. All in all, the surveyed firms of Manitoba have shown statistically-significant differences from the rest of Western Canada.

5.4.2.2 Managerial External Learning Economies

Two proxies are selected to represent this dimension of learning economies, namely, *SALEINT* and *MGUSC*.

5.4.2.2.1 Market Information (*SALEINT*)

Market information is fundamental to effective and efficient operation, in particular the generation of new product ideas. In this context, it is reflected in the percentage of sales revenues contributed by various market areas. Among the four main categories of market areas (shown in Table 5.4), international sales (the proxy *SALEINT*) are of least importance to the surveyed firms of Manitoba. They only account for 5.4 percent of the total sales of Manitoba firms. Local sales currently constitute most of the sales of the surveyed Manitoba firms, some 35.3 percent of the total. The next important market areas are those outside the province of Manitoba, which account for another 34.7 percent. The sales to the U.S.A. have picked up the remaining 24.6 percent of the total sales of Manitoba firms. This Manitoba situation is apparently different from the other Western provinces both in weights and in order of importance of these market areas. Their most active market areas are those outside their own provinces but within Canada (30.1 percent of their total sales); the local markets of the firms account for 29.4 percent of their total sales and are followed by international sales (27.1 percent) and lastly the sales to the U.S.A. (13.4 percent).

Table 5.4

Managerial Information
Market Area
Percentage of Sales Revenues, 1990
by Firm Size and Geographical Division

Firms	Within Province	Elsewhere Within Canada	Within U.S.A.	Other Countries (*SALEINT*)
Manitoba	35.3	34.7	24.6	5.40
Other W. Prov.	29.4	30.1	13.4	27.1
				(*d.f.*=21)
				(*t*=-2.88***)
Small	41.8	36.7	14.5	7.0
Large	20.2	25.8	27.9	26.1
				(*d.f.*=21)
				(*t*=-2.55***)
Overall	32.6	32.7	19.6	15.1

ource: Survey by the author.
*Note: The information in parenthesis refer to the degrees of freedom (d.f.) or calculated t-statistic (t) of the Student-t-test analysis. Single * implies that the result is statistically significant at the 0.10 level; double **, 0.05 level; triple ***, 0.01 level.*

On applying the Student-t-test analysis to this proxy for the mean variations between the Manitoba firms and the other Western province firms, it is found that the calculated t-statistic rejects its null hypothesis at the 0.01 level of significance with 21 degrees of freedom in the one-tailed test. Hence, the overall picture shall read as one in which the surveyed Manitoba firms have a higher accessibility to local market information than their counterparts in the other Western provinces. This observation points to the fact that Manitoba is having a strong resource base, in this case, market information resources, for electronics activities. Most importantly, the proxy *SALEINT* have underscored the characteristics of Manitoba firms as being distinct from the other firms in Western Canada, a distinction confirmed by statistical testing.

5.4.2.2.2 Office Computer Programming Consultation (*MGUSC*)

To measure the overall control of modern offices within a computerized environment, entrepreneurs and top management requires a certain level of proficiency in monitoring computer networks. For the purpose of this study, it is important to determine the geographical origins of that proficiency. By identifying whether these sources are "inhouse", "within province", "within Canada or whether they originate in the U.S.A.", and "other countries", one is able to provide geographical linkages.

For the surveyed firms in Manitoba, the proxy *MGUSC*, which represents managerial information originated outside the province but within Canada or the U.S.A. ranks a distant second from the inhouse source of managerial information; that is, 7.7 percent of the expenditures on managerial consultation have been spent on outside-province sources, but as much as 89.8 percent of such expenditures are spent on inhouse supports (Table 5.5). These two sources of supports have already shared 97.5 percent of such expenditures. That leaves 2.3 percent of such expenditures to the within-province supports, and a negligible 0.2 percent to other countries. For the surveyed firms in the other Western provinces, *MGUSC* still ranks second to inhouse supports but with a higher share of such expenditures (some 10.9 percent of the total) than the former and a lower share for the latter (77.7 percent of the total expenditures). With lesser reliance on inhouse supports, those derived from the province and other countries assume relatively higher importance than is the case with the Manitoba counterparts. Supports from the province now account for 3.7 percent of the total expenditures of the other Western firms, leaving the other 7.7 percent of such expenditures be attributed to "other countries". As it happens, the result of the Student-t-test analysis reveals no significant differences between the surveyed firms in Manitoba and those in the other Western provinces in the tapping of managerial information from out-of-province sources. The relatively lower level of expenditures of the Manitoba firms spent on *MGUSC* is statistically equivalent to that of the firms in the other Western provinces. Therefore, as deemed from this proxy *MGUSC*, the surveyed firms in Manitoba do not have special characteristics different from their counterparts in the other Western provinces in accessing managerial information from non-local resources.

Table 5.5

Managerial Information
Office Procedure (Computer) Supports
Percentage of Such Expenditure, 1990
by Firm Size and Geographical Division

Firms	In-House (*MGINH*)	Within Province	Elsewhere Within Canada/ U.S.A. (*MGUSC*)	Other Countries
Manitoba	89.8	2.3	7.7	0.2
Other W. Prov.	77.7	3.7	10.9	7.7
	(*d.f.*=32)		(*d.f.*=33)	
	(*t*=1.80**)		(*t*=0.09)	
Small	84.9	11.7	2.90	0.5
Large	76.8	3.2	14.8	5.2
	(*d.f.*=32)		(*d.f.*=33)	
	(*t*=0.30)		(*t*=-1.87**)	
Overall	81.4	8.0	8.0	2.6

ource: Survey by the author.
*Note: The information in parenthesis refer to the degrees of freedom (d.f.) or calculated t-statistic (t) of the Student-t-test analysis. Single * implies that the result is statistically significant at the 0.10 level; double **, 0.05 level; triple ***, 0.01 level.*

5.4.2.3 Overall External Learning Economies

Three proxies have been selected to measure the accessibilities of overall external learning economies, namely, *VENT*, *SUBSID*, and *INCUBATOR*. The first two proxies refer to financial resources, while the last proxy refers to the role played by innovation centres.

5.4.2.3.1 Financial Resources (*VENT* & *SUBSID*)

Financial resources are deemed to be important institutional assets providing overall information required for electronics firms. In the spirit of learning economies, these resources are generally divided into those that are available inhouse, within the localities but outside the firms, and those outside the localities of the firms. The "within-the-locality" category can be further subdivided into sources from "venture capitalists" (proxy *VENT*), "government agencies" (proxy *SUBSID*), "local banks", or "other" local resources. The contribution of these financial resources has been reported in Table 5.6 according to geographical regions.

Table 5.6

Managerial Information
Financial Supports
Percentage of Monetary Values, 1990
by Firm Size and Geographical Division

	In-House	Within Province				Outside Province
Firms		Private Venture (*VENT*)	Banks	Govt. Agencies (*SUBSID*)	Others	
Manitoba	61.5	4.9	17.2	7.3	0.1	9.0
Other W. Prov.	49.9	14.0	12.4	8.2	1.5	14.0
		(*d.f.*=32)		(*d.f.*=32)		
		(*t*=-1.51*)		(*t*=-0.04)		
Small	60.0	7.1	16.9	5.7	0	10.3
Large	55.9	9.6	14.0	9.2	1.2	10.1
		(*d.f.*=32)		(*d.f.*=32)		
		(*t*=-0.06)		(*t*=-0.89)		
Overall	56.6	8.7	15.3	7.7	0.6	11.1

ource: Survey by the author.
*Note: The information in parenthesis refer to the degrees of freedom (d.f.) or calculated t-statistic (t) of the Student-t-test analysis. Single * implies that the result is statistically significant at the 0.10 level; double **, 0.05 level; triple ***, 0.01 level.*

Among these various sources of financial supports, local government agencies (*SUBSID*) and venture capitalists (*VENT*) rank third- and second-last contributors to the surveyed Manitoba firms; they modestly account for 7.3 percent and 4.9 percent of the total financial resources. Accordingly, inhouse self-financing is the principal financial source, which amounts to 61.5 percent of the total financial resources of the surveyed Manitoba firms. To the Manitoba firms, local banks are their second most important source of financial supports, accounting for 17.2 percent of their total financial resources. The resources coming from outside the localities of the surveyed Manitoba firms rank third in consequence of their nine percent contribution to total financial resources. The remaining negligible 0.1 percent of their total financial resources is attributable to the other sources within the localities of the surveyed Manitoba firms. In contrast to the Manitoba scenario, *VENT* and *SUBSID* have a relatively greater role to play in supporting firms of the other Western provinces. VENT becomes the second most important source of financial supports of the firms in the other Western provinces, accounting for 14 percent of their total financial resources. Although *SUBSID* ranks the second-least important of all other financial resources of the firms in the other Western province, it carries more weight in them than in Manitoba; that is, it accounts for 8.2 percent of total financial resources of the former. In a similar vein, inhouse self-financing remains the top financial contributor of the firms in the other Western provinces, although its weight has declined to 49.9 percent of their total financial resources. Fourteen percent of their total financial resources are contributed by the sources outside the localities of the firms; another 12.4 percent came from local banks; the remaining 1.5 percent from other local resources.

As far as the Student-t-test analysis for the proxy *VENT* is concerned, the null hypothesis is rejected by the calculated t-statistic at the 0.10 level of significance with 32 degrees of freedom in the one-tailed test. These results suggest that Manitoba firms have accessed *VENT* statistically less than their counterparts in the other Western provinces. These facts have underscored the endowment of a weaker resource base, namely, the venture capital companies in Manitoba. These results, nevertheless, paint a picture in which Manitoba firms can distinguish themselves from their counterparts in the other Western provinces; though they have not been able to carry heavier weights than the latter. These results give a mixed picture, one in which the Manitoba firms can distinguish themselves from their counterparts in the other Western provinces, but not in the expected manner of being able to carry heavier weights than the latter. Instead, the Manitoba firms have accessed *VENT* statistically less than their counterparts in the other Western provinces. This last fact has undermined their distinctiveness from electronics firms in the other Western provinces.

On applying the Student-t-test analysis to *SUBSID*, it is found that its null hypothesis cannot be rejected at the 0.10 level of significance with 32 degrees of freedom in the one-tailed test. This result suggests that the Manitoba firms do not differ in a statistically-significant manner from those in the other Western provinces in the weights put upon the accessibility to local government agencies for overall information. *SUBSID* would be a poor proxy to highlight the activities of the Manitoba firms.

5.4.2.3.2 Inside or Outside Innovation Centres (*INCUBATOR*)

Innovation centres have been regarded as the instrument of scientific infrastructure that will supply information on all aspects required for the well-being of the tenant firms, information ranging from technical, to managerial, financial or legal resources.

As counted in Table 5.7, the surveyed firms of Manitoba are mainly located outside any kind of innovation centres. As many as 84.2 percent of them are operating outside innovation centres. Only 15.8 percent of them are found within innovation centres. This is overshadowed by the survey firms in the other Western provinces. They go to the extreme that 93.3 percent of them (14 of 15 firms) are operating outside innovation centres; only 6.7 percent of them (i.e. a single firm) operated within an innovation centre.

The calculated t-statistic of the Student-t-test analysis informs us that the null hypothesis cannot be rejected at the 0.10 level of significance with 32 degrees of freedom in the one-tailed test. Hence, the proxy *INCUBATOR* will not serve to distinguish Manitoba firms from those resident in the other Western provinces.

In other words, despite the higher percentage of the surveyed firms in Manitoba operating within innovation centres, their inclination in this respect is not statistically significant in differentiating them from their counterparts in the other Western provinces. This observation points out that more Manitoba firms operate within the innovation centre (that is, the CIIT) than is the case in the other provinces because of the policy of the public sector to promote electronics activities; however, this propensity is not so marked as to warrant statistical significance.

Table 5.7

External Learning Economies
Overall Information: Inside or Outside Innovation Centres
by Firm Size and Geographical Division

	Inside	Innovation Centres (*INCUBATOR*)	Outside	Innovation Centres
Firms	No.	Percent	No.	Percent
Manitoba	3	15.8	16	84.2
Other W. Prov.	1	6.7	14	93.3
	(*d.f.*=32)			
	(*t*=0.80)			
Small	2	10.0	18	90.0
Large	2	14.7	12	85.7
	(*d.f.*=32)			
	(*t*=-0.37)			
Overall	4	11.8	30	88.2

ource: Survey by the author.
*Note: The information in parenthesis refer to the degrees of freedom (d.f.) or calculated t-statistic (t) of the Student-t-test analysis. Single * implies that the result is statistically significant at the 0.10 level; double **, 0.05 level; triple ***, 0.01 level.*

5.4.2.4 Entrepreneurial Learning Economies

Two proxies are selected to stand for entrepreneurial learning economies; that is to say, *MGINH* and *AGE*.

5.4.2.4.1 Managerial Information: Office Computer Programming Consultation (*MGINH*)

MGINH is defined as "the percentage of expenditures spent on computer programming consultation regarding office procedures from the entrepreneurs themselves".

Specifically, the surveyed Manitoba firms have attained a higher level of accessibility to such managerial information from the entrepreneurs themselves than those in the other Western provinces. Table 5.5 indicates that 89.8 percent of the expenditures on such managerial consultation of the surveyed Manitoba firms are spent on inhouse resources. In contrast, the surveyed firms in the other Western provinces have spent 77.7 percent of their expenditures on such resources.

On applying the Student-t-test analysis, it is found that the calculated t-statistic has rejected its null hypothesis at the 0.05 level of significance with 32 degrees of freedom in the one-tailed test. Essentially, the surveyed Manitoba firms would have a significantly higher level of accessibility to managerial entrepreneurial learning economies than that exhibited by the other firms in the Western provinces. These results indicate that Manitoba has been endowed with a stronger entrepreneurial base. That is to say, their entrepreneurs have stronger business computing skills than their Western counterparts. Most importantly, these results indicate that *MHINH* will be a good indicator to highlight the distinctiveness of the electronics activities in Manitoba from others in Western Canada.

5.4.2.4.2 Overall Information: Year of Establishment (*AGE*)

The year of establishment, or the proxy *AGE*, tries to capture the aggressiveness of the entrepreneurs, hence, their level of entrepreneurial learning economies derived from these individual entrepreneurs. The most recently established firms are hypothesized to be more likely to possess the more enthusiastic entrepreneurs, resulting in the achieving of a higher degree of entrepreneurial learning economies.

As arrayed in Table 5.8, the surveyed Manitoba firms were established more recently than those in the other Western provinces, specifically, around 1981. Firms in the other Western provinces were established on average around 1979. This observation suggests that the electronics activities in Manitoba are more likely than their other Western counterparts to possess enthusiastic entrepreneurs and to derive a higher degree of entrepreneurial learning economies from these individuals. However, the suggestion is repudiated by statistical analysis; for the Student-t-test analysis fails to reject the null hypothesis at the 0.10 level of significance at 31 degrees of freedom in the one-tailed test. In other words, this proxy *AGE* will not be a good indicator to differentiate Manitoba firms from those in the rest of Western Canada regarding the time of incorporation.

Table 5.8

Overall Information
Year of Establishment
by Firm Size and Geographical Division

Firms	Average Year of Establishment *AGE*
Manitoba	1981.44
Other W. Prov.	1978.73
	(*d.f.*=32)
	(t=0.80)
Small	1981.80
Large	1977.77
	(*d.f.*=31)
	(t=1.33*)
Overall	1979

Source: Survey by the author.
*Note: The information in parenthesis refer to the degrees of freedom (d.f.) or calculated t-statistic (t) of the Student-t-test analysis. Single * implies that the result is statistically significant at the 0.10 level; double **, 0.05 level; triple ***, 0.01 level.*

5.4.2.5 Section Summary

To summarize, the results of the Student-t-test analysis indicate that a number of external and entrepreneurial learning economy proxies are insignificant in distinguishing Manitoba firms from those in the other Western provinces. Specifically, five proxies are found to be insignificant in distinguishing the Manitoba firms from those in the other Western provinces. These proxies are *USCIENT*, *MGUSC*, *SUBSID*, *INCUBATOR* and *AGE*. Perhaps they may be identified as "common" proxies, applicable either in the Manitoba context or in Western Canada context. Meanwhile, it can be interpreted that the Manitoba surveyed firms do not differ from their Western counterparts in their level of accessibility to information supports derived from local resources such as local universities, business computing consultation firms, government financial agencies and innovation centres and from enthusiastic entrepreneurs themselves. Therefore, although Manitoba has been endowed with local resources such as universities, business computer consulting agencies, government financial agencies and innovation centres, all of which are capable of supplying the amount of scientists and engineers, computerized office procedures consultations and overall information, such a required resource base of electronics activities is no different from those in the other Western provinces.

Above all, Manitoba has also been endowed with enthusiastic entrepreneurs who are capable of supplying the necessary level of overall information; but such a favourable factor does not result in a significant difference from the other Western provinces. In these aspects, the Manitoba firms share the "common" characteristics of other Western firms in having the same kind of resource base as well as similar levels of accessibilities to the resource base.

However, the Student-t-tests also indicate that the other four proxies can significantly distinguish the Manitoba firms from those in the other Western provinces. These proxies are *TECHNF*, *SALEINT*, *VENT* and *MGINH*. Perhaps they may be identified as "Manitoba-specific" proxies. In other words, the Manitoba firms are different from their Western counterparts in their levels of accessibility to technical consultations, to market information through local agencies, to overall information through venture capital companies, and to computerized office procedures information through the entrepreneurs themselves. Specifically, the surveyed Manitoba firms exhibit statistically higher levels of accessibilities to "outside" technical consultations and to "inhouse" finances; on the contrary, they have lower level of accessibility to "outside" market information and to venture capital companies from their Western counterparts. From the locational point of view, the surveyed Manitoba firms have been tapping more local resources than their counterparts to achieve managerial entrepreneurial learning economies in "office computer programming consultations" through entrepreneurs themselves, and to achieve managerial external learning economies through local market information agencies; but less local resources than their counterparts to achieve overall external learning economies through venture capitalists or to achieve technical external learning economies through face-to-face technical consultations.

As conveyed by the data, the surveyed Manitoba firms depict Manitoba as a microcosm of Western Canada in which it shares some common features of the larger macrocosm. At the same time, it has special features that differ from the larger macrocosm, implying the electronics activities in Manitoba have some specific requirements of learning economies for growth. On the basis of the latter speculation, the establishment of two models of different geographical contexts, namely, the general Western Canada model and the specific Manitoba model is necessary and justified.

