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Technological development in Mississauga and Canada's Technology Triangle: A calibrated application of the product life cycle

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TECHNOLOGICAL DEVELOPMENT IN MISSISSAUGA AND CANADA'S TECHNOLOGY TRIANGLE: A CALIBRATED APPLICATION OF THE PRODUCT LIFE CYCLE

By

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B.A., University of Toronto, 1987

THESIS

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CHAPTER 1 INDUSTRIAL DEVELOPMENT AND THE THEORY OF LIFE CYCLES

1.0 TECHNOLOGICAL CHANGE, HIGH TECHNOLOGY AND THE PRODUCT CYCLE

There is little doubt that the following decades will unfold many problems associated with economic and socio-economic change in advanced countries. Technology is increasingly accepted as a forceful agent in society. (Premus, 1988; Zegveld, 1988) The result has been a wave of excitement over the potential of using technology intensive industry for regional development. Indeed, enthusiasm over high technology and R&D endeavours persist despite serious uncertainties over the connection between the two. (Malecki, 1986, p.51) The uncertainty that surrounds the concept of technological related development has its roots in the somewhat nebulous notion of high technology. High Technology, in its broadest sense, is defined as 'some discernable technical sophistication' and often depends on subjective criteria that are only minimally standardized. Despite the semantics involved, the technology intensive industrial sector is perceived to be more immune to both cyclical and structural changes in the economy. (Malecki, 1990; Oakey, 1988) This is especially significant since the successes associated with concerted high technology activity cannot be attributed to peculiarities in its firm size, structure, or prevailing organization type. In fact, the advantages associated with high technology in regional economic development are largely rooted to the nature of production (ie. the *dynamics* of high tech industrial behaviour) that predominates the technology intensive sector. (Armington, 1986, p.75)

Among the most effective paradigm that has been adopted to deal with the complexities of technological change is the product life cycle. (Storper, 1985) Whereas the old tradition of regional growth theory has tended to deal with static point of time relationships (ie. the rate of industrial development), the new tradition of regional science often emphasizes the dynamic, and even unstable, nature of the modern capitalist economy (ie. the *dynamics* of industrial growth). The product life cycle serves as a classic example of this 'new' tradition in regional science. In more specific terms, the product life cycle focuses on the nature, rather than the rate of technological change in existing industries. This difference in emphasis is a significant one since the nature of industrial and technological change is not easily quantifiable. Consequently, the procedures involved in the examination of industrial dynamics require at least some minimum threshold of simplification and categorization. Despite this need to simplify from the real world, the product life cycle provides a powerful body of theory that is capable of dealing with today's essentially dynamic and unstable economic and industrial environment. (Markusen et al., 1986, p.136)

1.1 TOPIC OF RESEARCH

The proposed thesis is an examination of high technology industrial development as it is occurring within Canada's industrial heartland. For several years now, high technology research has been the focus of many academics, both within Canada and abroad. (Bathelt and Hecht, 1990; Torretto, 1990; Malecki and

Nijkamp, 1988; Scott and Angel, 1987; Britton and Gertler, 1986; Hall and Markusen, 1985) In fact, some have concluded that the road to national and regional economic prosperity is best served by 'breeding', and later nurturing, a network of technology intensive firms (Malecki, 1989; Rothwell, 1983). These very same innovative clusters foster and maintain sophisticated and efficient systems of technological transference. (Debresson, 1989, p. 2) On the other hand, these prominent examples of technology oriented complexes remain unique. The result of such technological development is an industrial landscape that is increasingly divided into high technology and low technology production arrangements; an industrial landscape that is being divided into prospering and dying regional and local economies. (Gibbs and Edwards, 1985, p.164)

In Canada, the most classic case of concentrated high technology industrial activity is found in Mississauga and the CTT. (Bathelt, 1989; Britton, 1985) In the past, Toronto's technology oriented complex has been considered the hub of Canadian innovative activity. In more recent years, a reorientation of Canada's high technology capital has supposedly occurred. Indeed, Ottawa is labelled, by some, as 'Silicon Valley North'. (Steed and Nichol, 1985; Sweetman, 1982) Although these claims are the source of contention, they do suggest that the capacity to innovate has become more 'footloose' and less focused in the sense that several centres have become the recipients of impressive levels of indigenous technological development. (Sweetman, 1982) One such centre is known as Canada's Technology Triangle or the CTT. (Bathelt and Hecht, 1990)

Comprised of Kitchener, Waterloo, Cambridge and Guelph, *Canada's Technology Triangle* (CTT) has been on the receiving end of many flattering accolades. (Bathelt, 1989) But such merits and acknowledgements have not been subjected to adequate scrutiny. For this reason, it is necessary to observe the magnitude and nature of technological development within the Canadian Technology Triangle and the Toronto area. Specifically, high technology performance will be evaluated with respect to the levels of technology intensive growth being experienced. Due to the scope of Toronto's technology oriented complex, the evaluation of industrial and technological development in the Toronto area will be limited to comparisons and contrasts drawn from Mississauga's industrial community. It is expected that the level of high tech industrial development in Mississauga and the CTT (as represented by the presence of high technology firms in the cities of Mississauga, Kitchener, Waterloo, Cambridge, and Guelph) will be substantial and will not vary significantly across the region.

In the past, the state of technological development in a given region has typically been limited to absolute counts on such criteria as the presence of high technology firms, universities, government research facilities, and the like. (Bathelt, 1989; Steed and Nichol, 1985) This is very much the product of traditional location theory that, by its very nature, is inherently static. Although such analysis says a good deal about the presence or absence of technological development, it says little about the nature and state of technological development. It is not by coincidence, though, that the science of regional industrial development has been limited to bivariate and tabular forms of scrutiny. The scarcity of flexible forms of statistical analysis has resulted in a form of complacency that has undermined the theory of regional growth.

Perhaps the most overlooked model in regional industrial science is that of the Product Life Cycle (PLC) and its antecedent, the innovation life cycle (ILC). The theory of life cycles implies that competitiveness is linked to market oriented product innovation and that continued competitiveness and sales are linked to continuous innovations affecting both product performance and manufacturing process efficiency. (Rothwell and Zegveld, 1985, p.19) This pattern of evolving competitiveness, while sinuous in nature, is regular and predictable. Also, the evolutionary pattern can be broken down into a series of stages that are based on qualitative criteria (ie. the nature of the product line, production process, and labour force). It is within this context that *calibration* (the means by which a model is quantified) of the PLC and ILC has been impracticable. In recent years, the science of categorical data analysis has realized great strides in bridging the gap between traditional statistical analysis and the realities of categorical data. (Wrigley and Nijkamp, 1985; Ben-Akiva and Litnas, 1985) One vehicle that has simplified the analysis of soft-data is the multinominal logit model. Although other techniques exist, the logit model can prove effective in the calibration of the product life cycle model.

In summary, the primary objective of this dissertation is the application of the product life cycle to high tech firms in order to analyze, effectively, industrial and technological development within Mississauga and the CTT. Central to this objective is the calibration of the life cycle models by the discrete choice statistical procedure known as logit modelling. Inevitably, the calibration of the product life cycle model at a *multivariate* level (ie. the simultaneous consideration of all explanatory variables) will require the strength of a statistical technique that is capable of handling dependent variables that are of a low order and descriptive nature - the multinomial logit model has been selected as the means to these ends.

1.2 PERTINENCE OF RESEARCH

The proposed thesis is of particular importance to the science of regional industrial analysis. In more specific terms, the principal objective of this dissertation pertains to the calibration of the product and innovative life cycles, two of the more widely recognized frameworks within the realm of regional industrial science. It will be emphasized, here, that the theory of product life cycles is a descriptive model that, to date, has not been calibrated in any refined manner. Because of the calibration procedure, it is expected that the present understanding of industrial development in Mississauga and the CTT will be both enlarged and enhanced.

1.3 PROCEDURAL ANALYSIS

DATA SOURCES

The data used for statistical analysis in this study was obtained at the firm level through a questionnaire survey (Appendix A). The survey was pursued via personal interview and via mail in cases where personal interviews were not possible (of the 164 sample firms, 46 were surveyed in person while the remaining 118 were surveyed by mail). Data obtained from the questionnaire was the source of information needed to calibrate the two life cycles. Besides this, several supplementary questions provided information pertaining to locational preferences, linkage patterns, and other important general information.

The firms surveyed were those firms that have Standard Industrial Classification (SIC) codes analogous to traditional key technology industries. (See: Bathelt, 1989, p. 91) The industries and four digit SIC codes that represent key technology activity include: aircraft and aircraft parts manufacture (3211); communications and other electronic equipment manufacture (3351, 3352, 3359); office, store and business machinery (3361); pharmaceutical and medical industry (3741); scientific and professional equipment industry (3911, 3912); plastic and synthetic resins industry (3731), and other machinery and equipment (3341, 3371, 3372, 3381). While this breakdown of technology intensive industry is somewhat arbitrary, it is a standardized guideline that can be followed closely by using the Made In Ontario industrial directory. The other industrial directories, while providing useful information at the regional and national levels, do not provide the firm level information needed in this analysis.

As stated previously, the Made In Ontario industrial directory provides four digit SIC codes for each firm surveyed in its publication. The directory also provides all the information necessary for the interviewing process (i.e. address of the firm, phone number, and name of the contact person). In the study area (Mississauga and Canada's Technology Triangle), a total of 245 firms were found to match the classification codes set forth by the definition of key technology industry. Of these 245 firms, 129 were located in Mississauga while the remaining 116 were located in the cities that make up Canada's Technology Triangle. A total of 164 firms participated in the survey, 86 in Mississauga and 78 in Canada's Technology Triangle, for a combined response rate of 67%. Of the 71 firms that did not participate in the survey, 15 were either out of business or acquired by another firm. In summary, the response rate was strong and it was relatively consistent by location and by industry type.

METHODOLOGY

At this stage, the nature of calibrating the product life cycle needs to be focused on. Since both life cycles will be calibrated similarly, this section will emphasize the product life cycle. Consider, first, the general structure of the product life cycle as illustrated in Appendix B. From a multivariate perspective, the product life cycle has a dependent variable (ie. the stage of technological development of a product) and several independent variables (ie. the stage specific characteristics of a product's development).

Notice that the possible outcome for each variable, whether it be a response variable or an explanatory variable, involves a binary selection within each stage of development. For example, a value of one is assigned to the *category* (response variable) that complies with a given firm's stage of technological development (as defined by the criterion outlined in the theory of product life cycles). Similarly, for every explanatory variable there exists three *possible dimensions*, only one of which may be used to describe a given firm. Thus, for the category that is observed (say stage one), a value of one would be specified; on the other hand, all other categories (in this case, stage two and stage three) would be assigned values of zero. Calculated across an industry, or an entire region for that matter, it is not difficult to see the potential application of product life cycle rationale at a scale much greater than the individual product or firm. The proposed thesis concerns the application of life cycle rationale at the regional and industry scale.

