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High technology industry and material linkages in the Toronto region

Jim Torretto
Wilfrid Laurier University

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HIGH TECHNOLOGY INDUSTRY AND MATERIAL LINKAGES IN THE TORONTO REGION

By

Jim Torretto

B.A., Geography (Honours), Brock University, 1987

THESIS

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Abstract

This study examines the material linkage patterns of a sample of 80 high technology establishments located in the Toronto Census Metropolitan Area (CMA). The main focus of the research is to relate the spatial spread of linkages to aspects of plant structure, most notably ownership. In addition, an attempt is made to compare the linkage arrangements of firms in Toronto with other regional studies of high technology industry. The results reveal the expected linkage patterns with respect to ownership. Foreign owned companies show much lower levels of purchasing and selling within the Toronto economy than domestic firms. Further dimensions of plant structure were found to have differential impacts on linkages within the two ownership categories. An important finding here was that research and development spending is significantly related to local input linkages only among domestic plants. In addition, the degree of purchasing autonomy granted to foreign plants was found to have a major effect on their local purchasing patterns. Such findings have important implications for regions attempting to generate high technology growth since only certain types of high technology firms are shown to induce spatially concentrated backward and forward linkages.

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CHAPTER 1

Introduction

The phrase "high tech" has acquired many meanings in modern society. In everyday language, it can be used to describe anything perceived as new or sophisticated, ranging from super computers and space vehicles to architectural styles and even running shoes. In a more formal sense, it has also been applied in the business community where the term high technology industry has emerged as a popular catch-phrase for describing new growth industries that rely on advanced technology to produce sophisticated products. Often associated with innovation and economic development, high technology industries have achieved considerable significance in advanced industrial economies as a key to competitiveness in international markets. Not surprisingly, they have also been recognized at the regional scale as an antidote for industrial decline and unemployment in economically disadvantaged areas. However, while often assumed to be positive, the exact impact of high technology industry on regional economies is complex and not fully understood (Malecki, 1984). The tendency for these industries to generate employment at faster rates than other industries has been well documented (Riche et al., 1983 ; Markusen et al., 1986). However, another area of inquiry only recently addressed by locational analysts concerns the less visible growth inducing effects of material input and output linkages associated with high technology industry. From the research that exists in this area, it would appear that the spatial orientation of linkages in these industries are highly variable, depending greatly on the individual characteristics of high tech firms in addition to the area in which they are situated. This study therefore aims to investigate further the spatial behaviour of high technology industry with a case study of firm linkages in the Toronto Census Metropolitan Area (CMA). A particular research aim is to analyze the effects of plant structure and ownership on the spatial distribution of high technology linkages. The analysis of plant linkages will also reveal the extent to which agglomeration economies in the form of intra-regional trading have developed in the Toronto CMA for high technology industries.

Only recently have geographers investigated the locational attributes of high technology industry, represented in major works by Oakey (1981,1984), Castells (1985), Hall and Markusen (1985), Whittington (1985) Markusen et al. (1986), Rees (1986), Brotchie et al. (1987), Hall et al. (1987), and Oakey et al. (1988). These and other geographical works have noted that high technology industry is not spatially ubiquitous but instead shows a distinct tendency towards regional concentration, especially in the innovative phases of production. Therefore, from a policy perspective, understanding the processes behind spatial concentration is especially important for regions as they attempt to formulate strategies to encourage high technology development. Such regional efforts frequently attempt to emulate the tremendous growth of high technology industry that has occurred in the Silicon Valley region of southern California and the Route 128 area around Boston, Massachusetts. The spontaneous growth of the electronics and computer industries in these areas following World War Two has received a considerable amount of research attention (ie., Dorfman, 1983 ; Rogers and Larson, 1984 ; Oakey, 1984 ; Saxenian, 1985). It has also captured the attention of other regions that are interested in strengthening their local economies with these new growth industries, which has also led to an intense competition among regions in the United States for high technology investment (Farley and Glickman, 1986 ; Malecki, 1986).

On a favourable note, Markusen et al. (1986, 176), suggest that almost any place can compete in attracting high tech industry, which should be good news for policy planners. However, as Glasmeier (1988, 288) points out, it is not only the presence of high tech firms that regions are after, but also the underlying process of industrial linkage and new firm formation. For instance, earlier work by Glasmeier (1986) reveals that dispersed high technology locations are inclined to attract branch plant investment that is less likely to generate an integrated high tech industrial complex. A similar situation is reported by Hagey and Malecki (1986) in branch plants operating in the state of Florida. Therefore, the self-sustaining and spontaneous growth noted in the Silicon Valley and Route 128 regions has generally not been achieved in planned high technology centers. This has led some to question whether these two areas are historical exceptions of high technology agglomeration rather than regional prototypes for other areas to replicate (Saxenian, 1985 ; Gordon and Kimball, 1987). Nevertheless, it is being increasingly recognized that the success of regional high tech development depends not only on visible indicators such as new branch plant investment and resultant employment growth, but also on the generation of intra-regional linkage channels that provide an underlying basis for local integration and the potential for further high technology growth.

From a spatial perspective, identifying high technology agglomerations has been approached from two different angles. The first and more common can be referred to as the macro approach where high technology variables such as employment or business establishments are tabulated and compared among regions (ie., Armington, 1986 ; Markusen et al., 1986 ; Hall et al., 1987). The second methodology views agglomeration at micro-level by analyzing input and output linkages between industrial plants within a certain region, thus providing a measure of the functional aspects of agglomeration or the extent to which interaction occurs between high tech plants in close proximity. However, since plant-level information is needed, this sort of investigation is much rarer than the macro approach.

The presence of local linkages in high technology industries is generally regarded as a positive indicator of local integration. But there also arises a question of whether local linkages play an active role in regional high technology growth or whether they are simply an effect of such growth? Evidence from Boston (Bathelt, 1988) and Silicon Valley (Oakey, 1984) reveals the existence of well developed local supply linkages, implying that a concomitant feature of regional growth in these areas has been local integration. Have local supply sources abetted this growth? Citing differences in product innovation between firms in Silicon Valley and Scotland and relating these to differences in local input sourcing, Oakey (1984) contends that they have. This contention is supported by the findings of O'hUallachain (1984) and Hagey and Malecki (1986) which show that local supply sourcing increases with R&D spending. Therefore, it is conceivable that local linkages measure not only the level of local integration, but also the potential for further growth through innovation, new firm formation and their associated multiplier effects. In this sense, integrated high technology growth is a preferred regional development strategy.

While research has not yet established why some regions develop into functional linkage agglomerations, it is reasonable to assume that at a general level, two factors are at work. First, local environment, or the relative presence of high technology industry in a region, can be expected to influence the potential for local linkages to develop which is clearly evident in the regional comparisons of Oakey (1984). Secondly, it is quite apparent that business organization structure influences linkage patterns as shown in the works of Glasmeier (1986, 1988), O'hUallachain (1984) and Hagey and Malecki (1986). Therefore, it can be hypothesized that high technology agglomeration economies in any region are contingent upon the absolute presence of high technology industries as well as the regional mix of high technology firm types. An implication arising from this is that a large high technology base will not necessarily lead to regional integration unless the right kind of firms are present.

In light of the regional significance of high technology industry, it is somewhat surprising to find a general scarcity of research dealing with the spatial implications of its development in Canada. Steed and DeGenova (1983) describe the genesis of the high technology complex known as Telecom Valley in the Ottawa region noting the importance of federal government agencies as a location factor. Their survey also reveals that local input and output linkages are relatively insignificant compared to flows to and from other areas of Canada and the rest of the world. A more comprehensive article by Britton (1986) describes the geography of high technology industry in Canada showing the dominance of Ontario and Quebec in high technology manufacturing. Although data become fragmented at the metropolitan level, Toronto is clearly portrayed as the most dominant agglomeration of high technology industry followed by Montreal. It is therefore probable that if a functional high technology agglomeration were to develop in Canada, Toronto would be the most likely location. More recent work by Bathelt (1988 ; 1989) investigates, through plant-level surveys, the operation of high technology firms in the Ottawa area and the Kitchener-Waterloo-Guelph region known as the Canadian Technology Triangle (CTT). Of interest here is the relatively high amount of local input and output trading observed to take place in the CTT region compared to Ottawa. Beyond these works, there has been little effort devoted to unravelling the spatial behaviour of high tech industry in Canada.

Objective of Study

It is the intention of this study to investigate the spatial linkage patterns of high technology industries with a micro-level study of high technology establishments in the Toronto Census Metropolitan Area (CMA). The particular aim is to measure and interpret material input and output linkages of individual firms, thus measuring the extent to which functional agglomeration economies have developed in the Toronto region. This research is conducted under the framework suggested above: that local integration is dependent on the local high technology environment in the Toronto area and on firm structure. The large share of high technology industry in the Toronto region compared to other areas in Canada (Britton, 1986) should provide an amenable environment for local agglomeration economies to develop. Whether this is the case within high technology industry in general or is specific to certain types of firms will be investigated by relating local linkages to aspects of organizational structure. This is a topic which has rarely been investigated in the literature, in spite of policy implications that could be derived from knowing which firms are most likely to induce local growth effects. It is hypothesized that the most important firm specific determinant of linkage patterns will be ownership. The diverging purchasing and selling characteristics of foreign and domestic firms in Canada has been well documented by Britton (1980, 1982, 1985). While the above studies are based on aggregate industry statistics, these patterns are expected to hold true in the high technology sector as well.

A Framework For Analysis

To provide a methodological and contextual basis for this study, a review of literature pertaining to high technology industry and industrial linkages is required. The first section of Chapter 2 reviews how high technology industry has been defined in the literature, looking at various defining methodologies and the advantages and disadvantages inherent to each. The absence of a standardized Canadian definition makes this review important in order to formulate an appropriate definition later on in Chapter 3. The second section of the review looks at the methodology of industrial linkage study. Topics include a brief history of geographical linkage investigation, methodologies adopted and empirical results. Attention is focused on developing a conceptual framework in which to interpret industrial linkages based on the principles of environmental and firm specific influences that were briefly discussed earlier.

Chapter 3 outlines the methodology and design of the survey, the first concern being the formulation of an appropriate definition of high technology industry. Once defined, the geography of high technology industry in Canada is briefly examined to reveal its spatial development within the Canadian economy. Next, this definition is applied to the Toronto CMA and we establish the population of high technology establishments in the local area. The sampling procedure is then discussed followed by a description of the questionnaire used in the survey.

Chapter 4 identifies the major structural characteristics of sample firms such as size, R&D intensity, production methods, employment changes and occupational structure. This is a research area that has rarely been discussed in a Canadian context. Structural differences that exist between domestic and foreign owned plants are highlighted, some of which are later related to linkage behaviour in Chapter 5. Emphasis is placed on identifying aspects of organization that induce local linkage. The last part of the chapter compares local linkage orientation in Toronto with orientations found in other regions studied by Oakey (1984) and Bathelt (1988). This will provide a means to assess the development of agglomeration economies in Toronto compared to other regions. Chapter 6 concludes the discussion with a summary and interpretation of the major findings of the research.

CHAPTER 2

High Technology and Linkages: A Review of Literature

Although industrial linkages have long been studied by geographers, rarely have they been explicitly examined in high technology industries. The review therefore concentrates on the methodology of linkage investigation, reviewing empirical evidence from pertinent studies and highlighting, where possible, examples from high technology industries. Indeed, research has not yet established whether linkages in high tech industries are different from other industries although it is often implied that they are through intuitive reasoning. It is interesting to note however that there appear to be two different schools of thought in this respect. First, because input requirements and final products in high tech industries are specialized, often with negligible transport costs attached to them, linkages are often assumed to be geographically widespread in nature. However, empirical studies have also verified that high tech industries in certain regions such as Silicon Valley show a dense concentration of localized linkage patterns implying a convergence of spatial linkage ties. Nevertheless, before this review of linkages is presented, there is a basic need to understand the concept of high technology industry. Therefore, the first section of the review looks at how high technology industry has been defined in the literature. Since a general consensus on definition does not yet exist, emphasis is placed on developing a conceptual picture of what high technology is and how it can be measured.

2.1 Defining High Technology Industry

The issue of definition remains a conceptual stumbling block for empirical investigations of high technology industry. An initial inclination would be to include any industry that is growing or is likely to grow in employment, but this sort of classification is not very meaningful on grounds of subjectivity (Malecki, 1984, 263). An increasing emphasis has therefore been placed on objectifying the concept with available statistics, the result of which has been a wide variety of "objective" definitions that have failed to standardize the concept. A recent review by Thompson (1988) reveals the wide variety of criteria that have been used in U.S. based definitions (ie. a list of 24 definitions is presented). Also, the scale of resolution is important. Although most definitions rely on industry level statistics, Malecki (1984) notes that perhaps the most meaningful definition of high technology is at plant level, recognizing that some high tech industries are comprised of plants with routine production functions not unlike traditional industries. Nevertheless, Oakey et al. (1988) see the multitude of definitions as a result of the rush to operationalize a phenomenon which, until recently, has been used in a subjective manner. It would therefore seem necessary that a conceptual picture of high technology be developed before it can be empirically operationalized. With this in mind, the following discussion looks at the salient features of high technology industry as specified in various definitions.

Methodological Approaches: Subjective vs. Objective

Two broad methodologies have been used to define high technology industries. The first can be thought of as the subjective approach since it relies on the researcher's perception and intuition rather than empirical data sources in deciding which industries are high technology. Although this method is usually considered too author-specific and unreliable for widespread acceptability it has nevertheless been used in many empirical investigations (ie. Britton and Gilmour, 1978 ; Vinson and Harrington, 1979 ; Steed and DeGenova, 1983 ; Hay, 1984 ; Christie and Ironside, 1987). Its main advantage is practicality, permitting the researcher to sidestep the initial conceptual questions of what criteria to use.

In contrast, the second methodology is based on empirical data sources where the defining process is usually carried out in two steps. The first involves selecting criteria deemed appropriate for summarizing the essential attributes of high technology industries while the second step requires that numerical cutoff levels be applied to these criteria. To a large extent, the choice of criteria is restricted by the availability of suitable government statistics. In addition, these statistics should be regarded as surrogates since there is no direct measure of the degree to which industries are high technology (Oakey et al., 1988).

2.12 A Framework for Measuring High Technology

Oakey et al.(1988) have proposed a useful conceptual framework for viewing how the technological intensity of industries can be measured. It is suggested that high tech industries can be defined based on either the measurement of inputs or outputs of technological activity. Technological inputs are normally specified as scientific personnel and research and development spending at industry level. Because of the problems involved in measuring technological output which is essentially innovation, most researchers have concentrated on these input measures.

Input Measures of Technological Activity

It is helpful to make an initial distinction between high technology products and high technology processes, both of which have been discussed as possible input criteria (Hall et al.1987, 11). An assumption of most definitions is that high tech industries are more accurately identified on the basis of product rather than production characteristics. This implies that the degree to which sophisticated production techniques are used is not a good criterion since it will not adequately distinguish between high technology industries and other more traditional industries which also use such equipment. For instance, a study conducted in the U.K. by Northcott and Rogers (1984) found the primary users of sophisticated microelectronic production methods were in the paper, print and publishing and the food, drink and tobacco industries, which most would agree are not high technology. The implication is that sophisticated machinery is not generally considered the mechanism by which technology is inputed, or infused, into industries. The infusion is hypothesized to take place through the labour process, usually measured by either industry employment profiles highlighting the presence of scientific personnel or by research and development expenditures as a percent of company sales.

i) Scientific Personnel

Some argue that the relative presence of scientific, engineering and technical employment within industries should determine whether they can be called high technology. It is assumed that such occupations represent the active presence of knowledge based skills and expertise in industries leading to research and development and ultimately new or improved products.

There are many examples of occupation based definitions, the most notable of which is perhaps that of Markusen et al.(1986). They define high tech industries in the United States as those in which the proportion of engineers, engineering technicians, computer scientists, life scientists and mathematicians exceeds the national manufacturing average of 5.51 percent. The result is a list of 29 high technology industries at the three digit SIC level of aggregation (Appendix A). A similar methodology is used by Riche et al.(1983) although their definition uses a cutoff of 1.5 times the national average and [illegible] extends to service industries (Appendix B). Newton and O'Conner (1987) define 24 high technology industries in Australia based on occupation data which are rather surprisingly dominated by service sector industries (appendix C). In the United Kingdom, Breheny and McQuaid (1985) use occupational measures to define 10 core high technology industries (appendix D). Such international comparisons reveal that while criteria may be similar, high technology industries will vary among countries depending on their industry characteristics. These differences are also enhanced when different industrial classification systems are used.

ii) Research and Development

Research and development is also considered a distinguishing input of high technology industry, and it can be closely likened to the previous occupational criteria since both provide surrogates for measuring innovative activity. The "R" in R&D refers to research which can be further broken down into two components: basic and applied research. Basic research refers to scientific exploration in fields which may not immediately lead to commercial applications while applied research refers to scientific investigations that are anticipated to produce economic returns (Markusen et al.,1986, 14). On the other hand, development involves the application of research findings for the creation of new or significantly improved products or processes (Statistics Canada, 1988a). Above average expenditures for research and development can be imagined to arise out of the necessity to keep pace in the quickly changing and competitive environments that characterize some industries.

To operationalize this criteria, R&D expenditures are usually expressed as a percentage of industry sales, providing an index for comparison. For example, Riche et al.(1983) set the cutoff point at two times the national manufacturing average to identify six high tech industries at the 3 digit SIC level. (appendix E). A more lenient cutoff is set by the U.S. International Trade Administration (1983) to define 12 high tech industries based on research intensity (appendix F). In Canada, Britton (1986) uses industry R&D figures to distinguish six high technology industries (Appendix G). From these lists, a general observation is that R&D tends to be more discriminating than science and technology occupations in labelling industries high technology.

Operational and Conceptual Problems

Both R&D and occupational input measures have strengths and weaknesses which should be considered in light of their common usage in definitions. First, research and development is said to have two main drawbacks (Markusen et al.1986, 15). The first relates to the wide spectrum of activity it covers, from basic research to developmental efforts which may be present in differing mixes among industries but aggregated under the general heading of R&D. Another problem may result when dealing with industries that have very large sales figures such as the petroleum and chemical industries which will make R&D expenditures appear insignificant in comparison. Thus, R&D may discriminate against some of these larger industries. The major strength of R&D as a criterion is its direct measure of innovative activity, representing the commitment of firms to product improvement or new product development.

It can be argued that scientific occupations do not offer such a direct measure since scientists and engineers may not necessarily be engaged in innovative activity. Rather, the presence of these occupations will perhaps measure the potential for innovative activity to occur. Alternatively, the major strength of occupational measures is their standardization of measurement across industries which contrasts with R&D accounting methods.

A disadvantage common to both is the problem of aggregation in the SIC system. Data for these two measures are typically collected and presented at the 3 digit SIC level. Unfortunately, a variety of product groups may be aggregated to one particular industry at this level, each of which may vary in terms of technical sophistication. An example of this is the inclusion of gas meters and rulers in the category of scientific and measuring instruments in the British 1968 Standard Industrial Classification (Oakey et al., 1988). To a lesser extent this is present in the Canadian classification of electronic components (SIC 367) where certain "lower tech" products in terms of product sophistication and R&D potential are grouped together with active semiconductor components such as integrated circuits and microprocessors.