5.4.3 The Differentiation of Small from Large Firm Requirements

To recapitulate, attributing to the industry life-cycle concept has been its theorizing on the difference of the acquiring of learning economies of small firms from their larger counterparts. In essence, it is hypothesized that small firms feed on the attainability of external and entrepreneurial learning economies. The logit model has been appointed as the principal technique for the verification of these hypotheses (though owing to its unconvergence on the Manitoba data, it has been succeeded by the multiple regression technique for hypothesis testing in the Manitoba case). Being a discrete modelling technique, it is structured to contrast the characteristics of the small firms against those of the larger ones. Most importantly, owing to its explicitly denoting of the S-shape relationship between the explanatory variables and the dependent variable, it acts in accordance with the industry life-cycle concept. Although the use of the logit model has been sound at the theoretical level, its practicability in realities is still unknown. In essence, its applicability to the surveyed data remains an unanswered question. The foregoing line of discussion will proceed with the distinguishing of the characteristics, namely, the learning economy acquiring behaviours of the surveyed small firms from their larger counterparts and, hence, the substantiation of the fitness of the logit model to the surveyed data. The Student-t-test analysis is the means to take on this task. The same proxies explored in the previous paragraphs also function as the subjects of discussion in the following subsections, albeit now in the context of small versus large firms.

5.4.3.1 Technical External Learning Economies

As defined earlier, *USCIENT* and *TECHNF* are the proxies used for measuring the ability of the electronics firms to access technical external learning economies.

5.4.3.1.1 Local University Supports (*USCIENT*)

The industry life-cycle concept hypothesized that small firms are highly dependent upon the availability of external learning economies for growth or survival. It is averred that they have high dependency upon local resources for technical supports. It is then interesting to learn if the surveyed small firms are really different from their larger counterparts in their accessibility to technical information from local resources, specifically, in this case, local universities. In this regard, the proxy *USCIENT*, has been selected to reflect the presence of such a relationship between local universities on the one hand and the electronics firms on the other.

From the collected data, Table 5.2 has been prepared such that it proportions various sources of technical personnel supports. It shows that such personnel mainly come from local universities (the proxy *USCIENT*) rather than from the educational institutions of either other provinces or other countries. Of all the surveyed Western firms, there is a strong split of 79.7 percent to 21.3 percent in favour of technical personnel trained by local universities. Though both sizes of firms conform to this pattern, the weights in each category vary. The surveyed large firms have placed much reliance upon local universities for technical personnel; a strong 79.1 percent of their technical personnel come from local universities as against relatively weak outside sources that account for the other 20.9 percent. Meanwhile, those who come from other Canadian provinces also contribute as much as 14.7 percent of the large firms' technical personnel. On the other hand, local universities account for 70.9 percent of the technical personnel of small firms. This leaves the remaining 29.1 percent deriving from "outside" sources; but, in contrast with the large firms, the main "outside source is that of "other countries (excluding the U.S.A.)".

To corroborate, the one-tailed Student-t-test analysis is employed for the assessment of the variations between the means of this proxy of the surveyed small and large firms. As a result, the calculated t-statistic rejects its null hypothesis at the 0.05 level of significance with 32 degrees of freedom. This leads to the conclusion that the surveyed small firms have behaved differently from their large counterparts in recruiting technical personnel supports from local universities; at least, they have done so in the statistical sense. Moreover, these results has spelt out that the surveyed small firms have a lower level of linkage than their large counterparts with local universities for technical personnel supports. Therefore, in sum, though the surveyed small firms have had an absolute high level of supports from local universities for technical personnel, they are relatively lower than their large counterparts; and, such a difference is material enough to distinguish them from one and another, at least statistically.

5.4.3.1.2 Non-Face-To-Face Technical Consultation (*TECHNF*)

The proxy *TECHNF*, which is defined as "the percentage of time spent on non-face-to-face contacts for technical supports", is another measure for technical external learning economies. Specifically, it is a measure of the unavailability of such learning economies.

As disaggregated in Table 5.3, 69.3 percent of the time sought for technical consultation is made through non-face-to-face contacts, and therefore, only 30.7 percent occurs through face-to-face contacts by the surveyed firms. This general pattern varies in weights according to firm sizes. The weights of non-face-to-face contacts of the surveyed small firms (73.4 percent of their consultation time) are relatively higher than their large counterparts (60.4 percent of their consultation time) in general.

As far as the analysis of the Student-t-test is concerned, the calculated t-statistic rejects its null hypothesis at the 0.10 level of significance with 32 degrees of freedom in the one-tailed test. This result confirms that the surveyed small firms have spurned reliance on local resources for technical consultation. Instead, they reveal an inclination to seek technical consultation from sources outside their localities; an inclination not only stronger than that displayed by large firms but statistically significant as well.

5.4.3.2 Managerial External Learning Economies

To recall, *SALEINT* and *MGUSC* are the selected proxies adopted in this thesis to represent the managerial dimension of external learning economies.

5.4.3.2.1 Market Information (*SALEINT*)

SALEINT is a proxy for measuring managerial external learning economies. Specifically, it is a measure for the unavailability of market information from within localities.

With respect to the availability of market information, Table 5.4 reveals that "within province" and "the rest of Canada" are each contributing roughly one-third of the sales of the surveyed Western electronics firms. The source that is represented by the proxy *SALEINT*; that is, "the other countries" (excluding the U.S.A.) accounts for only 15.1 percent of the reported total sales. This generalization, however, will look slightly different when firm sizes are taken into consideration. The surveyed small firms have a particularly low level of accessibility to market information from non-local sources. Their sales in "the other countries" contribute the least amount of sales (7 percent of their sales only). The most important market area is that composed of the local markets (which account for another 41.8

percent). "The rest of Canada" (36.7 percent) and "the U.S.A." (14.5 percent) rank second and third in importance. Looking at the other side of the coin, the surveyed large firms have had "the other countries" ranked second in their hierarchy of market place, overshadowed by "the U.S.A." as the top market area. Hence, "the rest of Canada" and local markets are relatively unimportant; assuming the third and fourth positions in the ranking.

To further verify whether the surveyed small firms conformed to a distinctive character different from their large counterparts, the Student-t-test analysis was resorted to. The calculated t-statistic rejects the null hypothesis at the 0.01 level of significance with 21 degrees of freedom in the one-tailed test. Hence, the result tells us that the surveyed small firms are significant in seeking a low level of accessibility to non-local market information. In other words, they have behaved as expected in that they are disposed to settle for local market information as part and parcel of their willingness to tap external learning economies.

5.4.3.2.2 Office Computer Programming Consultation (*MGUSC*)

Another aspect of managerial learning economics is efficient and effective control of modern offices within a computerized environment. The sources for this kind of consultation include "inhouse", "within province", "in Canada and the U.S.A.", and "the other countries". Hence, the selected proxy for this dimension, *MGUSC*, is that of the category representing the sources "within Canada and the U.S.A." It is a measure of the unavailability of managerial information regarding computerized office procedures from within localities. For this proxy, small firms are expected to accomplish a lower level of accessibility to such managerial information than their larger counterparts.

As depicted in Table 5.5, in general, such consultation sought for under the headings "within Canada and the U.S.A." and "within province" each shares the spotlight with 8 percent of the reported expenditures on such consultations. The "inhouse" support is overwhelming (covered under Entrepreneurial Learning Economies with proxy *MGINH*). When it comes to sizes, the *MGUSC* response varies considerably. The surveyed small firms have effected very little consultations from these non-local sources (only 2.9 percent of their expenditures on this kind of consultation) in marked contrast to their larger counterparts (14.8 percent of their expenditures).

As far as the distinctive character of small firms is concerned, the result of the Student-t-test analysis affirms the difference between the surveyed small and large firms. The corresponding t-statistic rejects the null hypothesis at the 0.05 level of significance with 32 degrees of freedom in the one-tailed test. The Student-t-test result further confirms that the lower level linkage of the surveyed small firms with non-local resources is significantly different from the linkage enjoyed by their large counterparts. Putting this in the other way round, the surveyed small firms acquire a significant higher level of managerial information regarding computerized office procedures from localities.

5.4.3.3 Overall External Learning Economies

There are two basic dimensions to be covered for overall external learning economies; that is to say, financial resources and innovation centres. The proxies *VENT* and *SUBSID* are selected to measure the accessibilities to the former type of resources, while *INCUBATOR* is germane for the latter.

5.4.3.3.1 Financial Resources (*VENT* & *SUBSID*)

In line with the emphasis found in the literature, proxies *VENT* (venture capitalists) and *SUBSID* (government agencies) are selected to represent the availability of external learning economies with respect to overall information needed by electronics activities. Presumably, small firms are the awaiting ones to attain a different level of accessibility to overall information from local venture capital companies and government financial agencies than their larger counterparts.

Table 5.6 indicates that, overall, the surveyed firms have a particularly low level of accessibility to venture capitalists and government agencies. These two sources of financial resources rank third-least and second-least important; that is, they account for 8.7 percent and 7.7 percent of the total financial resources respectively. The least important source on the list is "other" local resources which accounts for 0.6 percent of the overall financial resources of the surveyed firms. In contrast, the inhouse self-financing variant (56.6 percent of the total financial resources) is more prevalent than any other sources. Hence, the other major financial sources in descending order of importance are "local banks" (15.3 percent) and those from "outside the province" (11.1 percent).

In terms of firm sizes, the surveyed small and large firms also demonstrate a very low level of accessibility to venture capitalists and government agencies for overall information. To the surveyed small firms, these two sources rank third-least and second-least in importance; that is, they are responsible for 7.1 percent and 5.7 percent of their financial resources respectively. The accessibility to the resources "outside the province" is virtually none. Hence, "inhouse" self-financing remains the most important source of financial resources, accounting for 60 percent of the total financial resources. There remains "local banks" to pick up the other 16.9 percent of the total financial resources of the surveyed small firms.

As far as the surveyed large firms are concerned, the proxies *VENT* and *SUBSID* rank third-least important (9.6 percent) and second-least important (9.2 percent) among other sources of overall information. Consistently, "other" local resources (1.2 percent) came last on the list. Meanwhile, the "inhouse" source maintains the top position; it accounts for as much as 55.9 percent of the total financial resources of the surveyed large firms. It is followed by "local banks" (14 percent) and those sources originating from "outside the province" (10.1 percent).

On applying the Student-t-test analysis to the proxies *VENT* and *SUBSID* one after the other, it is consistently found that they cannot reject the null hypotheses at the 0.10 level of significance with 32 degrees of freedom in the one-tailed tests. In other words, the surveyed small and large firms are not significantly different from one another in accessing overall information from local financial resources such as venture capitalists and government agencies. The surveyed small firms cannot, therefore, be distinguished from the surveyed large firms in terms of higher levels of accessibilities to local overall information.

5.4.3.3.2 Inside or Outside Innovation Centres (*INCUBATOR*)

Another dimension of overall external learning economies is that of the role played by innovation centres, represented by the term *INCUBATOR*.

It is elicited from Table 5.7 that the surveyed firms are mainly operating outside any kind of innovation centres. In general, no less than 88 percent of them are located outside innovation centres. A strong 90 percent of the surveyed small firms are located outside innovation centres; this is echoed by the 85 percent obtaining for large firms.

As far as the Student-t-test analysis is concerned, the result shows that the variations of the means of the surveyed small and large firms in this respect do not differ significantly from each other at the 0.10 level with 32 degrees of freedom in the one-tailed test. This result, therefore, is at variance with the presumption that small firms are mainly attached to innovation centres and that, in consequence, the mean applying to them should be significantly different, perhaps, higher than the mean representing large firms.

5.4.3.4 Entrepreneurial Learning Economies

To recall, the proxies *MGINH* and *AGE* are selected to represent entrepreneurial learning economies.

5.4.3.4.1 Managerial Information: Office Computer Programming Consultation

The proxy *MGINH* is designed to capture the level of availability of managerial entrepreneurial learning economies. Western experience shows that "inhouse" support (proxy *MGINH*) overwhelmingly surpasses any other source of computer consultation; 81.4 percent of such expenditures, in general, are spent on inhouse consultation (Table 5.5). For practical reasons this means that entrepreneurs would prefer to purchase and learn computer programmes or packages on their own rather than depend upon outside-firm consultants. Extrapolating further, it is disclosed that the surveyed small-firm entrepreneurs are much more eager to obtain "teach-yourself" type of systems (84.9 percent of the expenditures on computer consultation of small firms) than is the case with their bigger counterparts (76.8 percent of such expenditures of the large firms).

The result of the Student-t-test analysis indicates that the null hypothesis cannot be rejected at the 0.10 level of significance with 32 degrees of freedom in the one-tailed test. In consequence, the observer is left to conclude that small firms are having higher levels of accessibility to managerial learning economies, but, that this higher level does not distinguish them from the behaviour of large firms in a statistical sense.

5.4.3.4.2 Overall Information: Year of Establishment (*AGE*)

To recapitulate, the proxy *AGE* is designed to capture the availability of overall entrepreneurial learning economies contributed by enthusiastic entrepreneurs.

Table 5.8 indicates that the surveyed firms were in general established quite recently. On average, they were established around 1979. This observation denotes that the electronics activities of Western Canada in general possess enthusiastic entrepreneurs and derive a high degree of entrepreneurial learning economies from these individuals. The data also show that small firms were more recently established than their larger counterparts. As Table 5.8 indicates, they were established around 1982 while their larger counterparts were established around 1978; indicating that small firms are more likely than their larger counterparts to possess these enthusiastic entrepreneurs and derive a higher degree of entrepreneurial learning economies.

As far as the differentiation of small and large firms is concerned, the calculated t-statistic of the Student-t-test analysis rejects the null hypothesis at the 0.10 level of significance with 31 degrees of freedom in the one-tailed test. This result not only indicates that small firms aspire to a higher level of enthusiastic entrepreneurship than their large counterparts but also that they aspire to it to a significantly different degree. In other words, the surveyed small firms have measured up to the presumption that they should have a significant different, specifically, a higher level of overall information supports, through the efforts of their enthusiastic entrepreneurs, than their large counterparts.

5.4.3.5 Section Summary

To sum up this section, five out of nine proxies that indicate the behaviours of the surveyed small firms may be noticeably different from the surveyed large firms. These statistically-significant proxies are *USCIENT*, *TECHNF*, *SALEINT*, *MGUSC* and *AGE*. The statistical significance of these proxies denotes that the surveyed small firms have closely behaved as hypothesized. They are very much relied upon local resources than their larger counterparts would have be for survival. The surveyed small firms would have more accessibility to local market information than the surveyed large firms; a reflection of the lower levels of accessibility to international market information of the surveyed small firms than the surveyed large firms. Besides, in terms of managerial information, the surveyed small firms would have higher levels of local business computing consultations in this respect than the surveyed large firms as reflected by the lower level of accessibilities to non-local consultations on such matters of the surveyed small firms. Furthermore, the surveyed small firms would have a higher accessibility to overall information from enthusiastic entrepreneurs. Meanwhile, to say nothing of earmarking the hypothesized behaviours of the surveyed small firms, these proxies also stamp the unanticipated behaviours of these enterprises. The surveyed small firms, quite unexpectedly, denote a lower level of linkage with local universities for materializing technical external learning economies than the surveyed large firms. Besides, they demonstrate a lower level of accessibilities to local technical consultations in capturing technical external learning economies than the surveyed large firms. These unanticipated behaviours of small firms; that is to say, their lower level of information accessibilities from local resources lends supports to the fact that local technical facilities including universities are largely insufficient in serving their small client firms.

Hence, the statistically-insignificant proxies that do not claim differentiation of the surveyed small firms from the large ones are *VENT*, *SUBSID*, *INCUBATOR* and *MGINH*. As the first three of these proxies belong to the same dimension of overall external learning economies, they denote that these types of external resources are not particularly helpful or accessible to the surveyed small firms as to the surveyed large firms. As the last of these proxies belongs to the dimensions of entrepreneurial learning economies, it tells that small firms entrepreneurs are contributing their efforts in managerial information to their own firms as much as the bureaucrats of the large firms to their firms.

In a nutshell, the small and large surveyed firms behave differently on most of the learning economy proxies. The small firms and large firms are different in their acquiring of managerial and technical external learning economies, to say nothing of entrepreneurial learning economies regarding enthusiastic entrepreneurs. Meanwhile, they exhibit similarities in their requirement for overall external learning economies and entrepreneurial learning economies concerning business computing skills. The fact that small and large firms act distinctively on most of the learning economy proxies warrants the argument that the surveyed data are in compliance with the logit model. Therefore, the logit model should be a practical instrument and a good starting point of investigating the variations of behaviours of the small and large surveyed firms depicted by the industry life-cycle concept.

5.5 Chapter Summary

The methodology and the procedures used in collecting the required data for this study have been detailed in this chapter. In conformity with accepted practice, a pilot survey was conducted by means of in-person interviews and questionnaires. For the actual comprehensive survey, the Manitoba firms were requested to fill out the tailored questionnaires preparatory to in-person interviews. Owing to financial contraints, the firms in the other Western provinces were simply requested to complete the questionnaires to the best of their knowledge, and the interview stage was dispensed with. No less than 193 questionnaires were sent out, of which 71 were returned. This is a 36.79 percent crude response rate. Nevertheless, only 34 of them were judged usable for further analysis; they amount to a 17.62 percent response rate of the total questionnaires sent out. This response rate seems to be acceptable when contrasted with many other surveys that settle for no more than 10 percent response rate.

In general, the usable data reveal that the surveyed firms collectively bear the same characteristics as those of other industrial countries. They possess fast rates of growth, in terms either of sales revenues and employment, or both. They also illustrate the attribute of sophisticated technical contents such as high percent of technical labour and R&D expenditures in their production processes. At the firm-size level, the surveyed small firms seem to maintain consistently high levels of technical labour inputs. Their vigorous image, however, is somewhat tarnished by their significantly lower R&D-expenditures-to-sales-revenues ratio.

Another objective of this chapter is to assess the presumed distinctiveness of the Manitoba context in comparison with the rest of Western Canada and, in so doing, confirm the methodological approach of this study which hinged on the establishment of the two models of different geographical realms, namely, the general Western Canada model and the specific Manitoba model. For the four basic dimensions of learning economies, which are technical, managerial, and overall external learning economies and entrepreneurial learning economies, two or three proxies are selected for the measurement of their accessibilities. According to the Student-t-test analyses, one of the proxies for each of these dimensions is able to indicate statistically-significant differences between Manitoba firms and the others. With respect to technical external learning economies, *USCIENT* and *TECHNF* are the two proxies selected to measure the accessibility of technical information in terms of human resources and computer programming consultations respectively. The Student-t-test analysis confirms the latter proxy as being the superior attribute for identifying Manitoba firms as being distinct from the others. It establishes the observation that Manitoba firms have been more intent on seeking non-local technical consultations than firms in the other Western provinces.