The presence of a discrete dependent variable (as indicated by the three stages of technological development) requires that a statistical procedure other than multiple regression be approached in this analysis. For reasons to be stated later, the logit model is capable of circumventing the implications of multivariate analysis where discrete categories are involved. Indeed, the application of a multinominal logit model makes it possible to determine the stage and nature of industrial and technological development. The stage of technological development can be interpreted by analyzing the parameter estimate for the alternative specific constant. This estimate reveals the likelihood / preference of one observed category (ie. stage one) over another anchor group category (ie. stage three), all other factors being held constant or equal to zero. Similarly, the nature of technological development can be interpreted according to the parameter estimates computed for each alternative specific variable (ie. each stage specific characteristic). In this case, the parameter estimate suggests the likelihood / preference that a certain characteristic will be observed within one category more so than another anchor group category, all else being held constant or equal to zero. It should be noted that the significance of all these parameter estimates, as well as the general goodness-of-fit, can be verified by observing quasi T-test scores and various Rho-Square measures, respectively.

As an aside, the logit program that will be employed in this analysis is a modified version of Ben-Akiva's "logit-f" fortran package[1]. The"logit-f" package employs the multi-dimensional Newton-Raphson method to maximize the log of odds functions associated with any given multinomial logit model. In addition to

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[1] Ben-Akiva's logit-f program originated out of the early work of McFadden and has been continually altered for the past 20 years.

log-likelihood estimation, Ben-Akiva's package reveals estimated parameters and their T-ratios, associated variance/covariance matrices, several rho-square goodness-of-fit measures, and other essential statistics.

CHAPTER 2 AN INTRODUCTION TO THE NOTION OF HIGH TECHNOLOGY

2.0 THE ROLE OF TECHNOLOGY IN DEVELOPMENT

It is generally accepted that the process of innovation is an essential element in the development, growth, and structural transformation of the economy. In fact, the capacity of an entrepreneur to combine factors of production in a new and more efficient way is viewed both as the proof of the past and promise of the future. (Debresson, 1989, p.1) This is especially relevant within the manufacturing sector where sweeping structural changes are the order of the day. Manufacturing has become a dynamic milieu and, as such, this sector can no longer expect to operate in a static and certain environment. The translation of technological and scientific knowledge into the effective innovation of products, processes and services is thus an imperative objective for any society wishing to maintain its competitive edge. Consequently and inevitably, it will become crucial for industrial societies to stress more the role of research and development and innovation.

2.1 THE MEANING OF HIGH TECHNOLOGY AND RELATED CONCEPTS

High technology is a nebulous term that means many different things to many different people. To some, high technology is expected to provide jobs and improve productivity rates while others expect high technology to provide socially useful products and mechanisms. (Hall and Markusen, 1985) It is this very complex nature of the word that underscores the need for consistent nomenclature. In theoretical terms, high technology is best defined to include all those activities that are engaged in "the design, development, and introduction of new products and/or innovate the manufacturing process through the systematic application of scientific and technical knowledge." (Rees, 1986, p.3) Although this definition may appear intuitively obvious, it is exceedingly difficult to implement in practice. Consider the operational definition used by the United States Department of Congress: "high technology consists of those activities that commit more than 10% of their gross product towards R&D and/or those activities that commit more than 10% of their total labour force to scientific, engineering, and technical fields." (USDOC, 1983, p.36) Note here, that the threshold of 10% and the criterion selected (R&D expenditures and technical employment) are arbitrarily selected parameters. Compounding this definitional ambiguity is the ever changing nature of high technology - the high technology of yesterday is no longer the high technology of today. The end result is that high technology is a moving target that has more than one skin to shed.

Before moving on to the dynamics of high technology, it is a fruitful exercise to state, explicitly, the meaning of several concepts that are related to the notion of high technology. Two of these concepts are invention and innovation. Invention, on the one hand, is viewed as an act of technical creativeness involving the description of a novel idea that would normally be suitable for patenting. (Rothwell and Zegveld, 1985, p.42) Innovation, on the other hand, includes the technical design, manufacturing, management, and commercial activities involved in the marketing of a new or improved product or process. (Rothwell and Zegveld, 1985, p.42) Invention, therefore, marks only one element, albeit an important one, in the overall process of innovation.

Another term that deserves special emphasis is that of Research and Development (R&D). R&D is a systematic investigation carried out in the natural and engineering sciences by experiment or analysis to achieve a scientific or commercial advance. (Statistics Canada, 1987, p.42) Thus, research represents the original investigation that is undertaken in a systematic fashion to gain new knowledge. Development, on the other hand, emphasizes the application of these research findings for the creation of new or significantly improved products or processes. In total, the desire or ability to invent or innovate is very often a function of the desire or ability to perform R&D. Of course, this innovative process as it occurs within the technological development cycle is not complete until one of two events has occurred. In the first instance, successful managed innovation may foster continued development within a firm by improving product design and/or by improving the production process. In the second and more dramatic case, successfully managed innovation may provide the seeds of knowledge for a completely new product and/or firm. Both outcomes represent the completion, but not necessarily the termination of the innovative process. A healthy innovative process is cyclical and recurring.

2.2 THE IMPORTANCE OF HIGH TECHNOLOGY IN CANADA

Technical advance has long been considered a major source of economic growth. While verification of its exact importance is difficult, few will deny that technical progress, as embodied in the activity of the technology intensive firm, plays a key role in any nation's economic development. Hall, for example, concludes that high technology activity is the most dynamic job and wealth generating segment of the economy. Moreover, many of these new jobs are being created in those occupational categories that are well paid and prestigious in nature. (Hall, 1987, p.7-11) Rothwell and Zegveld echo these sentiments by stating that the high technology sector is a potent and necessary vehicle for the creation of new jobs, for regional economic regeneration, and for enhancing national rates of productivity through technological innovation. (Rothwell and Zegveld, 1985, p.195) In short, the international experience with high technology activity suggests that this sector of the economy is highly competitive and has many highly innovative firms whose activities will serve as a seedbed for future economic growth.

The performance of the high technology sector in Canada is evaluated in Table 2.1. Notice, first, that Canadian manufacturing activity is disaggregated into three broad industry groups that are

TABLE 2.1

SELECTED MANUFACTURING PERFORMANCE INDICATORS, BY INDUSTRY
(AVERAGE ANNUAL PERCENTAGE CHANGE FOR THE PERIOD 1973 - 1986)

LEVEL OF R&D INTENSITY BY SELECTED INDUSTRY	NUMBER OF FIRMS	TOTAL LABOUR FORCE	VALUE OF GOODS	PRICE INDEX† 1973-1983	REAL GDP PER CAP.‡ 1973-1983
HIGH R&D INTENSITY					
AIRCRAFT & AIRCRAFT PARTS	7.9	3.4	36.6	7.4	1.1
SCIENTIFIC & PROFESSIONAL EQUIPMENT	(1.6)	1.5	22.2	8.8	1.7
ELECTRONIC EQUIPMENT	8.7	1.0	31.3	11.8	2.5
PHARMACEUTICAL & MEDICAL	(.3)	1.2	27.1	9.8	3.7
MEDIUM R&D INTENSITY					
ELECTRICAL INDUSTRIAL EQUIPMENT	3.8	(1.5)	17.6	12.0	0
ELECTRIC WIRE AND CABLE	1.5	(1.4)	11.8	15.7	(1.2)
MOTOR VEHICLE PARTS	10.3	4.4	32.9	17.6	(1.0)
MAJOR APPLIANCES	.4	(2.1)	12.2	12.8	(.6)
LOW R&D INTENSITY					
STEEL PIPE AND TUBE MILLS	<	(.6)	14.8	12.3	(1.8)
PULP & PAPER MILS	(.2)	0	21.3	13.7	.3
SASH, DOOR & OTHER MILLWORK	(.1)	(.6)	11.0	13.3	.8
HOUSEHOLD FURNITURE	(2.6)	(.6)	12.5	10.9	1.1
TOTAL MANUFACTURING	1.7	.2	20.0	13.2	1.1

† Value Added Implicity Price Index, 1973 -1983.
‡ Real GDP per worker is a measure of Productivity.

SOURCE: Statistics Canada C, MANUFACTURING INDUSTRIES OF CANADA Cat. No. 31-209 (Ottawa: Supply and Services), various years.

differentiated by Research and Development levels performed. The first industry group, labelled 'R&D Intensive Activity', is comprised of the following technology intensive activities: Aircraft and Aircraft Parts Manufacture, Scientific and Professional Equipment Manufacture, Electronic Equipment Manufacture, and Pharmaceutical and Medical Products Production. The second industry group, 'Medium R&D Intensive Activity', includes four arbitrarily selected activities that require only modest expenditures in the area of Research and Development. In name these activities include: Electric Industrial Equipment Manufacture, Electric Wire and Cable Production, Motor Vehicle Parts and Accessories Production, and Major Appliance Manufacture. The final industry group listed, 'Low R&D Intensive Activity, involves very little value added processing and almost no Research and Development effort. The sample of industries included in this industry group are: Steel Pipe and Tube Milling, Pulp and Paper Milling, Sash/Door and Other Millwork, and Household Furniture Manufacture. Although each of these industry groups were derived in a somewhat arbitrary fashion (and are not completely exhaustive), they do illustrate some very important and consistent trends among activities of varying research intensity.

The manufacturing performance indicators that have been used to evaluate the three broad industrial groups, are five of the more commonly cited indicators of economic performance within the manufacturing sector. These indicators have been recorded as the average annual percentage change for the period specified and include information concerning: total number of establishments, total employment, total value of shipments of goods of own manufacture, inflation, and productivity.

The first performance indicator revealed in Table 2.1 represents the average annual percentage change in the total number of establishments for the period 1973 to 1986. The results recorded for this manufacturing performance indicator are unique in the sense that the 'Medium R&D Intensity' group obtained the largest and most consistent scores. The scores for this middle group ranged from .4% to 10.3% while several scores in the two remaining industrial groups were negative. Despite this 'strong' showing by the 'Medium R&D Intensive' sector, one must be guarded against any pre-mature conclusions; rapid firm formation means little if it is being matched by losses in employment and productivity. Further investigation of Table 2.1 will verify that this is the case for the second industrial group.