High Tech Industries Versus High Tech Plants

Another definitional issue which becomes apparent especially in a plant level investigation is when all plants within a particular industry are assumed to manifest the high technology criteria on which they were defined. However, since criteria are operationalized with industry averages, firms will naturally vary about these averages depending on their innovation strategies. Some may be distinctively above average while others may not display any of the criteria on which the definition was based (ie. Hagey and Malecki, 1986). This latter situation is more likely to occur in branch plant and subsidiary operations since these forms of manufacturing establishments typically specialize in final assembly operations rather than R&D and new product development. Thus, an inherent disadvantage of using industry based statistics in a definition is that they automatically cover the entire production cycle of commodities, ranging from early stage R&D oriented plants to mass production facilities.

Output Measures of Technological Activity

Definitions using output measures for criteria are much less common. This is probably due to the lack of government statistics in any major industrialized country that directly measure innovation output (Oakey et al., 1988). Despite this, Kelly (1986), used the SPRU data bank on significant innovations in the United Kingdom to construct an index of innovations per 1,000 workers. A similar definition in the U.S.A. is constructed by Norton and Rees (1979) where they use output measures to construct an index of innovations per net sales.

Oakey et al. (1988) contend that output measures are probably more accurate than input measures in defining high technology industry because they measure the actual result of innovative activity. However, this view does not take into account that not all innovative activity will result in commercially viable products. In addition, depending on the nature of the product and the competitive nature of the industry, innovations may be more difficult to attain in some products than others given equal amounts of research input. In this sense, simply counting patents or product innovations within an industry may not reflect the amount of innovative effort that has been inputed. This does not discount entirely the merits of using output measures. However, it should be recognized that input measures may be better suited for identifying the actual level of innovative effort.

Therefore, the conceptual picture developed here of high technology industry is one where organizations involved in the production of certain commodities respond to environmental and technological uncertainty with innovative effort in the form of research and development in order to compete and ultimately to survive. This conception of high technology industry is similar to that developed by Gillespie et al. (1986, 118). They see enhanced levels of R&D as a necessary component of some industries where quickly changing technology can leave products technologically and commercially obsolete after a brief period.

2.13 Defining High Technology Industries in Canada

This review has shown that high technology industries vary among countries. Even if the same criteria are used, national statistics on which definitions are based are country specific. Therefore, a suitable list of Canadian high technology industries should rely on appropriate

Canadian statistics. Unfortunately, in this respect, little attempt has been made at operationalizing a definition of high technology industry in spite of government statistics that would make such an exercise possible. Instead it appears that the subjective approach of defining is most common in Canada (ie. Britton and Gilmour, 1978 ; Steed and DeGenova, 1983 ; Christie and Ironside, 1988). All of these studies base their definitions on perceived product sophistication, and this results in little conformity among them. This approach may suffice for the particular aims of each study but it does not lend well to comparison.

Britton (1986) goes partial way into operationalizing the concept of high technology industry in Canada. Using R&D expenditures as a percent of industry sales, six high technology industries are identified (appendix G). However, a cutoff point for the R&D criterion is not given which makes this list of industries appear arbitrary.

Statistics Canada (1987) defines a list of high technology products rather than high technology industries (Appendix H). This definition is based on an OECD study that attempts to produce a standard list of high technology products for international statistical use. This is useful for drawing international comparisons, especially in the area of balance of trade figures (Statistics Canada, 1989). However, the data used to define these products are not based explicitly on Canadian industrial statistics which conflicts with the earlier assumption that a definition of high technology industry should be country specific.

It is apparent that the debate on high technology definition that has taken place in the United States and the United Kingdom has not materialized in Canada. Before any systematic investigation of this phenomenon can occur in Canada, its definition must be further standardized. Later in this thesis, a definition will be formulated based on the technological input measure of research and development.

2.2 Review of Industrial Linkage Studies

Industrial linkages defined as material flows of inputs and outputs between industrial establishments have long been a topic of investigation for industrial geographers and regional economists. In early classical location theory, they were not so much a separate topic as they were an implicit feature in locational models, treated as variables to be minimized or maximized based on least cost principles and rational decision making (eg. Weber, 1929 ; Losch, 1954). The switch to empirical studies, exemplified by the works of Hoover (1937) and Wise (1949), brought the actual spatial dimension of linkages into light. These and other early empirical studies (ie. Hall, 1962 ; Martin, 1966) emphasized the local agglomeration advantages that accrued to industries in the form of local input and output sourcing. Since these early studies, linkages have continued to be a popular topic among industrial geographers only recently appearing in geographical studies of high technology industry (ie. Oakey, 1981, 1984 ; Hagey and Malecki, 1986).

The switch to empirical study has also shifted emphasis from the effects that linkages have on transportation costs and industrial location into other areas concerned with the implications linkages can have on regional and national economies. In one sense, linkages represent channels of economic impulses where what happens economically at one location influences what happens at another (Hoare, 1985, 48). Therefore, linkages can be thought of as growth inducing effects analogous to their dynamic function in the formation of growth poles as theorized by Perroux (1955). In this vein, the spatial spread of linkages can be viewed in a strategic manner where, from a regional development perspective, local industrial integration ensures that growth inducing effects are internalized within regional boundaries. The measurement and importance ascribed to local linkages are clearly visible in the literature, recently appearing in the area of high technology production (ie. Hagey and Malecki, 1986). Indeed, the benefit of local linkages in high technology industries is measured not only by local multiplier effects, but also by the increased efficiency of industrial innovation and related spin-off activities which further augment local agglomeration advantages (Oakey, 1984). Strategic implications of linkages are also visible at the national level where, for instance, Britton (1980) discusses the detrimental effects that imports have on the creation of domestic supply channels in the Canadian economy.

2.21 The Methodology of Linkage Investigation

The study of industrial linkage has become structured by two broad methodologies. The first, known as the macro approach, is exemplified by the works of Streit (1969), Karaska (1969), Richter (1969), Roepke et al. (1974), Lever (1972), Czamanski (1971,1974,1976), Hoare (1975), Todd (1978) and Harrigan (1982). This approach is distinctive in its use of aggregate input-output data to make inferences about the spatial association of certain industries. If two industries are functionally linked using input-output data, and also show patterns of spatial proximity, it is inferred that they are spatially associated, locating near to each other in order to minimize the costs involved in transporting materials and goods. This normative approach has been criticized by Gilmour (1974, 338) who argues that spatial linkages and their locational importance can only be verified by examining the behaviour of individual fir. : and plants. Hoare (1985, 62) also questions the presumption that relationships at the aggregated industry level will hold for all firms and plants within these industries. Earlier findings by Hoare (1975) suggest that macro-linkage measures are not successful in explaining the location of industry within Greater London.

In contrast, micro-linkage studies rely on data collected at the level of the individual firm or plant and are typified by the works of Steed (1968), Keeble (1969), Wood (1973), Gilmour (1974), Lever (1974), McDermott (1976), Britton (1976), Marshall (1979), Oakey (1984), Hagey and Malecki (1986), Dias (1986), Dobson (1987) and Razin (1988). These studies are primarily concerned with identifying plant-level linkage patterns, emphasizing the presence and significance of local input and output contacts. A particular research effort has concentrated on identifying aspects of business organization that influence the spatial patterns of firm linkages. In addition, they highlight environmental or locational effects that cause linkage arrangements to vary depending on the region of study. The present analysis adopts this micro-linkage methodology.

The Methodology of Micro-Linkage Studies

At a conceptual level, it has become customary for micro-linkage studies to adopt an organization-based framework to investigate the spatial dimension of interplant linkages. Borrowing in large part from concepts of organizational science, this framework proposes an interactive relationship between industrial organizations and their environments in which interplant linkages represent the physical manifestations of interaction. Basic to this argument is the hypothesis that the geographical nature of linkages is influenced by two sets of forces : those internal to the firm and those external to the firm. The adoption of this framework has occurred relatively recently, first appearing in Marshall (1979). Later, McDermott and Taylor (1982) give a rigorous explanation of this theoretical stance as a basis for studying the spatial behaviour of industry.

Although the distinction between internal and external influences provides a convenient framework, their definition and empirical measurement has not led to a great deal of conformity among geographers. This is unfortunate since it leaves micro-linkage studies without a common methodological base, limiting the potential for comparing results. For this reason, a review of these concepts is necessary to clarify terminology and build a conceptual base for the current investigation of high technology industry.

2.22 The External Environment of Organizations

The external environment of business organizations is a difficult concept to define and operationalize because it can be viewed in a number of ways. A review of micro-linkage studies shows that, in general, two broad environmental frameworks have been specified. The first views environment in a rather abstract light, as the degree of uncertainty that firms face in their daily operation. The second takes a more geographical stance, interpreting environment as the spatial distribution of economic activity surrounding firms. By and large, the second stance is more frequently used in linkage studies.

i) Environment as Uncertainty

This view of environment is based on management science principles, most notably the structural contingency paradigm (Thompson, 1967 ; Lawrence and Lorsch, 1967). In it, environment is seen as those external organizations, such as suppliers, customers and competitors, which influence the behaviour of a focal organization (Dill, 1958). Thus, organizations adopt various strategies to cope with changing environmental circumstances that confront them. The formation of strategies in response to environmental change will ultimately be reflected in the structure of the organization (Marshall, 1979). Relating this concept of environment to geographical linkage patterns, it is hypothesized that various structural and strategic responses of firms to environmental change will affect the nature of a firm's trading relationships with its external environment (Marshall, 1979, 534).

Two main problems are encountered in applying this concept of environment to geographical linkage studies. First, there is the problem of measurement which has usually been accomplished by categorizing environment into various typologies based on the degree of uncertainty and change that organizations perceive. However, a review of management science literature shows there to be as many environmental typologies as there are studies (McDermott and Taylor, 1982). A second problem is the aspatial nature of this environment. This raises the question of whether such environmental considerations are causally related to the spatial linkage patterns of organizations (Marshall, 1979, 542).

ii) The Spatial Environment: Environmental Domain, Task Environment and Agglomeration Economies

The second method of specifying environment is similar in some respects to the previous method in its use of organizational principles. However, whereas the previous method is based on environmental perception, the second method is more concerned with the locational attributes of environment, providing a more intuitively reasonable point of entry for discussing the effect of environment on linkages.

It is argued in the management science literature that environment represents everything external to a focal organization, and in this sense, it has been referred to as the societal or macro environment (Kast and Rosenzweig, 1974). At a finer level, and more important to locational studies, are two segments of the total environment known as environmental domain and task environment. The environmental domain is said to encompass all external organizations that a firm could potentially interact with while the task environment refers to the organizations that a firm actually becomes involved with in exchange relationships. McDermott and Taylor (1982) suggest that these two levels of environment will have a spatial dimension for any organization. The domain of a firm may be likened to the spatial distribution of suppliers and customers that a firm could potentially interact with while the task environment can be interpreted as the actual spatial distribution of suppliers and customers of a firm.

It is possible to relate this organizational theory terminology to the more common term of agglomeration economies found in geographical literature. This latter term has a more qualitative meaning, summarizing the beneficial effects that accrue to manufacturing plants that operate in spatial proximity to one another. It is proposed that local linkages represent an important aspect of agglomeration economies and in a sense, can represent a way to measure it (Gilmour, 1974, 337). Therefore, the measurement of local task environment essentially becomes synonymous with measuring local agglomeration economies. Admittedly, this interpretation of agglomeration economies is somewhat narrow since it does not take into consideration other external economies that spatial clustering will produce. For instance, to measure agglomeration economies more broadly, Oakey (1984) includes local labour market advantages and accessibility of venture capital to local firms. To this list could be added local producer service inputs and infrastructural benefits that characterize urban areas. Nevertheless, local linkages measure an important dimension of agglomeration economies and are also comparatively easier to quantify than other measures.

The Measurement of Environmental Domain

It has become customary for most micro-linkage studies to concentrate on measuring actual linkage distributions or task environments rather than environmental domain because of the difficulty involved in measuring the latter. To provide an approximation of environmental domain, micro-linkage studies usually focus on the industrial structure of regions. For example, in Oakey's comparative study of high technology linkages in three regions, environment is measured by the relative presence of high technology industry in each area. As with Oakey (1984), a study of the U.K. electronics industry by McDermott and Taylor (1982) confirms the importance of environmental domain in explaining differential linkage patterns found between London, the Outer Metropolitan Area in South East England and Scotland.

The Task Environment of Different Regions

There is a much greater potential for comparison in the measurement of task environment. Obviously, interpretations from any comparison will have to be tentative given the different size of local areas in addition to varying sample structures across studies. However, one advantage evident in drawing such comparisons is that it permits qualitative statements to be made about the relative strength of local agglomeration economies in different regions. Such statements are difficult to justify when they are not referenced with comparison to other areas. For example, the implication of Karaska's work (1969, 368) that the ability of the Philadelphia economy to provide material inputs is limited because only 37 percent of input purchases originate from this area is difficult to interpret without reference to the ability of other regions to internalize inputs. In general, a weakness of geographical linkage studies has been a lack of consistency in measurement and data portrayal techniques that would permit useful comparisons across studies. In an attempt to consolidate some findings for comparative purposes, Table 2.1 displays local task environment measurements among studies with similar methodologies. In each, local task environment is measured as the percentage of total inputs and outputs by value that originate from or are sold to the local area.

Table 2.1: Percentages of Inputs Purchased and Output Sold Locally: A Regional Comparison

Author	Region	% local inputs	% local output
Gilmour (1974)	Montreal	31.6	27.3
Lever (1974)	Scotland	19.9	75.7
McDermott (1976)	Scotland	30.3	43.1
Hoare (1978)	Northern Ireland	28.2	34.6
Marshall (1979)	Northern Region, U.K.	36.4	29.5
O'hUallachain (1981)	Illinois	34.2	25.6
McDermott & Taylor (1982)	London	35.9	29.2
"	Outer Metro Area (South East U.K.)	30.3	25.8
"	Scotland	28.4	40.7
Average		30.6	36.8

Despite differences in the size of local areas and in sample structures, distinctive trends can be seen in Table 2.1. On the input side, samples typically purchase between 28 and 35 percent of their total input requirements from locally defined areas, the highest values in London and the Northern Region of England. Local outputs are generally slightly lower except in the case of Scotland. The typical range is between 25 and 30 percent, although for Scotland, local sales linkages range from 40 to 76 percent.

What can we infer about local agglomeration economies from these results? Notwithstanding the different sampling procedures, it appears that a degree of homogeneity exists among regions. Except for the high output linkages observed in Scotland, there does not appear to be a great deal of local specialization in any of the areas. However, it should be remembered that the local percentages are derived from a wide range of industry and organization types.

Evidence From High Technology Industries

There have been only a few micro-linkage studies of high technology industry to date (ie. Oakey, 1984; Oakey et al., 1988; Hagey and Malecki, 1986, Bathelt, 1988). Unfortunately, data portrayal techniques in these studies differ from those presented in Table 2.1, preventing a direct comparison between high tech and non-high tech sectors. Nevertheless, the works of Oakey deal explicitly with examining the effect of locational environment on linkage behaviour and innovation through a survey of small single-site firms in three different regions: the San

Francisco Bay area of California, the South East region of England and Scotland. The choice of these regions reflected a desire to study a range of high technology environments while keeping the internal characteristics of the sample relatively constant. Oakey's results show that environmental domain has a noticeable effect on local linkage arrangements (Table 2.2).

Table 2.2: Local High Technology Linkages in Three Regions (expressed as percentage of sample firms buying over 50% of inputs and selling over 50% of output in local region)

Location	N	Input		Output	
		n	%	n	%
South-East England	60	11	(18.4)	16	(26.7)
Scotland	54	6	(11.2)	11	(20.8)
San Francisco Bay	60	41	(68.3)	20	(33.3)

source: Oakey (1984)

Over 68 percent of sample firms in the San Francisco Bay area obtained over 50 percent of their input requirements from the local sources, verifying the existence of substantial agglomeration economies on the input side. In contrast, local linkages are less frequent in the two areas of the United Kingdom indicating less regional integration in the high technology sector.

Recently, Bathelt (1988) has investigated linkage structures of high technology firms in five different regions using a similar measurement technique to that of Oakey. However, his work combines linkage structures of both single-site firms and branch plants and subsidiaries which prevents a direct comparison between the two. Nevertheless, the results generally complement those of Oakey, especially with his finding of substantial local input purchasing in the Route 128 region of Boston. Indeed, 70 percent of the 35 firms sampled in this region obtained over 50 percent of their inputs from the local region implying agglomeration economies similar to those found in the Silicon Valley region. Much lower regional orientation was found in Atlanta, Research Triangle Park, North Carolina, and in Ottawa. Surprisingly, 47 percent of Bathelt's sample firms in the Canadian Technology Triangle area in Kitchener Waterloo obtained over 50 percent of their inputs locally, a situation which is probably due to the presence of Metropolitan Toronto in the locally defined area.

High Technology Industry, Local Linkage and Agglomeration Economies

In view of the agglomerative tendencies of high technology industry in core regions such as Silicon Valley and Route 128, Oakey (1984) draws an interesting parallel between these new agglomerations and the old Victorian industrial agglomerations in the United Kingdom studied by Wise (1949) and Hall (1962). These old agglomerations in cities such as London and Birmingham were also characterized by high levels of local input and output trading, indicating the presence of agglomeration economies. A shift was believed to have occurred with the newer growth industries of the 1960s and 1970 which tended to be less spatially tied to locations where suppliers or customers were. However, the new high technology regional agglomerations seem to indicate a convergence of suppliers and customers in a similar fashion to the Victorian style agglomerations. This seems to suggest that the benefits of close supplier and customer interaction enjoyed in the gun and jewelry quarter in Birmingham may be at work again in the formation of new high technology complexes. In this sense, we may have come full circle (Oakey, 1984).

While similar in some respects, it is likely that the formative processes of these older and newer agglomerations are quite different. The assumption among early linkage studies was that manufacturing agglomerations promoted high amounts of local input and output linkage, thereby reducing total transportation costs incurred by constituent firms. In this sense, transportation costs were seen as an important locational consideration which tended to bring related industrial plants closer together. However, the contemporary treatment of high technology agglomerations implies that informational feedback loops and the technical dependency between suppliers and customers is a more important formative aspect of clustering than transportation cost savings (Oakey, 1984). Thus, technical interdependency between linked firms becomes a distinguishing aspect of high technology agglomeration and is supported by empirical evidence showing R&D oriented firms to establish more local input linkages (O'hUallachain, 1984 ; Hagey and Malecki, 1986). Whether or not the spatial clustering induced by informational economies is as significant as the transportation cost savings achieved in earlier agglomerations is uncertain. However, the extraordinarily high input linkages found in the San Francisco Bay Area by Oakey (1984) and the Route 128 region by Bathelt (1988) suggest that high tech agglomerative forces may become especially intense in regions that have a strong R&D orientation.

2.23 Internal Organization Effects

The organization based framework also hypothesizes that factors internal to the firm will influence spatial linkage patterns. The challenge here has been to identify aspects of business structure that influence the spatial extent of linkages. However, it has also been recognized that business organization and strategy are comprised of a number of dimensions, making their measurement a complex task (Pugh and Hickson, 1976). Furthermore, it is difficult to identify and measure these dimensions in a brief cross-sectional interview (Marshall, 1979). For this reason, it has become customary for micro-linkage studies to use various surrogate measures to identify the salient features of organizational structure, the most frequently used of which is plant ownership.

a) Ownership Status and Linkage

A review of empirical studies reveals that plant ownership status is of primary importance in explaining linkage patterns (see Table 2.3). Generally, it is used to classify manufacturing establishments according to where management control is located. Centralized plants are those which have full management control on-site and include both single-site firms as well as headquarter plants of multisite companies.