This implies that they have had significantly less inclination to seek technical consultations. For managerial external learning economies, of the two proxies, *SALEINT* and *MGUSC*, only *SALEINT* confirms the distinctiveness of Manitoba firms from the others. This relationship implies that Manitoba has had a significantly lower level of interaction with international markets than firms in the rest of Western Canada; in other words, this substantiates the fact that Manitoba firms have pursued more interaction with local markets; hence, displaying a keen accessibility to local market information. For overall external learning economies, the proxy *VENT* has emerged as contributing significantly to the standing of Manitoba firms. Indeed, it underscores their significantly lower level of accessibility to venture capitalists for financial resources. For entrepreneurial learning economies, only *MGINH* happens to distinguish Manitoba firms from the others. This proxy affirms the higher value accorded inhouse self-teaching mode of contribution in comparison with other out-of-firm contributors. From these results and observations, it is obvious that the electronics firms in Manitoba share some common grounds with their Western counterparts regarding their acquiring of learning economies. Manitoba firms do not differ from their Western counterparts in their level of accessibility to information supports derived from local resources such as local universities, business computing consultation firms, government financial agencies and innovation centres and from enthusiastic entrepreneurs. Notwithstanding this, Manitoba firms still maintain their uniqueness in terms of their requirement of information supports from local resources and entrepreneurship endowment. The electronics firms in Manitoba rely on significantly higher levels of market information or computerized office procedures' consultations from local resources. Offsetting this, however is their tendency to be more dismissive of technical and overall information supports from local research facilities and venture capital companies than their Western counterparts. These unique identities of Manitoba firms show just cause for the establishing of two models of different geographical dimensions for this study.

The final objective of this chapter is to assess the differences between small and large firms as mandated by the industry life-cycle concept and hence provide justification for the practical application of the logit regression for the verification of this concept. With respect to technical external learning economies, both proxies, *USCIENT* and *TECHNF*, turn out to be statistically reasonable attributes distinguishing small from large firms. The former proxy shows that small firms have significantly lower levels of accessibilities to local universities for human resources. For its part, the latter proxy shows that small firms have significantly higher levels of accessibility to non-local sources for technical consultations. They expose the realities that local sources, which include universities and general facilities, cannot satisfy their requirements for technical information. With respect to managerial external learning economies, both proxies, *SALEINT* and *MGUSC*, also turn out to be significant in demarcating small-firm from large-firm characteristics. Together, they reflect the fact that small firms have experienced lower accessibilities to non-local managerial information in terms of both market conditions and computer-programming consultations. They thus imply that significant differences exist between small and large firms in their acquiring of managerial information for agglomeration. However, when shifting the perspective to overall external learning economies, none of the three proxies, namely, *VENT*, *SUBSID* and *INCUBATOR*, attributes any distinctiveness to small firms. In this case, the roles played by venture capitalists, government agencies and innovation centres fail to distinguish between small and large firms. Both types of firms are not significantly different in the levels of accessibilities to these sources of overall information for firm agglomeration. Finally, among the two proxies (*MHINH* and *AGE*) of entrepreneurial learning economies, *AGE* verified that small-firm entrepreneurs were inclined to be more aggressive than large-firm bureaucrats. Summarizing from all these results, it is found that the surveyed small firms display special characteristics of their own in terms of the accessibilities to technical, managerial external learning economies and in entrepreneurial learning economies. These specialized features of small firms lead one to conclude that the logit model should be a feasible instrument for investigating the variations of the small and large surveyed firms in their learning economy acquiring behaviours as depicted by the industry life-cycle concept.

Overall, this chapter has thoroughly delineated the data collection process. Most importantly, by employing the Student-t-test analysis, it has successfully drawn some borderlines between Manitoba firms and those in the other Western provinces, giving sufficient grounds for the establishment of two models of different geographical contexts while, at the same time, justifying the practicability of the logit regression technique in this study. Following the substantiation of model establishment and the verification of the feasibility of the logit regression technique, the next chapter will take up the task of reporting the modelling results.

Chapter Six

Model Analyses

6.1 Introduction

The last chapter centred on the discussion of the data collection process and the behaviours of surveyed electronics firms. For the collection of data, two surveys, namely, the pilot survey and the actual survey have been carried out. The pilot survey was conducted by means of in-person interviews and questionnaires. For the actual comprehensive survey, the Manitoba firms were asked to complete the questionnaires prior to in-person interviews. Because of financial constraints, the firms in the other Western provinces were asked to participate in the completion of the questionnaires; the interview portion of the survey was dispensed with.

Turning to the behaviours of the surveyed electronics firms, it has been observed that they inherit similar traits as those found in other industrialized countries: the qualities of having fast growth rates and high R&D inputs. At the firm-size level, in defiance of their lower R&D-expenditure-to-sales-revenues ratio, the surveyed small firms still maintain their vigorous image of having high rates of growth in both sales and employment and high levels of technical labour inputs. Distinctive differences in the requirements of external and entrepreneurial learning economics have been observed between the surveyed firms in Manitoba and those in the other Western provinces and between the small and large surveyed firms. Such differences substantiate the establishment in this study of two models of different geographical contexts; that is, the specific Manitoba model and the general Western Canada model. Furthermore, they also justify the use of the logit regression model at the practical level. However, one must note that regardless of the practical soundness of this modelling technique on the surveyed data, it has been judged inapplicable to the Manitoba case as the equation fails to converge in its estimation. Therefore, the study of the Manitoba firms has recourse to multiple regression techniques.

Following the justification of model establishment and the logit regression's applicability for the surveyed data, this chapter will proceed to reveal the empirical results of the two models defined in the previous chapter, justifying the two hypotheses that (1) external learning economies and (2) entrepreneurial learning economies are the two most important dimensions to the general well-being of small electronics manufacturing firms. To proceed, the technical robustness of the two models will be substantiated before interpretation of the results is made. Apart from the direct interpretation of the proxies in the two models one after another, some general guidelines will also be formulated in respect of the development of science park infrastructure as a means to nurture small electronics firms in Western Canada in general and in Manitoba in particular. Discussion of remedies for the deficient areas revealed by the regression model is left to the next chapter. The analyses of empirical results begin with the "general" logit model as follows.

6.2 Analyses of the "General" Logit Model

In the previous chapter, the Student-t-test analysis was employed to verify the suitability of the collected data to the logit model and, hence, the underlying perceptions of electronics activities in the industry life-cycle context. As a parametric statistical analysis, the Student-t-test analysis is conducted under the presumption that a certain kind of relationship exists between the two sets of sample data in the question; a relationship that is to be tested as the alternative hypothesis of the analysis. No estimation is made for the presumed relationship between the two sets of sample data in themselves. As the main objective of this section is to look for the dimensions or the determinants of the agglomeration effects of small (early stage) electronics firms in Western Canada, the relationship between the proxies on the one hand and the quantified agglomeration effects on the other has to be explicitly spelt out or estimated. This task cannot be handled by the statistical techniques employed in Chapter Five; it must be carried out by logit regression analysis. Therefore, the analyses of the small and large firm differences in Chapter Five can only serve as preliminary findings of the collected data for the predetermined relationships. In this context, the verification of the industry life-cycle concept in Western Canada should be based on the results of regression analysis reported in this section rather than the tentative conclusions drawn in Chapter Five. Nevertheless, the regression results will be cross-referenced with the observations in Chapter Five wherever appropriate.

6.2.1 Technical Properties

Routinely, the first step of researchers in analyzing the results of any regression model is to detect the existence of any violation of the underlying assumptions of the techniques. Unfortunately, such tests for the logit model are less well developed than those available for its multiple regression counterparts. For instance, it is well known that the Lagrange multiplier test is designed for the detection of heteroscedasticity in logit modelling (Davidson and MacKinnon, 1984), however, it is not provided in the mainframe SAS package that the author has been using. Besides, given the complicated and time-consuming calculation procedures involved in such tests, manual computation of the test scores is not possible. Nevertheless, some standard test statistics of inferences for the whole model and for individual variables are still commonly available in most computer packages. They serve to evaluate the extent of acceptance of an empirical model. In using the SAS-package procedures, the estimated parameters of the logit model and the corresponding test statistics are obtained and presented in Table 6.1.

Table 6.1
Logit Model for Western Canada

Explanatory Variables	(Expected) Est. Signs and Coeffs	Wald Chi-Squares
USCIENT	(+) +0.06	5.52**
TECHNF	(−) −0.04	2.95*
SALEINT	(−) +0.17	5.96**
MGUSC	(−) +0.05	4.02**
VENT	(+) +0.07	2.09
INCUBATOR	(+) +2.96	2.10
MGINH	(+) +0.35	3.62*
AGE	(+) −0.29	2.31
−2 Log L		25.65***
Deg.of Freedom	25	
No. of Obs.	33	

*Note: Single * implies that the result is statistically significant at the 0.10 level; double **, 0.05 level; triple ***, 0.01 level.*

The test statistic for the overall performance of the logit model is the −2 Log L (Likelihood) score. It is statistically significant at the 0.01 level; that is, there is the chance of one out of a hundred cases rejecting the overall significant relationship between the dependent variable and the explanatory variables. Therefore, the "goodness of fit" of the model is very satisfactory. The independent variables jointly could reasonably account for the occurrence of the dependent variable. This is translated to mean that external and entrepreneurial learning economics could fairly well determine the establishment of small electronics manufacturing firms in Western Canada in general. In other words, the earlier stated Hypotheses I and II, maintaining that these two types of learning economies are crucial factors for the agglomeration of high-technology industries, have been verified herein with special reference to electronics activities.

6.2.2 Results of the Proxies

Five out of eight independent variables are found to be statistically significant at various levels in determining the outcomes of the dependent variable, which is the probability of the birth of small electronics manufacturing firms in Western Canada. These include "*SALEINT*", "*USCIENT*", "*MGUSC*", "*MGINH* and "*TECHNF*". They are discussed in the following paragraphs in descending order of their levels of significance.

SALEINT is the most statistically-significant proxy for affecting the outcome of a small electronics firm in Western Canada. It has the unexpected positive sign. This means that the higher the percentage of sales to international markets, excluding the U.S.A., the higher the probability for the occurrence of a small electronics firm in Western Canada. It suggests that market information agencies external to the localities of firms are significant for the agglomeration of small electronics firms. Nevertheless, as reviewed in Chapter Five, the surveyed small firms interact with local market information agencies more than international market information agencies and, what is more, their local interactions are more active than their larger counterparts. The regression result has thus displayed a paradox: intimating that local market information may be deficient in promoting small firm agglomeration in Western Canada. Despite their lower level of interaction, the agglomeration of Western firms, and small firms in particular, is significantly furthered by international market information resources. In the follow-up telephone interviews, some of the respondents to the survey expressed their keen awareness of the importance of international markets.

They procure their best market information directly and swiftly from their overseas agents. Accordingly, their products are geared to the information provided by these agents. In contrast, some respondents are also concerned that local sources on international markets, such as journals, newspapers and government publications, are inadequate or out-of-date; these sources can hardly catch up with the swiftly changing international markets in relation to commercial, political, social, legal or economic factors. Therefore, without doubt, enhanced international market information resources will form a significant part in the agglomeration of small electronics firms in Western Canada in general.

The second significant proxy to be discussed is *USCIENT*. It is statistically significant at the 0.05 percent level. This confirms its positive impact upon the dependent variable. In other words, the higher the percentage of scientists or engineers of the firms that are recruited from local universities, the higher the probability of the occurrence of small electronics firms in Western Canada. Cross referenced to the observations in Chapter Five, this regression result reveals that although small firms may have a relatively lower level of accessibility to local universities for human resources than large firms, small firms are still very sensitive to such a relatively lower level of interaction with local universities. Perhaps their smaller scale of operations in comparison with their large counterparts makes them very responsive to a linkage with local universities. Taking a broader view of things may also reinforce the foregoing result. The OECD observed that, while most of the universities in Western Canada have established industry liaison offices for the promotion of industrial research, "nowhere, however, did we find a programme which was comparable in sophistication and capability to those found in the U.S. or European technical universities — universities which are aggressively expanding their linkages to industry" (OECD, 1988, p.45). Despite this, the model indicates that the ties between electronics industries and universities are generally working well in Western Canada.

MGUSC, a proxy of managerial information, is statistically significant at the 0.05 level. It turns out to be unexpectedly positively related to the odds of having a small electronics manufacturing firm in Western Canada. It suggests that information about office procedures coming from outside localities is more important than local sources. This result also creates a paradox in the sense that the higher levels of accessibility to local information, as reviewed in Chapter Five, the lower levels of impact to the agglomeration of small electronics firms in Western Canada. In other words, it is more beneficial to access "out-of-locality" information than "local" sources in this respect. Local resources, for some reason, do not satisfy the needs of local firms, or are relatively inferior or less developed than the "out-of-locality" sources. For the present, it is outside information resources that contribute to the well-being of small electronics firms. In the longer run, local resources might have to be improved to the point of being able to have this situation more balanced, or even to reverse it altogether.

MGINH also turns out to be statistically significant at the 0.10 level, positively affecting the odds of small firm development in Western Canada. This means that it is very important for entrepreneurs to learn their managerial skills (mainly computer-aided office procedures) from their inhouse experience. This result reinforces the observations in Chapter Five that the surveyed small firms garner a higher proportion of their information "inhouse" than do their larger counterparts. This finding is particularly crucial for small electronics firms because of their small sizes and very limited financial resources. Perhaps as a way to lower the costs of acquiring such managerial skills, entrepreneurs may have to learn from inhouse experience about computerized office environments on their own. The more managerial knowledge they have, the more likely their small businesses will be competitive. This knowledge will cover not only their sensitivity to inhouse problems but also inhouse adjustments to the changing market needs or the changing environment. The model shows that over time they will reap the benefits of entrepreneurial learning economies by possessing such managerial skills through inhouse experience.

TECHNF is statistically significant at the 0.10 level in negatively affecting the odds of having a small electronics firm. However, this result has two facets. On the one hand, it shows that general technical consultations to out-of-province sources have frequently been made (as observed in Chapter Five); on the other hand, its negative sign means that such non-face-to-face contacts are not as desirable as expected. Apparently, these contacts may be very costly in terms of either time or money to constituting a deterrent to outside consultations whose benefits cannot cover those costs. Implicitly, these results validate the important role of local technical resources. Looking forward, more local resources in this respect have to be set up or strengthened to meet the needs of the electronics clientele.

Three variables do not show up as statistically significant for explaining the odds of having a new and small electronics manufacturing firm. These are *AGE, INCUBATOR* and *VENT*. They are only insignificant in the sense that these learning economies have not been truly attained by industrialists or practitioners.

With respect to *AGE*, when the firm has been most recently established, it does not necessarily follow that entrepreneurship will automatically bring growth to the firm. This can be inferred from the observation that 72.23 percent of the Western small firms were established after 1980; and yet, the data do not give clear directions as to the outcomes in store for new small firms. It is usually presumed that newcomers should bring much entrepreneurship into their firms and industries. Nevertheless, as reviewed by the general model, this may not be applicable in this particular Canadian context. This is not to deny the enthusiasm and commitment of newcomers to their businesses or industries. As a matter of fact, they are in regular contacts with their business partners, such as bankers, lawyers, market researchers, academic engineers, and the like, for technical, financial, legal and managerial advice or information. Unfortunately, it may be their relatively minimal technical or professional training which hinders their business ambitions and, hence, the technological advancement of the industry. They may be having difficulty pursuing closely and appreciating fully the contemporary, sophisticated research published in professional journals or delivered at conferences or seminars. They are consequently handicapped in launching sophisticated research or tests on their own. In this respect, they become helpless in moving towards the leading edge of their industry sectors. All of these allegations are not without ground. To recapitulate, Kelly (1987) has reported that more than half (or specifically, 68 percent) of the founders of new small computer firms in the U.K. possess undergraduate degrees or the equivalent technical qualifications. This creates a large contrast with the Western Canada experience. An investigation of the survey data shows that only 39.11 percent of the small-firm entrepreneurs have at least an undergraduate degree in electrical, electronics or computer engineering. It seems that the improvement of the quality of entrepreneurship could be the most promising solution to the problem.

The statistical insignificance of *INCUBATOR* means that there is no material difference for the growth of electronics firms between being located within or without an innovation centre. In fact, in the course of this study, it was found that a number of the directors of the surveyed innovation centres[41] are experts holding post-graduate degrees either in engineering or in business administration. These scientific and managerial experts may be knowledgeable in technical know-how or the general operational routine required for electronics activities,

[41] *Most of which are located in research parks with close proximity to the technical universities. Manitoba is the exception largely because the innovation centre, namely, the CIIT, was located in downtown Winnipeg, rather than at the University of Manitoba, which is located south of the city.*

but they seem to be incapable of perceiving the larger picture of industrial development to the effect that their in-centre programmes or services are piecemeal or insignificant in promoting technology transfer for the future benefits of tenant firms. They are not really providing competitive services distinct from those outside the centres. Hence, the outcome of this proxy has raised doubts about the efficiency of the functions of those innovation centres. All in all, this result suggests that if innovation centres are effectively influencing the agglomeration of small electronics firms, the hiring of individuals to the management team who have an overall understanding of the mechanisms of agglomeration impacts upon innovation activities within the centres will be crucial to the success of the operations and prosperity of tenant firms.

When *VENT* does not show up to be statistically significant in the model, it suggests that venture capitalists, at least at present, may not be a crucial source of information support for the existing electronics firms in Western Canada. In other words, there may not be many firms enjoying benefits bestowed by venture capital activities, or, venture capital activities may be only a small part of the entire electronics activities of Western Canada. Follow-up research on this issue has shown that Western Canada receives very little venture capital assistance. Consider this fact: the number of members in the Association of Canadian Venture Capital Companies (ACVCC) is approximately 50 in all. Of these, eight are in Western Canada; five in Alberta and one in each of the other three Western provinces. Additionally, a further review of the survey data shows that only five out of the 20 small electronics firms in Western Canada have experience with venture capital activities. Although some entrepreneurs claim that venture capital is a very helpful resource for them, this source only provides 8.7 percent of their total financial resources (Chapter Five, Table 5.6). This discrepancy may be explained away through the observation that there are not too many generous venture capitalists around. The perceived financial returns to the venture capitalists are not realizable without high risks and, consequently, small electronics firms do not strike them as being attractive targets for investment. These difficulties have been reflected in the model.

Above all, the results of the general model have clarified the presumed relationships between the proxies on the one side and the agglomeration of small electronics firms on the other. The results are mostly consistent with those of the Student-t-test analyses. When the Student-t-statistics prompt the analyst to reject their null hypotheses, the Wald tests of the proxies in the logit model also follow suit in rejecting their null hypotheses as well. Statistically-significant proxies of the logit model do match the Student-t-test results in distinguishing the behaviours of the small surveyed firms from those exhibited by the large surveyed firms. However, three statistically-significant proxies of the logit model fail to accord with conclusions drawn from the Student-t-test analyses in Chapter Five. The value of logit modelling, therefore, is heightened as a supplement to the Student-t-test analyses in Chapter Five, since it is shown that certain proxies are really significant to the agglomeration of electronics firms while some others may not be so markedly effective. Its merits do not end there; for the general model has further elaborated on the direct impacts of the proxies of the external and entrepreneurial learning economies to the agglomeration of small electronics firms in contrast to their larger counterparts. In short, it serves the purpose of this study quite well.