The second indicator listed in Table 2.1 denotes the average annual percentage change in total employment for the period 1973 to 1986. In terms of the dynamics of employment change, this value underscores one of the major advantages that high technology activity holds over less research intensive activity. The consistently high rates of annual employment growth in this sector juxtapose the performance witnessed in other sectors - six of the eight industries making up the less intensive R&D industrial groups experienced losses in average annual employment while all the industries making up the technology intensive industrial group were significantly positive. These findings are supported by American findings where employment in the high technology sector grew 66% more quickly than employment in the non-high technology between the years 1976 and 1981. (Armington, 1986, p. 87)

The average annual percentage change in the 'Value of Shipments of Goods of Own Manufacture' represents the third major manufacturing performance indicator. This measure, a surrogate of total output generation, is defined as the net selling value of goods made by a reporting establishment from its own materials. Table 2.1 shows that the 'R&D Intensive' group experiences average annual increases in the value of shipments that range anywhere between 22% and 36% while the range for less research intensive activity falls between 11% and 32%. It will be noted, here, that these patterns of dynamic wealth generation in the technology intensive sector conform well with the findings of other similar international studies. (Fischer, 1988; Dobbs et al., 1987)

The 'Implicit Price Index' is an important consideration in the evaluation of manufacturing performance since this measure offers an inflationary perspective not found in other indicators. More specifically, the average annual percentage change in the value added price implicit index is an effective surrogate of the changing price of a producer's output and may, therefore, serve as an effective trace on inflationary trends at the producer level. It is clear from the values recorded in Table 2.1 that the technology intensive industry group experiences low levels of increase in average annual inflation. In fact, during the period

1973 to 1983 the average annual increase in the price index in the technology intensive industry group ranged from 7.4% to 11.8%; only one of the eight remaining sample industries attained a rate that fell within this range. From this perspective, high technology activity is commonly perceived to be immune to inflation both within Canada (Britton, 1985) and abroad (Malecki, 1986).

The final indicator listed in Table 2.1 is an often used measure of productivity. Stated simply, this measure of productivity is taken to be the ratio of real gross domestic product to the total number of employees in a given industry group. Notice, first, that the largest and most consistently positive levels of productivity are found within the research intensive industrial sector - values range from plus 1.1% to 3.7%. Elsewhere, the productivity figures are only modestly positive at best with values ranging between negative 1.2% and positive 1.1%. This tendency for technology intensive activity to be associated with superior levels of productivity is consistent with the findings of other similar studies and has been translated into the conclusion that such activity is, by its very nature, highly efficient and therefore highly competitive. (Hall and Markusen, 1985, p. 35)

Another significant performance indicator not included in Table 2.1 is the private rate of return that is received for each dollar of investment directed at Research and Development. Because technology intensive activity is largely a product of efforts pursued in the area of Research and Development, it is a useful exercise to analyze patterns of rate returns on various factor inputs. If, for example, the rates of return on R&D were significantly greater than the rates of return on other factor inputs (capital), one might anticipate that the potential to maximize the total rate of return would be greatest in the most R&D intensive sectors. Based on a study of nine Canadian industries, Bernstein concluded that the private rates of return on R&D were at least 2.5 to 4 times as great as those private rates of return on physical capital. (Bernstein, 1989, p.317) By ranking the nine industries according to R&D intensity, Bernstein concluded that the most technology intensive activities experienced the greatest returns on total investment - the gains in productivity from R&D investment were estimated to save approximately 1.1% of production costs in the research intensive industrial sector. (Bernstein, 1989, p.321) In summary, high technology activity is primarily a Research and Development oriented activity and associated with Research and Development efforts are superior rates of return.

While much has been said of the performance of the high technology sector (supply side dynamics), very little has been said concerning the demand for the products and services that result from these activities. Table 2.2 plots the total demand for both high technology goods production and all other goods manufacture for the period 1982 to 1987. Although high technology's share of total demand increased only marginally over the interval, it should be stressed that its five year growth increase stood at 63.8%. This growth rate was twenty percentage points greater than the growth

TABLE 2.2

TOTAL DEMAND † FOR MANUFACTURED GOODS IN CANADA, 1982-1987

ACTIVITY	TOTAL DEMAND † (IN MILLIONS OF CURRENT DOLLARS) 1982	1983	1984	1985	1986	1987	%CHANGE 1982-87
HIGH TECH‡ MFG.	31992	32864	40069	43496	47987	52403	63.8
ALL OTHER MFG.	209632	233981	271468	294560	303506	318915	44.8

† TOTAL DEMAND is the net of the whole value of shipments and imports OR the net of the Canadian market and exports.

‡ HIGH TECHNOLOGY as defined in Appendix C.

SOURCE: Minister of Industry and Trade and Commerce, MANUFACTURING TRADE AND MEASURES: TABULATIONS OF TRADE, OUTPUT, CANADIAN MARKET AND TOTAL DEMAND (Ottawa: Department of Industry, Science and Technology), 1988.

rate attained by the "all other manufacturing" group during the same time interval. Simply stated total demand for technology intensive goods and services is growing at a pace significantly greater than the total demand for all other goods. Even more importantly, the pace is expected to accelerate as never before seen:

> The U.S. Department of Commerce in 1985 reported that 90% of all scientific knowledge we have today was generated in the last thirty years.... there is little doubt that this knowledge pool and the demand for its byproducts [goods and services] will double by the end of this century. (Canada. Parliament.House of Commons, 1986, 16:14)

In the end, the potential for continued rapid growth in the high technology sector is unquestionably great. In fact, the demand for such goods and services is not at issue; the demand is there and it will grow like never seen before.

In conclusion, and from a strictly formal economic perspective, it can be said that the net economic effects of a new technology on the private sector of a small open economy (i.e. Canada) will be positive, even if monopoly profits are repatriated abroad. (Diewert, 1987, p.694) Therefore, industrial competitiveness in all areas of a nation's economic and socio-economic strata is influenced by its capabilities in science and technology. The factors discussed in this section lend support to such a strong conclusion: high technology activity is a buoyant job and wealth generator, it is highly immune to the ravages of inflationary spirals, it is a highly competitive sector of the economy with world wide market potential, and this sector is most likely to experience the benefits that are associated with significant levels of R&D investment. From a more empirical perspective, one has only to look to the industrial leadership of the United States to realize the significance of a concerted R&D effort. Similarly, Japan's rise to international competitiveness required a rapid ability to adopt existing technology to new applications. In both cases, the incidence of R&D within the high technology industrial sectors has been a major determinant of the rate at which economic and technological progress has occurred. (Fischer, 1988, p.282) The importance of this research intensive activity is underscored when one considers that the most rapidly growing area of world demand is for high technology products and that competition for these products is often based on the proprietary knowledge gained from corporate research and development. (Science Council of Canada, 1984, p. 29)

2.3 THE SPATIAL IMPLICATIONS OF HIGH TECHNOLOGY

Perhaps the most significant implication of high technology activity, at any scale, is the phenomenon known as technology oriented complex development. The term technology oriented complex (TOC) refers to the tendency for technology intensive entities (high technology firms, government research laboratories, universities) to cluster or agglomerate. (Steed and Nichol, 1985) The most classic cases of TOC development include Silicon Valley, Boston's Route 128, and the M-4 Corridor. Each of these technological clusters, and many more, has been thoroughly documented (see: Bathelt, 1989; Malecki, 1986). While few will deny the clustering nature of high technology, much remains to be said of how and why high technology activity clusters.

To understand the process of innovative agglomeration and therefore TOC development, one must look to the principles involved. In name, the key players are the New Technology Based Firm (NTBF) and the Large Technology Based Firm (LTBF). The NTBF represents the smaller more youthful element of the high technology manufacturing sector. These small but dynamic firms are characterized by informal organizational control, rapid and effective internal communication, and an affinity to take risks.

The LTBF, on the other hand, represents that element of technology intensive manufacturing that is characterized by highly structured and rigid organizational control, scale economies and standardized production, and strong access to world wide markets and large pools of venture capital (see: Rothwell, 1983). In total, the LTBF and NTBF realize a network of interaction that has come to be known as 'dynamic complementarity'.

For the reasons stated above, the large and small technology intensive firm have significant yet different roles to play during innovation. This holds true despite the heavy concentration of R&D expenditures in large firms. (Freeman, 1982, p.137) In fact, if the relationship between the NTBF and LTBF is restated in terms of innovatory effort, it is reasonable to assume that smaller firms may have several advantages in the early stages of inventive work where innovation is less expensive but subject to greater risk. On the other hand, large firms will take advantage of their scale and specialize in the area of innovative improvement and scaling up. Both forms of innovative emphasis can be modelled within the parameters of two widely used notions: entrepreneurial innovation and managed innovation.

Entrepreneurial innovation is based on the premise that new basic technologies emerge that are coupled in an unspecified way to new scientific developments that are largely exogenous to existing companies and market structure. It is the 'small' risk-taking entrepreneur who pounces on these opportunities and, via radical or breakthrough innovation, fosters the growth of new industries and product groups. Thus, the NTBF plays a key role in the dissemination of new technologies and is central to the application of new technologies for new applications. Managed innovation is the complement to entrepreneurial innovation. The former is based on the premise that as technology and the markets for that same technology mature, so too will inventive activity become progressively internalized. As expected, the large firm dominates this phase of innovation and, as such, is a key player in the application of new technology for existing applications. (Rothwell, 1983, p.21-23) Cast in this light, the relationship that exists between both the large and small innovative firm is critical to the innovative process:

> Both had their unique contribution to make; both were necessary, the former to the initiation of the new technological paradigm, the latter to rapid market diffusion and general commercial exploitation. (Rothwell, 1982, p.27)

From this it may be concluded that while LTBF's are very effective in creating new technological possibilities for in-house use only, they are not well equipped to exploit these new technologies outside their domicile. New firms are better adapted to pursue the initial market diffusion of these new technologies in the form of new firm formation and new product development.

The evolutionary dynamic of innovation must lead to the conclusion that NTFB's and LTBF's are functionally inseparable. From a more spatial perspective, priming the pump of technological accumulation (i.e. fostering the functional relationship between large and small technology based firms) requires breeding, and later nurturing, a spatially concentrated network of innovating firms. In such clusters, the technological capabilities of one firm builds upon and feeds those of another firm. The exceptional profits that typify innovative activity spur imitation and adoptive innovation in the vicinity and thereby trigger a circular and cumulative innovative cycle. The routine is reinforced as joint entrepreneurial profits promote continued interaction and inter-firm collaboration. (Debresson, 1989, p.12) It is in this fashion that the vigorous innovative efforts of many NTBF's in combination with the efforts of several established technology intensive firms will greatly increase the likelihood of fostering a concentration of innovations and therefore high technology activity. And with this technological clustering comes all the advantages that are associated with high technology. The entire manifestation has become known as the technology oriented complex and the breeding of such clusters has become a key policy goal for most national governments of the industrialized world. (Debresson, 1989, p.1)

2.4 HIGH TECHNOLOGY AND THE THEORY OF PRODUCT LIFE CYCLES

If Canada is to maintain its standard of living and international competitiveness, it must focus on developing and applying new technology as embodied in the activities of technology intensive manufacturing. (Department of Regional Economic Expansion, 1989, p.1) In general, economic development depends on technological change. And since technological change is a major player in the advance of productivity, global competitiveness, wealth generation, and employment, there is no real alternative to technological advance. It is a matter of survival. (Industry Committee. Canada, 1988, p.32) In total, agencies such as the Science Council of Canada agree that, with vision and careful planning, new technologies can be harnessed to maximize economic and socio-economic development. The Canadian government has endorsed this belief in science and technology by increasingly emphasizing the roles of the Technology Impact Program (TIP), the National Research Council of Canada (NRC), and the Canadian Institute for Advanced Research (CIAR).