Alternatively, decentralized plants possess only partial control of management functions on-site and are usually comprised of branch plants and subsidiaries. In the literature, this latter group is commonly referred to as externally owned and in cases where control is located in another country, foreign owned. On the other hand, centralized plants are typically combined under the title of domestically owned.

These plant-level ownership distinctions are important because they act as broad measures of company strategy that affect linkage patterns. For instance, Britton (1976) uses plant-level data to reveal the widespread use of intracorporate supply channels by foreign owned multinationals operating in southern Ontario. Such strategic considerations have important effects on the geographic spread of input linkages. Corporate sales strategies of externally controlled plants also affect the geographic orientation of forward linkages (White and Poynter, 1984). Evidence of ownership and local input linkages is presented in Table 2.3.

Table 2.3: Percent of Total Inputs From Local Area by Ownership Category: A Regional Comparison

Author	Region	ownership	
		local	external
Lever (1974)	Scotland	23.7	18.5
McDermott (1976)	Scotland	36.0	22.6
Hoare (1978)	Northern Ireland	46.7	13.5
Marshall (1979)	Northern U.K.	41.8	33.6
Average		37.1	22.1

There is an observable trend across plant-level studies which reveals higher local input sourcing among locally owned establishments with the significance of this relationship varying depending on the region of study. Using a different measurement technique, Dobson (1987) also finds ownership to be significant in explaining local input linkages. These patterns, whether by choice or by company directive, likely result from corporate strategies of externally owned multinationals to secure inputs through corporate channels. Also implied is a greater geographical awareness of potential suppliers than in the case of smaller locally owned firms.

A similar comparison is used to review the effects of ownership on local sales linkages (Table 2.4).

Table 2.4: Percent of Total Sales to Local Area by Ownership Category: A Regional Comparison

Author	Region	ownership	
		local	external
Lever (1974)	Scotland	87.9	65.1
McDermott (1976)	Scotland	49.1	36.8
Hoare (1978)	Northern Ireland	56.4	21.1
Marshall (1979)	N. Region U.K.	31.8	23.6
Average		56.3	36.7

As on the input side, locally owned establishments show higher levels of local output orientation. Externally owned plants which are typically much larger, export a greater proportion of output beyond the local region.

The effect that ownership has on high technology linkages is expected to follow the same patterns as other industries. Hagey and Malecki (1986) provide the most direct evidence, showing that locally owned high technology establishments in northern Florida rely more on local input suppliers than externally controlled branch plants.

b) Plant Size

Micro-linkage studies typically hypothesize an inverse relationship between plant size and local input and output linkages. It is expected that larger plants are able to internalize input requirements more readily within their production facilities, thereby reducing local input linkage opportunities (Gilmour, 1974). In contrast, smaller firms tend to rely more on external suppliers for input requirements, creating an increased potential for local input subcontracting to take place. On the output side, it is expected that larger firms will be more likely to sell output beyond the local market area to justify large volume production. By and large, these expectations are confirmed in the literature (Gilmour, 1974 ; Lever, 1974 ; McDermott, 1976 ; Marshall, 1979 ; Dobson, 1987).

Evidence from high technology industries is provided by Hagey and Malecki (1986). They find that smaller high technology plants purchase more supplies from local sources. However, this relationship is significant only among locally owned establishments, suggesting that the size of externally owned plants will not affect their regional input orientation.

c) Production Method

It has been hypothesized that differing manufacturing production systems will lead to distinctive spatial linkage patterns. Woodward's (1969) scale is frequently used to classify production systems into three categories: unit production, small batch production and mass production (for instance, Marshall, 1979). Taylor and Wood (1973) suggest that establishments using small batch production techniques are more likely to purchase inputs locally because communication with suppliers is more important when product design changes frequently. Thus, when production systems are flexible, there is a need for closer interaction with suppliers which may induce spatially close linkage ties. On the other hand, the standardized processes of mass production facilities are believed to lead to routine input requirements that can often be maintained with distant suppliers. Evidence from the literature tends to support this hypothesis (Marshall, 1979 ; O'hUallachain, 1984).

Production method can also be related to the spatial spread of output linkages. Since facilities involved in mass production usually produce in large volume, it is reasonable to assume that regional exports will be dominant. On the other hand, plants using unit or batch production techniques will more likely produce custom designed products geared towards local markets.

d) Plant Technology

Plant technology is usually measured by either plant capital intensity, research and development spending or the percentage of scientists and engineers in the workforce. Evidence suggests that increased plant sophistication increases local backward linkages. O'hUallachain (1984) finds a positive relationship between local purchasing and the two technical variables of R&D spending and capital intensity. Similarly, Hagey and Malecki (1986) find that the percentage of scientists and engineers in locally owned high technology establishments is positively and significantly related to local input sourcing. These tendencies are best explained by interfirm communication (Hagey and Malecki, 1986). It is suspected that technically sophisticated plants will require sophisticated inputs which will demand close communication ties between supplier and customer. Spatial juxtapositioning will abet this communication process.

e) Purchasing Autonomy

It is expected that an increase in purchasing decision making autonomy will increase the likelihood of decentralized branch and subsidiary facilities purchasing supplies from the local area. Hagey and Malecki (1986) find this to be the most important variable in explaining local input orientation of externally controlled high technology plants in Florida. However, rather surprisingly O'Farrell and O'Laughlin (1981) do not find a significant relationship between purchasing autonomy and local linkages. Autonomy has also been considered from a wider perspective, including managerial decision making in other facets of plant operations such as marketing, production, financial and personnel activities. Marshall (1979) has shown that externally owned plants with low levels of autonomy tend to secure higher proportions of inputs through corporate channels which consequently lowers local purchasing.

Other aspects of organization structure have been related to local linkage patterns in the literature, but they tend to be less conclusive in explaining linkage patterns. Some of these include plant age (Marshall, 1979) and distance to corporate headquarters (O'Farrell and O'Loughlin, 1981). While not an intrinsic part of organization structure, other works have also related industry type to levels of backward and forward linkages (ie. Keeble, 1969 ; Karaska, 1969). In one sense, the study of high technology linkages, while encompassing a number of industrial categories, is homogeneous in terms of technological intensity.

Summary

The interactive relationship between environment and organizational structure provides a theoretical framework in which to study actual linkage patterns. This relationship is a dynamic one where changes in organizational structure may lead to a changes in the local environmental conditions perceived by firms. Therefore, the number of potential "at risk" local suppliers and customers will vary as organizational characteristics vary, a process that is visible in observing how expanding firms outgrow local supply arrangements (Taylor, 1975) and how linkages are altered with management changes and foreign takeovers (Ashcroft, 1988).

CHAPTER 3

Methodology

3.1 High Technology Industry Definition

In this study high technology industry is defined in terms of R&D expenditures as a percent of company sales at the three digit SIC level. There are two main reasons for using this criterion. First, it was argued in chapter two that research and development is an integral feature of high technology industry, arising out of a need for firms to invest in the search for new products or processes in order to compete. Secondly, R&D data are readily available at the three digit SIC level. This is not the case for occupational data.

Setting an appropriate cutoff level for R&D spending poses another problem since the "high" in high technology is impossible to objectify. One of two paths is usually taken to address this problem. The first involves setting the cutoff level equal to the national manufacturing average (ie. Markusen et al. 1986) while the second approach sets the cutoff somewhere above the national average (ie. Riche et al., 1983). The second method is adopted in this study since the first may not adequately refine a list of industries dependent on advanced technology. Such a list may be more appropriately entitled "above average" rather than "high" technology industries. For this reason, the cutoff level applied to R&D expenditures is set at twice the national manufacturing average, producing a list of seven Canadian high technology industries at the three digit SIC level (Table 3.1).

Table 3.1: Study Definition: High Technology Industries in Canada

SIC	Industry	R&D (as % of sales)
363	Telecommunications Equipment	17.8
372	Aircraft and Parts	13.9
366	Other Electronic Equipment	12.8
367	Electronic Parts and Components	6.7
283	Drugs and Medicine	4.0
371	Business Machines	3.5
391	Scientific and Professional Equipment	3.5
manufacturing average		1.5

source: Statistics Canada (1988a, 62)

In comparing the high technology list in Table 3.1 to others, basic commonalities are found. Industries involved in the production of electronic components are included as well as primary users of these devices, such as the telecommunications, computer, aircraft, and scientific instruments industries. Perhaps the major difference, especially with definitions using more lenient cutoff levels, is the exclusion of the rest of the chemical related industries (of which drugs and medicine are a part) as well as industries producing final demand industrial and consumer goods. In the Canadian context, the other chemical products industry spends less on R&D than the national industrial average while the machinery industry is above this average but by less than twice. It is felt that a higher cutoff level will yield a more representative list of high technology industries and safeguard against some borderline industries being included. For instance, the more lenient definition of Markusen et al. (1986) includes the construction equipment, paints and varnishes, reclaimed rubber and the soap industries. It is debatable whether such industries should be part of a high technology definition.

3.2 High Technology Industry in Canada

A brief look at the geography of high technology industry in Canada is now presented, providing a rough approximation of the distribution of potential suppliers and customers for high technology firms. The lack of 3 digit SIC industry data at the sub-provincial level prevents a detailed locational analysis. Even at the provincial level, employment and value added data are fragmented, which leaves the number of establishments as the only consistently available comparative measure. These totals for 1985 are displayed in Table 3.2.

Table 3.2: High Technology Industry in Canada (Establishments by Provincial Areas and as a Percent of the Canadian Total)

Industry	Canada	Atlantic		Quebec	
		no.	%	no.	%
Aircraft/Parts	184	5	(2.7)	52	(28.3)
Telecom. Equip.	51	4	(7.8)	9	(17.6)
Electronic Comp.	234	7	(3.0)	37	(15.8)
Other Elec. Equip.	210	8	(3.8)	51	(24.3)
Business Mach.	149	2	(1.3)	26	(14.4)
Drugs & Medicine	134	3	(2.2)	45	(33.6)
Sci/Prof. Equip	614	31	(5.0)	136	(22.1)
Total	1576	60	(3.8)	356	(22.6)

source: Statistics Canada (1988b)

Table 3.2: continued

Industry	Ontario no.	Ontario %	Prairies no.	Prairies %	B.C. no.	B.C. %
Aircraft & Parts	72	(39.1)	26	(14.1)	29	(15.8)
Telecom. Equip.	22	(43.1)	12	(23.5)	4	(7.8)
Electronic Comp.	165	(70.5)	8	(3.4)	17	(7.3)
Other Elec. Equip.	107	(51.0)	13	(6.2)	31	(14.8)
Business Mach.	91	(61.1)	15	(10.1)	15	(10.1)
Drugs & Medicine	68	(50.1)	10	(14.7)	8	(6.0)
Sci/Prof. Equip.	295	(48.0)	89	(14.5)	63	(10.3)
Total	820	(52.0)	173	(11.0)	167	(10.6)

source: Statistics Canada, (1988b)

These provincial totals indicate that high technology industry is heavily concentrated in the central provinces of Ontario and Quebec, reflective of the overall spatial concentration of economic activity in this region. Ontario is clearly the dominant high technology province, accounting for more than half of all establishments. When combined with Quebec, these two provinces contain approximately three quarters of the Canadian total of high technology industry. The Prairie provinces and British Columbia have approximately equal proportions of establishments while the Atlantic provinces account for just 3.8 percent of the total.

Unfortunately, specifying sub-provincial high technology location patterns is difficult due to gaps in Statistics Canada data. Britton (1986), attempts to fill these gaps at the CMA level by aggregating comparable statistical units. His analysis highlights the overall dominance of Toronto and Montreal in all areas of high technology production. By comparison, all other CMA aggregations are relatively unimportant in terms of high technology industry location. Ottawa is somewhat noteworthy in its specialization in some areas of high technology production such as business machines, communications equipment and scientific and professional equipment.

3.3 High Technology Industry in The Toronto CMA

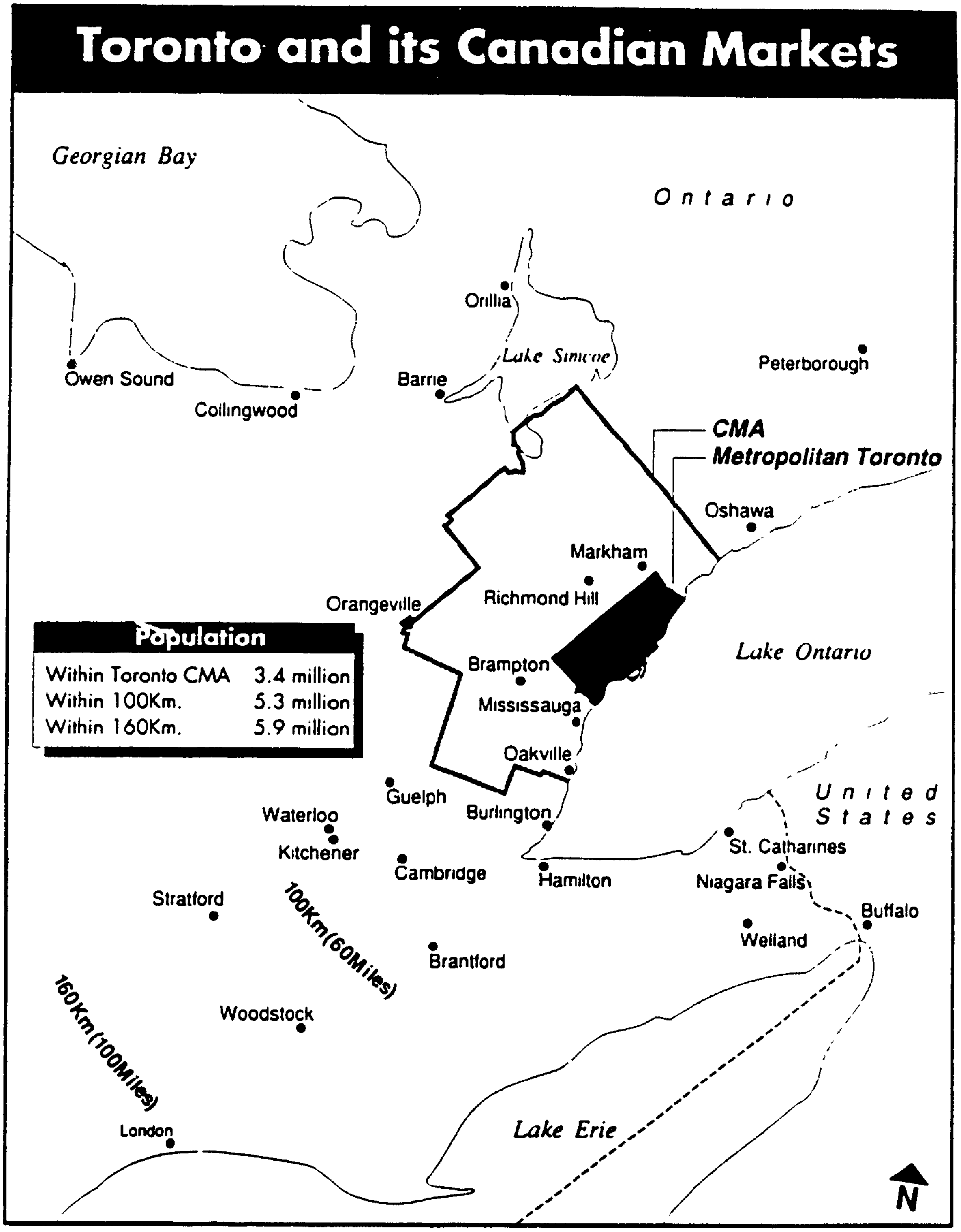
The local area in this study follows the area defined as the Toronto Census Metropolitan Area (CMA), a region identified by Statistics Canada on the basis of commuter flows (Map 1, pg 49). This area, covering approximately 5,300 square kilometers, had a 1986 population of 3,536,499, representing 14 percent of the Canadian total. In economic terms, this region clearly dominates the Canadian urban system, containing 19 percent of total Canadian manufacturing value added (de Reus, 1989). In addition, the Toronto CMA has the largest concentration of corporate headquarters in Canada, reflecting its preeminence as a location for foreign investment in manufacturing and related producer services. Other favourable high technology location factors include the concentration of high order service functions, two universities and six colleges in the metropolitan area, a highly skilled workforce, good air and highway accessibility and numerous cultural amenities.

To measure the presence of high technology industry in the Toronto CMA, Scott's Industrial Directory (1989) was used to classify individual establishments based on product characteristics. These establishments and their employment totals were tabulated for each industry. Assigning plants to particular industries was not a straightforward process since establishments frequently listed multiple product lines that spanned across different industries. In such cases, plants were assigned to the industry which the majority of its products lines belonged. This was somewhat problematic in the case of the other electronic equipment industry since its product lines often took up the minority of production in multiple product plants. To address this problem, the product lines of this industry were added to the scientific and professional equipment industry category, in effect leaving six high technology industries. Since the objective of this study does not address sectoral linkage differences, this amalgamation of industries will have no effect on linkage results as they are presented.

The presence of high technology industry in terms of establishments and employment are given in Tables 3.3 and 3.4. Totals for Metropolitan Toronto, Mississauga, Markham and the rest of the Toronto CMA are disaggregated to highlight the dominance of Metropolitan Toronto and the emergence of Mississauga and Markham in high technology manufacturing.

In total, 645 high technology establishments with a corresponding 57,941 jobs are located in the Toronto CMA. When compared with provincial totals in Table 3.2 it is clear that Toronto represents the dominant high technology agglomeration in Canada in terms of the number of establishments. Although the data derived from Scott's Industrial Directory somewhat overstates the number of manufacturing plants in the Toronto CMA due to the inclusion of some distributors, in all likelihood there are more high tech establishments in the Toronto CMA than in the Prairie provinces, British Columbia and Atlantic Canada combined. Such a

Map 1



City of Toronto Planning and Development Department spatial concentration should provide great potential for agglomeration economies to develop through material linkages.

Table 3.3: High Technology Industry in the Toronto CMA (Establishments by Areas)

Industry	Metro Tor.	Mississauga	Markham	rest CMA	Total
Aircraft/Parts	18	12	1	5	36
Telecom. Equip	23	13	0	15	51
Electronic Comp.	67	17	21	20	125
Business Mach.	22	26	19	9	76
Drugs & Med.	33	17	3	5	58
Sci/Prof. Equip	137	70	26	66	299
Total	300	155	70	120	645

source: personal tabulations from Scott's Industrial Directories: Ontario Manufacturers (1989)

The scientific and professional equipment industry represents the largest high technology sector in terms of establishments while the aircraft and parts industry has the least number of establishments but the greatest share of high technology employment. Metropolitan Toronto dominates in terms of both establishments and employment, containing approximately 47 percent of the region's establishments and 54 percent of total employment. The peripheral communities of Markham and Mississauga have also developed notable concentrations of high technology industries. Britton (1986) identifies these two areas as recently expanding high technology nodes, equalling if not surpassing the rapid high technology growth seen in the Ottawa region. It is likely that these two surrounding regions have been the locational recipients of overspill high technology investment from the built up Metropolitan Toronto area.