6.3 Analyses of the Results of the Specific Manitoba Model

Turning to the discussion of the specific Manitoba model, the results of the Student-t-test analyses in Chapter Five are less directly relevant to the issue of differentiating the requirements for small and large firm growth. In Chapter Five, the Student-t-test analyses were applied to the proxies for differentiating the firms in Manitoba on the one hand from those in the rest of Western Canada on the other. This specific Manitoba model simply accounts for the various dimensions of learning economies to small-firm agglomeration; its sample data are mainly the small firms in Manitoba. As explained in previous chapters, the treatment of the specific Manitoba model is basically a practical last resort in those areas where the logit modelling has failed to give clear directions. Therefore, the interpretation and discussion of the results of this specific Manitoba model have to be undertaken with this limitation in mind.

6.3.1 Technical Properties

The specific Manitoba model is a multiple regression model. To justify the reliabilities of its results, some testing of the violations of CLNR assumptions have been undertaken.

A residual analysis has been performed to ensure that the basic assumptions of the CLNR are met. A residual analysis is the graphical test which involves the plotting of the residuals on the vertical axis against the corresponding observed Y values on the horizontal axis for all n observations. Applied here, the results show no apparent systematic pattern for the residuals of each proxy. They spread and deviate randomly above and below the index line where the error term is set to zero. Thus, it may be concluded that the fitted model appears to be appropriately presented (Berenson et al., 1983). Moreover, the model involves only 11 valid firms but has 7 explanatory variables. With such a small number of observations and a relatively large number of explanatory variables, it can be suspected that the regression is overspecified and, hence, biased. In such circumstances, a forward stepwise regression procedure[42] has been used to eliminate the redundant variables. In each stage of the procedures, the problem of overspecification can be overcome. To satisfy all the assumption tests, the best-fit version of the Manitoba multiple regression model is presented in Table 6.2.

The test statistics for the overall performance of the multiple regression model are estimated by the F-ratio. The model shows a satisfactory "goodness of fit" with an F-ratio of 11.82, which is statistically significant at the 0.05 level. Generally, this means that there is the chance of five out of one hundred cases of rejecting the overall significant relationship between the dependent on the one hand and the explanatory variables on the other hand. Technically, the null hypothesis, that all of the explanatory variables are different from zero, is accepted; the alternative hypothesis, that not all of them are significantly different from zero is rejected. Accordingly, it generally confirms the conclusion that the proxies that represent external and entrepreneurial learning economies can explain the variations of the growth rates of small electronics manufacturing firms in Manitoba. In other words, it verifies Hypotheses I and II.

The explanatory power of the proxies can also be collectively felt by the value of the adjusted R^2 or $\overline{R}^2$. The estimated $\overline{R}^2$ indicates that the explanatory variables can explain 88 percent of the variations of the dependent variable. This shows a high explanatory power of the proxies as a group.

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[42] *A stepwise regression is a search procedure to find the "best" set of independent variables from a large number of explanatory variables. If the variable made a significant contribution to the fit of the model; that is, having a significant F-test statistic, it would be included in the multiple regression; otherwise, it would not. Hence, variables are either added to or deleted from the regression model at each step of the model-building process. In a case where variables are added to it at each step of the model-building, it is known as a forward stepwise regression procedure. In a case where variables are deleted from the regression model at each step of the model-building process, it is known as a backward stepwise regression procedure (Berenson et al., 1983).*

Table 6.2

Manitoba Multiple Regression Model

Explanatory Variables	(Expected) Est. Signs and Coeffs	t-Values
USCIENT	(+) −0.00061	−2.47*
TECHNF	(−) −0.00044	−2.24
SALEINT	(−) +0.00260	+4.18**
MGUSC	(−) −0.00190	−7.02***
SUBSID	(+) +0.00190	+4.48**
INCUBATOR	(+) −0.00140	−0.11
AGE	(+) +0.00420	+4.34**
Intercept	3.7800	19.93***
F-ratio	11.82	11.82**
Adjusted R^2	0.88	
No of Obs.	11	

*Source: Single * implies that the result is statistically significant at the 0.10 level; double **, 0.05 level; triple***, 0.01 level.*

6.3.2 Results of the Proxies

Independently, five out of the seven proxies are statistically significant at various levels. These five are *MGUSC, SUBSID, AGE, SALEINT* and *USCIENT.*

MGUSC is statistically significant at the 0.01 level. As expected, it bears an estimated negative coefficient of 0.0019. This means that the higher the percentage of expenditures spent on office-procedure managerial information outside localities, the lower the employment growth rate of firms in Manitoba. Hence, the returns accruing from indulging in consultations from outside localities cannot be expected to cover the cost and effort expended. This implies that lack of face-to-face contacts may contribute to imprecise information for solving the exact problems facing the firms. Paradoxically, there are also insufficient local resources to serve local firms that are then compelled to turn to outside consultations.

SUBSID is statistically significant at the 0.05 level. It yields the expected positive sign for its estimated coefficient of 0.0019. This means that the higher the financial support coming from the provincial and federal levels of government through different programmes, the higher the employment growth of small firms in Manitoba. It further confirms that government financial agencies play an important role in the growth of small firms in Manitoba. Moreover, in due course, face-to-face contact between the two parties is a crucial form of communication to pass along general information. This result thus suggests that the larger the amount of monetary support entrepreneurs receive from government financial agencies or programmes, the more contacts will be required with government officials who are familiar with business or have a very strong technical background. Formally and informally, government agents would pass along other types of information to firms as well. In effect, this result matches the understanding of the industry sector gained by this author from the interviews with the entrepreneurs and top managers of Manitoba firms. A number of them revealed that their prospects were somehow tied to the support provided by government financial agencies or programmes; for example, the Western Economic Diversification Fund of the Western Economic Diversification Department (WED).

AGE is another statistically-significant proxy (at the 0.05 level) for explaining the variations of employment growth rates of the Manitoba electronics manufacturing firms. It yields the expected positive sign for its coefficient of 0.0042. This means that the more recent the year of establishment of the firms in Manitoba, the higher will be their rates of employment growth. This coincides with the hypothesis that new-firm owners are presumably very enthusiastic, energetic or even aggressive, and may have new ideas and new products in mind to fit market needs. Their commercial insights will bring them not merely successful businesses, but also the overall growth of electronics industries. In turn, the result confirms the theoretical perception that entrepreneurial learning economies are positively contributing to the growth of small electronics firms as well as industries.

SALEINT produces an unexpected positive sign for its estimated coefficient of 0.0026, and is statistically significant at the 0.05 level. The result lends credence to the view that market information sources outside the province are crucial and positive factors for firm growth in Manitoba. Accordingly, it reflects the deficiencies of local sources in the provision of market information as argued in the logit model.

USCIENT is also statistically-significantly (at the 0.10 level) explaining the variations in employment growth rates of Manitoba small electronics manufacturing firms. It unexpectedly has a negative sign for its coefficient of 0.00061. Hence, a direct and dismaying interpretation of this is that the higher the percentage of scientists or engineers recruited from local universities, the lower the employment growth of firms will be. Yet in contradistinction, there is a significant relationship between firms on the one hand and local universities on the other. The main reason for this is the lack of regular contacts between small firms of electronics communities and academics. In one interview, an engineering professor at the University of Manitoba claimed that only 10 percent of his colleagues would have regular contacts with electronics industries, and even then the contacts were conducted mainly through the industrial liaison office of the ITD located within the Fort Garry campus of the University of Manitoba. These contacts are usually in the form of contracted research and development projects or consultations. They are also biased against small firms. To explain the phenomenon, the professor pinpointed a lack of motivation as the "culprit of all possible evils". In the first place, faculty members are used to being overloaded with their academic duties. Therefore, to initiate contacts expressly with a view to assisting industry would demand extra time and energy from academics. Most importantly, they do not perceive that they receive a fair share of return for their inputs. The reason for the lack of contacts, in particular with small firms, may be the fact that most of the small-firm entrepreneurs are not graduates of the engineering faculty of the University of Manitoba. An examination of the crude surveyed data shows that only 41.67 percent of founders or top management of small firms who have majored in either electrical, electronics or computer engineering are graduates of the University. Hence, the lack of communication between the engineering faculty members and small-firm entrepreneurs, to say nothing of their unfamiliarity with each other, is not altogether surprising.

Two proxies are not shown to have a statistically-significant effect on the employment growth of Manitoba's small electronics manufacturing firms. These are *TECHNF* and *INCUBATOR*. The former can be interpreted as indicating that local firms do not rely heavily upon local or out-of-locality research facilities for technical information or advice. This may imply that the need for most technical advice would have been solved somehow within localities. Hence, this result reflects the competence of general local research facilities and services as perceived by electronics activities. The result of the latter proxy may be interpreted as showing that innovation centres are still not functioning sufficiently well to make a real difference. Setting aside their statistical insignificance in the model, these two proxies have deeper meaning for the development of science parks and will be dealt with in Chapter Seven.

6.4 Summary

Discussed in this chapter are the regression results of the two models, one general and one specific. The general model is drawn from the observations of Western Canada, while the specific model refers to the Manitoba experience. Setting aside their differences in mathematical forms, both models confirm the two overall hypotheses of the industry life-cycle concept, namely, that (1) external learning economies and (2) entrepreneurial learning economies are determinate dimensions to either the favourable odds of having a small electronics firm as against a large firm, or to the rate of growth of a small electronics firm. Furthermore, the two models have also jointly confirmed that some proxies are essential factors affecting the well-being of small electronics firms.

As far as the general model is concerned, it confirms that entrepreneurial learning economies (as proxied by *MGINH*) positively affect the favourable odds of having a small as against a large electronics firm in Western Canada. In relation to external learning economies, the model has directly confirmed that there has been a close and positive tie between local universities on the one side and electronics communities on the other (as proxied by *USCIENT*). Moreover, the model suggests that there is a negative relationship between distant technical resources (as proxied by *TECHNF*) and small electronics firms. This result validates the important role of local technical facilities. However, indirectly, it hints that there may be some severe deficiencies in certain types of information available in localities. For instance, local agencies seem to lag in providing market information, in particular that bearing on international markets (as proxied by *SALEINT*), and also are inferior in managerial consultations (as proxied by *MGUSC*). Furthermore, these types of consultation have to be provided by long-distance sources. Nevertheless, three proxies are dealing with entrepreneurship (as proxied by *AGE*) and all-round information (as proxied by *VENT* and *INCUBATOR*) are statistically-insignificantly affecting the dependent variable. Reflections on the implications of these findings for the agglomeration of small electronics firms will be reviewed for Chapter Seven.

As far as the specific Manitoba model is concerned, it has directly confirmed that information provided by local-government financial agencies (as proxied by *SUBSID*) and entrepreneurship (as proxied by *AGE*) expectedly and positively influence the growth of Manitoba's small electronics firms. It also indirectly establishes that local agencies are deficient in providing managerial consultations (as proxied by *MGUSC*), and in providing marketing information (as proxied by *SALEINT*), both of which have to be sought from out-of-province sources. Paradoxically, it confirms that there is a significant relationship between local universities and electronics communities, but in a negative way (as proxied by *USCIENT*). The activities of technical consultations either made within localities or outside localities are insignificant for the growth of small electronics firms in Manitoba (as proxied by *TECHNF*). The same results are obtained for all-round external learning economies within the realm of innovation centres (as proxied by *INCUBATOR*).

Therefore, the two models have not only directly confirmed the positive proxies important to the well-being of small electronics firms, but more interestingly, they also reveal some of the deficient areas that local agencies have to address in the future. First, both models assert that local managerial facilities or infrastructures are inadequate, since many such consultations have to be made via outside localities (as *MGUSC* shows significantly in both models). As for managerial agencies, local market agencies are also inferior in providing up-to-date market information either for local or international markets (as *SALEINT* shows significantly in both models). As far as financial and other general counselling are concerned, the Manitoba firms seem to have benefited from financial agencies (as *SUBSID* appears significant in the specific model), but this is not generally the case for other provinces (as *VENT* is not significant in the general model). Likewise, when the Manitoba firms indicated that entrepreneurship rather than advanced educational backgrounds is important for the occurrence of new firms (as *AGE* attests in the specific model), the overall picture does not reflect the same thing (as *AGE* does not show significantly in the general model). On the contrary, when the general model directly confirms that there is a positive relationship between local universities and electronics communities (as *USCIENT* is significant in the general model), the Manitoba case shows that a relationship between the two parties exists in a negative way. Meanwhile, when the general picture shows that outside consultations with respect to technical information are significant for the well-being of small firms (as *TECHNF* is significant in the general model), the Manitoba case reveals that these kinds of consultations are of no significance from outside sources. Meanwhile, in both models, *INCUBATOR* emerges as statistically insignificant in explaining the well-being of small electronics firms.

Elaborating on the results of the two models further, success in small electronics firms requires a wide variety of information. In turn, this information is very demanding on effective support from various local institutions. For accessibility to technical information, both models suggest that local universities play an important role in training new blood for electronics industries, and in providing up-to-date scientific knowledge to small electronics firms. Specifically, the Manitoba model suggests that the University of Manitoba would have a crucial role to play for the agglomeration of small electronics firms in the province. For accessibility to managerial information, both models suggest that the presence of business computer consultation firms is important. In particular, the general model indicates that such consultation firms should be able to provide precise office procedural information to local electronics firms in a positive manner. Another type of managerial information is that of market situations. In this respect, local sales agencies and market research companies may contribute positively to electronics firms for reliable and updated market information. Meanwhile, financial agencies could be an important source of overall information for entrepreneurs of small electronics firms. The specific model particularly indicates that government financial agencies are the most important sources of this type of information. Nevertheless, in the general model, the venture capital proxy does not show up as statistically significant to the growth of small electronics firms. The regressions also show that innovation centres may not be as promising as expected in providing overall information to small electronics firms. Apart from institutional support, the quality of entrepreneurship is also crucial for the occurrence of small electronics firms. The general model has pinpointed the fact that business computer skills are one of those key qualities for handling modern office procedures. Meanwhile, the specific model argues that enthusiasm for acquiring information of all aspects is the kind of crucial entrepreneurial quality that translates into overall success of firms and the related industry.

To sum up, in this chapter, we have reported the detailed results of the two models and have compared their similarities and differences. Hence, it is the position of the author that whenever the proxies have been expectedly confirmed by either of these models, then their underlying activities have to be maintained and expanded. More importantly, the models have revealed several deficient areas; these kinds of deficiencies constitute interests that deserve further research. To that end, more in-depth analysis of all the deficient areas will be explored in Chapter Seven, along with some suggested remedies for them.

Chapter Seven

Model Results
and
Successful Science-Park Development

7.1 Introduction

In the last chapter, the model results were reported and explained with reference to the data and observations drawn from the survey. To complete the task, this chapter will consider further the meaning of those results for science-park development. To proceed, this chapter takes a problem-solving approach to the deficiencies of factors important to science-park development. Basically, it holds to the view that, first, when the model results subscribe to the expected sign, they confirm *a priori* relationships between the explanatory and the dependent variable; secondly, that the unexpected model results are not random and can be plausibly explained; thirdly, that the insignificant proxies in the models should not be dismissed but, rather, they should be explored further in relation to science-park development. Above all, the inclination of this thesis is to advocate the pursuit of a scientific infrastructure strategy that will pull all the physical, technical, human and financial resources together in order to foster innovation activities. To be specific, the contemporary industry strategy should be one that emphasizes science parks as the breeding grounds of small electronics firms; for upon them industrial restructuring and regional development are both contingent.

The foregoing analyses of the results of the *general* and *specific* models have validated the industry life-cycle as a conceptual foundation for understanding the growth of small electronics manufacturing firms in Western Canada in general and in Manitoba in particular. They confirm that external and entrepreneurial learning economies are essential dimensions triggering the growth mechanisms of those small firms. More importantly, they endorse the supposition that scientific infrastructures are the seed beds of small electronics manufacturing firms. This chapter picks up on these points.

7.2 Successful Science-Park Development according to the General (Logit) Model for Western Canada

The general model emphatically indicates that there are *a priori* directions of relationship between key factors on the one hand and the favourable odds for the emergence of small manufacturing firms on the other. The favourable odds of the emergence of small manufacturing firms in general are positively related to local research institutions and universities for technical supports, and entrepreneurs' computing learning experience conducted inhouse. These odds are lessened, however, by recourse to distant technical consultations involving outside localities.

Hence, from the perspective of means of communications, face-to-face (local) contacts are more important to the operation of firms than non-face-to-face (distant) contacts. Through the presence of various local facilities and services, such as research facilities and universities, vital in providing accurate and relevant information for the development or commercialization of new products, small electronics manufacturing firms in Western Canada may reap the benefits of external learning economies and expand in consequence. The presence of entrepreneurship, that is, the quality of decision-makers with advanced business computer knowledge and skills for efficient office procedures, is another indispensable dimension contributing to the same outcome. Some out-of-locality facilities are essential for the agglomeration of small electronics firms as well. These facilities include agencies which provide market information, particularly about international markets and business computer firms which conduct distance consultations. From another perspective, this means that local agencies may not be capable of providing sufficient information or services to small electronics firms in Western Canada.

One can conclude from this that for agglomeration impacts of all these dimensions and proxies to be functional within a specific locality, the planned science park should keep on maintaining, extending and improving the existing channels of technology transfer between research entities and information agencies on the one hand and between information agencies and electronics communities on the other. In the remaining part of this section, and based on the general model results, the problems of the development of science-park infrastructures will be addressed directly.

For the provision of *scientific or technical knowledge and know-how*, the general model verifies the importance of close proximity to local universities. In the course of all types of face-to-face contacts, quality information will be mutually and swiftly passed along from one party to another. In a way, these kinds of resource centres are intended to support different aspects of electronics industries. Some scientific testings would be very costly for small firms to perform on their own in terms both the sheer costs involved and the rate of utilization of expensive scientific instruments. Paradoxically, those same instruments may be underutilized in advanced education or research institutions. Therefore, a policy of sharing instruments will reap the benefits of maximizing their utilization. In such a way, social costs (over-capitalization or under-capacity) could be mitigated or even eliminated. With sufficient demand for the use of scientific instruments, permanent jobs would be created for their maintenance and operation: idle time waiting for jobs will have been minimized. Hence, it is suggested that some sort of industry-university networking bodies, or, government and private research facilities, have to be installed so as to serve as liaison channels between the parties. Moreover, the logit model shows that the more entrepreneurs have to resort to distant technical consultations, the less likely small electronics firms will prosper. To handle this problem, it is suggested that local research facilities have to meet local industrial needs and that their relationship with electronics industries has to be reinforced.