Thus, the word *high technology* carries with it many images of pristine industrial development. Yet, in spite of the fact that indigenous innovative capability has been the target of most economic policy objectives, there is no denying the difficulty involved in capturing the essence of this equivocal notion. In its most simplified form, high technology represents a sector of industrial activity that is well-disguised, rapidly changing, and enormously important to national and regional economic well-being. Not surprisingly, the static and rigid frameworks of traditional regional science have not the flexibility to handle the "super-dynamics" of technological change as embodied in high technology industry. There is, however, a paradigm that is structured around the premise of technological change. In name, this framework is called the theory of the *product life cycle* and, as will be seen, it is designed for the analysis of technological change as it occurs within the technology intensive sectors of the economy.

CHAPTER 3 PRODUCT LIFE CYCLES AND THE CONCEPTUALIZATION OF TECHNOLOGICAL CHANGE

3.0 INTRODUCTION

A recent renewal in the interest of the product and industry life cycle has resulted in a much needed emphasis on present industrial location patterns and regional economic development. More specifically, the notion of technological change has become an essential ingredient in modern industrial geography. It may safely be said that "the relationship between technological change, industrial change, and regional development stands out as a fruitful avenue of research for industrial geographers". (Malecki, 1981, p.292) Since the notion of the product life cycle is structured around these very same relationships, it is fair to assume that the model deserves greater and continued development. As such, this chapter will trace the evolution of product life cycle rationale. It will be concluded that today's version of the product life cycle model is qualitatively strong and is not limited to the descriptive spectrum of industrial location theory and regional science.

3.1 AN INTRODUCTION TO THE NOTION OF TECHNOLOGICAL CHANGE

In its most formal sense the thrust of the technological continuum is directed at the degree of orderliness in human activity. This evolution of order is the product of technological change as generated and replicated through the tool-skill combination principle. This notion represents all efforts that are directed at the integration of current technological capabilities in order to create a larger and more advanced pool of technical know-how. (Weinel and Crossland, 1989, p.804) In this sense, technological progress implies that the processes acquired to predict and control all economic consequences will, inevitably, improve the set of attainable social outcomes in the workplace, both qualitatively and quantitatively. The manifestations of technological progress can take several forms, ranging from the introduction of new methods that are used to produce existing products to the introduction of new designs that may be used to create new products. For the purposes of this paper, technological change and development will refer to the evolution of a product, industry or region. The nature and dynamics of this evolutionary process will be defined within the context of product life cycle rationale.

3.2 TECHNOLOGY IN ANTIQUITY

The impact of technological change has been known to influence our civilization for many centuries. Even prior to the industrial revolution, innovations such as the printing press, gunpowder, and glass windows created new industries and thereby altered society. (Thwaites and Oakey, 1985, p.1-4) In fact, the first explicit theoretical studies concerning technological change date back to the early 1500's. The treatises of Buringuccio (Pyrotechnia, 1540), Agricola (De Re Metallica), and Ramelli (Le Diverse et Artificiose Machine, 1588) mark the most direct line of ancestry in this historical path of technological theorizing:

> In these works, amid technological detail and fascinating pictorial representation of existing and imagined machinery, there were some of the first conceptions of technological change, that is, ideas about the most effective ways to organize and diffuse technological development practices. (Jamison, 1989, p.507)

By the end of the 16th century, most aspects of learned culture had successfully incorporated the mechanics associated with technological innovation and change. Academically trained scholars turned to the science of 'technics' to understand not only the meaning of natural processes but also the processes subject to man's influence - ie. the economy. Economic and socio-economic processes were viewed as machine-like components, the mysteries of which could be solved through the science of technics. (Jamison, 1989, p.510) In this way, early scientists may be recognized as the original source of explicit theory concerning technological innovation and change.

By the beginning of the 17th century, the scientific spirit of the era of Enlightenment had manifested itself in all aspects of learned culture. (Jamison, 1989) The concept of technological change was made popular in the field of economics by Ricardo (Thwaites and Oakey, 1989, p.7), however, it was not until 1930 that efforts were formally directed at measuring the influence of technological change upon economic development. It is at this point that the 'pioneers' of the product life cycle made their presence felt.

3.3 PIONEERS OF THE PRODUCT LIFE CYCLE

It is generally accepted that the first formal attempt at employing product cycles to any form of economic analysis was pursued by Simon Kuznets (1930) and Arthur Burns (1934). Recognizing that their economy was inundated by ceaseless change, and faced with the realization of the Great Depression, these two individuals found that the need for an effective explanatory framework was more than just an academic need. Similarly, the National Bureau of Economic Research was firmly convinced that this great variety and frequency of economic change was being mirrored in an analogous set of intricate social changes. (Burns, 1934, p.111) It is because of this similarity in rationale that the National Bureau sponsored the works of Kuznets and Burns.

As is suggested above, Kuznets and Burns reflect a similarity in view point. Specifically, both individuals viewed industrial expansion paths in terms of "secular movement" analysis. The notion of the secular movement is described as follows:

> articles are subject to violent disturbances; but if a sufficient period is considered, these disturbances balance each other, and the average value approaches fixed conditions . . . Here, as in astrology, it is necessary to recognize secular variations, which are independent of periodic variations. (Kuznets, 1930, p.59)

As alluded to above, movements in industrial activity were increasingly observed as being differentiated by their duration and form. That is to say, lines of primary secular movement trace paths that are typically continuous and irreversible while the lines of secondary secular movement trace paths that are highly volatile and undulating.

At this point it should be noted that primary and secondary secular movements were issues that had been studied prior the works of Kuznets and Burns. Although these earlier studies were of a purely descriptive nature, they did mark the point of departure for what was to become the backbone of secular movement analysis.

Consider, for example, a study by J. Van Gelderen in 1913. Van Gelderen, by fitting sawerbach price curves to business cycle trends, realized that business cycles are short term waves in national economic life. Furthermore, these short term fluctuations are superimposed on long term waves. In considering the relevance of these longer waves, Van Gelderen states:

> A movement of so general a character cannot be due to local or accidental factors. Rather, we have, here, a phenomenon as much inherent to the capitalist system as other changes in the face of economic life. (Kuznets, 1930, p.269)

The causal factors of movement alluded to here, are made specifically in reference to what Van Gelderen calls a "springflood" period. The notion implies that the long waves of economic (industrial) development, once initiated, bear the seeds of their self destruction. That is to say, the end of a "springflood" period comes because every economy (industry) is pegged to a threshold on potential market saturation and therefore a threshold on potential growth. Of course, subsequent "springfloods" can be triggered by technological development - Van Gelderen calls this the process of "capitalist reproduction".

Despite these early attempts to formalize long wave analysis, the topic is usually associated with the Russian economist N.

Kondratieff. In his 1922 study, Kondratieff, analyzed a set of price and production time series data for the period 1790 to 1920 and concluded that three long term cycles could be identified. (Rothwell and Zegveld, 1985, p.17) These long waves were, on average, about 50 years in length and prevalent in the United States, France, West Germany, and England. It was also observed that:

> The dynamics of the world conjuncture is rhythmical... We have to distinguish two main kinds of cycles: a long cycle that covers about 50 years, and a short industrial cycle of about 10 years. (Kondratieff, 1926, p.242)

The similarity between the findings of Kondratieff and Van Gelderen is thus consistent.

While Kondratieff did not explicitly include technology as a causal factor in long wave formation, he did suggest that when a major wave of expansion was under way, previously dormant inventions would increasingly become targets of investment and likely find commercial application. (Rothwell and Zegveld, 1985, p.28) Despite this superficial consideration of the role of technological change in long wave cycles, Kondratieff's analysis of cycles was the most statistically sound for its day.

Bearing in mind all that has been said of the primary and secondary secular movements to this point, it becomes apparent that the actual nature of these movements has not received appropriate consideration. It is within this dimension that the work of Kuznets and Burns marks a turning point in the analysis of secular movements.

It will be recalled that the primary secular trend of an industry's production may be likened to a persistent underlying movement of its output over a period that is long in relation to the changes associated with the secondary secular movement. Add to this the fact that industries reveal a retarded growth pattern that is limited to a finite level of maximum size and it becomes evident that any particular industry lives a life characteristic of several distinct stages of development. (Burns, 1934, p.31) Kuznets and Burns, realizing this, searched for a curve that would exhibit a finite limit and a declining rate of percentage increase. In addition to this, the curve was to show the changes in absolute increases as dependent upon the stimulating influence of output size and the retarding influence of the approach to the limit. Kuznets opted for the Gompertz curve while Burns chose the simple logistics curve - both were found to fit the data on production trends sufficiently (see: Kuznets, 1930, p.61-65).

It is this application of the law of mathematical expression as embodied in growth curves that allowed Kuznets and Burns to derive what is termed the law of industrial growth. According to this law, the course of the life history of a typical industry may be categorized into several stages - the stage of 'nascence', the stage of 'maturation', and the stage of 'decadence'. As for the dynamics of this law of industrial growth, Kuznets states:

> The general curve of secular movements could be used as a die in which to cast most of the facts and interrelations of the complex economic reality. For with this general process of growth there go not only important shifts in the character of the industrial technique, but also changes in the relation between labour and capital, changes in the distributive process, in the character of the market, in the type of business organization, and in the respective roles of

industry. (Kuznets, 1930, p.326)

Therefore, for every stage within the process of growth, there can be associated a special arrangement of components that are subject to change and reorientation over time. This recognition of the internal dynamics of industrial and product development is of great importance since it marks the birth of what can truly be called life cycle rationale.