Table 3.4: High Technology Industry in the Toronto CMA (Employment by Area)

Industry	Metro Tor.	Mississauga	Markham	rest CMA	Total
Aircraft/Parts	11,390	5,719	15	736	17,860
Telecom. Equip.	1,887	1,877	0	4,373	8,137
Electronic Comp.	5,157	581	1,024	800	7,562
Business Mach.	746	1,770	643	288	3,447
Drugs & Med.	5,013	2,036	42	1,109	8,200
Sci/Prof. Equip.	6,928	2,784	689	2,334	12,735
Total	31,121	14,767	2,413	9,640	57,941

source: personal tabulations from Scott's Industrial Directories: Ontario Manufacturers (1989)

3.4 Sampling Procedure

To obtain plant level data on plant structure and linkage behaviour, personal interviews were conducted with company officials from a sample of high technology plants in the Toronto CMA. Scott's Industrial Directory (1989) was used to supply a list of high technology companies along with their addresses. While it was not possible to interview all 645 high technology plants in the local area (Table 3.3), 134 firms were approached for interview. Of these plants, 80 (60%) agreed to participate in the survey, 14 (10%) refused to take part while ongoing communication was established with the remaining 40 (30%) firms. When a sufficiently large sample was extracted, further communication with these firms was not followed up. The final sample of 80 firms represents 26.5 percent of the total population of high technology firms in Metropolitan Toronto and 12.4 percent of the firms in the larger CMA area (Table 3.6). In employment terms, the sample constitutes 50.1 percent of high technology employment in Metropolitan Toronto and 27 percent of the CMA total (Table 3.6).

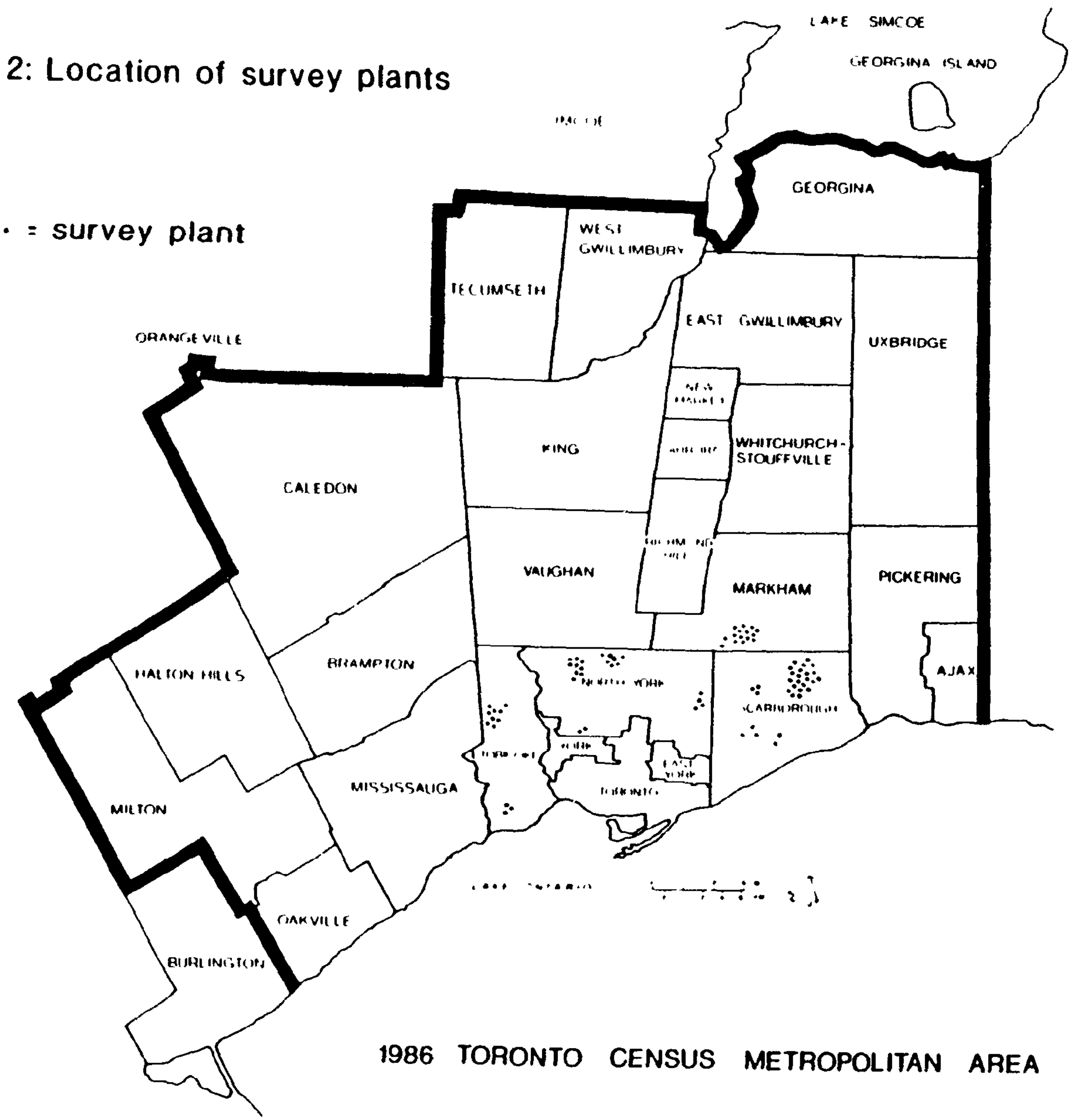
To minimize time and travel expenses, the plants contacted were spatially concentrated within several industrial districts in and around Metropolitan Toronto (Map 2). Of the 80 firms interviewed, 65 are located in Metropolitan Toronto, the majority of these situated in the boroughs of Scarborough and North York. The remaining 15 interviews took place in the Town of Markham which borders Metropolitan Toronto on the north. The constraints of cost and distance meant that not all high tech firms within the wider CMA were considered for interview. For instance, firms in Oakville, Mississauga, Brampton, Pickering, Ajax, Vaughan, Richmond Hill as well as firms in outlying areas such as Milton, Halton Hills, Caledon, King, Whitechurch-Stouffville and Newmarket were not within a viable range for interview. While this geographic bias in the sample prevented drawing a random sample from the entire CMA, there is no reason to suspect that linkage characteristics of firms interviewed are different from those of the larger population of firms.

Sample Stratification: Ownership and Sector

The primary stratification variable was ownership. The aim was to have approximately equal numbers of foreign and domestic establishments in the final sample. Scott's Industrial Directory (1989) was used to select establishments from the industrial districts shown in Map 2. For reasons outlined in the previous section, firms were selected based on their location within the Toronto CMA. The firms that were considered within range tor interview were selected randomly. In addition, there was an ongoing concern for having an equal representation of foreign and domestic firms in the sample. While not always possible to differentiate between foreign and domestically owned plants from information supplied in the directory, approximately equal numbers of foreign and domestic plants are in the final sample. As revealed in Table 3.5, 43 domestically owned plants comprised of 30 single location firms, 7 branch/subsidiary plants and 6 headquarters plants were interviewed. Of the 37 participating foreign plants, 27 have their headquarters in the United States while the other 10 are European-owned. It is believed that

Map 2: Location of survey plants

• = survey plant



1986 TORONTO CENSUS METROPOLITAN AREA

enough plants are included for each ownership sample to be representative of their larger populations.

The sample was also roughly stratified by sector in order to give a good mix of the high technology industries defined (Table 3.6). Since this study does not aim to analyze inter-industry differences in operation and linkage orientation, the small number of establishments representing most industries is not of great concern. To a large extent, this sectoral distribution was conditioned by the number of plants available for interview in each industry in addition to their location within the Toronto region. Thus, the scientific and professional equipment and electronic parts and components industries constitute the majority of sample plants whereas the less numerous aircraft and telecommunications industries are the least represented.

Table 3.5: Survey Sample : Ownership

Ownership	N	Employment	Emp. (Mean)
Domestic	**43**	**3191**	**74.2**
single location	30	1065	35.5
branch/subsidiary	7	916	130.9
headquarters	6	1210	242.0
Foreign	**37**	**12404**	**335.2**
USA	27	9659	357.7
European	10	2745	274.5
Total	**80**	**15,595**	**194.9**

Table 3.6 : Sectoral Breakdown of Firms Surveyed

Industry	N	% of Plants in Metro Tor.	% of Plants in CMA	Emp. (1989)	% Total Emp. in Metro Tor.	% Total Emp. in CMA
Aircraft and Parts	6	33.3	16.7	5,262	46.2	29.5
Telecom. Equip.	8	34.7	15.7	485	25.7	6.0
Elect. Parts/Comp	22	32.8	17.6	4,002	77.6	52.9
Business Machines	11	50.0	14.5	586	78.6	17.0
Drugs and Medicines	11	33.3	19.0	2,396	47.8	19.0
Sci/Prof. Equipment	22	16.1	7.4	2,882	41.6	22.6
Total	80	26.5	12.4	15,595	50.1	25.9

Questionnaire Design

The questionnaire administered with company officials is displayed in Appendix I. An underlying assumption of micro-linkage investigation is that organizational characteristics such as ownership and size will influence geographical linkage patterns. Therefore, the questionnaire focuses on measuring salient features of company structure along with their material linkage patterns. This methodology assumes that organizational characteristics will explain "why" linkages are arranged in certain geographical patterns. The actual question of "why are your material linkages arranged in such a manner?" was not used in the questionnaire. It is probable that if such open ended questions were asked, aspects of company structure, such as size and research intensity, would not enter into their answers. More likely, other responses would be given such as the knowledge of and quality of suppliers in different geographical areas. However, it could be expected that these subjective reasons will vary systematically according to organizational type. Nevertheless, it is the focus of this study to concentrate on objectively measured organizational determinants of linkage rather than subjective evaluations of company officials.

Appointments were usually scheduled with plant or operations managers and in the case of smaller firms, with owners. Seventy-four of these were administered personally, four by telephone and the remaining two by mail. The interviewees were usually knowledgeable about the questions pertaining to organizational structure. In some cases, more than one person per company were called upon to obtain accurate information. More difficulty was encountered in obtaining responses about input origins and sales destinations. Usually it took a few readings with accompanying explanation for company officials to ascertain how to answer the questions. Once realized, it frequently took considerable time for them to apportion the percentage value of linkage shipments to and from the six specified geographical areas. It is likely that if the questionnaire was not administered personally the frequency and quality of answers to these questions would have been much reduced. In total, 78 of the 80 firms surveyed supplied information on input sources and 79 indicated the geographical distribution of sales linkages.

Unfortunately, many of the questions concerning the top two material purchases, in section (H) of the questionnaire, did not prove useful for subsequent analysis. The purpose was to investigate whether the nature of individual inputs in terms of technical sophistication, design change, and communication levels with suppliers, affected their spatial origins. For instance, Hagey and Malecki (1986) have shown that technically sophisticated inputs tend to be obtained from nearby sources more frequently than routine inputs. However, the results from these questions were thought to be too unreliable for further analysis. This is due mainly to the lack of consistent scaling intervals in most of these questions. In addition, it was difficult for respondents to identify specific input commodities, more often defining inputs in a broad sense such as "electronic components" which are composed of a variety of different commodities. Analysis of input linkages is therefore based on data collected in section (G) of the questionnaire.

CHAPTER 4

Characteristics of Firms Surveyed

There has been relatively little investigation of firm level aspects of high technology industries in Canada. It is therefore the aim of this chapter to identify some of the major structural characteristics of high technology establishments in the Toronto CMA emphasizing differences that exist between foreign owned and domestic firms. This is accomplished under four main headings: i) size, age and employment characteristics ii) plant technology iii) production and product characteristics and iv) occupational and organizational structure. While structural differences between foreign and domestic firms can be expected to arise out of differing strategic circumstances, they may also contribute to variations in linkage patterns, a subject which is investigated in the next chapter.

4.1 Plant Structure: Size, Age and Employment Characteristics

a) Employment Size

The eighty firms in the sample are grouped into three employment-size categories in Table 4.1. As expected, domestic plants are generally smaller than foreign plants due in large part to the presence of 30 single location firms within the sample. Looking at sample means, the average domestic firm employs 74 compared to the 335 average of foreign plants. Therefore, even though ownership is portrayed as the primary determinant of plant structure and linkages in subsequent analyses, the large size of foreign plants compared to domestic plants may also be an underlying cause of differences observed between the two. However, the effects of size on various measures of plant structure are not investigated in this study. In the next chapter, the relationship between plant size and local linkages is addressed in section 5.2.

Table 4.1: Plant Size by Ownership

		Employment					
Ownership	N	< 50		51 - 150		150 +	
		n	%	n	%	n	%
Domestic	43	27	(62.8)	12	(27.9)	4	(9.3)
Foreign	37	13	(35.1)	14	(37.8)	10	(27.0)
Total	80	40	(50.0)	26	(32.5)	14	(17.5)

domestic firms: mean = 74.2 std. dev. = 123.2
foreign firms : mean = 335.2 std. dev. = 675.5
T ratio = 2.49 , p = 0.015

b) Plant Age

When the sample is grouped into four age categories in Table 4.12, differences in the age structure of foreign and domestic plants are revealed. A difference of means test shows that foreign plants are significantly older than domestic plants. As seen in the table, 53 percent of foreign firms were established in Toronto before 1970 compared to 28 percent of domestic firms. If such trends are reflective of high technology industry in Toronto in general, it may be that domestic firm start-ups have increased relative to foreign start-ups in high technology sectors over the last two decades.

Table 4.12: Plant Age by Ownership

Ownership	N	1980-1989 n	%	1970-1979 n	%	1960-1969 n	%	< 1960 n	%
Domestic	43	15	(35%)	16	(37%)	7	(16%)	5	(12%)
Foreign	36	7	(19%)	10	(28%)	4	(11%)	15	(42%)
Total	79	22	(28%)	26	(33%)	11	(14%)	20	(25%)

domestic firms: mean = 15.8 std. dev. = 12.0
foreign firms : mean = 24.1 std. dev. = 15.8
T statistic = 2.65 , p = 0.01

c) **Employment Changes**

It is commonly assumed that high technology industries exhibit above average employment growth compared to other indu :ial sectors. In addition, high technology employment is said to be resistant to cyclical fluctuations in economic activity (Markusen et al., 1986). Both of these assumptions have naturally led to economic development policies formulated around high technology industry both at national levels (ie. Nelson, 1984) as well as local levels (deBettencourt and Mier, 1984 ;

Malecki, 1984). However, empirical evidence tends to show that employment gain in high technology industries is by no means automatic. For instance, Hall (1987) notes that high technology employment in the United Kingdom actually declined between the years 1971 and 1981 by 10.9 percent. In the United States, while an overall growth rate of 42.8 percent was exhibited in the same time period, one third of the 100 four digit industries defined by Markusen et al. (1986) declined in employment. Therefore, employment gain in high technology industry appears conditional on the industry and the country or region of study.

In light of these observations, employment changes within the present sample over different time frames are looked at, first in terms of aggregate employment changes followed by the incidence of expanding and contracting firms.

1) Aggregate Employment Changes

The first analysis looks at employment changes of plants established before 1980; there are 51 of these (Table 4.13).

Table 4.13 : Employment Changes in Sample Firms 1980-1989

Ownership	N	Emp. 1980	Emp 1989	Emp. Change	% Change
Domestic	24	1,472	1,840	368	25.0
Foreign	27	7,679	10,503	2,824	36.8
Total	51	9,151	12,343	3,192	34.9

Overall, 3,192 new jobs were created, representing a 34.9 percent increase in plant employment since 1980. Also of interest is the higher growth rate of foreign establishments which would appear to bode well for policy encouragement of foreign investment in high technology industries in Canada. Whether or not these growth trends are consistent throughout the 1980s is another issue in light of the general economic recession that Canada experienced between 1981 and 1984. To elaborate on this point, Tables 4.14 and 4.15 analyze the employment changes in these 51 plants at two time intervals in the 1980s, first between 1980 and 1984 and then between 1985 and 1989.

Table 4.14 : Employment Changes in Sample Firms 1980-1984

Ownership	N	Emp. 1980	Emp 1984	Emp. Change	% Change
Domestic	24	1,472	1,716	244	16.6
Foreign	27	7,679	8,882	1,203	15.7
Total	51	9,151	10,598	1,447	15.8

Table 4.15 : Employment Changes in Sample Firms 1985 - 1989

Ownership	N	Emp 1985	Emp 1989	Emp. Change	% Change
Domestic	24	1,716	1,840	124	7.2
Foreign	27	8,882	10,503	1,621	18.3
Total	51	10,598	12,343	1,745	16.5

These tables reveal that overall employment growth rates in the two time periods are approximately equal. Comparing domestic and foreign plants, growth rates are approximately equal between 1980 and 1984. However, between 1985 and 1989, the growth rate of foreign plants becomes over twice that of domestic plants owing to the drop in the domestic growth rate from 16.6 percent to 7.2 percent. Therefore, employment growth in foreign owned plants has been relatively constant in the 1980's while the growth rate of domestic plants has shown signs of slowing in the second half of the decade.

2) Expanding and Contracting Firms

While the overall growth in employment among sample firms is impressive, this does not imply that all firms expanded in employment. Another way of examining employment changes is to look at how many firms expanded and contracted in these time frames. (Tables 4.16 and 4.17).

Table 4.16 : Expanding and Contracting Firms, 1980 - 1984

Ownership	N	Expanding	Contracting	No Change
Domestic	24	18 (75%)	6 (25%)	0
Foreign	27	17 (63%)	8 (30%)	2 (7%)
Total	51	35 (69%)	14 (27%)	2 (4%)

Table 4.17 : Expanding and Contracting Firms, 1985 - 1989

Ownership	N	Expanding	Contracting	No Change
Domestic	24	11 (46%)	10 (42%)	3 (12%)
Foreign	27	14 (52%)	9 (33%)	4 (15%)
Total	51	25 (49%)	19 (37%)	7 (14%)

Between 1980 and 1984, 69 percent of the plants expanded in employment, 27 percent contracted and 4 percent remained the same. In the 1985-89 time frame, the expansion rate dropped to 49 percent while the contraction rate increased to 37 percent. This is somewhat surprising since plants seem to have expanded more in the recessionary period in 1980-84 than in the later recovery period. Looking at ownership differences, 75 percent of domestic plants expanded between 1980-84 compared to the 63 percent rate of foreign plants. However, in the latter time frame, the expansion rate of foreign plants is now higher than domestic plants, although both showed a decline from the previous period.

The above analyses appear to verify the assumption that high technology industry is a net generator of employment. In addition, foreign plants show higher increases in employment than domestic plants in both absolute and percentage terms in the 1980-1989 period. This may indicate a difficulty encountered by small domestic plants in expanding their operations in the often risky environment of high technology industry.

4.2 Plant Technology

a) Research and Development Spending

Plant-level data on R&D spending can be used to indicate the extent that sample plants satisfied the 3 percent R&D cutoff level adopted in the definition of this study. As displayed in Table 4.18, of the 71 plants that reported estimates of R&D expenditures, 31 (44%) did not reach the 3 percent cutoff level set in the definition. This illustrates the danger of assuming that all plants belonging to high technology industries will display high technology characteristics. It also points to a general weakness of high technology definitions that rely on industry level statistics. Ownership comparisons show that a higher percentage of foreign plants failed to meet the specified cutoff indicating a greater R&D effort among domestic plants.

Table 4.18: R&D Expenditures as a Percent of Sales: Survey Firms

Ownership	N	< 3%	> 3%
Domestic	38	13 (34%)	25 (68%)
Foreign	33	18 (58%)	15 (45%)
Total	71	31 (44%)	40 (56%)

To investigate further the R&D activity of sample firms, Table 4.19 divides R&D expenditures into three size categories. The results show domestic firms to be more evenly spread among the three categories with most (42%) spending less than five percent of sales on R&D. In contrast, 67 percent of the foreign firms surveyed spend less than five percent on R&D. Overall, domestic plants spend an average of 8.5 percent of sales on R&D while foreign plants spend 5.3 percent. A difference of means test does not reveal a significant difference in R&D spending between the two ownership groups ($p = 0.111$) although the tendency is for domestic firms to be more R&D intensive.