With respect to the acquisition of *managerial information*, the general model also directly confirms its importance. Meanwhile, in order to strengthen managerial efficiency, it is suggested that the quality of entrepreneurs may have to be upgraded through programmes, courses or seminars offered by continued education that provide formal learning opportunities of the latest business computer skills and techniques for effective office management. Perhaps in recognition of their efforts, entrepreneurs should be awarded certificates or diplomas upon the completion of those courses. By upgrading and retraining entrepreneurs in business computer knowledge and skills for manipulating market condition data, there will be no lack of stimulation of new ideas, and in turn, of new products, keeping the electronics industries at the leading-edge of all manufacturing activities.

Apart from these direct affirmations, the general model also discloses the deficient aspects of local agencies. For one, there is an absence of on-the-edge *international market information* from local sources. The information obtained from journals, newspapers and government publications is known to be patchy and somewhat dated. Most often, government publications are also tardy in reporting up-to-date international market information. It is suggested that if science parks are to be successful, then the establishment of agencies or facilities that provide timely international market information is essential.

Another deficiency can include the inferior provision locally of *managerial information* regarding computerized office procedures so that local electronics firms have to seek consultations outside their localities. This is an expensive way to tap information. To cope with this reality, it is suggested that some quality business computer networks have to be set up either by independent business entities or by attachment to the existing system of advanced educational institutions. Above all, channels have to be provided for entrepreneurs to acquire managerial skills under a computerized office environment. In such circumstances, their business computer skills might have to be upgraded or strengthened.

More interestingly, this study calls into question the importance of *all-embracing information resources* such as venture capital companies, innovation centres and entrepreneurship to the well-being of small electronics firms in the literature. It is noteworthy that these factors prove to be statistically insignificant in the general model.

As remarked earlier, the failure of local venture companies in promoting the agglomeration of small electronics firms in general could be the result of their rare presence in Western Canada. It is important to remember that, of the 50 members of the ACVCC, that is, the Association for the Canadian Venture Capital companies, only eight are in Western Canada. Furthermore, the survey indicates that these within-province venture capital companies provide only 8.7 percent of the financial support utilized by the small electronics firms in Western Canada. Under such circumstances, it is not surprising to see that these financial companies would supply a very negligible amount of information and are powerless to contribute positively to the electronics firms. The foregoing discussion, therefore, serves to cast doubt on the supposition that even a greater number of local venture capital companies in Western Canada would markedly improve the growth prospects of small electronics firms in the region. In other words, if science parks in Western Canada are to act as the functional infrastructure necessary to nurture small electronics firms and innovation activities, the development of their own in-park venture capital activities is deemed a matter of some urgency because the sector in general is likely to fall short of meeting the needs of small high-tech firms. As a matter of fact, among the several science parks in Canada, only those in British Columbia have these venture capital activities. They are all furnished by the Discovery Enterprises Incorporation, a wholly-owned subsidiary of Discovery Foundation,[43] the organization which administers all research parks, namely, the Discovery Parks, within the province. Apart from British Columbia, no such in-park venture capital activities have been established in the other Western provinces so far. Arguably, the continued thriving science-park development in British Columbia relies upon the strengthening of venture capital services delivered by the Discovery Enterprises Incorporation. The other Western provinces have yet to reach the stage of establishing their own venture capital institutions orientated specifically to science parks.

In view of the situation of current budget constraints for all universities, it would be desirable for park administrators to pull all possible financial resources from public or private sectors within provinces, and from the national or international communities, for the establishment of investment funds. For instance, the Pennsylvania "challenge grant" programme in the U.S.A. is a seminal case in point. The grant was established in 1984 under the Board of Ben Franklin Partnership Fund and is largely a state government-supported investment fund appointed by the Governor and the General Assembly of Pennsylvania. The objective of this programme is to meet the capital needs of small businesses in their early stages of product or process development. The investment funds offered through this programme are of three major types: grants (financial assistance offered for entrepreneurs to acquire fixed assets such as land, buildings, machinery and equipment and which do not need repayment), loans (to acquire fixed assets and need repayment) and equity financing (commonly known as venture capital financing through purchases of shares in entrepreneurs' businesses). The fund would receive a return from repaid loans, equity participation or royalties paid by firms on sales of products. Returns of the funds are intended to be reinvested in the form of revenue bonds salable to the public to ensure that new monies is continuously flowing into the fund. Each fund has a minimum life of seven years so as to ensure the small businesses involved will acquire full support in the critical years (Miller and Cote, 1985).

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[43] *The Discovery Foundation is an organization with the mandate of uniting elements of the research communities, such as the universities of British Columbia, with business and government for the building of technology companies through various activities such as establishing science parks in the province of British Columbia.*

The basic problem revealed by the insignificance of the *INCUBATOR* proxy is that the resident firms have no special advantages over those located outside innovation centres. This may reflect the fact that these innovation centres are run by individuals who have had either general managerial training (with a Master of Business Administration degree) or technical training (with a postgraduate engineering degree). Therefore, from the perspective of industrial growth or regional development, they may have missed the deeper meaning underlying the operations of innovation centres or science parks. Subsequently, the administration provides no special services or facilities to meet the real needs of tenant firms. In this respect, it is suggested that the management of these innovation centres may have to receive special training to become aware of the special needs of their tenant firms which are different from any usual management-tenant relationship. More importantly, their studying of theoretical postulates of industrial agglomeration will be very helpful for them to understand the whole picture of industrial and regional development. Hence, it is recommended that at least one of the directors of the park administration team should have received professional training in industrial development or growth and, better still, instruction in the mechanisms surrounding agglomeration of innovation activities.

In retrospect, as discussed in Chapter Six, the less appropriate general and technical educational backgrounds of the top decision-makers may be a possible explanation for the modest contributions of enthusiastic entrepreneurs to their firms. To recall, in Western Canada, the percentage of electronics decision-makers without university degrees or technical college training in electrical, electronics or computer engineering is higher than in other industrial countries such as the U.K., for example. Although these entrepreneurs are capable of establishing close contacts with their external information sources, they may be handicapped by their minimum professional training in absorbing valuable information or knowledge for the advancement of their products. Hence, the flourishing of science park infrastructures is very much dependent upon upgrading the technical professional training of these top decision-makers. It is desirable that the engineering departments of local universities be encouraged by the park administration to expand their enrollments in these programmes; such expansion should reach entrepreneurs and top management as well. These professional courses may assume different approaches; for one, they can be offered by the continuing education division over a period of several months. Alternatively, they may be carried out in the form of workshops, conferences or seminars which last for one day, several evenings or a weekend. Through this variety of face-to-face meetings, top decision-makers of electronics firms are provided with ample opportunities to seek direct advice from their instructors, thereby establishing a formal channel of communication with local universities. As a result, these entrepreneurs are now adequately equipped to interpret valuable information from various external sources.

To sum up, the evaluation of the success of science parks is based on the extent of bestowing external and entrepreneurial learning economies to their tenant firms. Therefore, a successful science park has to be an infrastructure that can provide those benefits. In order to provide those benefits, the park administration has to be able to recruit all important elements within reach. Thus, before any action is to be taken, administrators have to learn about the needs of the targeted industries and firms. In the light of experience in Western Canada, as inferred from the general model, I will suggest the following as the core elements contributing to the success of science-park development.

(1) With respect to the accessibility to *technical information*, the presence of in-park research facilities such as government or private laboratories is essential. Moreover, close proximity of science parks to universities should be encouraged. It must be ensured that through the industry-university networking bodies such as the liaison offices, scientific and technical knowledge will be easily passed along to entrepreneurs or top management of tenant firms. Thus industrial research will be reinvigorated. Moreover, to solve the problem of inefficiency attaching to out-of-province technical consultations by entrepreneurs, on-site research facilities should be geared to meeting industrial needs and their relationship with electronics firms should be strengthened.

(2) For the provision of *managerial skills and knowledge* joint accessibilities of tenant firms to some private entities and government agencies in the park are required.
   (a) With regard to *office procedures* under a computerized environment, the park should encourage the presence of quality business computer firms in the park for customized consultations and for upgrading entrepreneurs' effective command of their computer systems.
   (b) With regard to *market information*, efficient agents in providing fast and on-the-edge local and international information are recommended to be present in the park.

(3) For the provision of *overall information*, the following measures have to be taken.

(a) In view of the presence of only a limited number of *private venture capital companies* available to electronics industries, the park administration should think of establishing their own venture capital funds to serve tenant firms and the targeted industries.

(b) In view of the general lack of in-depth understanding of the agglomeration of innovation activities by *park officers*, the park administration should think of retraining their staff members to recognize the deeper theoretical postulates of science park infrastructures to promote industrial and regional development. It is also recommended that the park administration hire a director who is knowledgeable in the mechanisms of actuating agglomeration of the targeted industries, such as the electronics industries.

(c) In view of the limitations in the *general and technical education levels of the new entrepreneurs*, the park may have to make arrangements for upgrading their levels to a desirable standard.

If all the foregoing suggestions are observed by the park administrators, then it can be anticipated that the park officers will become alive to the fact that their particular responsibilities extend far beyond the conventional daily passive routines. They should serve as a proactive team that render swift and effective communication among all key players in the park such as university administrators, government agents, laboratory personnel, marketing agents, management agents, business computer agents, venture capitalists, and the industrialists themselves. Perhaps a computer network that connects all these parties together will invalidate the excuse of communication breakdowns among them. Most importantly, working within the same spatial boundaries, these parties will be able to make face-to-face contact whenever this is called for. Eventually, the benefits of external and entrepreneurial learning economies will not be rhetoric only to tenant firms but reality instead.

7.3 The Specific Model for Manitoba

In contrast with the general model that spells out some overall directions for the development of science parks, the specific model focuses on the development of science parks in Manitoba alone.

This specific model indicates that *the presence of local government financial agencies* in offering monetary support for various projects will allow small firms to have easy access to the essential knowledge, skills and instruments required for new product development and commercialization. Among those government agencies, the Western Diversification Fund of the federal Western Economic Diversification Department has been singled out as the one best received by entrepreneurs. Hence, it is easy to jump to the superficial conclusion that such government programmes should be made more visible in the park and leave it at that. However, further consideration is warranted.

According to the experience of the entrepreneurs in Manitoba, many other government financial programmes or agencies are subject to the criticism of being "ineffective" in delivering their support or activities. Some entrepreneurs think that some of the administrators of those government agencies are "playing favourites" and the programmes they delivered have been "abusively" used by a few individuals of electronics industries; therefore, they are not able to discriminate between the "most-needed" and the "optional-needed". Entrepreneurs also see the root of these problems as the absence of qualified personnel who should have the required expertise to evaluate proposals presented by applicants. Operating advice will hardly be sought by entrepreneurs from those bureaucrats who are unable to give insightful diagnosis and recommendations to their real problems at hand. Entrepreneurs also are aware of the fact that though some government bureaucrats may have a strong managerial educational background, they fail to act as good business advisors. They may provide general managerial advice but lack business acumen. Owing to their lack of experience in the business world, they are unable to identify the business opportunities or problems of electronics firms. Hence, limited by their understanding of electronics activities, they may misallocate valuable resources to some activities that bear no business or commercial value in the marketplace but are simply interesting to bureaucratic and academic researchers. Frustrated by these problems, some entrepreneurs are reluctant or hesitate to seek assistance from agencies of this kind.

In the circumstances of ineffective government programmes for delivering financial and business advice, perhaps, the establishment of an investment fund for the park is to be recommended. This fund should pull together financial resources from various sources such as government agencies, pension fund institutions, the special investment arms of banks or insurance companies, and other large corporations and wealthy individuals whenever and wherever they are found. The fund should be administered by a board of directors drawn from various backgrounds, especially drawing on electronics activities veterans and senior financial administrators such as bankers. Their experience may help the evaluation process of allocation of funding. In particular, they may help start-up firms by providing them with information regarding the network of suppliers, financiers, lawyers, accountants and other technical professional ancillaries for "how to" (not whether to) carry out projects legally and satisfactorily (OECD, 1988). Hence, business plans of the financed projects, under the watchful eyes of these talented electronics business champions and professional financial administrators, may then be revised to ensure the investments of the fund are safeguarded. Although these veterans may not (or, cannot) dismiss the CEOs of the commercial entities or reverse the decisions of entrepreneurs, they can, at least, monitor the availability of funding for applicant firms in the consequent budget year. Therefore, they are able to ensure that the fund provided ends up in "smart" and proper hands. By and large, the fund may well be structured at different tiers: grants, loans or equities.

However, apart from the availability, accessibility and the administration of the funds, there is also a problem of convincing entrepreneurs to apply for the funds. In the interview process, an electronics entrepreneur explicitly stated that he neither knew what venture capital is nor how to use it. On the other hand, another entrepreneur expressed his intention to maintain full control of his firm and, therefore, shies away from venture capitalists. He is afraid that such financial benefits have to be gained at the expense of production and managerial control of his firm. Not only did he think that the venture capitalists are asking for too much in return, he assumed that the nature of of their interest is purely profit-motivated.

There can be no question that these entrepreneurs have honestly reviewed their perception of venture capital funds while undoubtedly, financiers may have their own priorities. It seems that the gap between these two parties is prejudicial to the perception of this kind of fund. To the author, this kind of fund should be deemed one of many potential resources within a part of industrial process. Through business meetings among the players, some enduring technical and managerial problems will be reviewed with new perspectives, and, perhaps, solutions to them could eventuate. It may be true that some administrative power of the entrepreneur upon his or her own firm has to be shared by new venture capitalists or their representatives; such share-input is very beneficial to the firm. Working together for the common interests of the firm, the new administration should be entrusted to find ways of maintaining or promoting the competitiveness of the firm. In due course, new lines of production may be found to keep the firm, as well as the original entrepreneur, financially afloat. Therefore, it is recommended that the true nature of new venture capital funds should be made clear to the electronics communities for the common good. Under such promotional campaigns, entrepreneurs will have a fair chance of learning more about the feasibility of such resources to their operations. When the cloud of myth has been blown away, the electronics communities may have more trust and faith in accepting new venture capitalists as business partners.

Another proxy that directly confirms the hypothesis of *entrepreneurial learning economies* is that of AGE. The enthusiastic behaviour of younger entrepreneurs is particularly true of small firms in Manitoba but not in Western Canada in general. The specific model implies that enthusiastic or new electronics practitioners in Manitoba subscribe much more to the quality of entrepreneurship than do their counterparts in the other provinces in Western Canada (referring to the results in the general model). From this, it is easy to come to the conclusion that this advantage has to be maintained. Nevertheless, the issue involved here is about how exactly to keep up the qualities of entrepreneurship.

There are three major channels through which entrepreneurship, or, the generation of enthusiastic or new entrepreneurs, can be promoted. Firstly, this can be done by the regular advanced education system where engineering and managerial knowledge and skills are taught to potential entrepreneurs such as the graduating students of universities or even some of the engineering faculty members. Meanwhile, in order to stimulate new ideas and have them materialized, awards should be given by universities or government to students whose competition projects are outstanding in terms of their practical feasibility. With all these measures, it is then hoped that the generation of new entrepreneurs would be augmented. Secondly, existing industrial scientists or technicians may have to be retrained by the advanced educational institutions. This suggestion is based on the presumption that the more exposure to, and understanding of, the state-of-the-art technologies, the more likely the practitioners will come up with new ideas for application. Without sufficient knowledge, they might not have the required confidence to launch ambitious ventures; without knowing much of the present stage of technological development, they might never be able to get their ideas off the ground. Through these realignment courses, they should develop a self-image of scientific pioneers rather than one of technicians. Nevertheless, it also has to be emphasized that managerial knowledge and skills will be an important part of the whole process of generating or refreshing entrepreneurship. Thirdly, it may well be worth the trouble locating and tracking the successful "native sons and daughters" so as to persuade them to "come home" once they have accumulated valuable national or international experience in technology, marketing, financing or management. The whole idea is to take these celebrities for demonstration effects (a policy, incidentally, much favoured by Taiwan to attract experts home from Silicon Valley).

Similar to the result of the general model, this specific model also finds that the small firms in Manitoba are very dependent on the availability of market information from non-local resources for survival. Accordingly, it reflects the deficiencies of *market information* available in localities. As the PEMD scheme of the External Affairs Department has been praised by a number of electronics industrialists for facilitating face-to-face contact with consumers, this type of programme should be applied more vigorously in the park so as to alleviate the problem of market information deficiency. Yet the problem would not be entirely solved in this way. In a proactive manner, some further measures have to be taken before it is too late. For instance, in an interview, a former electronics manufacturer complained that he was not well informed of the rapidly changing market environment. Caught by the keen competition of new products, the specialized products of his company which had been in demand in the last decade were pushed to the end of their products' life cycle. His products became obsolete and sales declined rapidly, confronting the firm with the problem of closure. Without the timely provision of market information, no preparation for the next new wave of competition will be sufficient to overcome the turmoil. Eventually, the firm may have no choice but to switch its operations from electronics manufacturing to wholesale activities simply to stay solvent.

In view of the breakdown of many of the local information resources for the delivery of updated and specific international information to entrepreneurs, the attracting of agencies which are capable of supplying leading and specific market information concerning the desire of acquiring international patrons is vitally significant to the survival of small electronics firms in science parks. The attraction of multi-national corporations, or their R&D departments, or some renowned private electronics research laboratories into the park setting may be of great importance to the provision of such knowledge and information. The rationale of this can be explained as follows. These large firms are usually characterized by the complexity of their organizational structure (for example, their division into numerous departments).

History indicates that owing to this complexity, internal conflicts between top management and their subordinates often occur. In particular, the internal conflicts between top management and managerial personnel of the R&D departments are common events within these large corporations. A reason for the occurrence of such interdepartmental conflicts will be this: top management of these giant companies often consists of individuals with strong backgrounds in management training; these individuals are in general relatively conservative and less ready to engage in high-risk projects. In such circumstances, the new product ideas or projects which require a certain degree of risk-taking that are proposed by the scientific personnel of the R&D departments are often ignored or downplayed. Frustrated by the over-conservativeness of top management, a condition compounded by management's rejection of their new product development projects, these scientific experts of the R&D departments often leave their parent companies in order to establish their own. The market information concerning the needs of international customers may have been gained by these new entrepreneurs from their previous employer firms. Having evolved from such background, these spin-offs stand a good chance of capturing the markets for their new products.

One of the fathers of the transistor, William Shockley, is a case in point. After quitting the institutional environment of Bell Laboratories, he had, by 1958, laid a foundation stone for Silicon Valley, namely, the Shockley Semiconductor Laboratory at Palo Alto. His inability to work congenially with fellow researchers led to the splintering of the Shockley team, the formation of Fairchild Semiconductor and, thereafter, the continual departure of that company's workers to create a spate of small firms of their own (not least of whom was Robert Noyce, the founder of Intel and from 1988 the CEO of Sematech, the American semiconductor industry's attempt to match Japan in advanced process technology) (Todd, 1990). Saxenian (1985) estimates that between 1959 and 1979, as a result of engineers and other professionals leaving the company, Fairchild Semiconductor spawned 50 new high-technology companies in Santa Clara County located within the Silicon Valley.