As an aside, the work of Joseph Schumpeter deserves some attention as far as it relates to the work of Burns and Kuznets. At approximately the same time that Burns and Kuznets were studying the inner workings of secular movements, Schumpeter was attempting to formalize the central role of technology within the context of Kondratieff's long wave theory. (Hall and Mark, 1985, p.6) Schumpeter spoke explicitly of technological revolutions as the driving force of economic growth. The initiation of these technological revolutions was described as follows:

> Whenever in a given situation new things have been done by some, others can, on the one hand, copy their behaviour in the same line and on the other hand, get the courage to do similar things in other lines, the spell being broken and many details of the behaviour of the first leaders being applicable outside their field of action. (Schumpeter, 1939, p.28)

In other words, it is the entrepreneur who, in the face of profit opportunities vigorously exploits the emerging techno-economic conditions. In the end, this leads to a swarming effect of imitators - a swarming effect that can be associated with a wave of new investment. Of course, the boom conditions associated with this entrepreneurial bandwagon wane as competition increases and technological monopoly profits pass. It must be stressed that before the system can reach a stable equilibrium, a new wave of innovations will occur with major destabilizing effects. In total the process became known as "creative capital destruction". (Rothwell and Zegveld, 1982, p.28)

By dropping this process of creative capital destruction down a level, to that of the industry, the law of industrial growth is approximated in logic; the former stresses economic development, the latter, industrial development. The key here, is that parallels in rationale were occurring. The door to understanding the dynamics of industrial/economic development had been opened. The time had arrived for the industrial geographer to walk through that door and formalize a model of the life cycle.

3.4 THE REEMERGENCE OF THE PRODUCT LIFE CYCLE

Despite the great advances made in the analysis of industrial development during the 1930's, the notion of the product cycle became a victim of neglect. With the exception of Aldefer and Michl, the notion of the product cycle had been ignored in favour of Capital Stock Adjustment Theory and its many direct descendants. By the late 1950's several fundamental shortcomings had been found in the emphasis on capital as the dominant explanatory variable for the processes of economic growth and change. (Thwaites and Oakey, 1985, p.15)

The lack of success with capital stock theory initiated what has been coined "neo-technology" theories. The first of these was proposed by Posner in 1961 and was called the Technology - Gap Model. The second of these, and marking its rediscovery after 20 years of neglect, was the product Cycle Model as forwarded by Vernon and Hirsch.

In an attempt to explain U.S. trading behaviour (and in an attempt to explain the Leontief Paradox) Raymond Vernon was impelled to turn to this "promising line of generalization and synthesis". (Vernon, 1966, p.190) By employing the product cycle, Vernon planned to put less emphasis upon comparative cost doctrine and more upon the timing of innovation, the effects of scale economies, and the role of uncertainty influencing trade patterns. Following the findings of the New York Metropolitan Region Study in the 1950's, Vernon realized that particular stages of product development carried with them a particular set of locational ramifications. These stages of product development were termed the 'new product' stage, the 'mature product' stage, and the 'standardized product' stage.

In the early phases of product development (the new product stage) producers were confronted with many critical conditions. For example, the product was generally unstandardized, thus widening the potential range of its inputs, its processing, and its final specification. Given these conditions, Vernon hypothesized that several locational implications would result. First, a producer would prefer those locations that would allow flexibility in changing its inputs. Secondly, those locations that are conducive to swift and effective communication between producer, customer, supplier, and competitor would be assumed preferable. Of course, such locations are typical of the industrialized nation's advanced agglomeration. (Vernon, 1966, p.195)

In the "mature product" stage, a certain degree of standardization occurs due to an expansion in demand for the product. While product differentiation does not end, price competition is seen as having an increasingly important role to play. As a result of this increased price competition a commitment to some set of product standards becomes necessary. This opens up technical possibilities for achieving economies of scale. Similarly, a reduction in the uncertainties of production processes, markets, competition, and so on enhances the usefulness of cost projections. In total, these changing factor requirements result in locational needs that are far less severe than in the first stage.

The standardized product stage marks the final level of product development. At this stage, the full brunt of price competition is felt while product differentiation becomes less significant. The subsequent locational requirements are footloose in the sense that production becomes relatively fixed (thus allowing for infrequent and negligible input changes, reduced need for rapid communication, and so on), markets become well defined (thus regularizing demand), and firm strategies become oriented to long range planning. A greater freedom in the location of production facilities at this stage is, therefore, evident.

As suggested earlier, the product cycle provides an arena, of sorts, in which international trade patterns play off against one another. One of the premier cases of international trade operating within the confines of the product cycle is offered by the Leontief Paradox. This case finds its origins in the logic of Capital Stock Adjustment theorists. More specifically, the Heckscher-Ohlin theory suggested that U.S. exports should be, in general, more capital intensive than U.S. imports. In 1952, though, Wassily Leontief proved that U.S. exports were more labour intensive than imports. (Rothwell and Zegveld, 1985, p.23).

According to Vernon, this phenomenon could best be explained by following the changing trade flows that result from the aging of a product. Early in the product's development,

> comparative advantage is determined by product innovation in response to perceived market demand. This leads to sales at home and abroad and to the rapid exploitation of both static and dynamic scale economies. Imitators (from abroad) enter a disadvantage because of teething problems and the time involved in production learning and achieving scale economies. (Posner, 1961, p.21)

As the stage of product development progresses, the possibility of fully exploiting economies of scale increases. It therefore becomes more likely that the international firm begins servicing the markets of less developed countries from abroad - especially if those new locations are characteristic of low labour costs. If the foreign labour cost differentials are large enough to offset the transport costs of shipping that product back to the innovating country, then it is possible that the innovating country will become an importer of that very same product.

While this logic is relevant to the Leontief Paradox, it does not account for the problem of capital scarcity in lesser developed nations. Simply stated, will the general scarcity of capital in the less developed countries not prevent investment in facilities for the production of standardized products? Vernon claims that this is not the case:

> One has to notice that public international lenders tend to lend at near uniform rates, irrespective of the identity of the borrower and the going interest rate in his country. Access to capital by underdeveloped countries, therefore, becomes a direct function of the countries' capacity to propose plausible projects to public international lenders. (Vernon, 1966, p.207)

In light of this, it is a country's ability to propose plausible projects to international lending agencies that allows the obstacle of obtaining capital to be resolved (Today, this conclusion would be the subject of significant debate). Such plausible projects are more likely to be found at later stages of product development when processing uncertainty is minimal and markets are well defined. If the lesser developed country can add to this the feature of low labour costs, then its output may be directed both at its own market and at the market where the product was originally innovated. In this case a country such as the United States may come to depend on less developed nations for capital intensive imports. The product cycle thus resolves Leontief's Paradox of international trade.

3.5 REFINING THE PRODUCT CYCLE: THE INNOVATION LIFE CYCLE

The importance of the time-space limitation (ie. the effects of time on the development of an industrial entity) in the innovative process has only recently been formalized into a workable industrial location and regional science model. Inspired by the works of organizational theorists such as Lawrence, Lorsch, and Woodward (Lorsch and Morse, 1974; Lorsch and Lawrence, 1970), industrial geographers attempted to formalize a geography of enterprise. (Wood, 1978, p.143) The rationale of the novel *open systems approach* implied that there would be a new set of spatial implications to be associated with organizational decision making and, therefore, organizational development. In terms of the theory of product life cycles, a mutual relationship was observed between the rate and type of innovative activity, the state and nature of process and product development, and the locational requirements of a given firm. Perhaps the most effective conceptualization of this series of entwined relationships is provided for by the classic study of Utterback and Abernathy (1975). As such, we turn to this archetype to develop a sense of the most current version of product life cycle analysis. This modern version, known as the *innovation life cycle* framework, draws on the realities of both the process and product cycle to develop a single paradigm that is capable of capturing all the dimensions of an open systems approach to technological development.

<u>THE PROCESS CYCLE</u>

The *process life cycle* suggests that as a production process develops over time, it does so with a characteristic evolutionary pattern. Specifically, the manufacturing process becomes more capital intensive, direct labour productivity improves through greater division of labour and specialization, the flow of materials within the process takes on more of a straight line flow quality, the product design becomes more standardized, and the process scale becomes larger. (Utterback and Abernathy, 1975, p.641) Furthermore,

> as the process continues to develop toward states of higher productivity through incremental changes in these factors, a cumulative effect is achieved that significantly alters the overall nature of the process. (Utterback, 1982, p.11)

Considering these regularities in the development of productivity factor characteristics it becomes possible to derive a discrete set of stages which best represent trends in the cumulative development of an industrial entity. Bearing this in mind, Utterback and Abernathy conclude that three different stages of process development existed: the 'uncoordinated', the 'segmental', and the 'systemic'. Although several other effective conceptualizations of the innovation life cycle exist (see: Rees and Stafford, 1986; Hall, 1986), the following discussion draws largely on the seminal work and terminology set forth by Utterback and Abernathy (1975).

The 'uncoordinated' stage (stage one of the process cycle) of process development demarcates the early years of a firm's operation. The continuous flow of competitive improvements is fostered by vigorous market expansion. A corollary to these competitive improvements is the constant revamping of product and process. Because the process is composed largely of manual operations, it is not surprising that great product diversity exists among competitors. The character of this stage requires that the process be fluid with loose relationships between process elements - the firm must be capable of responding easily and quickly to environmental change.

The 'segmental stage' (stage two of the product cycle) is characterized by a more mature product. At this phase of the cycle, products become less differentiated and, as a result, price competition becomes a major concern. To complement this increased competitiveness, production systems become more mechanistic thereby increasing the systems's efficiency. On the other hand, but with similar logic, the production process tends to become tightly integrated through automation and process control. In total, the production processes in this phase will be segmented since some sub-processes will be automated while others will be labour intensive.

The 'systemic stage' (stage three of the process cycle) is characterized by a limited number of negligible improvements to the process elements. This results due to the fact that the process becomes so well integrated and highly developed that any changes become very costly. Intuitively, this is logical since even a minor change in a highly automated process may require changes in product and process design throughout the system. Although process redesign is not a regularity in this stage, there are instances where it is either wise (as in the case of a new and relevant technological development) or necessary (as in the case of a sudden shift in market requirements). In the event that these changes are resisted, the firm would either expose itself to economic inefficiencies or necessitate "revolutionary" change as opposed to evolutionary change in the future.

THE PRODUCT LIFE CYCLE

Just as the process life cycle can be viewed as a series of three distinguishable stages, so too can the product life cycle be viewed " in a predictable manner with initial emphasis on product performance, then emphasis on product variety and later emphasis on product standardization and cost". (Utterback and Abernathy, 1975, p.642) Again, drawing on the framework of Utterback and Abernathy, three stages of product development will be analyzed: the 'performance-maximizing', the 'sales-maximizing', and the 'cost-minimizing'.

The 'performance-maximizing' stage (stage one of the product cycle) is indicative of rapid rates of product change that are characterized by large profit margins. A firm in this early phase of the product life cycle might be expected to emphasize unique products and product performance on the grounds that a "new capability" could expand the requirements of customers. By integrating the early stages of both the product and process cycles, it can be generalized that markets are ill defined, products are nonstandard, and the production process is undeveloped.