In addition to providing estimates of plant-level R&D expenditures, branch plants and subsidiaries were also asked to indicate corporate levels of R&D spending. This measure can give an indication of the relative amount of R&D investment and autonomy that is decentralized to externally owned establishments (Table 4.2). Although not dealing specifically with high technology industries, a similar exercise is undertaken by Rugman (1981) who investigated the R&D behaviour of foreign multinationals in Canada relative to their corporate spending levels.

Table 4.19: R&D Expenditures of Firms by Ownership

Ownership	N	< 5% n	%	5-10% n	%	> 10% n	%
Domestic	38	16	(42%)	10	(26%)	12	(32%)
Foreign	33	22	(67%)	7	(21%)	4	(12%)
Total	71	28	(39%)	17	(24%)	16	(23%)

domestic firms: mean = 8.5 std. dev. = 8.1
foreign firms: mean = 5.3 std. dev. = 8.4
T statistic = -1.62 , p = 0.111

Table 4.2: Percent Plant and Corporate R&D by Ownership

Ownership	N	% Plant R&D	% Corporate R&D
Domestic	38	8.5	9.6
Foreign	33	5.3	13.6

The interpretation from Table 4.2 is clear. Although domestic plants on average spend more on R&D than foreign plants operating in Canada, at corporate level, foreign companies are more research intensive than Canadian firms. This suggests that the amount of R&D expenditures decentralized from foreign headquarters to manufacturing plants in the Toronto region is relatively low in the high technology sector. A similar situation is portrayed by Rugman (1981) for Canadian industry in general, although in his sample domestic plants had still lower R&D

levels than foreign controlled branch plants.

These results imply that foreign multinationals prefer to centralize a large portion of R&D activity at headquarter locations. Rugman (1981) relates this process to the theory of internalization in multinational firms where it is argued that company functions are located and distributed on the basis of both country specific and firm specific advantages. Studies have shown that R&D is most efficient when a centralized strategy is adopted (Fisher and Behrman, 1979). In addition, firm specific advantages relating to technological secrecy may also be put at risk when R&D is decentralized.

Type of Research and Development

Three distinct types of research and development have been identified. Basic research is concerned with scientific research with no immediate or foreseeable commercial application. Product R&D refers to innovative effort devoted to inventing new products or improving old ones while process R&D involves research into bettering production methods. Table 4.21 indicates the type of R&D conducted by sample establishments, many of which undertook more than one type.

For the most part, product R&D is conducted by sample plants followed by process R&D. As expected, the incidence of basic scientific research is low. Somewhat surprising is that there are no appreciable ownership differences, with both having approximately equal percentages of each type of R&D. Others have noted that externally owned establishments are less likely to undertake product development and more likely to be involved in process R&D (Oakey et al., 1982). This is not the case with high tech industry in Toronto.

Table 4.21: Type of R&D of Firms by Ownership

Ownership	N	Basic		Product		Process	
		n	%	n	%	n	%
Domestic	34	5	(15%)	30	(88%)	10	(29%)
Foreign	24	3	(13%)	21	(88%)	6	(25%)
Total	58	8	(14%)	51	(88%)	16	(28%)

b) Science and Engineering Occupations

A distinguishing feature of high technology industries is their tendency to employ relatively larger proportions of technical personnel compared to other industries. It is expected that sample plants will follow this pattern, although it is difficult to compare with industry level data in a Canadian context.

To measure the presence of technical occupations, sample firms were asked to indicate the number of plant employees that held university degrees in science and engineering disciplines. These were subsequently divided by total plant employment to give relative percentages of scientists and engineers per plant workforce. Table 4.22 breaks down these percentages into three categories by ownership. In addition, a difference of means test is conducted between the two ownership groups.

While the table shows a tendency for domestic firms to be concentrated in the largest size category (greater than 10 percent of workforce), a difference of means test reveals no significant difference between the group means of the ownership categories (p = 0.371).

Table 4.22: Scientists and Engineers as a Percent of Plant Workforce by Ownership

Ownership	N	< 4% n	< 4% %	4 - 10% n	4 - 10% %	> 10% n	> 10% %
Domestic	43	9	(20.9)	15	(34.9)	19	(44.2)
Foreign	35	15	(42.9)	8	(22.9)	12	(34.3)
Total	78	24	(30.8)	23	(29.5)	31	(39.7)

domestic firms: mean = 12.3 std. dev. = 13.9
foreign firms : mean = 9.6 std. dev. = 11.2
T statistic = -0.90 , p = 0.371

4.3 Production and Product Characteristics

a) Production Methods

To measure production method, Woodward's (1969) scale is used to distinguish between unit, batch, and continuous mass production techniques. Although plants were asked to identify the dominant method of production used, in some cases more than one method was specified (Table 4.23).

Table 4.23: Production Method of Firms by Ownership

Ownership	N	Unit	Small Batch	Mass
Domestic	43	9 (21%)	35 (81%)	7 (16%)
Foreign	37	5 (14%)	24 (65%)	10 (27%)
Total	80	14 (18%)	59 (65%)	17 (21%)

Small batch is by far the most prevalent form of production among the high technology sample plants (65%). In contrast, mass production is used by 21% of sample plants while unit/prototype production is the least used at 18%. Since multiple responses were given by some plants, a chi square analysis of production method by ownership is not appropriate. From visual inspection of Table 4.23, domestic plants appear to use unit and batch production in greater numbers than foreign plants. However, the difference is not great, with 79% of foreign plants using either unit or batch production techniques and 27% using mass production. Therefore, it appears that high technology production in Toronto is geared more towards shorter, flexible production runs rather than standardized mass assembly operations. This may reflect the notion that high technology products are subject to frequent design changes, thereby encouraging flexible production methods. It is also likely that the overall small size of sample plants limits the possibility of mass production techniques.

b) Main Product Lines

Firms were asked to indicate the number of distinct product lines produced at their plants. The majority (70%) produce more than one product line (Table 4.24). This may be a reflection of batch production methods which allow flexibility in altering product specifications. On average, domestic plants produce 8 different product lines while foreign plants produce 23, which would apparently indicate a significant difference between the two. However, the high mean value of foreign firms is heavily weighted by a few large firms which listed an extraordinarily high number of product lines. Indeed, a difference of means test shows an insignificant difference between the two ownership groups (p = 0.369).

Table 4.24: Number of Product Lines of Firms by Ownership

Ownership	N	1		2-5		over 5	
		n	%	n	%	n	%
Domestic	43	15	(34.9)	21	(48.8)	7	(16.3)
Foreign	37	9	(24.3)	14	(37.8)	14	(37.8)
Total	80	24	(30.0)	35	(43.7)	21	(26.3)

domestic firms: mean = 8.1 , std. dev. = 27.3
foreign firms: mean = 23.2 , std. dev. = 98.1
T statistic = 0.91 , p = 0.369

c) Broad Product Markets

The main products of sample plants were classified into three categories based on the type of market they served (Table 4.25). The first includes producers of components or semi-finished products which act as inputs in further manufacturing operations. The second category is composed of producers of final demand goods serving industrial, large commercial, professional and government markets while the last category includes manufacturers of final demand consumer goods.

Table 4.25 : Output Markets of Firms by Ownership

Ownership	N	Component n %	F.D.-Ind/Prof n %	F.D.-Cons n %
Domestic	43	16 (37.2)	22 (51.1)	5 (11.6)
Foreign	37	15 (40.5)	14 (37.8)	8 (21.6)
Total	80	31 (38.8)	36 (45.0)	13 (16.3)

chi square = 2.063 p = 0.36

The overall distribution shows that final demand industrial, large commercial, professional and government markets are the most prominent customers for sample plants followed by component markets. The final demand consumer market is served by only 16.3% of the total sample. This may explain in part the dominance of batch production among the sample since mass production is frequently seen in consumer products which take on standardized designs and are produced in large volumes. However, the small amount of consumer goods manufacturers in the sample is also largely due to the nature of the industries surveyed. The way high technology industries were defined meant that many consumer goods industries such as the electrical appliance and household audio and video equipment industries were excluded. The only industry with substantial links to final consumers is the business machines industry which manufactures computers and computer peripherals. All others are mainly concerned with either components/subassemblies or with industrial, professional, government or large commercial markets. A chi square analysis of ownership by product market indicates a statistically insignificant relationship between the two.

4.4 Occupational and Organizational Structure

a) Occupational Profile

The occupational structure of high technology firms has rarely been addressed in the literature. Markusen (1985) suggests that the high technology labour force is bifurcated between high paid professional occupations and lower paid clerical and assembly occupations. This somewhat questions the notion that high technology industry is a source of well-paid skill oriented jobs. The present analysis distinguishes between production and office related jobs, the latter of which are disaggregated into R&D, marketing/sales, and purchasing occupations

(Table 4.26).

Table 4.26: Occupational Profile of Firms (Mean Percentages)

% Employment	Domestic	Foreign	Total
% Production	58	43	51
% R&D	12	6	9
% Marketing	10	6	8
% Sales	n.a.	12	n.a.
% Purchasing	7	4	6
% Other	13	29	26
Total	100	100	100

Total employment within the sample is almost evenly divided between production employment and other non-production occupations. This may indicate a need for high amounts of producer service inputs in high technology production such as research and development and marketing. Breheny and McQuaid (1985) make a similar observation in their survey of high technology establishments in the United Kingdom. Also of note is the lower percentage of production workers among foreign owned plants-43 as compared with 58 percent.

Employment within the key decision making areas of marketing, purchasing and research and development is generally higher in domestic plants. This may be due to the fact that upper management personnel in small domestic firms often are involved in all areas of the firm. It may also reflect how foreign branches and subsidiaries rely on corporate information channels for R&D, marketing and purchasing support. The percentages of scientists and engineers per plant workforce for the two ownership categories were noted earlier in Table 4.22. Twelve percent of domestic firm employees are university degreed scientists and engineers which matches the 12 percent of the workforce employed in R&D activities shown in Table 4.26. Among foreign firms, while an average of 9.6 percent of employees have science and engineering degrees (Table 4.22), only 6 percent of employees undertake R&D activities on a regular basis. This suggests that scientists and engineers in domestic firms are more likely to engage in R&D than their counterparts in foreign firms.

The percentage of personnel involved in sales functions was difficult to ascertain among small domestic firms because of the difficulty in separating marketing and sales personnel. It would appear however, that sales employment is significant among foreign owned plants. Also notable is the large percentage of employment contained in the 'other' category. Although not specified in the survey, occupations in this category are likely composed of other office functions such as general administration and clerical work which could be termed non-key decision making in comparison to those involved in the other functions already mentioned. If this is the case, in general, domestic plants would appear to be more production and science oriented than foreign plants.

b) **Organization Structure and Environment**

It has been suggested that organization structure is dependent upon the environment that confronts organizations. Burns and Stalker (1961) propose that any management structure will fall somewhere along a continuum between mechanistic and organic styles of organization. The mechanistic form of management with many distinct levels of management hierarchy and short spans of control is most suited for stable or unchanging environments (McDermott and Taylor, 1982). On the other hand, organic management style has fewer and less distinct levels in the management hierarchy and wide spans of managerial control. This flexible style of organization is best suited for quickly changing environments which may be expected to exist more frequently in high technology production. Bahrani and Evans (1987) attribute such environmental considerations as a cause for the distinctive organizational forms that high technology firms in Silicon Valley have taken.

To operationalize the concept of environment, a scaling system similar to Marshall (1979) was used. Plants were asked to score on a scale of 1 to 5 the following;

i) level of market competition
ii) frequency of product design change
iii) frequency of production process change

These scores were totalled for each firm and classified into three environmental typologies. Scores of seven or less were classified as stable environments; eight to eleven were called intermediate; scores of twelve and above were classified as dynamic environments. Hayter (1982) suggests that foreign multinationals in Canada face less environmental uncertainty because of their large size. Table 4.27 displays the environments perceived by sample plants among the two ownership categories.

Table 4.27: Environmental Typology of Firms by Ownership

Ownership	N	Stable n %	Intermediate n %	Dynamic n %
Domestic	43	7 (16%)	25 (58%)	11 (26%)
Foreign	37	14 (38%)	13 (35%)	10 (27%)
Total	80	21 (26%)	38 (48%)	21 (26%)

chi square = 5.752 p = 0.0563

The above results confirm the expectation that foreign plants tend to operate in more stable environments than domestic plants.

It is proposed that the effect of environment on organization can be observed by measuring the extent to which various management tasks have become formalized through structured departments. Plants were asked to indicate the degree of formalization of purchasing, marketing and research and development activities within their management structures (Table 4.28).

Table 4.28: Presence of Key Departments in Firms by Ownership

Department	Domestic n	Domestic %	Foreign n	Foreign %
% separate R&D	19	(44.2)	15	(40.5)
% part-time R&D	15	(34.9)	9	(24.3)
% no R&D	9	(20.9)	13	(35.1)
% separate purchasing	24	(55.8)	29	(78.4)
% informal purchasing	19	(44.2)	8	(21.6)
% no purchasing	0		0	
% separate marketing	23	(53.5)	27	(73.0)
% informal marketing	20	(46.5)	8	(21.6)
% no marketing	0		2	(5.4)

Looking at purchasing and marketing, the results show that these management functions tend to be more formalized in foreign establishments. Just over 50% of domestic plants have departmentalized these functions while 78% of foreign plants have separate purchasing departments and 73% separate marketing departments. Turning to R&D, 35% of foreign plants have no R&D activities compared to the 21% level of domestic firms. Of the 24 foreign owned plants that undertake R&D activities, 15, or 63% do so in separate R&D departments. In comparison, 19 of the 34 (56%) domestic plants involved in R&D have formalized departments. It is likely that less formal departmental arrangements among these firms is caused as much by their small size as they are by the effects of environmental uncertainty. In small firms, it may be unnecessary to formalize functions in separate departments when they can be handled by the owner and other key management personnel. However, it is the contention of Knight (1985,1986) and Boag and Munroe (1986) that this amalgamation of strategic management areas in small high technology Canadian firms has lead to "top heavy" scientific business operations with less expertise in marketing. This is believed to hinder the export viability and survival of small high technology firms in Canada.

It is possible to compare findings on R&D departments with similar studies by Christie and Ironside (1988) and Oakey et. al. (1988) (Table 4.29).

Table 4.29: Percent of R&D Departments By Region

Region	N	Full-Time (%)	Part-Time (%)	No R&D (%)
Toronto	43	55.9	44.1	21
San Francisco	37	62.2	37.8	14
SE England	37	51.4	48.6	20
Scotland	29	62.1	37.9	31
Alberta	67	62.7	37.3	33
Total	213	59.2	40.8	24

Since the samples of Christie and Ironside (1988) and Oakey et al. (1988) are composed of small indigenous firms, only domestic plants from Toronto are included in this comparison. As can be seen, R&D activities in Toronto plants are similar to those of other regions, all having a slightly higher ratio of full-time to part-time departments. The prohibitive costs of maintaining a full-time R&D staff often means that part-time work by the owner and perhaps the technical director and production engineer may be an optimal level from a financial standpoint for small firms (Oakey, 1984, 97). It is not possible to make similar comparisons with other departments although it is reasonable to assume that comparable levels will be evident among small single location firms in the other regions.

Summary

This chapter has revealed some of the major structural characteristics of high tech firms in the Toronto CMA. Differences between foreign owned and domestic plants have been explored. In some instances, these differences are fairly significant, for instance with respect to plant size, age and research intensity. In a sense, these ownership differences point to two different forms of high technology production in Canada, reflective of diverging corporate and strategic circumstances between the two. In the next chapter we consider how these structural differences affect the nature of spatial trading relationships of high technology firms.

CHAPTER 5

Analysis of Linkage Patterns

In order to investigate the material linkage patterns of high tech firms over space, plant level data were collected on the geographical extent of plant purchasing (input) and sales (output) linkages. The analysis of these patterns is divided into three sections. The first concentrates on measuring the input-output task environments of sample firms. This is first done with the entire sample in what could be termed aggregated task environments. Next, the influence of ownership is looked at emphasizing differences in local backward and forward linkages as well as differences in importing and exporting behaviour. Notwithstanding the importance of local linkages, the generation of exports in high technology industries is generally regarded as an indicator of a country's technological and competitive standing at the international level (Statistics Canada, 1984, 11).

The second section focuses on local linkages in the Toronto CMA where an attempt is made to distinguish other aspects of organization structure besides ownership that influence the manner in which firms become locally integrated. The final section comments on the extent of high technology agglomeration economies in the Toronto region by comparing results with the high technology regional studies of Oakey (1984) and Bathelt (1988).

The measurement technique used asked respondents to estimate percentages of inputs and outputs that were obtained or distributed to various geographical areas. This is the usual technique employed in the absence of actual monetary values of shipments (an exception is found with Lever, 1974). Respondents were asked to assign percentages to the following six geographical areas: i) the Toronto CMA ii) the rest of Ontario iii) Canada - East iv) Canada - West v) United States vi) rest of world. It was felt that dividing the task environment in such a manner would disaggregate linkage data enough for meaningful analysis as well as permit respondents to give reasonable estimates without burdening them with too many areal categories to assign percentages. In addition, it is important to note that input percentages included purchases from both manufacturers and distributors, a point not often clarified in linkage studies.

The local area is defined as the Toronto CMA while the rest of Ontario may be considered a regional trading area. Disaggregating the rest of Canada into Canada - East and Canada - West will be useful for showing the extent of east-west high technology trade flows. The United States was expected to be the origin and destination of a large volume of trade in high technology commodities due to its large market size and proximity.

5.1 The Measurement of Task Environment

Table 5.1 displays the spatial spread of input and output by value, representing the input and output task environments of sample plants. Specified in the table are the mean percentage and standard deviation associated with each geographical area. The discussion of results concentrates on the mean values although the usually large standard deviations around these means implies a good deal of variability in linkage patterns.

Table 5.1: Percentage of Firm Inputs Obtained From, and Output Sold to Specified Areas (By Value): Mean, Standard Deviation

Location	% Inputs		% Output	
	$\bar{X}$	$\bar{S}$ *	$\bar{X}$	$\bar{S}$ *
Toronto	45.1	30.8	28.5	24.9
rest of Ontario	6.9	11.5	14.1	12.2
Canada - East	2.8	6.3	12.2	12.4
Canada - West	1.1	3.4	9.9	11.0
United States	30.8	29.9	26.2	28.1
rest of world	12.4	19.4	8.6	15.9

* These $\bar{S}$ values are intended to be descriptive and, hence, sometimes exceed the mean. No normalization of data was done in order to preserve the original values of measurements. The same holds true for all other tables.

It is apparent that input and output flows of the firms surveyed show distinctive spatial patterns. Input purchasing tends to be concentrated in two regions; the Toronto CMA and the United States. The 45 percent obtained from the Toronto region represents over 80 percent of all Canadian input purchases indicating Toronto's dominating role as a regional supplier of high technology inputs, not surprising given the overall concentration of high technology industry in Ontario and Toronto in particular. Somewhat surprising however are the limited input linkages with the Montreal region in eastern Canada, the second largest high technology agglomeration in Canada according to Britton (1986).