Gene Amdahl, an outstanding engineer of IBM is another example. Unhappy with the conventional grooves of IBM, Amdahl, an innovator renowned for his Model 360 mainframe released onto the market in the mid-1960s when he was serving at IBM's R&D centre in Menlo Park, California, abandoned the company and created a rival mainframe firm in 1970. After nine years he left the eponymous firm to start afresh with an alternative (and far less rewarding) mainframe company, Trilogy, and then in 1987 proceeded with a third start-up, Andor. The latest venture, with headquarters in Cupertino, California, is banking on the success of its small mainframe, a small machine hinging on VLSI circuitary and compact central processors (Todd, 1990).

Apart from the role played by multi-national corporations in spinning off entrepreneurship, some other forms of coordination and communication, such as non-profit-making electronics professional associations, may also be possible. For instance, the presence of the EIAM in the park may serve as an inducement. In organizing joint functions, such as conferences and seminars with other international electronics associations, EIAM could bring together foreign distributors, practitioners or even potential customer groups to meet with local entrepreneurs. Through face-to-face contact with these key industrial players, local entrepreneurs could obtain updated international market information that might stimulate ideas for new product development or new market opportunities. Perhaps the relocation of the ITD, the university-industry networking body, together with the strengthening of its activities in the provision of international knowledge for innovation firms may play a bigger role than before. The final goal is to encourage the formation of cooperative international market research projects between management faculty members and entrepreneurs.

Meanwhile, the specific model confirms that the small firms in Manitoba, like their counterparts in other Western provinces, are counting on distant *managerial information*, or, more specifically, out-of-province *business computing consultations* with respect to office procedures. However, it shows that the problem confronting the small firms in Manitoba is more serious than that afflicting other Western firms. The latter receive some positive effects from distant consultations (as estimated in the general model). The small firms of Manitoba are worse off not just because of the inadequacy of local support but also because high costs cannot be justified by their induced benefits. It has been observed that a large number of computer service firms exists in Manitoba. However, the model implies that they are incapable of customizing their services to fit the local needs of electronics industries. Solutions are not difficult to envisage. From the perspective of this thesis, which concerns agglomeration effects, in the long run, the intent should be to provide activities capable of tailoring their services to individual client needs and to locate these directly in the park. This would invoke regional development through the agglomeration of economic activities that go beyond electronic businesses alone.

The specific model also confirms the importance of the linkages between *universities* on the one hand and small electronics firms on the other, albeit in a way different from what the general model suggests. The latter indicates an expected positive relationship whereas the former endorses a negative relationship. This signifies that there may be some distinct obstacles in this kind of linkage in Manitoba which varies from the general picture of Western Canada. Solutions to this problem may take two paths. One is to find out the sluggish areas and to remove them. The other path is to provide new channels to make the linkages work.

For instance, as revealed by the specific model, the presence of local universities (mainly, the University of Manitoba) is regarded as a curse rather than a blessing for small electronics manufacturing firms of the province. As mentioned previously, this observation is largely a result of the lack of frequent contacts between entrepreneurs on the one side and the engineering academics on the other. As voiced by an engineering professor from the University of Manitoba, the lack of frequent contacts between the two parties basically stems from a lack of motivation of the engineering academics to contact the industries. In addition, there is the lack of familiarity between the engineering academics and the founders of small electronics firms. Owing to the lack of contacts with entrepreneurs, academics have lost touch with the industries and are unaware of, or less sensitive to, the technological needs of electronics activities. It is observed that the engineering curriculum does not offer the most contemporary know-how. The forthcoming scientific personnel (graduating students) are not trained at the University of Manitoba with the most advanced technologies that meet the practical requirements of industry. Specifically, some entrepreneurs complain that they experience great difficulty in finding engineers in the field of electromagnetic graphics. Others have complained of the difficulties in finding new, well-trained local computer graduates who know the C-language or are familiar with the UNIX computer network.[44] This inadequacy of locally-trained engineers or computer personnel has led some Manitoba firms to resort to either retraining their own labour force or recruiting qualified personnel from outside the province, from Alberta for example. However, recruiting qualified personnel from outside the province is very costly because the firm has to advertise nationally and provide housing allowances and relocation compensation to the people hired. Similarly, the retraining of scientific personnel is also very costly. As a senior executive of an interviewed firm revealed, the retraining of an employee in microelectronics technology and software C

[44] *The UNIX computer network is an operating system for a wide variety of computers, from mainframes to personal computers, that supports multitasking and is ideally suited to multiuser applications (Pfaffenberger, 1992).*

within the firm, for example, would require 15 working days. Worse still, there were cases where employees who had received particular, on-the-job training subsequently left the firm for a better paid job elsewhere. The costs involved could be even more daunting since the employers have to provide on-the-job training to their employees from scratch. With these inadequately-trained engineers and scientists and the time and pecuniary costs involved in recruiting and retraining these personnel, the acquisition of on-the-edge knowledge and skills for new product development will be very expensive and inefficient.

An experienced entrepreneur of one of the surveyed firms complained that the knowledge and skills he once acquired from the University of Manitoba are no longer adequate for him to develop or fabricate new products in meeting the rapidly changing requirements of the users. In order to acquire on-the-edge technical knowledge and skills, he had been desperately seeking help from the University of Manitoba. Unfortunately, the technical courses and programmes offered by the university did not cope with the rapidly changing, technical world and, hence, could not offer the kind of scientific knowledge and skills that he required for his new product development projects. He thus contemplated going to the U.S.A. for training. However, owing to the costs involved in travelling and high tuition fees for course enrollment, he was compelled to drop the whole retraining plan. Consequently, his new product development projects were often terminated and the survival of his company was, in reality, at stake.

In these circumstances, it is highly recommended that the ITD, the technical liaison office between the university and the electronics industries, should adopt a more active, or even proactive role than has been the case hitherto in organizing programmes or activities capable of promoting contacts between the two parties. In its agenda, ITD should have considered the implementation of share-profit types of research contracts that provide incentive or motivation to the university scientists to work with entrepreneurs. Such research contracts should allow the university scientists to derive income from their participation in the activities. For example, both industrialists and scientists could share the rights to the patents for their new invention. Ideally, such cooperation would reveal the real technical requirements of electronics industries. At that juncture, the university curriculum could be geared to the direction of the advancement of electronics activities.

The increase of familiarity or understanding among all parties through these contacts and through mediation is of vital importance to the well-being of small electronics firms.

As suggested by an engineering professor, more often than not, in practice, entrepreneurs of small firms may only need "trivial" or "petty" technical skills or advice rather than really high-level expertise in developing their new ideas or products.

Perhaps the establishment of informal contact channels such as business clubs or other activities such as conferences aimed at promoting friendship or mutual understanding among the parties would also serve a useful purpose. After all, there are mutual benefits to all parties involved in the electronics industries when dialogue increases. These suggested measures could effect a turnaround in the ongoing alienated relationship among interested parties in electronics activities. Results suggest that the local university can be a significant factor in promoting the prosperity of small electronics firms of Manitoba. However, if the university is not to have an adverse effect on the viability of these firms, facilitating of contact between small firms and academics must be continually attended to.

Unlike the general picture of Western Canada, acquisition of *technical information* from distant sources does not show up as being of significance to Manitoba firms. This suggests that entrepreneurs may be able to solve their technical problems locally. It reflects the general adequacy and importance of local research facilities in providing technical know-how for meeting the demands of small electronics firms. In the surveys, several government programmes/agencies have been widely praised by entrepreneurs. There is strong agreement that the administrators of the IRAP of the federal NRC and the Technology Commercialization Programme of the provincial ITT are fellow members of the science community and speak the same technical language as their electronics clients. The programmes are managed in an efficient manner which involve minimum bureaucratic complexity and are capable of delivering adequate and precise scientific support to small electronics firms. Essentially, with their technical expertise, they are capable of evaluating the proposals precisely and efficiently and, therefore, are able to shorten the whole evaluation process and are capable of giving intelligent technical advice to their electronics applicants. Hence, these well-received government initiatives ought to be strengthened and packaged for delivery by ITD as part of its technical and scientific transfer within the park. Moreover, luring of laboratories, such as the Industry and Technology centre of the EITC, to the park is another possible way both to lighten the burden of universities and to supplement their responsibilities.

Perversely, the *all-embracing infrastructure* proxy, *INCUBATOR*, does not register significantly in affecting the well-being of small firms in Manitoba in contrast to its role elsewhere in Western Canada. Very specifically, this means that the CITT of Manitoba, the only innovation centre in Manitoba, has not been serving the electronics communities in the fashion originally intended. This is most likely a result of the lack of incisive understanding of innovation activities on the part of the management. It is suggested, therefore, that personnel who have a better understanding of the mechanisms of high-technology industrial agglomeration should be given responsibility within the management team.

In summary, to produce a successful science park in Manitoba, the park administration has to pull together the resources of different agencies, facilities or services and bring them into the park in order to enable tenant firms to realize external and entrepreneurial learning economies.

Essentially, for the accessing of technical information, in particular the on-the-edge scientific knowledge available in the University of Manitoba, the ITD, or any institution of this kind, should focus its activities on enhancing contacts between academics and on-site industrialists. These contacts can take the form of profit-sharing research contracts, conferences, seminars, and many other informal or casual meetings within the park. In due course, the kind of mutual trust, respect, and familiarity or friendship built upon those encounters will be helpful for all parties, stimulating them to come to some creative scientific ventures for the advancement of small electronics firms. Regarding general local technical resources, the multiple regression model shows that within-province research facilities and services have been meeting the needs of electronics communities. In this regard, it is recommended that the well-received government initiatives such as the IRAP of the federal NRC and Technology Commercialization Programme of the provincial ITT ought to be made more visible by ITD within the park. Moreover, the relocating of the Industry and Technology Centre of the EITC, the government electronics laboratory, within the park is necessary.

With respect to the availability of *managerial information*, similar agencies are involved but with different emphases. First of all, for the provision of managerial information regarding the computerized office environment, computer consultant firms capable of tailoring their services to needy client firms should be part of the supporting system of entrepreneurship provided by the park. Secondly, for the provision of market information, or international information in particular, government agents that have been well praised and recognized by the industries such as the PEMD initiative of the External Affairs Department, should continue their services for tenant firms on a more intimate relationship. Meanwhile, as argued earlier, the attraction into the park of the R&D units of leading corporations in electronics industries, together with some renowned research corporations and non-profit-making professional or business associations, is a way current international market conditions can trickle down to the smaller counterparts in the park. Through joint ventures or cooperation between the smaller and larger firms of the park, the larger firms will not only be able to release information on current industrial events, but more importantly, they can predict the future of the industries, and, hence, the prospects of their firms. Finally, the relocation of the ITD right into the park will strengthen the administration of all these activities for increasing innovativeness.

For the provision of *overall information* to the tenant firms, the presence of government financial assistance agents in the park will provide direct and quick responses or evaluations to the applicants. It would help if the Western Diversification Fund were to be more visible in the park. In view of the scarcity of venture capital companies and the setbacks of government financial agencies in delivering information for their client firms, the park may run its own venture capital funds that may deliver not only financial assistance but other business and legal information to the tenant firms as well. Experience also shows that some entrepreneurs are either intimidated by, or ignorant of, venture capital funds. Therefore, some measures have to be taken to raise the awareness of the entrepreneurs regarding this kind of activity. Entrepreneurship has to be promoted within the resources of the park not simply for new firms of this generation but also for firms of the next generation. Above all, the overall success of the park depends upon the hiring of personnel who know about the agglomeration mechanisms of innovation activities with regard to effective implementation of the "right" programmes for technology transfer within the park.

7.4 Chapter Summary

At the conceptual level, both models validate the presumption that external economies are crucial elements for science-park development. They suggest that the success of a science park depends upon the interplay of technology transfers between on-site facilities on the one hand and electronics communities on the other.

As far as the acquiring of technical information is concerned, both models have pointedly highlighted the role played by local universities. The general model speaks of the necessity of close proximity of science parks to local universities and the possibility of an enhanced role for liaison offices. Meanwhile, the specific model refers to the ITD, an industry-university networking body located within the University of Manitoba. The strengthening of the activities of this intermediary will definitely facilitate technical transfer between academics and in-park industrialists. This institute should promote actions aimed at increasing technological cooperation between the two parties. Formal and informal meetings among the parties are meaningless without sincere thought of mutual trust and benefits. Nothing will be passed along if communication does not come to this level. Regarding general technical facilities, the logit model reveals the inefficiency of non-local technical resources. The strengthening of in-park research facilities such as government or private laboratories is recommended. On the other hand, the multiple regression model hints at the paltry contribution of non-local technical agencies in contrast to the competence of general local research resources. Implicitly, it signifies the requirement of efficient on-site scientific facilities for fruitful science-park development. In this regard, the ITD would be well advised to focus on delivering the well-praised government initiatives such as the IRAP and Technology Commercialization Programmes. Moreover, the transfer of the Industry and Technology Centre of the EITC, the provincial electronics laboratory, to a site on the park would be definitively advantageous.

Regarding the provision of managerial information under a highly-computerized working environment, both models show that entrepreneurs should always be willing to learn the state-of-the-art technologies for efficient office management. In this respect, computer consultant firms will serve as a part of the managerial system, but these computer firms should be capable of providing good quality or flexible services to client firms. As denoted by the results of both models, local market resources are badly deficient in terms of managerial information. Without the provision of fast and on-the-edge market information, especially international information, by local agencies of all kind, small firms will be driven to the verge of bankruptcy in consequence of their sluggish adjustment to unanticipated changes in market preferences.

For the provision of overall information, both models show that the establishment of venture capital funds by the park administration and innovation centres are indispensable parts to the success of science parks. However, for delivery of effective overall information supports within these innovation centres, the logit model suggests that the park administration should consider retraining their staff members to recognize the theoretical principles allowing science-park infrastructures to promote industrial and regional growth. Moreover, both models agree that the park management team should include of a lead person who is knowledgeable and can guide individuals to take advantage of the mechanisms of industrial agglomeration. This person is equally crucial in ensuring that the other staff members make this mechanism work efficiently.

Meanwhile, the qualities of entrepreneurship can be promoted via the instrument under the wings of science parks, as verified by both the general and specific models. The logit model suggests that the prosperity of science parks in Western Canada depends on the strengthening of the computer skills of entrepreneurs. Moreover, in view of the deficiencies in the general and technical education levels of new entrepreneurs, the park may have to make arrangements for upgrading their levels in these areas. In Manitoba, in the light of the remarkable contribution of enthusiastic entrepreneurs and their new start-ups to the electronics sector in Manitoba, it is recommended that this kind of entrepreneurial atmosphere should prevail in the park. The continuous generation of new entrepreneurs will also be furthered through the regular advanced education system, retraining existing industrial scientists or technicians and encouraging the successful and experienced "native sons and daughters" to "come home" to establish their own firms within the park.

7.5 Final Message Regarding Science-Park Development

Without doubt, the most important function of science parks is to provide an environment where targeted industries or firms can reap the benefits of external and entrepreneurial learning economies. Despite the detailed revelation of the general and the specific circumstances of the two models, there is a crucial single element that has not been spelt out: the commitment of all parties to the course of electronics development. Strong and persistent commitment of one or some of the industrial practitioners can turn around the sluggish attitude toward science-park development.

The successful development of Stanford Industrial Park was closely linked with the personal effort of a university official, Professor Fred Terman, Dean of the Electrical Engineering School at Stanford University from 1946 to 1955 (Haug, 1986). During his tenure as Dean, Dr. Terman supported the park by convincing many large electronics companies to locate near Stanford University, by encouraging many Stanford engineering graduates to set up science-based businesses near the campus and also by helping them obtain capital from various financial agencies. Two such students were Mess Hewlett and David Packard who today own Hewlett-Packard, one of the multi-billion dollar corporations in the U.S.A. (Taylor, 1985).

Similarly, the successful development of the Research Triangle Park in North Carolina is a result of the faithful commitment of university officials. After the park's establishment in 1958 by Governor Luther Hodge, development was initially slow. It was not until 1965 that the park took off with the luring of the R&D units of IBM on site by university officials. Historically, in order to attract this research facility into the park, an exception to the regulations of the park was made. Through agreement, IBM employees were not only allowed to research into, and to develop, computers and the associated hardware but also to manufacture them in the park (Hamley, 1982). With the enticing of this R&D facility to the site, a total of 9,000 jobs were created. More importantly, the credibility which IBM gave to the park led to major openings by Burroughs-Wellcome and others. It served as a key demonstration for all those contemplating the development of a science park (Monck et al., 1988).

The enthusiasm of government officials, on the other hand, contributed significantly to the birth and rapid expansion of Sophia Antipolis. The initial inspiration of Sophia Antipolis can be attributed to the efforts of a French government official, Senator Pierre Laffaitte, who had served in the national legislature in Paris and as director of the Paris School of Mines. He took the lead in envisioning Sophia Antipolis, and procured government funding for it (Rogers and Chen, 1990). Since its establishment in the 1960s, the occupation rate of Sophia Antipolis had been fairly satisfactory. However, in 1985, with the financial commitment of the key officials of the Department of des Alpes Maritime in establishing *a pepiniere*, an innovation centre known as Sophia Antipolis Technologies Reception Centre providing accommodation and numerous services such as essential administrative, commercial or technical information or services for new start-up enterprises, the rate of growth of the park has increased impressively ever since. In 1985, a total of 120 firms, organizations, societies and associations were operational, providing employment for about 5,000 workers. However, by 1991, the number of companies in the park amounted to 650, while the number of employees totalled 12,000 (Laffaitte, 1985; Rogers and Chen, 1990; AURRP and IASP, 1991).

The successful development of the University of Texas's Balcones Research Park in Austin is largely a contribution of the efforts of both the key individuals in the government and the universities. In the beginning, the growth of the park had been quite slow, then a dramatic change occurred when the Microelectronics and Computer-Technology Corporation (MCTC), a U.S. research consortium of 20 major electronics firms, 454 researchers and staff members and an annually subsidized Japanese Fifth-Generation Computer Project, chose this Research Park at Austin over 57 other U.S. cities as its headquarters in 1983 (Rogers and Chen, 1990). The attraction of MCTC was largely a result of the imaginative packaging of inducements offered by the city and the University of Texas. Concessions such as the offering of $23.5 million for the provision of office and laboratory space for the MCTC within the university campus, $40 million to expand their electrical engineering and computer programmes and the dedication of academic staff and students, supplemented the inducements. Among the most outlandish concessions was the provision of an executive jet by the city government and the University of Texas for the use of corporate officers (Ibid., and Todd, 1990). The attraction of this research corporation allowed the park to leapfrog right into high-technology stardom within the U.S.A. Essentially, the relocation of this research facility caused other would-be residents to think seriously about locating their firms on the site as well (Todd, 1990). Since 1983, the MCTC has attracted the R&D units of several of its 20-member companies to relocate in Austin (e.g., 3M, Motorola and Lockheed). For the facilitating of entrepreneurial spin-offs, 3M transferred 3,000 R&D workers in microelectronics to Austin in 1984 (Rogers and Chen, 1990).