The 'sales-maximizing' stage (stage two of the product cycle) emphasizes an increased awareness by both producers and consumers of a particular product - thereby reducing market uncertainty. As a result of this, higher levels of competition based on product differentiation makes product design the dominant concern. This stage closely corresponds to that of the segmental stage in process development. Together, process changes will largely be stimulated by the demand for increased output. Moreover, the system may tend to have discontinuous process innovations that involve new procedures of organization, production, and product design.

'Cost-minimizing' (stage three of the product cycle) is a result of the evolution of the product life cycle to a point where the product becomes standardized in nature. Indeed, as the basis of competition begins to shift to product price, margins are reduced, the industry often becomes an oligopoly, and economies of scale become the primary emphasis in production. For every instance in which price competition becomes necessary, production processes become capital intensive to the point where lower costs can be achieved only by relocating factor inputs in a most efficient way. By combining the final stages of the product and process cycle it might be said that product and process modifications must be dealt with as a system. That is, because investment in process equipment is high and product and process change are independent, product and process innovations may be principally incremental.

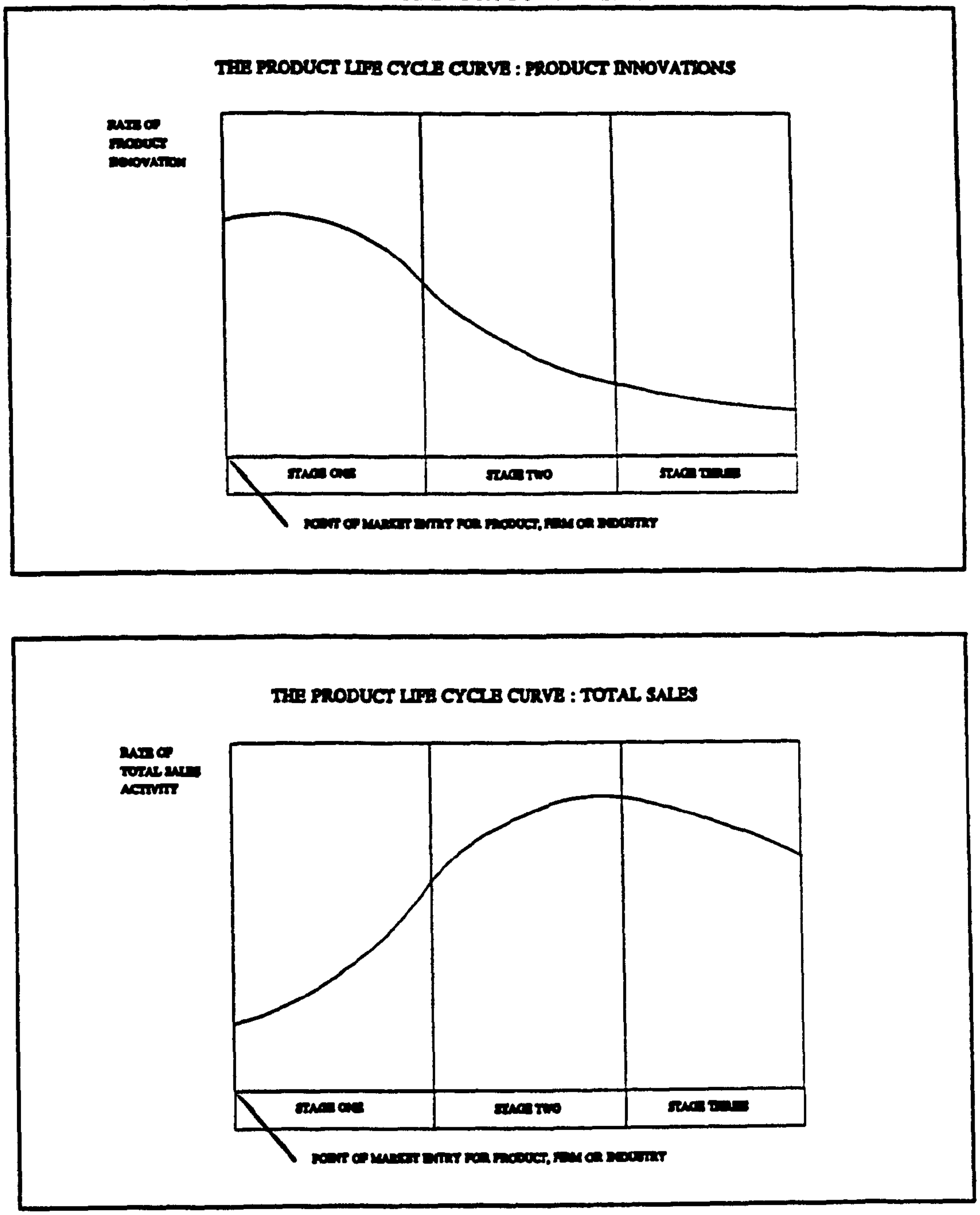
THE INNOVATION LIFE CYCLE

Figures 3.1 and 3.2, and Table 3.1 provide a graphic summary of the product, process, and innovation life cycle models and their associated curves. Figure 3.1 displays the general form of the product life cycle curve (in terms of the rate of product innovation and total sales activity). Notice the movement and slopes of each curve after the point of product entry into the market. Total sales increases through time until an unknown upper asymptote is reached; the rate of product innovation, however, is prominent in early stages of development and then declines to a negligible level as late stage development is attained.

Figure 3.2 illustrates the curves of product and process development and describes the nature of the innovative process according to the three stages of technological development. Specifically, the figure illustrates the transformation of the continuous product and process life cycle curves into a categorical description of technological development through time. The end result is a series of discrete stages that are indicative of the total innovative process. Table 3.1 simply plots the three stages of the innovation life cycle (the 'fluid', 'transitional', and 'specific' patterns) according to the stage specific characteristics of industrial technological development. It is

FIGURE 3.1

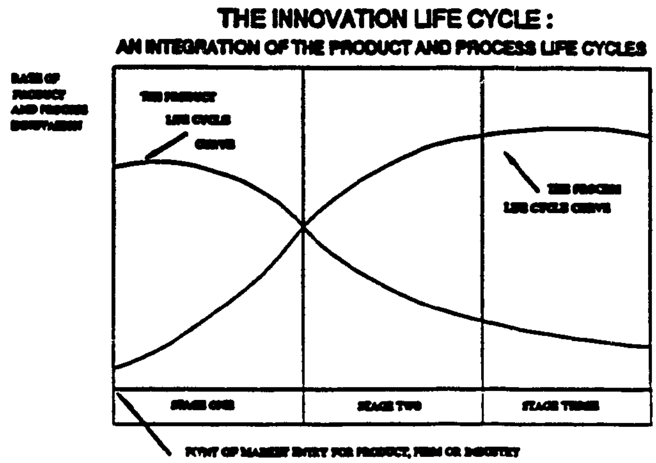
GENERAL FORMS OF THE PRODUCT LIFE CYCLE CURVE



SOURCE: (Rothwell and Zegveld, 1981, p.42)

FIGURE 3.2

THE INNOVATION LIFE CYCLE : FROM CONTINUOUS CURVES TO DISCRETE STAGES



STAGE 1 ------------------------------------> STAGE 3

NATURE OF PRODUCTION	UNCOORDINATED LABOUR INTENSIVE PRODUCTION	>>>>>>>>>>>> >>>>>>>>>>>>	SYSTEMIC CAPITAL INTENSIVE PRODUCTION
PRODUCT EMPHASIS	PRODUCT PERFORMANCE	>>>>>>>>>>>> >>>>>>>>>>>>	PRODUCT COST MINIMIZATION
NATURE OF THE INNOVATIVE PROCESS	>Product innovation need stimulated >Process innovation is stimulated by by specific output requirements. >The R&D to Sales Ratio is high and is primarily directed at product innovation.	>Product and process innovation are increasingly technology stimulated. >The R&D to Sales ratio remains high but it is primarily directed at process innovation.	>Product and process innovation are increasingly cost stimulated. >The R&D to Sales ratio becomes negligible. >Product innovation is virtually non-existent.
INNOVATIVE STAGE	FLUID	TRANSITIONAL	SPECIFIC

TABLE 3.1

THE STAGE SPECIFIC CHARACTERISTICS OF THE INNOVATION LIFE CYCLE

INNOVATION LIFE CYCLE ATTRIBUTE	STAGE OF TECHNOLOGICAL DEVELOPMENT: FLUID PATTERN	TRANSITIONAL PATTERN	SPECIFIC PATTERN
Product Line:	diverse, often including custom design.	includes at least one product that is standardized in production.	products are differentiated and highly standardized.
Mfg. Process:	flexible with almost no automation.	becoming more rigid with "pockets" of automated subprocesses.	efficient, capital intensive, and very rigid.
Aim in competition:	functional product performance.	product variation.	pressure to reduce cost and improve quality.
Form of Control within the Firm:	informal and entrepreneurial.	through liaison relationships, project and task groups.	through emphasis on structure, goals and rules.
R&D inspired by:	the needs of the market.	the need to increase the scale of production.	the need to reduce cost.
Nature of Labour Force:	highly skilled and well educated.	a balance between technical and non-technical labourers.	predominantly administrative and non-technical.
State of Market:	ill defined with the potential for vigorous market expansion.	minimal market uncertainty; entry remains profitable.	no market uncertainty; entry is very difficult.

SOURCE: Interpreted from Abernathy and Utterback (1975) and Rothwell and Zegveld (1981).

within this form that the dependent / independent relationships of the innovation life cycle are made most clear.

In conclusion, any analysis of regional industrial development within the parameters of the innovation life cycle framework can be pursued by considering the cumulative or additive effects of many individual life cycles within a region (ie. regional life cycle) or within an industry (ie. industry life cycle). This analysis will focus on the pattern of life cycle development as it is occurring within Mississauga and the CTT high technology industry. Therefore, our primary interest is based on the cumulative effect of many individual innovation life cycles, each representing one high technology firm in the Mississauga and the CTT region. The synthesis of all of these individual cycles will constitute the phenomena that has come to be known as the regional industrial life cycle. (Rees, 1986, p.32)

3.6 LIMITATIONS OF THE PRODUCT LIFE CYCLE MODEL

The product life cycle, while very attractive on paper, is not free from criticism. In fact, the theory of product cycles is said to be "too simple and too generalized". (Taylor, 1986, p.751) Paradoxically, this source of rejection to some has been the source of attraction to others. Kuznets, for example, in his quest for an approach that could handle an economic system characterized by ceaseless change felt that "mastery lay in limitation". (Kuznets, 1930, p.3) Similarly, Vernon states that "the great appeal of the product life cycle is its simplicity". (Vernon, 1966, p.191) The point to be emphasized is that the model is and always has been intended to provide an explanatory framework for interpreting the evolution (in form and space) of product, corporate entity, and industry. As such, the model fulfils its explanatory role since it is helpful in bridging the gap between description and analysis (see: Britton, 1985; Malecki, 1981) in the study of industrial and regional development.