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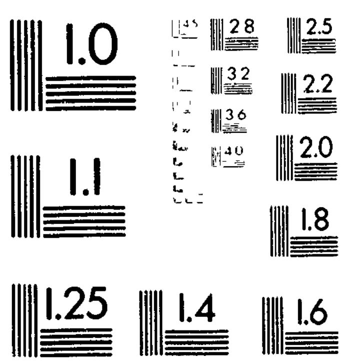

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Input sources from western Canada are also rare, which in summary suggests that east-west input flows are relatively insignificant in high technology industries. Much more dominant is the north-south trading axis with American suppliers and to a lesser extent other world suppliers. This importing pattern is expected since 27 of the 37 foreign plants surveyed are headquartered in the United States.

The distribution of high tech output is more evenly spread throughout the six geographical areas. Within Canada, sales extend more uniformly in an east-west direction implying that the distribution of high technology industry in Canada does not influence forward linkages to a large degree. This could arise from the fact that many high technology final product markets are not within high technology sectors. As was the case with input purchasing, the Toronto CMA and the United States are the largest output markets although in terms of percentages, the dispersal of output is more balanced. As expected, the foreign export market is dominated by the United States, which alone is the destination of over 75 percent of exports.

5.12 Ownership Influences on Task Environment

As discussed in chapter two, business organization structure is hypothesized to affect geographical linkage patterns. In this sense, the input-output task environments displayed above should be regarded as aggregate task environments since they have arisen from a variety of organizational forms. The following section concentrates on the effects of ownership, noting differences between foreign and domestic firms.

Input Linkages

Table 5.12 displays the input linkages of foreign and domestic firms to the six specified areas. In addition to means and standard deviations, a difference of means test (t-test) is carried out between foreign and domestic groups for each specified area. As expected, differences in purchasing patterns are quite distinct between the two groups, especially in the local area. Domestic plants, on average, obtain over 61% of their inputs from the Toronto region. The average among foreign plants is just over 29 percent. Input linkages to other parts of Canada are relatively similar in the two groups. However, the lower use of local sources among foreign plants is made up for by much higher import levels compared to domestic plants. The average foreign plant imports 61% of its inputs from abroad compared to the domestic rate of 28.5 percent. These linkage arrangements suggest that diverging strategies of input sourcing exist between the two ownership groups. It is likely that the predominance of imports among foreign firms is a consequence of intracorporate supply arrangements in addition to a greater geographical awareness of supply sources. From a development standpoint, it is suggested by Britton (1980) that the importing behaviour of foreign multinationals short circuits domestic supply channels and externalizes multiplier effects beyond the Canadian economy. This should be of greater concern when dealing with high technology industries since they are usually viewed as strategic to national economic development. However, the inclusion of industrial distributors in the present study will complicate interpretations concerning the spatial multiplier effects associated with measured linkage patterns, a topic which is discussed later.

Table 5.12: Input Sources by Ownership: Mean, Standard Deviation and Difference of Means Test (t-test)

Input Source	Domestic (n=41)		Foreign (n=37)			
	$\bar{X}$	$\bar{S}$	$\bar{X}$	$\bar{S}$	T ratio	prob.
Toronto	61.1	27.2	29.1	26.5	-5.37*	.00
rest of Ontario	5.7	7.2	8.3	14.9	0.99	.33
Canada - East	3.0	6.7	2.6	5.9	-0.32	.75
Canada - West	1.6	4.5	0.4	1.2	-1.67	.10
United States	20.2	19.8	42.6	32.8	3.60*	.00
rest of world	8.3	12.5	16.9	24.3	1.95	.06

* significant at 0.05

a) Inputs From the Toronto CMA

To examine further the nature of input linkages in the Toronto CMA by ownership category, Table 5.13 divides local linkages into three size groups. Upon visual analysis of the table, it can be seen that 61 percent of domestic plants obtain greater than 50 percent of their total inputs from the Toronto CMA showing a clear orientation to local suppliers. Alternatively, most foreign establishments (54%) purchase less than 30 percent from this area indicating that proximity to customers may be of more limited concern compared to domestic plants. In light of these figures, the proposition that substantial high technology agglomeration economies exist in the Toronto region may not be applicable in a general sense, but rather is particular to domestic firms. In general, these findings concur with others concerning the local purchasing behaviour of not only high technology but also branch plant operations in general.

Table 5.13: Percentage of Total Inputs Purchased in Toronto CMA by Ownership

Ownership	N	< 30%		30 - 50%		> 50%	
		n	%	n	%	n	%
Domestic	41	6	(14.5)	10	(24.4)	25	(61.0)
Foreign	37	20	(54.1)	10	(27.0)	7	(17.1)
Total	78	26	(33.3)	20	(25.6)	32	(41.0)

chi square = 19.8 p = 0.0002

While it was not the intent of this study to analyze differences in local linkage between high tech and non-high tech industries, comparisons can be made with earlier studies. Based on the overall sample average of 45.1 percent, local input linkages in Toronto appear well developed compared to such areas as Montreal (Gilmour, 1974) Scotland (Lever, 1974 ; McDermott, 1976) and London (McDermott and Taylor, 1982) which were based on a variety of industry types (see Table 2.1). When disaggregated by ownership, the foreign average of 29 percent local purchases is similar to other areas although still somewhat higher (ie. Lever, 1974 ; McDermott, 1976 ; Hoare, 1978). Domestic establishments tend to be much more locally oriented than in other areas. Thus, it may be that high tech sectors are generally more likely to develop local input linkages than other industries, contrary to the frequent assumption that, because of their sophisticated input requirements, they will be less likely to find inputs in local areas. In the Toronto case, the influx of microelectronic and other component devices, largely through distributor channels, has led to a convergence of geographical input linkages, the importance of which to high tech location, new firm formation and innovation is uncertain. In this sense, Toronto may be a unique example of high technology agglomeration rather than being indicative of high tech industry linkage patterns in general.

To expand on this, further analysis of local input linkages disaggregates supply sources into three categories: manufacturers, distributors and subcontractors. Shown in Table 5.14, domestic and foreign plants were asked to specify for their top two material input purchases by value, the type of supplier they were purchased from. This analysis concentrates on cases where inputs originated from the Toronto region.

In many cases, specific inputs were purchased from more than one source in which both manufacturers and distributors were used. Of 55 specific input commodities obtained from the Toronto CMA by domestic plants, approximately equal percentages are purchased from manufacturers and distributors while just 11 percent are purchased from subcontractors. There is a tendency for foreign firms to establish more local input

Table 5.14: Type of Suppliers in Toronto CMA: Source of Top Two Material Inputs

Ownership	Inputs From Toronto	Manuf. n	Manuf. %	Subcont. n	Subcont. %	Dist. n	Dist. %
Domestic	55	33	(60.0)	6	(10.9)	34	(61.8)
Foreign	27	19	(70.4)	2	(7.4)	11	(40.7)
Total	82	52	(63.4)	8	(9.8)	45	(54.9)

linkages with manufacturers rather than distributors. This was further in evidence when firms were asked to specify the percentage of total local inputs by value that originated from manufacturers and distributors. Among domestic plants, 71 percent of local input values came from distributors compared to a 48 percent level among foreign plants. Therefore, even though foreign firms prefer to use non-local suppliers in an aggregate sense, they nevertheless prefer manufacturers as supply sources in the local area. The predominance of distributor use, especially among domestic firms, is noteworthy in the context of local multiplier effects since they largely represent leakages from the local area to value added facilities in other parts of the world. The emergence of distributors in local supply chains in the high technology sector has also been noted by Oakey (1981) and Hagey and Malecki (1986). Distributors are likely a dominant feature of urban agglomerations that lack production capability in the full range of high technology components, notably semiconductors and related devices.

b) Input Linkages - Domestic Plants

Domestic firms were further subdivided based on plant status to see if input linkages vary among single location firms, headquarter plants and Canadian-owned branch plants. It is expected that since single location firms are typically small and run by local entrepreneurs, their input linkages will be predominantly local. Headquarter operations may also display strong local input linkages since their center of operations is in the local area which should mean they have an awareness of local supply sources. Branch plants and other decentralized forms of manufacturing typically display lower degrees of local input integration. However, this may be somewhat offset in the current sample since five of the six respondents in this category are headquartered in the Toronto area. The input sources among these three types of domestic plants are displayed in Table 5.15

The ability to draw statistical comparisons between the group means for each input source is somewhat constrained by the small sample sizes of the headquarter and branch/subsidiary categories. Nevertheless, difference of means testing reveals significant differences on two occasions (Table 5.15). Single location firms purchase a significantly higher percentage from the Toronto region than branch and subsidiary plants. They also tend to purchase more from the local area than headquarter plants although this difference is not significant. Therefore, as expected, single location firms show the greatest orientation to local suppliers while branch operations show the least.

Canadian owned branches, however, still purchase more inputs locally (41.2%) than foreign owned branch plants (29.1%, Table 5.12). In addition, headquarters plants obtain a significantly higher percentage of inputs from the rest of the world category than single location firms. Input linkages to the rest of Ontario, Canada and the United States are relatively similar among the three plant types. In each case, the United States represents the second largest supplier of inputs, behind the Toronto CMA.

Table 5.15: Input Sources Among Domestic Plants: Mean, Standard Deviation

Input Source	SLF (n=29)		HQS (n=6)		Branch/Subs. (n=6)	
	$\bar{X}$	$\bar{S}$	$\bar{X}$	$\bar{S}$	$\bar{X}$	$\bar{S}$
Toronto	66.6	23.4	54.7	30.1	41.2	27.2
Ontario	4.9	7.4	5.5	5.1	9.5	8.1
Canada - East	2.8	5.7	0.7	1.0	6.7	12.1
Canada - West	0.9	3.3	1.7	4.1	5.0	3.4
United States	18.3	18.5	17.8	18.6	31.8	26.5
rest of world	6.5	11.0	19.7	15.6	5.8	12.0

SLF - single location firm
HQS - headquarters

T test results:
SLF vs. Branch/Subs. significant at 0.05 (input source: Toronto)
SLF vs. HQS significant at 0.05 (input source: rest of world)

c) Input Linkages - Foreign Plants

The status of foreign plants can also be divided into two categories representing U.S. based multinationals and European multinationals. It is expected that local purchasing will be similar among these two categories although import sources may differ, reflecting a possible tendency to secure inputs through corporate channels. These results are displayed in Table 5.16.

Table 5.16: Input Sources Among American and European Plants: Mean, Standard Deviation and Difference of Means Test

Input Source	American (n=27)		European (n=10)			
	$\bar{X}$	$\bar{S}$	$\bar{X}$	$\bar{S}$	T ratio	prob
Toronto	29.0	24.7	29.4	32.5	0.04	.97
rest of Ontario	8.5	17.0	7.9	7.1	-0.15	.88
Canada - East	2.2	4.2	3.7	9.4	0.49	.63
Canada - West	0.5	1.4	0.2	0.6	-0.85	.40
United States	52.2	31.6	16.7	19.8	-3.30*	.00
rest of world	7.6	12.7	42.1	30.6	3.46*	.00

* sign. at 0.05

In this case, 27 of the 37 plants are American owned which again limits the reliability of statistical testing. However, the linkage expectations outlined above are in general evidence with both types of plants showing approximately equal tendencies in local and Canadian input purchasing. In addition, import sources are clearly affected by ownership as 87% of U.S. multinational imports originate from the United States. Similarly, European owned plants obtain 72% of their imports from abroad where it is assumed a large portion originates from their home countries.

2) Output Linkages

A similar methodology is used to explore the geographic dispersal of output linkages (Table 5.17). Unlike the case with input linkages where geographical patterns are largely shaped by availability factors, sales linkages may be interpreted to reflect company strategy and, in some instances, management success (Oakey et al.,1988). Evidence from the high technology sector shows that local sales are generally lower than local purchases, likely arising from the specialized nature and transportability of high technology industrial output (Oakey, 1984, 84).

Table 5.17: Sales Destinations by Ownership: Mean, Standard Deviation and Difference of Means Test

Sales Area	Domestic (n=43)		Foreign (n=37)			
	$\bar{X}$	$\bar{S}$	$\bar{X}$	$\bar{S}$	T ratio	prob.
Toronto	33.6	29.6	22.4	16.1	-2.12*	.04
rest of Ontario	12.5	12.6	16.0	11.8	1.27	.21
Canada - East	8.2	9.9	16.9	13.5	3.30*	.00
Canada - West	5.3	5.9	15.3	13.0	4.21*	.00
United States	29.6	28.1	22.2	28.0	-1.16	.25
rest of world	9.9	17.4	7.1	14.0	-0.76	.45

* significant at 0.05

On average, domestic plants sell a significantly higher percentage of output locally although the difference between ownership groups is not as distinct as on the input side. This translates into a higher level of regional exports among foreign plants (77.6%) compared to domestic plants (66.4%). Although there is not a significant difference in ownership means in Ontario, foreign plants distribute significantly higher proportions of their sales to other regions in Canada. Therefore, although foreign plants generate greater regional exports, their national export average (29.3%) is lower than the domestic export rate (38.5%). In addition, the relatively even distribution of foreign sales throughout Canada tends to confirm that foreign high technology branches are primarily interested in spreading sales throughout Canada rather than exporting their products. Alternatively, the 38.5 percent export rate of domestic firms points to their relatively good performance in entering international markets.

The poor exporting behaviour of foreign multinationals in Canada has been identified by Britton (1980) as another detrimental aspect of foreign manufacturing investment. The current results confirm that such an exporting pattern exists within high technology sectors, a situation which should be interpreted with some concern since the success of high technology companies is often thought to be contingent on penetrating international markets.

a) Output Linkages in the Toronto CMA

Table 5.18 investigates further the ownership differences in sales linkages within the Toronto CMA. Domestic plants are more equally distributed among the three output categories with most selling over 30 percent of their output locally. In contrast, foreign plants are bunched within the 10 to 30 percent category which may reflect a common local sales strategy among them. The more diversity in local output percentages among domestic firms may be reflective of a wider range of plant types and sales strategies. It seems that the largest percentage of domestic firms concentrate their sales effort on the local market, which may indicate a reluctance of some firms to expand their operations through exporting. The results also show that some domestic plants have moved a substantial proportion of their sales past the local market into other regions of Canada and abroad, which is indicative of an export led growth strategy.

Table 5.18: Percent of Total Output Sold in Toronto CMA by Ownership

Ownership	N	< 10%		10 - 30%		> 30%	
		n	%	n	%	n	%
Domestic	43	11	(25.6)	15	(34.9)	17	(39.5)
Foreign	36	6	(16.7)	24	(66.7)	6	(16.7)
Total	79	15	(19.0)	39	(49.4)	23	(29.1)

chi square = 8.25 p = 0.0161

In comparing aggregate local sales linkages in Toronto (28.5%) with other regions, similar levels are found in Montreal (Gilmour, 1974) and London (McDermott and Taylor, 1982) while local sales are generally higher in the lesser developed regions of Scotland (Lever, 1974 ; McDermott, 1976) and Northern Ireland (Hoare, 1978) (see Table 2.1).

Comparing ownership categories, domestically owned plants in Toronto tend to produce more regional exports than similar plants in other areas. To a lesser extent, this same pattern also exists with externally owned establishments (see Table 2.4). Therefore, it appears that high technology industries on the whole establish more dispersed forward linkages, suggesting that high technology agglomeration economies are more specific to local input purchasing.

b) Output Linkages - Domestic Plants

Domestic plants are again disaggregated into single location firms, headquarters and branch plant categories to see if their respective task environments vary (Table 5.19).

Table 5.19: Sales Destinations of Domestic Plants: Mean, Standard Deviation

Location	SLF (n=30)		HQS (n=7)		Branch/Subs (n=6)	
	$\bar{X}$	$\bar{S}$	$\bar{X}$	$\bar{S}$	$\bar{X}$	$\bar{S}$
Toronto	36.5	30.1	27.0	27.0	26.4	11.9
rest of Ontario	11.7	13.1	19.2	12.0	10.0	10.0
Canada - East	7.4	9.9	14.0	12.0	6.4	7.5
Canada - West	6.1	6.2	6.8	5.7	0.7	1.9
United States	27.8	26.9	20.8	7.9	45.0	36.6
rest of world	3.0	17.8	12.2	9.7	11.4	22.7

T test results:

SLF vs. Branch/Subs. significant at 0.05 (location: Canada-West)
HQS vs. Branch/Subs. significant at 0.05 (location: Canada West)

As expected, single location firms show the highest level of local sales orientation although a difference of means test does not reveal a significant difference between the three plant types in this respect. The only statistically significant difference occurs in the smaller sales linkages to western Canada among branch plants relative to single location firms and headquarters plants. While not significant, branch plants display the strongest export performance of the three, dispatching 45 percent of output to the United States and another 11.4 percent to other world markets. By comparison, 36.8 percent of single location firm output and 33 percent of headquarter plant output is exported.

c) **Output Linkages - Foreign Plants**

Turning now to foreign plants, the same analysis is applied to American and European plants in Table 5.20. The results show very similar sales linkages between American and European firms. Both concentrate the majority of their sales on the Canadian market showing an increased propensity towards east-west trade flows in contrast to domestic sales patterns. Both export approximately equal percentages to the United States, which may indicate that European plants serve a dual purpose of catering to both the Canadian and U.S. markets.

Table 5.20: Sales Destinations of Foreign Plants: Mean, Standard Deviation

Location	American (n=26)		European (n=10)			
	$\overline{X}$	$\overline{S}$	$\overline{X}$	$\overline{S}$	T ratio	prob
Toronto	22.0	15.0	23.4	17.4	0.22	.82
rest of Ontario	17.0	12.2	13.5	10.6	-0.79	.43
Canada - East	18.3	14.7	13.5	9.4	-0.95	.35
Canada - West	14.5	13.4	17.1	12.4	0.52	.61
United States	21.3	28.7	24.5	27.4	0.30	.77
rest of world	9.0	14.9	8.0	12.3	0.23	.82

* difference of means test shows no significant differences between American and European plants at 0.05 level of significance

5.2 Other Organizational Determinants of Local Linkages

Thus far attention has been focused on revealing geographical linkage patterns by ownership. While considerable differences were noted in our study, the literature also suggests that other aspects of plant structure will influence linkage patterns, especially in a local context. However, it is unlikely that any other organization characteristics will influence linkages to the extent of ownership. Indeed, most aspects of business structure are themselves dependent on ownership which suggests that examining the effects of other organizational characteristics should be carried out separately for each ownership category. To date, only Hagey and Malecki (1986) have investigated the effects of plant structure on high technology linkages although their work looks only at input linkages.

Simple correlation coefficients are used to relate various plant characteristics to the percentage of local input and output linkages among foreign and domestic plants. Unfortunately, the nature of the data collected precluded the application of multivariate statistical techniques that would have allowed the simultaneous effects of these variables on local linkages to be viewed. Therefore, the following results should be interpreted with this in mind.

5.21 Organizational Determinants of Local Purchasing

The first analysis looks at the association between various plant characteristics and local input sourcing (Table 5.21). Correlation coefficients between the percentage of local input linkages and plant characteristics are calculated separately for each ownership category.