Similarly, UK evidence suggests that key individuals of localities are responsible for the blooming of science-park development there. As Monck et al. (1988, p.79) note,

> "... the catalyst for this (the rapid emergence of science parks since the early 1980s) was the emergence of a few key individuals in universities, development agencies and local authorities. These individuals recognized the need for change and were aware of developments in high-technology in the U.S.A. and the contribution that research parks and innovation centres were making. They include, amongst others, Sir Frederick Crawford, the Vice Chancellor of Aston, who had been Pro-

> fessor of Electrical Engineering at Stanford; Warick University's Vice Chancellor, Professor Butterworth, and his registrar Mike Shatock; Tony Pender, the Chief Executive of English Estates; Edward Cunnington, the Director of the Product Planning and Development Division of the Scottish Development Agency; and Ian Page, the Industrial Development Co-ordinator at Bradford Metropolitan Council. All these individuals were influenced by the experience of John Bradfield, the Bursar of Trinity College, who established the Cambridge Science Park, and in many cases, by what they had been in the U.S.A. They were instrumental in deciding to establish the ... science parks at places such as Aston, Warwick, Bradford, etc."

Finally, as Schamp (1987, p.121) notes, "... it took a considerable time (for the Stanford University Park and the Research Triangle Park) to attract a large number of enterprises and to create new jobs ..." Moreover, a report of the U.S. Office of Technology Assessment on Technology, Innovation and Regional Economic Development notes that science parks take a long period of time, often 15 to 30 years to become successful (Cox, 1985). Alderly (1985, p.292) also observes that "... it will be between 15 and 20 years before a science park, under normal financing conditions, can be 'profitable' ... " To Miller and Cote (1985, p.127), "... developing a research and technology park is a long-term process. Planning horizons of twenty to thirty years are not uncommon."

In such circumstances, a compelling case can be made for the long-term and persistent commitment of the key local individuals in particular the university managers and key government officials, to the well-being of science parks. Without it, the future of science parks is much less assured.

Chapter Eight

Summary and Conclusions

This study was triggered by the doubts which have arisen concerning the ongoing high-technology industry and science park strategies which have been applied to regional development, particularly in Manitoba. It started with a broad background review of such strategies not only in Manitoba but also in Canada as a whole. In addition, the experience of some other advanced industrialized countries was reviewed. The review has singled out the hopes attached to electronics industries and science parks in the process of regional development. Apart from the ongoing practical emphases of electronics activities and science-park development, this study also considers theoretical perceptions in explaining their possible functions in regional development. The primary objective of this study was to look for the determinants of those functions. Such determinants are derived from the industry life-cycle theory, which appears to be the most appropriate theoretical base to this study. The determinants were then verified by empirical trials, that is, regression modelling. The results of the empirical testings were interpreted in the light of future development of electronics activities. As a result of these exercises, the study has practical suggestions for the future promotion of science parks, the nursery beds for such industrial activities. Therefore, this Chapter highlights the salient features underpining the explanations.

Recently, high-technology industries have become the main ingredients of the most popular strategies for regional development in the advanced world. They are considered as panaceas for overcoming an unfavourable industrial structure, and, hence, economic ills in peripheral regions. Science parks, among various industrial development strategies, have emerged as the most promising means for nurturing these industrial activities. Notwithstanding the fact that much effort has been devoted to promoting high-technology industries and science parks for regional advancement, many lagging regions are still handicapped by poor industrial structures and gloomy economic conditions, most importantly, high rates of unemployment. The crux of the problem appears to be a lack of thorough understanding by regional planners of the forces contributing to prosperous science-park development. Consequently, they frequently fail to appreciate the importance of developing a critical mass of high-technology industries in the process of regional transformation.

Against such a background, the objective of this study was to identify the forces underlying successful science-park development. I go about this task by revealing the determinants of the agglomeration of high-technology industries; the yardstick for flourishing science-park development. Furthermore, electronics industries are selected as the touch-stone for high-technology industries.

The primary geographical area of interest is the province of Manitoba, one of the peripheral regions of Canada, Manitoba has put its hopes in high-technology industries, electronics activities in particular, for its regional economic transformation. However, in view of the fact that only a small sample of electronics firms was able to be collected in the initial survey, the study area was extended to cover all provinces in Western Canada, an extension which served to place Manitoba in a larger context. In so doing, the collected samples for this study were adequate to ensure statistical consistency in terms of reliable results and meaningful interpretations of the results.

Meanwhile, electronics industries, as the most promising high-technology sector for regional growth, were the focus of investigation. Small firms constitute the largest proportions of establishments of high-technology industries and are well recognized as the most vigorous organizations in high-technology industries. In this regard, the selection of the small entities of electronics activities as the study units is beyond reproach.

Branching into normative and behavioural paradigms, location theory serves as the theoretical framework of this study. In brief, building on the assumption of perfect information, the normative paradigm of location theory emphasizes the decision-making process of entrepreneurs as it comes to bear on internal and external economies of scale and their use in cost minimization. In contrast, the behavioural paradigm is based on the imperfect information assumption and looks upon the acquisition of learning economies to attend information maximization. Owing to the doubts cast upon the perfect information assumption of the normative paradigm, to say nothing of the stressing of the importance of information to innovation activities in the industrial literature, the latter has been chosen as the more appropriate conceptual framework for this study.

Nevertheless, under the banner of the behavioural paradigm, there are three major schools of thought explaining innovation activities: they are Marxists, business cycle theorists and industry life-cycle theorists. Marxists, who have traditionally structured their theories under the political constraints of the capitalist system, deem the existence of multi-national firms and of the monopolistic market structure as the major stumbling blocks to the establishment and development of small high-technology firms. For their part, business-cycle theorists give prominence to technological breakthroughs that generate new firms (presumably predatory competitors or imitators) in the marketplace as the governing condition for innovation activities. In other words, both theories see the supply side of the marketplace, specifically the competitors which may be in the guise of giant corporations or imitators induced by the capitalistic-political or technological environment, as the major threats to the adaptability of economic activities. In contrast, the industry life-cycle concept places market demand as the principle factor governing industrial advancement. It asserts that early-stage (small) firms, facing stochastic market demand conditions, are subject to unstable sales and stressful economic situations. The decisions of entrepreneurs (presumably small-firm owners) are aimed at the attainment of external and entrepreneurial learning economies for the development of innovation or new products to serve current market needs. Meanwhile, later-stage (larger) firms face a relatively less stochastic set of market demand conditions. They enjoy more stable sales and therefore are less subject to financial stress. Their major decisions concerns the attainment of internal learning economies or the avoidance of internal learning diseconomies for efficient production of the standardized products and/or new products. Following the lead of the demand-side economics, this study has selected the industry life-cycle concept from other candidates of the behavioural paradigm to serve as its theoretical base. In my view, it is the consumers rather than competitors in the marketplaces that hold the key to the advancement of innovation activities and, hence, eventually, to industrial structural changes.

Therefore, based upon the industry life-cycle concept, this study holds that external and entrepreneurial learning economies are the determinate dimensions to the agglomeration of small electronics firms. The remainder of the study attempts to verify this assertion.

Ideally, the verification of an industry life-cycle concept that accommodates the thesis is best attained through use of logit modelling. Logit regression is advantageous because it can explicitly denote the S-shape relationship between the explanatory variables and the dependent variable. Besides, as a discrete modelling technique, it can also contrast the characteristics of the small against the large firms. Unfortunately, the data may not allow such modelling to converge in its estimation. Therefore, the multiple regression technique enters the picture as an alternative.

When multiple regression is used in this context, the model is then designed to estimate the parameters of the dimensions of learning economies directly affecting the agglomeration of small electronics firms without contrasting them against their larger counterparts. Meanwhile, this application of multiple regression in effect deems that the S-shape profile of the industry life-cycle can be truncated into different segments, meaning that the behaviour of early-stage (small) firms varies from their later-stage (larger) counterparts. Accordingly, large firms become the outliers that have to be deleted from the multiple regression modelling.

Following this line of thinking, the thesis is adapted to test the hypothesis that (1) external learning economies, and (2) entrepreneurial learning economies are the determinate dimensions to either the favourable odds of having a small electronics firm as against a large firm, or a better rate of growth of a small electronics firm as opposed to the rate applying to a large firm.

Based on the industry life-cycle concept, a number of variables measuring industrial agglomeration and the availability of external and entrepreneurial learning economies are selected for modelling. As far as the dependent variables of the two types of modelling are concerned, when the observation is a small firm, the dependent variable will take the value of 1 for the logit model; otherwise, the value of 0 is assigned to it (as to the larger firm). Conversely, it is then represented by the rates of growth (in terms of employment) of small firms in the multiple regression.

As far as the variables representing external learning economies are concerned, the explanatory variables are selected to denote the (un)availability of information supports from either universities, or general technical facilities, or market information agencies, or business computer firms, or venture capitalists, or government financial agencies and innovation centres containing the locations of the firms. For the entrepreneurial learning economies, the explanatory variables have to reflect the availability of information supports from owner-entrepreneurs themselves in terms of their expertise in business computer manipulation and their enthusiasm in acquiring information for production.

The relevant data were collected by means of questionnaire surveys. Before the formal questionnaires were sent to the identified electronics firms in Western Canada, a pilot survey was completed. Owing to financial constraints, the pilot survey was confined to Winnipeg. Accordingly, in-person interviews with senior managerial personnel of the electronics firms were carried out. Eventually, 193 questionnaires were mailed out and 71 of them were returned, a 36.79 percent crude response rate. Unfortunately, only 34 (or 44.89 percent of the returned questionnaires) could be used, resulting in an actual response rate of 17.62 percent. Nineteen (55.88 percent) of these were from Manitoba, nine (26.47 percent) were from British Columbia, three each (8.82 percent) were from Saskatchewan and Alberta.

To ensure that the collected data complied with the requirements of this study, Student-t-test analyses were applied to the proxies indicating the intrinsic characteristics or the learning economy acquisition behaviours of electronics activities. These tests attempted to establish whether the survey data really contained the asserted intrinsic characteristics of electronics activities as mentioned in the previous chapter. Moreover, they were useful for verifying the establishment of two spatial models and the use of logit regression as the primary modelling technique in this study. The Student t-test analyses indicate that the variables or proxies are more or less compatible with the general image of electronics activities. The surveyed small firms maintain consistently high rates of growth in sales and employment; they show high levels of technical labour inputs, though being significantly lower than the larger counterparts in R&D-expenditure-to-sales-revenues ratio. Meanwhile, on applying the same Student-t-test analyses to the proxies of the learning economies with reference to the surveyed firms in Manitoba and those in the rest of Western Canada, the results lead to the conclusion that these two groups of firms exhibit unique differences in their learning economy acquisition behaviours. Hence, the methodological approach of this study, specifically, the establishing of two models of different geographical contexts, has been justified. By the same token, the surveyed small firms behave differently from their larger counterparts in most of the learning-economies proxies. In this context, the use of the logit modelling technique for differentiating these two groups of firms on their information acquisition behaviours depicted by the industry life-cycle concept has been substantiated.

As far as the results of the two models are concerned, their overall performance has been very pleasing. The logit model (the general or Western Canada model) has its -2 Log L score statistically significant at the 0.01 level. For their part, the independent variables of the multiple regression model (the specific Manitoba model) can explain 88 percent (that is, its R^2 value) of the variations contained in the dependent variable (that is, the employment growth of the Manitoba small firms). The F-ratio for the multiple regression model is statistically significant at the 0.05 level. The number of statistically-significant variables in both models is higher than the insignificant ones. Five out of the eight independent variables in the logit model are statistically significant at least at the 0.10 level; similarly, five of the seven independent variables in the multiple regression model are statistically significant at least at the 0.05 level.

The general model confirms that entrepreneurial learning economies (as proxied by *MGINH*) are positively affecting the favourable odds of having a small electronics firm in Western Canada. With respect to external learning economies, the results of the general model reflect that, as expected, there is a close and positive interaction between local universities and electronics communities (as proxied by *USCIENT*). Meanwhile, the occurrence of a small electronics firm may have to count on non-local agencies for the provision of market information, especially that concerning ever-changing international conditions (as proxied by *SALEINT*). By the same token, non-local agencies seem to be more effective in offering managerial (as proxied by *MGUSC*) or technical advice (as proxied by *TECHNF*) than their local counterparts. The weak support of the local agencies in these respects have been lucidly exposed.

As estimated by the model, three proxies do not show up to be statistically significant in influencing the odds of having a small electronics firm in Western Canada. In other words, these show that (1) enthusiasm of entrepreneurs (as proxied by *AGE*) may not necessarily yield the expected results; (2) support of venture capitalists (as proxied by *VENT*) is either too lukewarm or intimidating to generate effective results; and (3) the services offered by innovation centres (as proxied by *INCUBATOR*) are too superficial to breed a critical mass of electronics firms for regional restructuring within their realm.

The specific Manitoba model has obtained the statistically-significant expected results that (1) local-government financial agencies (as proxied by *SUBSID*), (2) entrepreneurship (as proxied by *AGE*), (3) non-local agencies offering managerial advice (as proxied by *MGUSC*), and (4) international market information (as proxied by *SALEINT*) are positively affecting the growth of the small electronics firms in Manitoba. Unexpectedly, local universities (as proxied by *USCIENT*) reflect a statistically-significant negative impact upon the growth of the small electronics firms in the province. In contrast, the non-local agencies providing technical consultations (as proxied by *TECHNF*) and the locating of the firms in the innovation centres (as proxied by *INCUBATOR*) are not statistically-significant in contributing to the growth of the small electronics firms.

The results of the models have more or less consistently confirmed the two hypotheses that : (1) external learning economies, and (2) entrepreneurial learning economies are the essential dimensions to the survival and promotion of the small electronics firms setting aside geographical differences. In other words, as to external learning economies, both models, at the conceptual level, have pinpointed institutional structures as being essential in permitting science parks to create a critical mass of electronics activities.

Regarding the accessibility to technical information, establishing on-site research facilities and services would be advantageous. In Western Canada, locating parks in the vicinity of universities and government or private laboratories is strongly recommended. Similarly, in Manitoba, successful science-park development hinges upon the close proximity of the local university, namely, the University of Manitoba. However, before the university's transferring of on-the-edge scientific technologies and, hence, its positive impact upon electronics tenant firms can be accomplished, it is necessary for the ITO to commit itself to either establishing or strengthening regular formal or informal contacts between engineering academics and on-site entrepreneurs. Meanwhile, ambitious relaunching of well-praised government initiatives such as the IRAP and the Technology Commercialization Programme and relocating of the provincial laboratory (that is, the Industry and Technology Centre of the EITC) within the park may further accelerate the transfer of scientific knowledge to tenant firms.

Turning to managerial skills and knowledge, the attraction of quality business computer consultant firms and agencies capable of providing up-to-date local and international market information on site is required if Western Canadian parks are to succeed. Regarding the Manitoba scenario, the supporting system of tenant firms should accommodate the business computer consultant firms accomplished in tailoring services to the needs of their clientele. Moreover, it should include launching the government PEMD initiative and luring or relocating R&D units of leading electronics corporations, renowned research corporations, non-profit-making professional or business associations and the ITD capable of channelling on-the-edge and precise information concerning international market situations to tenant firms. For the accessibility to overall information, the following steps have to be taken. In Western Canada, establishing a pool of venture capital funds should be singled out as the major mandate of science-park development. Moreover, it is vital to make park officials aware of the theoretical postulates of science-park industrial strategy; or, better still, hire personnel who are knowledgeable regarding the agglomeration of innovation activities. In the Manitoba case, it is highly recommended that the University of Manitoba Research Park pulls together its own venture capital funds so as to divert financial assistance as well as other business and legal information to its electronics clients. However, in view of the fact that some entrepreneurs are either intimdated by or unknowledgeable of venture capitalists, measures may have to be taken to acquaint entrepreneurs with such activity. In addition, the hiring personnel who know about the mechanisms regarding the growth of innovation activities with regard to effective implementation of programmes for technology transfer in the administration team of the park is a necessity. Finally, promoting well-recognized government financial programmes, such as Western Diversification Fund within the park would undoubtedly facilitate the transfer of overall information to client firms.

In respect to entrepreneurial learning economies, strengthening of business computing skills of on-site electronics entrepreneurs should not be ignored in Western Canada. Moreover, given the gaps in general and technical education levels of new or enthusiastic entrepreneurs and, hence, their inefficiency in acquiring overall information about electronics production, the parks may have to implement relevant programmes of re-education. In Manitoba, as enthusiastic entrepreneurs are of particular importance to small electronics firms, the research park should generate new entrepreneurs continuously through implementing a regular advanced education system, retraining existing industrial scientists or technicians or convincing the successful "native sons and daughters" who have gained adequate national or international experience to establish their firms within the research park. In a way, these recommendations relating to the success of science parks echo what was hypothesized at the very beginning of this study. The determinants to the agglomeration of small electronics firms in the science park setting have been confirmed by the results of two models. In other words, the hypotheses of this study have proven to be valid.

Nevertheless, a final word of caution is in order. The whole science-park strategy is a long term process requiring long-term commitment and faith.

To sum up, the model results suggest that growth of small electronics firms hinges upon the availability of external and entrepreneurial learning economies, confirming the industry life-cycle hypotheses for innovation activity agglomeration. Meanwhile, they also reinforce the usefulness of the modelling techniques, namely, the logit and multiple regression models, for the verification of this conceptual framework. Therefore, the theoretical and methodological competence of this study has been proven.

Despite the conceptual and methodological soundness of this study, it is not without flaws. The sample size of 34 electronics firms is small. This leads one to question the credibility of the results of the modelling techniques for their explanation of electronics agglomeration. To recapitulate, the logit modelling technique encompasses all 34 surveyed electronics firms in Western Canada; whereas, the multiple regression model covered only 11 observations in Manitoba. To achieve more legitmate results, one may argue that the extension of the study area to cover the other peripheral regions (Atlantic Canada, NW Territories and Yukon) for the collection of more sample units may be necessary. However, it is noteworthy that the electronics activities of this country are highly concentrated in its industrial cores: Ontario and Quebec (see Chapter One). Therefore, even if a high response rate of approximately 18 percent, as shown by this study, can be achieved, there is neither a guarantee that there will be a dramatic increase in the number of participating firms in the prospective industrial research nor that the small sample-size problem will be resolved. After all, notwithstanding this small sample-size scenario, both models have exhibited satisfactory results in this study. These circumstances, therefore, suggest that the incidence of a small sample size is a reality one has to cope with for future electronics investigation in peripheral regions of Canada.