Closely related to the above criticism is the argument that the Product Life Cycle is not "quantifiable". (Taylor, 1986, p.755-758) While this might have been a legitimate concern in the past, it is not necessarily the case today. The problem of Product Life Cycle Model calibration in the past is directly related to the limitations involved with traditional statistical procedures. That is, traditional statistics are primarily limited to phenomena involving continuous dependent variables. Given the qualitative and discrete nature of all product life cycle variables, there is admittedly a problem with calibration through traditional statistical methods. Recent developments in the statistical analysis of *soft data*, however, has alleviated many of the problems associated with the calibration of descriptive models (see: Ben-Akiva and Litinas, 1985; Wrigley, 1985). It will be emphasized, here, that further advances in the application of the product life cycle will require the employment of these methods of soft data analysis (ie. the logit model).

A third major criticism involving product life cycle rationale concerns the notion of essentialism. Essentialism is defined as the practice whereby intransitory industry characteristics have been equated to essential rules of industry behaviour. (Storper, 1985, p.260) An essentialist paradigm may, therefore, take a given set of empirical characteristics of past economic behaviour and assume them to be mechanisms which will determine the array of future possibilities for economic development. In such cases, a model may serve as a cognitive filter in the sense that it is incapable of dealing with the full ontology of the phenomenon at hand. (Storper, 1985, p.260-261)

It will be recalled that the product life cycle is based on a set of properties that appear to be essentialist in nature. That is to say, the characteristics of each stage of technological development are derived from empirical and historical observations, a reality that has lead some to believe that the model is overly deterministic. (Taylor, 1986) In spite of the 'essentialist form' of the product life cycle theory, it must be stressed that the biases of essentialism may be avoided. Two of the most effective means of avoiding essential bias are (1) to monitor, modify, add or delete any variables that are essentialist in nature and (2) to test the results of a potentially essential model against the results of alternative theoretical frameworks. In terms of the variables that make up the product cycle, modification and adjustment may include consideration of recent trends in the nature of production (ie. just-in-time delivery systems and flexible automation). In the second case, verification of product life cycle rationale may be achieved by considering the evaluation of other frameworks on the same phenomenon (ie. do the predominant product cycle characteristics of a given activity, say new technology intensive manufacturing, correspond to the logic of their linkage patterns as suggested by the theory of agglomerations and linkages?). In the end, essentialism is avoidable; this requires both the consideration of the changing industrial environment as it concerns product cycle rationale and the consideration of alternative regional growth theories that serve as partial checks on the conclusions drawn by product cycle analysis.

A final criticism of the model pertains to its tendency to revolve around the premise technological change. As a result of this technological emphasis, the life cycle paradigm has been accused of "disembodied, unilinear, technological determinism". (Taylor, 1986, p.162) While this statement is certainly not irrelevant, it is quite misleading. True, the model does represent the product and/or industry as a disembodied entity, however it must be acknowledged that any theory must abstract from reality. The product life cycle breaks the technological entity (whether it be a firm, product, or industry) into its most essential components - this is an absolute necessity if the components of industrial evolution are to be traced and evaluated. Furthermore, to allege that the product life cycle is unilinear is to disregard the most recent refinements made to the model. The work of Utterback and Abernathy marks the transition of product cycle logic away from unilinearity by suggesting several ways to define and alter the traditional sinusoidal path of the life cycle curve (Rothwell and Zegveld, 1985); for this reason, both the product cycle and innovation life cycle frameworks will be subject to calibration. Lastly, though the model is constrained within the parameters set forth by technological change, it must be stressed that technological change can, and often does, influence all aspects of a given industrial environment.

CHAPTER 4 PROCEDURAL ANALYSIS

4.0 TOWARDS A THEORETICAL FRAMEWORK

The present science of regional industrial development relies on "the culling of disparate theoretical fragments in order to provide a satisfactory set of explanations" (Markusen et al., 1986, p.132) - i.e. site factor analysis, agglomeration and linkage theory, technology-gap theory. The integrated application of such alternative models will, therefore, facilitate the proposed analysis of industrial and technological development in several important ways. First of all, the employment of various frameworks provides an effective platform for testing the results of product and innovation life cycle analysis. Secondly, these frameworks occasionally cover aspects of regional development that may be neglected by the theory of product cycles (i.e. the notions of new firm formation and spin-off activity are dimensions of technological development not considered within the parameters of the product life cycle). Lastly, the quality of hypothesis testing is greatly improved when a number of alternative theoretical perspectives are approached and integrated. Indeed, hypotheses tested in and amongst the frameworks of other theories cannot but strengthen the overall quality of analysis.

The ensuing sections will formally introduce the theories that will be employed in this analysis of technological development. Each of these theories will carry (a) hypotheses that can be tested against analogous hypotheses found in the product and innovation life cycle and/or (b) hypotheses that can be fit into the framework of the product life cycle. As such, each hypothesis will be stated formally and will be discussed in so far as it relates to the analysis of regional technological development.

4.1 PRELIMINARY HYPOTHESES CONCERNING TECHNOLOGICAL DEVELOPMENT IN MISSISSAUGA AND THE CTT

> Tomorrow's industries are not born in yesterday's regions...as leading sectors decline in importance, so do the regions that contain them (Knudsen, 1990. p.6)

The notion of technological growth and development is perceived to be the result of processes which create intense interaction between entrepreneurs, research institutions, venture capitalists, experienced suppliers and subcontractors, and various other business services. (Steed and Nichol, 1985, p.6) Such dynamism, which is characteristic of many technology intensive regions - Boston's Route 128, North Carolina's Research Triangle, Scotland's Silicon Glen and England's M4 Corridor - is acknowledged as a major source of recent thrusts in 'reindustrialization', most notably because of its ability to spawn radically new techno-economic possibilities in the market place.

While there appears to be considerable variation in the indigenous innovative capacity of different regions, a standardized measure for determining the scope of such techno-economic development does not exist. This potentially debilitating factor is very much rooted to the problem that is associated with defining and operationalizing the notion of technology and its antecedents. Of the many different indicators of technological capacity that do exist (i.e. rates of spin-off activity, patent activity, or Research and Development), only one will be approached on a consistent basis: the rate of innovative density.

The ratio of innovative density is a straight forward and widely used surrogate of the scope of regional technological development. (Meyer-Krahmer, 1985) The measure is defined as the ratio of all R&D performing firms to all industrial plants and is based on the premise that 'not to innovate is to die'. This can be taken a step further by noting that self-generating regional growth tends to be found only where an industry remains highly dynamic and this dynamism is fuelled by continuous R&D efforts. (Malecki, 1986, p.64) In a 1985 study performed by Meyer-Krahmer, it was shown that the innovative density within the most dynamic industries of Britain's agglomerated regions was about 1 to 5 and that this figure was comparable to similar measures taken elsewhere. (Meyer-Krahmer, 1985, p.528-530) Consequently, the ratio of 1:5 will serve as a benchmark for dynamic innovative potential in a given region.

Several preliminary hypotheses may be formulated from the preceding discussion. First of all, it may be hypothesized that the rate of innovative density within Mississauga and the CTT is internationally competitive. Secondly, it may be postulated that the rate of innovative density will not vary significantly between Mississauga and the centres that make up Canada's Technology

Triangle. Finally, it is expected that the rate of innovative density will vary significantly by form of ownership (ie. independent ownership versus foreign ownership).

4.2 SIGNIFICANT SITE FACTORS IN THE LOCATION OF HIGH TECHNOLOGY INDUSTRY

Industrial location variables can typically be classified into two categories. There are those location variables that are related to the friction-of-distance and those that are related to site attributes. Friction-of-distance variables measure the costs of moving materials, products, people or ideas in terms of distance, money or time. Conversely, site attribute variables are concerned with characteristics of points in space. (Rees and Stafford, 1986, p.42-44) Although traditional industrial location theory has emphasized the role of the friction-of-distance variable, the role of the site attribute variable has increasingly become the focus of concern in the most technology intensive regions: the firms occupying such regions tend to produce high value added components for which transportation charges per unit are low. (Rees and Stafford, 1986, p.42)

Nowhere is the impact of the site attribute variable more strongly felt than it is for the firms comprising the high technology manufacturing sector. (Rees and Stafford, 1986, p.42) The most commonly cited site factors include: the presence of labour - Rees and Stafford (1986), Markusen et al (1986), Oakey (1985); the presence of quality and varied modes of transportation

- Markusen et al (1986), Oakey (1985), Scott (1982); the presence of academic institutions - Malecki (1989), Rees and Stafford (1986); the quality of life and amenities - Markusen et al (1986), Schmenner (1982); and the presence of a well developed industrial infrastructure - Rothwell and Zegveld (1985), Scott (1982). The factors deemed most important to a (re)locating high technology establishment inevitably embrace those locations with ready access to large pools of highly skilled and educated labour, various modes of transport (particularly air transport), and academic institutions. Moreover, those locations which have a well developed urban economy (ie. a 'healthy business climate') and a strong presence of amenities (whether they reflect the natural environment or built environment) are often found to be most desirable by firms within the high technology sector.

In conclusion, several site factors have been found to be more commonly demanded by entrepreneurs within the high technology sphere of industry than others. For this reason, it would seem that an analysis of the most demanded site factors within an industry or region might go far in revealing information concerning the nature of production. Specifically, if the presence of other firms (both high tech and non high tech), the presence of universities, the presence of large pools of skilled labour, the presence of natural and cultural amenities, and access to various modes of transportation is considered to be of considerable importance to the firms comprising an industry or region, then it might be concluded that that group of firms displays locational requirements analogous to the requirements of high technology activities. It is expected that a large proportion of the technology intensive firms in the Mississauga and the CTT region will exhibit an affinity for the factors described above.

4.3 LINKAGES AND REGIONAL INDUSTRIAL DEVELOPMENT

It is often said that one of the first steps that is undertaken in the integration of production is the "forging of physical connections" between a productive unit, its suppliers, and its final consumers. (Walker, 1988, p.382) Therefore, the linkage essentially represents the lifeblood of the productive entity; it accounts for all of the flows of materials, information, money and labour that move between and amongst the various limbs of the industrial establishment.