Table 5.21: The Relationship Between Firm Characteristics and Local Purchasing: Simple Correlation Coefficients

Characteristic	Domestic		Foreign	
	n	corr.	n	corr.
size (emp.)	41	-0.21*	37	-0.21
% R&D (plant)	37	0.35**	33	0.13
% sci/engineers	41	0.01	35	0.10
age (years)	41	-0.15	36	-0.25*
no. prod. lines	41	-0.08	37	0.44**
environment	41	0.06	37	0.23*
autonomy - purch.	--	--	36	0.62**

* significant at 0.10
** significant at 0.05

Domestic Plants

The most important finding among domestic plants is the significant positive correlation (0.35) between R&D spending and local input sourcing. Thus, increased research effort may induce closer technical ties between suppliers and customers in which case spatial proximity may become particularly important. A similar relationship is found among locally owned high tech firms by Hagey and Malecki (1986). Such findings auger well for economic development strategies built around encouraging research and development. They also support the hypothesis that the development of agglomeration economies in high tech industries is dependent on research intensive firms. The expected negative relationship (-0.21) between size and local linkage indicates a tendency for smaller domestic firms to rely more on local suppliers. Combined with the findings on R&D, it would appear that small research oriented firms are those most likely to develop local input linkages in the domestic category. The remaining variables are not significant at the 10 percent level which is somewhat surprising in the case of the percent of scientists and engineers/workforce in light of the significance of R&D spending.

To examine the effect of production system on local input linkages, domestic plants were categorized into two groups based on whether mass production is used (Table 5.22).

Table 5.22: Percent Local Inputs by Production System: Domestic Plants

Production System	% local inputs
mass production (n = 7)	53.6
unit/small batch production (n = 36)	62.6
Total	59.6

T-test: T ratio = 0.87 p = 0.41

The small number of mass production plants in the sample limits the potential of making generalizations. Nevertheless, there is only a slight tendency for plants using mass production techniques to be less reliant on local suppliers. This suggests that production system does not have an appreciable effect on how domestic plants become linked with local suppliers.

Foreign Plants

From Table 5.21, it is apparent that a different set of plant characteristics influences the extent to which foreign plants become locally integrated. Most important is the positive relationship between purchasing autonomy, measured on a ten point scale, and local linkage. As expected, the more control that foreign plants have in making purchasing decisions, the increased likelihood of local linkage. Therefore, corporate strategy considerations are relatively more important than other more visible plant characteristics such as size or

R&D expenditures.

As the number of product lines increase in foreign establishments, so does the amount of local input linkage. A wider diversity of output may require a wider range of input requirements, thus leading to more local linkages. In addition, it is possible that corporate supply channels can fulfil only a portion of supply items when there are many input requirements.

There is also a tendency for local linkages to decrease as the age of foreign plants increase. This is contrary to the view that local integration increases with time as branch and subsidiary plants become more aware of local suppliers. However, other studies have also found that the age of externally owned plants does not positively influence local input sourcing (Marshall, 1979).

A positive relationship is also found between environment and local input linkages. In this case, environment is measured by the degree of product and production process change as well as the degree of competition perceived by firms. It would appear that the more environmental change and uncertainty that confronts firms, the higher will be their local supply linkages. This could be explained by the need for closer ties to suppliers when products and production techniques change with increased frequency.

Further support for this hypothesis is given by the positive signs associated with the plant technology variables of R&D (0.13) and skilled personnel (0.10) (Table 5.21). However, while a positive relationship exists between R&D and local input linkage, it does not achieve statistical significance as was the case with domestic plants.

Therefore, increasing R&D capability in foreign establishments will not lead to an appreciable gain in local input sourcing.

In order to observe the effects of production system on local linkages Table 5.23 differentiates between mass production plants and unit/small batch producing plants.

Table 5.23: Percent Local Inputs by Production System: Foreign Plants

production system	**% local inputs**
mass production (n = 10)	19.5
unit/batch production (n = 27)	32.7
Total	29.1

T-test: T ratio = 1.22 p = 0.23

There is a slight tendency for foreign plants using unit/small batch production to establish more local supply linkages than mass production plants which concurs with the findings of Marshall (1979) and O'hUallachain (1984).

5.22 Organizational Determinants of Local Sales Orientation

Attention is now turned to examining the plant specific influences of local selling behaviour (Table 5.24). In this analysis, correlation coefficients are used to measure the association between the percentage of sales sold within the Toronto CMA and various plant characteristics.

Table 5.24 : The Relationship Between Firm Characteristics and Local Sales: Simple Correlation Coefficients

Characteristic	Domestic		Foreign	
	n	corr.	n	corr.
size (emp.)	43	-0.20*	36	-0.36**
R&D (plant)	38	-0.09	33	0.05
% sci/engineers	43	-0.11	35	0.14
age (years)	41	0.15	36	-0.07
no. prod. lines	43	-0.05	36	0.40**
environment	43	-0.06	36	-0.03

* significant at 0.10
** significant at 0.05

Domestic Plants

The general lack of significance among the variables indicates that selling strategy cannot be easily related to various measurable plant characteristics. The only variable to attain significance at the 10 percent level is plant size. The negative relationship found here (-0.20) is expected since it is likely that larger plants will require wider market areas to sell greater quantities of output. The negative signs associated with R&D (-0.09) and percent of scientists and engineers in the workforce (-0.11) suggests that increasing plant sophistication leads to greater regional exports. While little research exists in this area, it is possible that research and development is a partial component of export strategy. It may also be that commitment to R&D will lead to more competitive products allowing firms greater access to more widespread markets.

Table 5.25 displays local sales orientation by production system among domestic plants. It is apparent that production system has little effect on local selling, which is contrary to the expectation that unit/batch producers will exhibit higher levels of local linkages.

Table 5.25: Percent Local Output by Production System: Domestic Plants

production system	**% local sales**
mass production (n = 7)	33.1
unit/small batch production (n = 36)	33.6
Total	33.6

T-test: T ratio = 0.04 p = 0.97

Foreign Plants

From Table 5.24, local sales orientation among foreign establishments is primarily associated with two variables: plant size and number of product lines. The expected negative relationship between size and local sales is found, showing a more pronounced influence compared to the domestic group. In addition, as the number of product lines per plant increases, so does the amount of local sales. Another contrast between the ownership categories is the positive relationship found between R&D spending, the percentage of scientists and engineers and local sales orientation. It may be that an increase in plant technology as measured by these two variables could induce more local sales among foreign plants although the relationship is not strong.

As shown in Table 5.26, foreign plants using mass production techniques tend to sell less output within the Toronto CMA. Since mass production is more frequently found in larger plants, it is likely that such results are also a reflection of size. Nevertheless, the effects of production method on local sales is more pronounced in foreign plants as opposed to domestic plants.

Table 5.26: Percent Local Sales by Production System: Foreign Plants

production system	% local sales
mass production (n = 10)	10.6
unit/batch (n =27)	26.4
Total	22.4

T-test: T ratio = 2.73 p = 0.01

5.3 Assessing Agglomeration Economies in the Toronto CMA

In order to comment on the extent of high technology agglomeration economies in Toronto, results are compared with the high technology surveys of Oakey (1984) and Bathelt (1988). This offers an opportunity to compare differences in regional integration among areas noted to be in varying development stages of high technology industry location. Since Oakey's sample is comprised of small independent firms only while Bathelt includes multilocational firms as well, comparisons are done separately for each, adjusting for these differences. In accordance with Bathelt, firms are assumed to be regionally oriented if they purchased over half of their input values or if they sold over half of their output values within the locally defined area. It should also be noted that Bathelt defined local as a 50 mile radius about sample plants while Oakey's local radius was smaller at 30 miles.

The first comparison looks at the regional orientation of single plant firms in the San Francisco Bay Area, South East England and Scotland. This is first done on the input side (Table 5.27). Since only 30 single location firms are in the current sample of which 29 supplied linkage information, the comparability among regions is somewhat constrained. However, based on the above table, it appears that local agglomeration economies for input purchasing are highly developed in the Toronto region for small single site firms. Twenty of twenty-nine of these firms (69 percent) purchase over 50 percent of their total inputs from within the Toronto region. While not surprising to find that significant local purchasing takes place in such a large industrial agglomeration like Toronto, it was not expected that levels comparable to the San Francisco Bay area would be encountered. As a possible explanation, the Silicon Valley region is noted for the actual design and fabrication of sophisticated microelectronic components that are basic inputs in many high technology products such as computers and scientific instruments. Toronto also has firms that supply these components but they are typically industrial distributors rather than manufacturing establishments implying a different structural characteristic of the Toronto agglomeration. By comparison, the South East region of England and Scotland have much lower levels of regional integration, reflective of local environments that are much less conducive to developing high technology backward linkages.

Table 5.27: Percentage of Single Site Firms Acquiring Over 50 Percent of Inputs From Local Area: A Regional Comparison (i)

Location	**N**	**more than 50% inputs from local area** n	**(%)**
South-East England	60	11	(18.4)
Scotland	54	6	(11.2)
San Francisco Bay	60	41	(68.3)
Toronto*	**29**	**20**	**(69.0)**
Total	203	78	(38.4)

* calculations from present study

source: Oakey (1984)

To make comparisons with Bathelt (1988), all survey plants are included, which may lead to interpretive problems since firm types vary from sample to sample. For instance, 55 percent of Bathelt's sample plants in the Canadian Technology Triangle (CTT) are single site firms compared to the 36 percent representation in the Toronto sample. Nevertheless, the figures given can be viewed as broad indicators (Table 5.28).

Table 5.28: Percentage of Firms Acquiring Over 50 Percent of Inputs From Local Area: A Regional Comparison (ii)

Location	N	**more than 50% of sales to local area**
Atlanta	25	39%
Research Triangle	29	30%
Boston	40	70%
CTT	32	47%
Ottawa	33	27%
Toronto*	**78**	**47%**
Total	237	43%

* calculation from present study

source: Bathelt (1988)

As expected, the Route 128 region around Boston shows the greatest regional orientation, reflecting its reputation as a leading high technology production centre in the United States. Toronto is most similar to the Canadian Technology Triangle area around Kitchener-Waterloo, which is surprising given the absolute size differences between these two areas. However, this similarity can be explained by the inclusion of the Toronto region in the CTT's local area, putting in range the vast array of suppliers in the Toronto and surrounding area. In addition, the larger number of independent firms in the CTT sample should also have an impact on these results. This tends to confirm that Toronto acts as a major supply and distribution centre for high technology industries located in surrounding communities. Firms in the Toronto CMA show greater regional orientation than firms in the Research Triangle Park of North Carolina, Atlanta and Telecom Valley in Ottawa. The relatively recent emergence of high technology manufacturing in these areas is a likely reason why regional supply linkages have not evolved to any great extent.

Attention is now turned to comparing the local output orientation of Toronto firms with those of the three regions studied by Oakey (1984). (Table 5.29). Again, the Toronto region is most similar to San Francisco although the difference between the regions is less pronounced than on the input side. In addition, regional orientation is much lower on the output side in all regions, likely a reflection of specialized nature of high technology output.

Table 5.29: Percentage of Firms Selling Over 50% of Output Within Local Area: A Regional Comparison (i)

Location	N	more than 50% of sales to local area	
		n	%
South-East England	60	16	(26.7)
Scotland	53	11	(20.8)
San Francisco Bay	60	20	(33.3)
Toronto*	**30**	**9**	**(30.0)**
Total	203	56	(27.6)

* calculations from present study

source: Oakey (1984)

Now comparing with Bathelt (1988), a similar situation is uncovered (Table 5.30). As in the previous comparison, local output orientation is low in all regions, Toronto being no exception. Coupled with the results from the input side, it would appear that high technology agglomerations are characterized by high levels of local input orientation but not necessarily high levels of local output linkage. To understand why this occurs, it is necessary to conceptualize how spatial proximity between suppliers and customers may arise in the various production stages that characterize high technology industries.

Table 5.30: Percentage of Firms Selling Over 50% of Output Within Local Area: A Regional Comparison (ii)

Location	**N**	**more than 50% of sales to local area**
Atlanta	25	14%
Research Triangle	29	18%
Boston	40	23%
CTT	32	25%
Ottawa	33	19%
Toronto*	79	**20%**
Total	238	20%

* calculations from present study

source: Bathelt (1988)

5.31 An Input-Output Interpretation of High Technology Agglomeration

Oakey (1984) draws attention to an important point when considering the implications of local input and output linkages. The output of component manufacturers will represent the inputs of producers in later production stages. Therefore, a chain of production can be imagined where materials and subassemblies are exchanged between linked firms that specialize in various intermediate product areas, finally converging at final assembly locations. It is Oakey's contention that noted high technology agglomerations such as Silicon Valley and the Route 128 area of Boston are exceptional because they specialize in the manufacture of both high technology components and high technology final products. Therefore, material linkages between these two types of producers are made in close spatial proximity where a tremendous growth in the number of small component producers has taken place as opportunities have arisen to supply final good producers with component inputs.

Implicit to the formation of such an agglomeration is the role of small firms to fill supply niches of larger firms. In addition, a basic locational necessity for this to occur is the presence of an innovative and entrepreneurial labour force that can react to these market opportunities. On the other hand, evidence from Toronto suggests that many components have been transplanted into the region through distribution and sales outlets (see Table 5.14) suggesting that value added need not occur in the local area for firms to enjoy the benefits of many local supply sources. Whether or not this has any effect on the efficiency of linkages in terms of support services and innovation behaviour has not yet been investigated.

The above scenario explains in part why high levels of local input orientation are found in high technology agglomerations. However, we are left to explain the relatively lower levels of local output orientation. This situation may result from the regional exporting behaviour of high technology industry in all stages of the production chain. For instance, Oakey (1984) notes that Silicon Valley firms export not only final demand goods such as computers, but also printed circuit boards and other custom designed components. In this sense, component producers can serve a dual purpose of supplying local market niches in addition to exporting their products, ensuring regional exports in all facets of high technology manufacturing. To determine whether such a scenario has developed in Toronto, sample firms were divided into component and final good producers by ownership (Tables 5.31, 5.32).

Table 5.31: Percent Local Input/Output of Component Producers and Final Demand Good Producers: Domestic Plants

Product	n	% Input-Tor.	n	% Output-Tor.
Component	14	60.5	16	38.4
Final Demand	27	61.4	27	30.7
Total	41	61.1	43	33.6

Table 5.32: Percent Local Input/Output of Component Producers and Final Demand Good Producers: Foreign Plants

Product	n	% Input-Tor.	n	% Output-Tor.
Component	15	28.7	14	21.1
Final Demand	22	29.4	22	23.3
Total	37	29.1	36	22.4

It is not surprising to find that component producing domestic plants sell more of their output locally than final good producers. It is notable however that these firms export 60 percent of their output beyond the Toronto region. The lower regional orientation of component producing foreign plants is likely due to their more standardized and larger scale manufacturing processes. Local suppliers are used with approximately equal frequency among component and final good producers in both ownership categories. In summary, these results confirm the regional export orientation of component and final good producers supporting the notion that all areas of the high technology production chain are export oriented.

Summary

The findings in this chapter indicate that, comparatively speaking, substantial agglomeration economies have developed in the Toronto CMA for high technology industries as measured by the degree of local linkage. However, this situation does not apply in a general sense but is specific to certain types of high technology plants. In particular, local linkages are especially well developed among domestic firms compared to foreign owned establishments. In addition, agglomeration advantage applies mainly to local input sourcing, a consistent finding in most studies of high tech linkages. An implication gathered from these results is that not all high technology firms will provide the same regional benefits in terms of generating spatially concentrated input and output linkages.

CHAPTER 6

Summary and Implications

This study has investigated the spatial linkage patterns associated with high technology industries in a sample of 80 firms in the Toronto CMA. It is somewhat surprising to find a general lack of research in this area despite the strategic importance often attributed to high technology industry in regional development. Particular research emphasis was placed on analyzing the impact of plant structure on linkage patterns. In general, the results confirm important differences in linkage patterns between foreign and domestic firms. Other aspects of organizational structure within the two ownership categories were also found to affect firm linkage patterns, the most important of which is research and development. These firm level differences are important from a developmental standpoint since local input-output flows are generally regarded as an indicator of agglomeration economies and a contributing factor in regional high technology growth.

High Technology Firm Characteristics

The analysis of firm characteristics was structured around revealing differences between foreign and domestic firms. In general, the results indicate contrasting organizational structures between the two which is expected to arise out of the much different corporate circumstances surrounding them. Some of the more important structural characteristics and their regional development implications are summarized below.

<u>1) Employment:</u> Employment changes in sample firms indicate the high technology sector to be an expanding segment of the Toronto economy. Between 1980-1989 employment in the firms surveyed increased by 35 percent. Somewhat surprising were the higher growth rates observed in foreign multinationals which expanded by 36.8 percent compared to the 25 percent level of domestic plants in the same time frame. Such employment growth should auger well for economic development policies that encourage foreign high tech investors to locate in Canada. It should also counter some of the arguments against foreign ownership since employment growth is often regarded as the bottom line in economic development strategies. However, there are other aspects of foreign ownership that are cause for concern such as innovation behaviour and linkage patterns, which are less visible but perhaps equally important for future growth prospects in high technology industries.

<u>2) Research and Development:</u> Levels of R&D spending show that sample plants were not overly research intensive with 44 percent of them falling below the 3 percent level of sales specified in the definition (see Table 4.18). As expected, foreign plants tended to spend a lesser percentage of sales on R&D than domestic establishments. Such differences in R&D commitment between foreign multinationals and domestic plants has raised concerns over the effects of foreign ownership in host countries (ie. Firn, 1975 ; Britton and Gilmour, 1978). While the effects of foreign R&D behaviour on the Canadian economy have been debated primarily on economic grounds (ie. Britton and Gilmour, 1978 ; Safarian, 1979), the present study introduces a spatial effect which should also be

considered. Enhanced levels of R&D spending tends to induce more local input linkages in the Toronto region, promoting local high technology multiplier effects and agglomeration economies that may assist in the innovation process. In this sense, lower R&D spending by multinationals may preclude their involvement and contribution to a spatially integrated high technology environment.

3) Age: The Toronto region may be considered a mature high technology region based on the age structure of sample firms, especially in the foreign category. In this respect, Toronto is similar to the Route 128 region of Boston. Within the total sample, 25 percent of sample firms located in Toronto before 1960, similar to the 28 percent of firms in this age category found in Boston (Bathelt, 1988). By comparison, only 3 percent were found to be in this age bracket in Ottawa (Bathelt, 1988). Among foreign owned plants, 42 percent existed since before 1960 compared to 12 percent of domestic plants (see Table 4.12). Therefore, a high proportion of foreign high technology investment occurred prior to the growth of indigenous high technology manufacturing and also before the onset of the microelectronics revolution in the 1960's. It would therefore appear that foreign plants have adapted and transformed their product lines over the years to stay within the high technology sector.

4) Production Techniques: High technology industry in Toronto is geared towards flexible production methods. It is expected that the overall small size of sample firms, even within the foreign category, accounts for the predominance of unit and batch production techniques. It is also likely that the nature of the industries defined and their product markets induce shorter production runs. Using R&D as the criterion and

setting the cutoff level at twice the national manufacturing average excluded some industries whose products have achieved standardized design and mass production. This may be considered a strength of the current definition.

Ownership and Linkages

The effect that ownership has on linkage patterns is quite striking, especially on the input side. Domestic plants were found to purchase 61 percent of their input values from sources in the Toronto CMA. The equivalent value for foreign plants was just 29 percent. From a national perspective, domestic plants import an average of 28.5 percent from other world suppliers compared to the 60 percent level of foreign plants (see Table 5.12). While such high import penetration among foreign plants should be cause for concern, the widespread use of distributors, particularly among domestic plants, complicates the application of the multiplier concept to these measures. Accounting for over 71 percent of local domestic purchases and 48 percent of foreign purchases, distributors have emerged as an important component of local agglomeration economies in Toronto. Linkages with local manufacturers would in a sense be preferable since they would allow for more direct communication ties between suppliers and customers which may be critical when collaborating product designs and specifications. Since distributors typically carry standardized products, there may be less opportunity for firms to acquire specialized custom designed components which could possibly limit the potential for upstream and downstream innovation between component and equipment manufacturers.