Glossary

ACVCC	Association of Canadian Venture Capital Companies
ARD	American Research and Development
AURRP	Association of University Related Research Parks
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing
CEOs	Chief Executive Officers
CIIT	Canadian Institute of Industry and Technology
CIM	Computer-Integrated Manufacturing
CLNR	Classical Linear Normal Regression
COMEF	Committee on Manitoba's Economic Future
DEC	Digital Equipment Corporation
DG	Data General
DIPP	Defence Industries Productivity Programme
DRIE	Department of Regional Industrial Expansion
EIA	Electronics Industry Association
EIAM	Electronics Industry Association of Manitoba
EITC	Economic Innovation and Technology Council
GE	General Electric Company
IASP	International Association of Science Parks
ICs	Integrated Circuits
IBM	International Business Machines
IRAP	Industrial Research Assistance Programme
IST	Department of Industry, Science and Technology of Canada
ITC	Department of Industry, Trade and Commerce of Canada
ITD	Institute of Technology Development
ITT	Department of Industry, Trade and Tourism
LQs	Location Quotients
LSE	Least Square Estimators
MCTC	Microelectronics and Computer Technology Corporation
MIT	Massachusetts Institute of Technology

MLE	Maximum Likelihood Estimation
MLH	Minimum List Headings
MRC	Manitoba Research Council
MPT	Managerial, Professional and Technical Staff
MTS	Manitoba Telephone System
NASA	National Aeronautics and Space Administration
NRC	National Research Council
OECD	Organization for Economic Cooperation and Development
IT&T	International Telephone and Telegraph
OLS	Ordinary Least Squares
PEMD	Programme for Export Market Development
R&D	Research and Development
SCs	Semiconductors
SEDCO	Saskatchewan Economic Development Corporation
SERC	Science and Engineering Research Council
SIC	Standard Industrial Classification
TECHNET	Technology Networking Programme
TED	Targets for Economic Development
UKSPA	United Kingdom Science Parks Association
VLSI	Very Large-Scale Investigation

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Appendix

Questionnaire

I. Background Questions:

CODE

1. When was your company founded? ______________ (C1.1)

2. In terms of the products or services, your company is a

1. Hardware Manufacturer. (C1.2)

2. Software Manufacturer. (C1.3)

3. Assembler. (C1.4)

4. Wholesaler. (C1.5)

5. Retailer. (Multiple answer is possible.) (C1.6)

3. What is the status of your company to the corporation as a whole? (C1.7)

1. Head office.

2. Branch.

3. Other (Please specify):______________________

4. Does your company manufacture any of the following products? Please circle the type(s) of products produced by your company.

1. Consumer electronic products. (C2.1)

2. Component electronics products. (C2.2)

3. Telecommunications. (C2.3)

4. Other communications. (C2.4)

5. Computer and other electronic office equipment. (C2.5)

6. Industrial controls:

a. controls for regulators, resistors. (C2.6)

b. controls for communications applications. (C2.7)

c. controls for environmental applications. (C2.8)

d. other (please specify):

______________________________ (C2.9)

____

____

7. Electronic instrument:

a. industrial test/measurement/analytical equip. (C2.10)

b. health care(or medical) test/measurement/ analytical equipment. (C2.11)

c. other (please specify): (C2.12)

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8. Computer aided production. (C2.13)

9. Navigation, avionics or defence electronics. (C2.14)

10. Automotive electronics.

11. Other (please specify): (C2.15)

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5. (Answer this question only if your company produce the electronic parts or components products.)
Please circle the <u>type(s) of electronic components</u> produced by your company.

1. Capacitors. (C3.1)
2. Chokes, and Inductors/Coils. (C3.2)
3. Cores, Magnets, and Ferrites. (C3.3)
4. Crystals, Oscillators, Crystal and Piezoeletric Filters. (C3.4)
5. Delay lines. (C3.5)
6. Filters, Powers Supplies. (C3.6)
7. Filters, RF and Signal. (C3.7)
8. Integrated Circuits, Hybrid Circuits, and Function Modules. (C3.8)
9. Microwave Components. (C3.9)
10. Resistors. (C3.10)
11. Thyristors. (C3.11)
12. Transistors. (C3.12)
13. Photonic devices. (C3.13)
14. Potentiometers, Trimmers, Rheostats and other controls. (C3.14)
15. Discrete Semiconductors. (C3.15)
16. Transformers. (C3.16)
17. Other (please specify): (C3.17)

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6. (Answer this question only if your company is involved in Computer- Aided Production.)
Please circle the <u>type(s) of computer-aided production</u> produced by your company.

1. Manufacturing Control Systems (MCS). (4.1)
2. Computer-Aided Design and Manufacturing (CAD/CAM). (4.2)
3. Numerical Control Tools. (4.3)
4. Process Control. (4.4)
5. Automatic Test Equipment. (4.5)
6. Computer-Aided Engineering. (4.6)
7. Automated Material Handling. (4.7)
8. Data Acquisition. (4.8)
9. Programmable Controllers. (4.9)
10. Factory Data Collection. (4.10)
11. Computer Numerical Controller. (4.11)
12. Intelligent Robots. (4.12)
13. Numerical Control Tape Preparation. (4.13)
14. Other (please specify): (4.14)

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____

II. Questions on Internal Learning Economies:

1. What were the <u>sales levels</u> of your company in the last five fiscal years? (For confidentiality, you may round up the figures to the nearest 1,000's, 10,000's or 1,000,000's.)

Year	Amount	
1986	________	(C5.1)
1987	________	(C5.2)
1988	________	(C5.3)
1989	________	(C5.4)
1990	________	(C5.5)

2. What were the level of <u>registered capital (i.e. equity or retained earning)</u> of your company in the last five fiscal year? (For confidentilaity, you may round up the figures to the nearest 1,000's, 10,000's or 1,000,000's.)

Year	Amount	
1986	________	(C6.1)
1987	________	(C6.2)
1988	________	(C6.3)
1989	________	(C6.4)
1990	________	(C6.5)

3. Please indicate the <u>total number of employees</u> for each of the last five fiscal year?

Year	Number	
1986	________	(C7.1)
1987	________	(C7.2)
1988	________	(C7.3)
1989	________	(C7.4)
1990	________	(C7.5)

4. Does your company indulge in any <u>R&D activities</u>?
   0. No.
   1. Yes.

      If yes, please indicate the <u>amount of expenditure on R&D</u> during the last five fiscal year. (For confidentiality, you may round up the figures to the nearest 1,000's, 10,000's or 1,000,000's.)

Year	Amount	
1986	________	(C8.1)
1987	________	(C8.2)
1988	________	(C8.3)
1989	________	(C8.4)
1990	________	(C8.5)

5. How many <u>qualified scientists and engineers</u> are there in your company in the last fiscal year?

   ________ (C8.6)

6. *What is the level of profitability of your company?(C8.7)*
   a. *Very profitable.*
   b. *Moderately profitable.*
   c. *Marginally profitable.*
   d. *Unprofitable.*

III. *Questions on External Economies of External Learning Economies:*

1. *On the basis of monetary value, please indicate the proportion(percent) of inputs, i.e., raw material, components, sub-assemblies and/or finished goods that your company obtained for production from each of the geographical areas where these inputs are manufactured.*
(C9 - C13)

	In-House	*Within Winnipeg	*Elsewhere Within Manitoba	Elsewhere in Canada	U.S.A.	Other Int'l	Total %
Raw material, semi-processed, or processed material	( )	( )	( )	( )	( )	( )	100%
Components	( )	( )	( )	( )	( )	( )	100%
Sub-Assemblies	( )	( )	( )	( )	( )	( )	100%
Finished Goods (hardware)	( )	( )	( )	( )	( )	( )	100%
Finished Goods (software)	( )	( )	( )	( )	( )	( )	100%

* Priority items.

2. On the basis of monetary value, please indicate the proportion of technical supports that your company obtained from each of the geographical areas. (Only complete those technical support items which are applicable to your company.) (C15 - C20)

	*Within Winnipeg (incl. in-house supports)	*Elsewhere Within Manitoba	Elsewhere in Canada	U.S.A.	Other Int'l	Total %
Raw Material Design/Development (D.D.)	( )	( )	( )	( )	( )	100%
Product D.D.	( )	( )	( )	( )	( )	100%
[1]Process D.D.	( )	( )	( )	( )	( )	100%
[2]Quality Assurance (Q.A.) for D.D of Raw Material	( )	( )	( )	( )	( )	100%
Q.A. for D.D. of Product	( )	( )	( )	( )	( )	100%
Q.A. for D.D. of Process	( )	( )	( )	( )	( )	100%
Computer Programming Consulting for Office Procedures	( )	( )	( )	( )	( )	100%

[1]Process refers to the automation, manufacturing (industrial) software or computer-aided production.

[2]Q.A. (Quality Assurance) refers to all activities necessary to ensure that the final product will perform satisfactory in service.

3. (Answer this question only if your company obtained any of the aforementioned technical supports *__from within Winnipeg.)__* *Please indicate* *__the proportion of technical supports__* *that your company obtained from the following types of organizations within Winnipeg. (Only complete those technical support items which are applicable to your company.)*

(C21-C26)

	In-House	*Gov't Inst.	*University (ies)	*Private Companies	Others	Total %
Raw Material Design/Development(D.D.)	( )	( )	( )	( )	( )	100%
Product D.D.	( )	( )	( )	( )	( )	100%
Process D.D.	( )	( )	( )	( )	( )	100%
Quality Assurance (Q.A.) for D.D of Raw Material	( )	( )	( )	( )	( )	100%
Q.A. for D.D. of Product	( )	( )	( )	( )	( )	100%
Q.A. for D.D. of Process	( )	( )	( )	( )	( )	100%
Computer Programming Consulting for Office Procedures	( )	( )	( )	( )	( )	100%

4. *On the basis of monetary value, please indicate the proportion (percent) of financial supports (for R&D, operation, labour training)that your company derived from each of the institutions.*

Geographical Areas	*Percent of total finanical supports*	
In - house	( )	(C27.1)
****(-I.Within Winnipeg:)***		
1. Banks.	( )	(C27.2)
2. Private venture capitalists.	( )	(C27.3)
3. Gov't venture capital program.	( )	(C27.4)
4. Other gov't agencies/programs.	( )	(C27.5)
5. Other private financial institutions.	( )	(C28.1)
****(-II.Elsewhere within Manitoba:)***		
1. Banks.	( )	(C28.2)
2. Private venture capitalists.	( )	(C28.3)
3. Gov't venture capital program.	( )	(C28.4)
4. Other gov't agencies/programs.	( )	(C28.5)
5. Other private fincancial institutions.	( )	(C29.1)
(-III.Elsewhere in Canada:)		
1. Banks.	( )	(C29.2)
2. Private venture capitalists.	( )	(C29.3)
3. Gov't venture capital program.	( )	(C29.4)
4. Other gov't agencies/programs.	( )	(C29.5)
5. Other private financial instit.	( )	(C29.6)
(-IV. Others: Please specify)		
1. ____________________	( )	(C29.7)
2. ____________________	( )	
3. ____________________	( )	
Total	*100%*	

5. *Please indicate the proportion of sales in each of the geographical areas.*

Geographical Areas	***Percent of Sales***	
**1. Within Winnipeg*	( )	(29.8)
**2. Elsewhere within Manitoba*	( )	(29.9)
3. Elsewhere in Canada	( )	(29.10)
4. U.S.A.	( )	(29.11)
5. Other Int'l.	( )	(29.12)
	100%	

6. Please indicate the <u>proportion of scientists/engineers and technical staff</u> that your company recruited from each of the geographical areas / institutions.

Geographical Areas		% of Technical Staff		% of Scientist/ Engineers	
*a. Within Winnipeg.		( )		( )	(C30.1-2)
i. from U. of M.	( )		( )		(C30.3-4)
ii. from Red River Comm.	( )		( )		(C30.5-6)
iii. others ed. inst.	( )		( )		(C30.7-8)
*b. Elsewhere within Manitoba.		( )		( )	(C31.1-2)
c. Elsewhere in Canada.		( )		( )	(C31.3-4)
d. U.S.A.		( )		( )	(C31.5-6)
e. Other Int'l.		( )		( )	(C31.7-8)
Total :		100%		100%	

7. Please indicate the <u>proportion (%) of time</u> allocated on average to different modes of communication in the negotiations with customers, suppliers, financial or technical consulting agencies which lead to a sale of output, a purchase of input, the decision-making on financial situation or the obtaining of technical supports for the company. (C32.1-C32.16)

	Face-to face	Telephone	Mail	Telex/fax	Other Modes	Total Time
Sale of Output	( )	( )	( )	( )	( )	100%
Purchase of Input	( )	( )	( )	( )	( )	100%
Decision-making on Financial Situation	( )	( )	( )	( )	( )	100%
Obtaining Technical Support	( )	( )	( )	( )	( )	100%

7. Please circle and specify the type of physical setting your company located in.
   1. Industrial park. (33.1)
      Please specify (name of the park):
      ____
   2. Gov't-owned building. (33.2)
      Please specify (name of building):
      ____

8. Is your company a member of the Electronics Industry Association of Manitoba? (33.2)
   0. No.
   1. Yes.

9. Is your company a member of the Manitoba Software Association? (33.3)
   0. No.
   1. Yes.

8. Please indicate the amount of sales of the last fiscal year for the following production items which are applicable to your company.

Production :	Amount of Sales
1. Consumer electronic products.	________ (C34.1)
2. Component electronics products.	________ (C34.2)
3. Telecommunications.	________ (C34.3)
4. Other communications.	________ (C34.4)
5. Computer and other electronic office equipment.	________ (C34.5)
6. Industrial controls:	
a. controls for regulators,resistors.	________ (C35.1)
b. controls for communications applications.	________ (C35.2)
c. controls for environmental appl.	________ (C35.3)
d. other (please specify): ________ ________ ________	(C35.4)
7. Electronic instrument:	
a. industrial test/measurement/ analytical equip.	________ (C35.5)
b. health care(or medical) test/ measurement/analytical equipment.	________ (C36.1)
c. other (please specify): ________ ________ ________	________ (C36.2) ________ ________
8. Computer aided production.	________ (C36.3)
9. Navigation, avionics or defence electron.	________ (C36.4)
10. Automotive electronics.	
11. Other (please specify): ________	(C36.5)
Total Sales :	________

9. *Have your company ever received any R&D grants and loans from the government?* *(C37.1)*
   0. *No.*
   1. *Yes.*
      If yes, please indicate the amount in the last five fiscal years?

Year	**Amount**	
*1986*__________		*(C38.1)*
*1987*__________		*(C38.2)*
*1988*__________		*(C38.3)*
*1989*__________		*(C38.4)*
*1990*__________		*(C38.5)*

10. *Is your company a subcontractor(supplier) of the government?* *(C38.6)*
    0. *No.*
    1. *Yes.*
       If yes, are these subcontracts crucial for the survival of your companies? *(C38.7)*
       0. *No.*
       1. *Yes.*

IV. Questions on Entrepreneurship:

1. *What is the education/family background, the major field of study and the years of experience in the electronics industry of the owner/founder(the head, regional head or the general manager) and the engineering manager of your company?*

*I. **Founder/owner** (Regional Head or General Manager):*

1. Education Background:

A. Technical Education Background:

i. Higest Level of Education: *(C39.1)*

1. *High school graduate.*
2. *Diploma/certificate.*
3. *Bachelor of Arts.*
4. *Bachelor of Science.*
5. *Master of Arts.*
6. *Master of Science.*
7. *Ph.D.*
8. *Other (please specify):*

____

ii. Name of Educational Institute from which you achieved your highest level of education: *(C39.2)*

1. *University of Manitoba.*
2. *University of Winnipeg.*
3. *Red River Community College.*
4. *Other (please specify):*

____

iii. Major Fields of Study (multiple answer is

possible):
1. Electrical and ComputerEngineering (C39.3)
2. Mechanical Engineering. (C39.4)
3. Other (please specify):

____

2. Management Training Background:
   1. Non-credit Management Courses. (C39.5)
   2. Diploma/Certificate in Management. (C39.6)
   3. Bachelor of Commerce. (C39.7)
   4. Master of Business Adminstration. (C39.8)
   5. Other (please specify): (C39.9)

   ____

3. Years of Experience:
   - in this company: ______________ (C40.1)
   - in this industry: ______________ (C40.2)

4. Has(Had) your parent(s) ever started his/her own company/business?
   0. No. (C40.3)
   1. Yes.

5. What is your ethnic origin/mother tongue? (C40.4)
   1. British
   2. French
   3. German/Dutch
   4. Polish
   5. Ukrainian
   6. Other (please specify) : ______________________

6. Was your company established on the basis of an innovation idea (i.e. new product/process idea)?
   1. Don't know. (C40.5)
   2. No.
   3. Yes.

   If yes, where did this innovation idea come from? (C40.6)

   1. Education Institution : (please specify)

      ____
   2. Gov't Institution : (please specify)

      ____
   3. Private Sector : (please specify the name of the company)

      ____
   4. Other (please specify):

      ____

II. **Engineering Manager:**

A. Education Background:

1. Technical Education Background:

i. Highest Level of Education:

1. High school graduate. (C41.1)
2. Diploma/certificate.
3. Bachelor of Arts.
4. Bachelor of Science.
5. Master of Arts.
6. Master of Science.
7. Ph.D.
8. Other (please specify): ____________________

ii. Name of Education Institution from which you received your highest level of education: (C41.2)

1. University of Manitoba.
2. University of Winnipeg.
3. Red River Community College.
4. Other (please specify): ____________________

iii. Major Fields of Study (multiple answer is possible):

1. Electrical and Computer Engineering. (C41.3)
2. Mechanical Engineering. (C41.4)
3. Other (please specify): ____________________ (C41.5)

2. Management Training Background:

1. Non-credit Management Courses. (C41.6)
2. Diploma/Certificate in Management. (C41.7)
3. Bachelor of Commerce. (C41.8)
4. Master of Business Administration. (C41.9)
5. Other (please specify): ____________________ (C41.10)

3. Years of Experience:

- in this company: ______________ (C42.1)
- in this industry: ______________ (C42.2)

4. Has(Had) your father/mother ever started his/her own company/business?

0. No. (C40.3)
1. Yes.

5. What is your ethnic origin/mother tongue? (C40.4)

1. British
2. French
3. German/Dutch
4. Polish
5. Ukrainian
6. Other (please specify): ____________________