Output linkages show a more dispersed pattern than input linkages reflecting the regional export nature of high technology plants. While foreign plants show greater regional exports (77.6%) than domestic plants (66.4%), from a national perspective, domestic plants export 39.5 percent beyond the Canadian marketplace compared to the 29.3 percent level of foreign establishments (see Table 5.17). Whetner or not the comparatively poor exporting performance of foreign plants is of strategic concern is questionable since their low exports are more a result of corporate sales strategies than a sign of competitive weakness. However, some argue that the existence of foreign multinationals prevents the development of indigenous technological capacity in these industries which, if allowed to develop, could potentially lead to greater exports than their foreign counterparts (Britton, 1985). In the case of domestic plants, especially single location firms, export levels should be evaluated differently since entry into international markets is generally regarded as a key to high technology success in a small open economy such as Canada. With domestic plants exporting an average of almost 40 percent of output to other world markets, it appears that indigenous high technology companies have met with considerable success in entering foreign high technology markets. The United States is clearly the most dominant export market, accounting for almost 75 percent of total exports, an equivalent level to Canadian manufacturing in general (Beamish and Munroe, 1986).

Local Linkages and Plant Structure

Simple correlation coefficients were used to relate other organizational variables to local linkages within each ownership category. Among domestic plants, the only variable to affect local input linkages significantly was R&D. The positive relationship found here corresponds with earlier findings by O'hUallachain (1984) and Hagey and Malecki (1986), demonstrating that regional input interaction increases as domestic plants become more R&D intensive. The expected negative relationship between plant size and local input linkage was also found although it is not as strong as the R&D effect. These results point to the importance of small research oriented firms in the development of spatially integrated high technology growth. From a policy stance, it would therefore be desirable to create an environment that would encourage the development of these types of firms.

The results from the foreign category show a different set of plant variables to influence local inputs, the most important of which is the amount of purchasing autonomy delegated from headquarter plants. The strong positive correlation here suggests that corporate purchasing strategies are a primary cause for the differences seen in local purchasing behaviour among foreign-owned plants. There is also a tendency for plants using mass production techniques to establish fewer local ties which may indicate that input structures of such firms are less conducive to generating local linkages. Also observed was a positive relationship between the number of product lines and local input linkages, a situation which probably arises out of the more variable input structures of multiple product plants.

The most important difference between the two ownership types concerns the effects of R&D on local input sourcing. While the relationship is positive in both ownership categories, R&D does not significantly induce more local inputs in foreign plants. It might be hypothesized that R&D in Canadian firms may arise out of or be aided by local supply conditions whereas in foreign firms, it is more likely prompted by corporate strategies rather than the offerings of the local environment. Whatever the case, R&D in foreign branches does not produce the same integrative effects observed in domestic plants.

Turning to local sales linkages, differences were again noted between the two ownership groups. The only variable to achieve significance at the ten percent level among domestic plants was plant size, suggesting that selling strategy cannot be easily related to plant characteristics. Alternatively, a stronger negative relationship between plant size and local sales was found among foreign plants. As expected, foreign plants using mass production techniques sold much less output locally, contrasting with the negligible effect of this variable in domestic plants. Foreign plants that produce many product lines also tend to sell a higher percentage of output locally which may be a reflection of the effects of more flexible production systems.

To determine the extent to which high technology agglomeration economies have developed in Toronto, comparisons were made with Oakey (1984) and Bathelt (1988). On the input side it was surprising to find that comparable local purchasing existed between single site firms in

Silicon Valley and the Toronto region. However, the widespread use of industrial distributors for inputs in Toronto suggests a different form of agglomeration, one that is not based on local value added in the component stages of production. Comparisons with Bathelt (1988) reveal well developed local input ties in Toronto compared to Ottawa, The Research Triangle Park and Atlanta, each of which have only recently developed high technology industrial bases. The greater regional orientation of firms in Boston was expected. However, it was somewhat surprising to see that similar levels of local sourcing exists in the Kitchener-Waterloo (CTT) area in Canada. The inclusion of Toronto in the local area surrounding the CTT likely accounts for the great amount of local purchasing found in this area, also hinting at the important influence Toronto has as a distribution centre for high technology inputs in southern Ontario.

Comparisons of local output linkages showed much greater homogeneity among all the regions studied by Bathelt and Oakey, including Toronto. From this it can be concluded that local sales is not an integral part of high technology agglomeration economies. This situation is expected to arise out of the sophisticated nature of high technology products which induces exporting among both component and final good producers.

High Technology Linkages and the Principle of Agglomeration

At a broad level, explanation of high technology agglomeration has usually been accomplished using two separate frameworks. At a macro-scale, agglomeration is viewed in an aggregate sense as the tendency of high tech industry to cluster in certain regions. While a general theory of high technology agglomeration does not exist, there nevertheless has been a tendency for geographers to interpret spatial agglomeration as an additional facet of theories such as the product life cycle of Vernon (1966) and the theory on temporal waves of innovation (Kondratieff, 1935; Schumpeter, 1939). Thus, the tendency for certain regions to become seedbeds of R&D and product innovations introduces a locational dimension to the historical and economic processes of industrial innovation. At a micro-scale, agglomeration is viewed in a more dynamic sense as locational benefits that accrue to individual high tech establishments that are in close proximity to one another. This study has concentrated on one such firm level benefit - local linkages.

The findings at micro level appear to complement macro level observations in that R&D oriented firms tend to establish the most local linkages, implying greater spatial concentration in early product development stages. Thus, it may be hypothesized that spatial linkage ties converge over space as plants become more technologically sophisticated, presumably to achieve greater accessibility in terms of acquiring both sophisticated material components and high level technical information associated with them. Alternatively, linkage ties appear to become more widespread as plants undertake more routine production and are able to draw on corporate sources for standardized input requirements. Thus, we may expect high technology agglomerations dominated by branch plants to have predominantly non-local linkages which may in turn limit future growth potential in terms of regional multiplier effects, spin-offs and innovation performance.

The findings also suggest that the linkage effects of R&D are not homogeneous across all plant types, just as R&D is not homogeneous to all plants within high technology industries. With regard to the second point, it should be obvious that R&D is not exclusive to high technology industries and therefore, the convergence of linkage ties can be expected to occur for any R&D oriented plant regardless of its industrial category. In this respect, the title of high technology becomes somewhat artificial at plant level. Nevertheless, we may expect a greater proportion of R&D oriented firms will be within high technology industries because of their greater overall R&D intensity. Secondly, the analysis also revealed that R&D in foreign establishments does not produce a significant increase in local input sourcing to the extent seen in domestic firms. This suggests that the most propulsive form of R&D is conducted in locally owned establishments. An example of this may be seen in the Research Triangle Park in North Carolina where the attraction of R&D facilities of major corporations apparently has not spurred substantial development of local linkages and spin-offs (Malecki, 1986). It is possible that such R&D is undertaken independent of local economic conditions.

Conclusion and Directions For Further Research

Since a very limited microelectronics industry exists in Canada, it has been suggested that the potential in the high technology sector lies in the application of technology and not in technology itself (Williams, 1984). While this means a long-term reliance on countries such as Japan and the United States for advanced microelectronic devices, it does not necessarily imply a competitive weakness in the many application areas of microelectronics that are emerging. As Williams later states, "Let Silicon Valley become the hewers of wood and drawers of water for a change." (p.59). Indeed, sophisticated electronic components have become an almost ubiquitous resource in the Toronto region, providing benefits of accessibility to user companies without actually having local value added.

This application oriented environment of high technology production in Canada has important spatial implications for regions attempting to develop integrated high technology growth. The current results indicate that distributors have become an important functioning aspect of high technology agglomeration economies in Toronto. It may be hypothesized that increasing the range and quality of semiconductor components held by local distributors will in turn increase the potential for local firms to innovate in application areas. The current results showing research oriented firms establishing more local linkages implies that proximity to component suppliers, whether distributors or manufacturers, may aid in the innovation process. Obviously, the mere presence of components will not in itself lead to greater local linkages and innovation. A basic prerequisite for such growth processes to occur is a talented supply of entrepreneurial labour that can make use of these components in various application areas. Nevertheless, their presence may be expected to have some effect, especially for firms that are considering product or production process innovations or those which are in the midst of such efforts.

A number of important research issues may be raised from this study. First, from a methodological standpoint, there is a need for more consistency in linkage measurement and in presenting findings so that cross study comparisons can be made more easily and accurately. Secondly, at present the explanation of mechanisms which induce relatively greater local linkages in R&D oriented plants relies more on intuitive reasoning rather than empirical evidence. Further research could therefore focus on determining the significance and perhaps the efficiency that spatial proximity between suppliers and customers brings to the R&D process. Lastly, the significance of local distributors in the formation of high tech agglomeration economies in Toronto warrants further research into their role in high technology firm creation and innovation. Specifically, where do distributors of these products locate and why, and could their location be influenced by policy measures? And also, would the establishment of distributor outlets aid in developing entrepreneurial success and innovation in lagging regions? If this is the case, high technology agglomeration economies may be more footloose than originally thought, provided that entrepreneurial and technical skills are present.

Appendix A

High Technology Industry Definition: Markusen et al. (1986)

SIC	Industry
376	space vehicles and guided missiles
357	office computing machines
381	engineering, laboratory and scientific instruments
366	communications equipment
383	optical instruments and lenses
286	industrial organic chemicals
372	aircraft and parts
283	drugs
291	petroleum refining
382	measuring and controlling instruments
367	electronic components and asswmbly
281	industrial inorganic chemicals
282	plastics and synthetic resins
351	engines and turbines
348	ordnance
289	miscellaneous chemicals
386	photographic equipment
362	electrical industrial apparatus
361	electrical transmission equipment
353	construction equipment
285	paints and varnishes
303	reclaimed rubber
356	general industrial machinery
374	railroad equipment
365	radio and TV receiving equipment
287	agricultural chemicals
354	metal working machinery
384	medical and dental supplies
284	soap

Appendix B

High Technology Industry Definition: Riche et al. (1983)

SIC	Industry
131	crude petroleum and natural gas
162	heavy construction, except highway and street
281	industrial inorganic chemicals
282	plastic materials and synthetics
283	drugs
284	soaps, cleaners and toilet preparations
285	paints and allied products
286	industrial organic products
287	agricultural chemicals
289	miscellaneous chemical products
291	petroleum refining
301	tires and inner tubes
324	cement, hydraulic
348	ordnance and accessories
351	engines and turbines
352	farm and garden machinery
353	construction, mining, material handling machinery
354	metalworking machinery
355	special industry machinery, except metalworking
356	general industrial machinery
357	office, computing and accounting machines
358	refrigeration and service industry machinery
361	electric transmission and distribution equipment
362	electrical industrial apparatus
363	household appliances
364	electric lighting and wiring equipment
365	radio and TV receiving equipment
366	communication equipment
367	electronic components and accessories
369	miscellaneous electrical industry
371	motor vehicles and equipment
372	aircraft and parts
376	guided missiles and space vehicles
381	engineering, laboratory, scientific equipment
382	measuring and controlling instruments
383	optical instruments and lenses
384	surgical, medical, and dental instruments
386	photographic equipment and supplies
483	radio and TV broacasting
489	communication services
491	electric services
493	electric, gas and other utility services
506	wholesale trade, electrical goods
508	wholesale trade, machinery equipment
737	computer and data processing services

7391 research and development laboratories
891 engineering, architectural and surveying services
892 noncommercial scientific research organizations

Appendix C

High Technology Industry Definition: Newton and O'Connor (1987)

Industry

Mining - uranium ores
Mining - oil and gas
Services to mining NEC (undefined)
Mining exploration (own account, undefined)
Services to mining NEC (petrol exploration)
Services to mining NEC (mineral exploration)
Services to mining N[illegible] (mining exploration)
Manufacturing - synthetic resins and rubber
Manufacturing - organic industrial chemicals
Manufacturing - pesticides
Manufacturing - petroleum refining
Manufacturing - alumina
Manufacturing - electronic equipment
Electricity - generation, transmission, distribution
Water supply - storage, purification, distribution
Office and business machines wholesalers
Finance, property and business services - surveying services
Finance, property and business services - technical services
Finance, property and business services - data processing
Universities
Research and scientific institutions
Meteorological services

Appendix D

High Technology Industry Definition: Breheny and McQuaid (1985)

SIC	Industry
2570	Pharmaceutical products
3302	Electronic data and processing equipment
3441	Telegraph and telephone apparatus and equipment
3442	Electrical instruments and control systems
4443	Radio and electronic capital goods
3444	Non-active electronic components
3453	Active components and electronic sub-assembly
3454	Electronic consumer goods and other electronic equip.
3640	Aerospace equipment manufacture and repairing
7902	Telecommunications

Appendix E

High Technology Industry Definition: Riche et al., (1983)

SIC	Industry
283	Drugs
357	Office, computing and accounting machines
366	Communication equipment
367	Electronic components and accessories
372	Aircraft and parts
376	Guided missiles and space vehicles

Appendix F

High Technology Industry Definition : U.S. International Trade Administration (1983)

SIC	Industry
376	Guided missiles and spacecraft
365	Radio and TV receiving equipment
366	Communications equipment
367	Electronic components
372	Aircraft and parts
357	Office and computing machines
348	Ordnance and accessories
283	Drugs and medicines
281	Industrial inorganic chemicals
38	Professional and scientific instruments
351	Engines and turbines
282	Plastic materials and synthetics

Appendix G

High Technology Industry Definition: Britton (1986)

SIC	Industry
357	Business machines
359	Other machinery
372	Aircraft parts
366	Communications equipment
283	Drugs and medicine
391	Scientific and professional equipment

Appendix H

High Technology Product Groups: Statistics Canada (1987)

1. aerospace
2. computers
3. electronic equipment
4. telecommunications equipment
5. scientific instruments
6. electrical machinery
7. non-electrical machinery
8. chemicals

Appendix I

SURVEY OF HIGH TECHNOLOGY PLANTS IN METROPOLITAN TORONTO

A) GENERAL PLANT CHARACTERISTICS

1. Ownership of organization. domestic _____ foreign _____

2. Status of plant.

   a) _____ subsidiary (go to 3)
   b) _____ branch plant (go to 3)
   c) _____ single location firm (go to 6)
   d) _____ headquarters of multisite company (go to 6)

3. Where is parent company headquarters located? (city, province/state)
____

4. How many other plant locations are there in Canada? _____ rest of world _____

5. When was this plant established? ______

6. When was parent company established? ______

7. How many employees had this plant in 1980 _____ 1985 _____ 1989 _____

8. How many are directly employed in production? ______

B) PRODUCT AND PRODUCTION CHARACTERISTICS

9. How many product lines does this plant produce? ______

10. For how long have you produced your main product line? ______

11. For this main product line, how would you rate the following?

   i) level of competition 1 2 3 4 5
   ii) frequency of product design change 1 2 3 4 5
   iii) frequency of production process change 1 2 3 4 5

12. What is the dominant method of production at this plant? (circle appropriate answer)

a) unit/prototype production b) small batch c) routinized mass production

C) RESEARCH AND DEVELOPMENT

13. Estimate R&D expenditures (as a percent of sales) at this plant ______ at corporate level ______

14. How many university degreed scientists and engineers are there in this plant's workforce? ______

15. At this plant, is there a: a) separate R&D department b) part-time R&D department c) no R&D department

16. If there is a separate or part-time R&D department, how many does it employ? ______

17. What type of R&D is carried out at this location?
a) basic scientific research b) product R&D c) process R&D

18. For plants with headquarters located elsewhere, what degree of control does this plant have in the following areas? (1 = none ; 5 = full control)

i) developing short-range R&D programs	1	2	3	4	5
ii) developing long-range R&D programs	1	2	3	4	5
iii) altering/improving R&D directives sent from headquarters	1	2	3	4	5

D) PURCHASING

19. Is there a separate purchasing department at this plant? (Y/N) _____

20. How many are employed/involved in purchasing functions? ______

21. For plants with headquarters located elsewhere, what degree of control does this plant have in the following areas?

i) recommending need for new suppliers	1	2	3	4	5
ii) choosing suppliers	1	2	3	4	5

E) MARKETING

22. Is there a separate marketing department at this plant? (Y/N) _____

23. How many are employed/involved in marketing functions? _______

24. For plants with headquarters located elsewhere, what degree of control does this plant have in the following areas?

i) pricing	1 2 3 4 5
ii) distribution	1 2 3 4 5
iii) marketing research	1 2 3 4 5
iv) product planning	1 2 3 4 5

F) SALES

25. How many are employed/involved in sales functions? ______

26. For plants with headquarters located elsewhere, what degree of control does this plant have in the following areas?

i) defining geographical extent of sales area	1 2 3 4 5
ii) choosing customers	1 2 3 4 5

G) PRODUCTION INPUTS AND OUTPUTS

27. Approximately what percentage (by value) of your input purchases (raw materials/components) are acquired from the following areas? (Toronto region extends to Oakville, Brampton, Newmarket and Pickering).

_____% Toronto region
_____% rest of Ontario
_____% Canada - East
_____% Canada - West
_____% United States (indicate top two states ______________________)
_____% rest of world

28. What percentage of your Toronto region input values come from distributors? ______

29. Approximately what percentage of your total sales go to these regions?

_____% Toronto region
_____% rest of Ontario
_____% Canada - East
_____% Canada - West
_____% United States (indicate top two states ______________________)
_____% rest of world

H) TOP TWO INPUT PURCHASES

30. What are your two largest material input purchases (by total value) that go into the production of your final products?

INPUT 1: ____________________
INPUT 2: ____________________

31. How often does the design of each input change?

INPUT 1: a) monthly b) yearly c) 2 - 5 years d) over 5 years
INPUT 2: a) monthly b) yearly c) 2 - 5 years d) over 5 years

32. How much communication do you have with the supplier of each input?

INPUT 1: a) large amount b) moderate amount c) low amount
INPUT 2: a) large amount b) moderate amount c) low amount

33. How technologically sophisticated are these inputs?

INPUT 1: a) highly technical b) moderately technical c) non-technical
INPUT 2: a) highly technical b) moderately technical c) non-technical

34. What kind of contact do you usually have with suppliers of these inputs?

INPUT 1: a) face to face b) telephone c) mail/fax d) other
INPUT 2: a) face to face b) telephone c) mail/fax d) other

35. Is the supplier of each input a, (multiple answers possible)

INPUT 1: a) manufacturer b) distributor c) subcontractor
INPUT 2: a) manufacturer b) distributor c) subcontractor

36. Where are the suppliers of these inputs located? (check)

INPUT 1	INPUT 2	LOCATION
______	______	Toronto region
______	______	rest of Ontario
______	______	Canada - East
______	______	Canada - West
______	______	United States
______	______	rest of world

I) MAIN PRODUCT LINE

37. How often does the design of your main product change?

a) monthly b) yearly c) 2 - 5 years d) over 5 years

38. How much communication do you have with customers of your main product?

a) large amount b) moderate amount c) low amount

39. How technologically sophisticated is this product?

a) highly technical b) moderately technical c) non-technical

40. What kind of contact do you normally have with customers?

a) face to face b) telephone c) mail/fax d) other

41. Is your main product a,

a) sub-assembly/component b) final demand product - industrial / professional / government c) final demand - consumer

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