Linkages can be interpreted within two dimensions. In the first dimension linkages are defined in terms of directional flows. The flows of raw or semi-finished inputs (i.e. subassemblies in computer production) toward the productive unit are called backward linkages while the movement of finished goods toward the market are called forward linkages. In the second dimension linkages are defined by the role that they play in production. In this case, all of those linkages that result due to a lack of in-house technical capability are called complementary linkages while all of those linkages that result due to an inability of in-house production to meet demand are called concurrent linkages. (Scott, 1982, p.20-22) However defined, the smooth functioning of these linkages is of paramount importance to any firm. From a regional planning perspective, the continuous development of internal linkages within a region forms the backbone of a 'healthy' regional economy.

At this point, it might be recalled that new technology based firms are said to benefit most significantly from the presence of an agglomeration economy. It will also be recalled that the agglomeration economy epitomizes a clustering of locational advantages, many of which are related to input retrieval and market access. In the terminology of linkages, this suggests that many small technology intensive firms rely on sources of outside technical expertise rather than indigenous competence across a complete range of science and technology functions. (Walker, 1988, p.968) The large foreign owned subsidiary, on the other hand, is notorious for its heavy reliance on parent-based intra-corporate flows which inevitably take the form of standardized non-local linkages. (Britton, 1985, p.67-68) These observations are magnified in importance when it is realized that small domestic firms with strong local linkage networks experience the greatest rates of product innovation. (Walker, 1988, p.968)

Based upon the above knowledge of past linkage patterns, the following hypotheses can be postulated. First of all, it is to be expected that small independent domestic firms will develop a stronger network of local linkages than those networks developed by their foreign owned counterparts. Second, it is anticipated that those firms with the greatest network of local linkages will also exhibit the highest rates of product innovation. In total, it might be said that the more intense the pattern of local linkages, the stronger the likelihood for healthy interaction within the industrial community.

4.4 OTHER CONSIDERATIONS: NEW FIRM FORMATION AND THE EFFECTS OF PLANT SIZE

New Firm Formation:

An analysis of the processes involved in new firm formation can go far in revealing the dynamism (or lack thereof) of indigenously based industrial development. While the absolute rate of firm formation is perceived to be an important indicator of industrial development, the nature of these formation patterns is often overlooked. Perhaps the most important dimension to be considered within the ontology of firm formation concerns the relationship that exists between the new technology based firm and the source of this entity (the 'incubator' or donor organization). The incubator firm represents the most direct line of ancestry in the development of a newly formed industrial establishment. For this reason, any information concerning the structural and locational dynamics of a region's main incubators will, in fact, identify the genesis of existing industrial infrastructure.

The phenomenon of new firm formation is often considered in terms of the structural dynamics which characterize the donor organization. One of the more commonly used structural classification schemes of firm formation is known as the acorn/spin-off framework. (Steed and Nichol, 1985) The acorn is said to represent any industrial entity that has emerged out of an idea developed by some entrepreneur(s) from either a university and/or a government laboratory. The spin-off, on the other hand, represents an establishment that has emerged out of an idea developed by some entrepreneur(s) from the private sector of manufacturing. (Steed and Nichol, 1985, p.8). In each case the entrepreneur builds on an idea that is, in most cases, developed by the incubator. Indeed, in an attempt to minimize the effects of early stage unpredictability, and in an attempt to hedge against the possibility of early firm failure, many entrepreneurs will maintain their position within the donor company while attempting to kick start their new technology based firm. This routine is known as the 'soft-start' and it serves as an important buffer to the realities of early firm formation (ie. unpredictable revenue schedules and possible firm failure).

Although the structural considerations made possible by the acorn/spin-off framework represent an important dimension of firm formation, the locational dynamics of the incubator - new technology based firm relationship add an equally significant dimension. More specifically, the location of the incubator with respect to the location of its new technology based offspring may be used to indicate the propensity for existing industrial infrastructure to generate locally-based industrial entities. Thus, the epitome of self-generating and self-sustaining industrial capacity is best described by those regions containing a high proportion of new technology based firms that are generated by those donor establishments that are indigenous to the region; new firm formation that is sponsored by non-local incubators will, in many cases, represent increases in branch plant activity, a contribution that may add to industrial growth but not necessarily industrial development. (Malecki, 1989)

Based on the preceding discussion the following hypothesis may be proposed. If a new technology based firm is generated from a locally based incubator firm then it might be expected that the given new technology based firm will display characteristics that are most indicative of technology intensive activity (ie. high rates of R&D expenditure, product innovation, and so on).

Size:

The effect of size on industrial performance creates an issue that is, at times, contentious. This point is especially relevant in the debate concerning the relationship between foreign ownership and industrial underdevelopment (Britton and Gertler, 1986; Britton, 1985 a). It will be recalled that the foreign owned subsidiary has been targeted as the primary cause of the ills that permeate Canadian industrial development. This picture, however, becomes somewhat blurred when the implications of firm size are introduced into the equation. Indeed, the suggestion that foreign owned firms are often very large firms has persuaded some to theorize that industrial underdevelopment is more a result of firm size than a result of form of ownership. From a product cycle perspective, this assertion is certainly logical. Large firms very often represent those industrial entities that are approaching late stages of technological development (ie. rigid automation, standardized products lines, market saturation, and so on).

Although size can go quite far in explaining the variations in foreign owned industrial performance, it does not justify all of the variation. Foreign owned subsidiaries tend to locate with the primary intention of satisfying local demand (barring the granting of a world product mandate by the parent corporation). In light of this, the presence of such firms will inevitably limit the opportunity for other indigenous based firms to develop and perhaps survive - consider Checkland's Upas Tree Effect in Beesely and Hamilton (1984). In spite of the fact that the Upas Tree Effect is inherent to all industrial landscapes (regardless of ownership), the contributions made to local industrial development by the large domestic firm sector far outweigh the contributions made by its foreign based counterpart. Stated simply, the foreign owned firm does not support an extensive network of local backward linkages; and of the linkages that do exist, most are large standardized intra-corporate flows that are destined for international boundaries. From this line of reasoning comes the assertion that foreign ownership may well sponsor industrial growth (ie. absolute employment growth due to plant site selection) without industrial development (ie. short-circuiting of the local linkage network).

Regardless of the semantics concerning the connection between foreign ownership, plant size, and industrial performance, there is no question that foreign ownership holds a disproportionately high share of the large plants. This fact, in combination with the principle of industrial truncation, cannot but lead one to believe that the foreign firm is indicative of late stage product cycle development. This holds true for foreign owned firms of all sizes. From this we may hypothesize that the foreign owned subsidiary will exhibit indications of reduced industrial performance and this will hold true in spite of the size of the facility in question.

4.5 THE PRODUCT LIFE CYCLE IN A UNIVARIATE ENVIRONMENT

The Product Life Cycle, in its most simplified form, is a paradigm which expresses a series of characteristics that can be attributed to a product, firm or industry at a given point in time. For this reason, we have considered the theory of product cycles and its antecedents in a form that is multivariate in nature. That is to say, the framework has been presented in a manner that equates a particular stage of development (the dependent or response variable) to a string of characteristics (the independent or explanatory variables) for a given economic entity (product, firm, or industry). From a practical standpoint, however, the analysis of technological development according to product and innovation life cycles is best served when these cycles are introduced into a bivariate environment. It is within such an environment that the dynamics of the life cycle can be scrutinized without necessitating the need for interpreting interaction effects amongst the explanatory variables - a phenomenon which can be handled only after the simple one-way relationships have been approached.

As a result of the complexity involved in the analysis of multiple interaction effects, the initial employment of the product cycle will be directed at understanding the relationship between the stage of development and the appropriated characteristics. In addition to this, the product cycle will be utilized (in a similar fashion) to test some of the hypotheses developed in alternative theoretical frameworks. For example, do the firms that are categorized as 'stage one' exhibit a tendency towards complex linkage networks? Do 'stage three' firms display high levels of foreign ownership? And which of the high technology industries fall within the category of stage one development on the most frequent basis? These and many other questions will be confronted in the bivariate environment. It is expected that such an investigation will serve as an effective first step in the attempt to calibrate the product life cycle.

4.6 THE PRODUCT LIFE CYCLE IN A MULTIVARIATE ENVIRONMENT

The product life cycle is primed for the analysis of industrial and/or technological development at the multivariate level. By multivariate analysis we refer to the simultaneous consideration of all explanatory variables geared towards describing the stage of technological development. The contents of Table 4.1 illustrate this conclusion quite clearly. As stated

TABLE 4.1

STAGE SPECIFIC CHARACTERISTICS AND VARIABLE CODES OF THE LIFE CYCLE

INNOVATION LIFE CYCLE ATTRIBUTE	STAGE OF TECHNOLOGICAL DEVELOPMENT FLUID PATTERN	TRANSITIONAL PATTERN	SPECIFIC PATTERN
Product Line: (prd)	diverse, often including custom design. (prd1)	includes at least one product that is standardized in production. (prd2)	products are differentiated and highly standardized. (prd3)
Mfg. Process: (prc)	flexible with almost no automation. (prc1)	becoming more rigid with "pockets" of automated subprocesses. (prc2)	efficient, capital intensive, and very rigid. (prc3)
Aim in competi- tion: (com)	functional product performance. (com1)	product variation. (com2)	cost reduction and quality. (com3)
Control within the Firm: (org)	informal and entrepreneurial. (org1)	through liaison relationships, project and task groups. (org2)	through emphasis on structure and rules. (org3)
R&D inspired by: (ino)	the needs of the market. (ino1)	the need for increased scale of production. (ino2)	the need to reduce cost. (ino3)
Nature of Labour Force: (emp)	highly skilled and well educated. (emp1)	a balance between technical and non-technical labourers. (emp2)	predominantly administrative and non- technical. (emp3)
State of Market: (mar)	ill defined with the potential for vigorous market expansion. (mar1)	minimal market uncertainty; entry remains profitable. (mar2)	no market uncertainty; entry is very difficult. (mar3)

SOURCE: Interpreted from Abernathy and Utterback (1981) and Rothwell and Zegveld (1985).

previously, the life cycle is comprised of several discrete stages each containing a series of qualitative attributes that are stage specific. Stage one, for example, is characterized by diverse product lines often requiring custom design; the production process is highly labour intensive; the competitive emphasis is geared towards product performance; and control within the organization is informal and entrepreneurial. Viewed in this light, it is apparent that each stage carries, with it, a typical set of characteristics - these characteristics represent the "personality" behind the industrial entity.

Although the simplest way to model the relationship between the stages of development and the characteristics of those stages would appear to take the form of some extension of the regression model, it must be reiterated that we are dealing with a framework that is both descriptive and qualitative in nature. As a consequence, the application of the traditional regression form $Y = \alpha + \beta X + \epsilon$ becomes unsuitable in those cases where the dependent variable is discrete in nature. In the end, an alternative form of statistical analysis is required - it comes in the form of logit modelling as defined within discrete choice theory.

4.7 AN INTRODUCTION TO THE THEORY OF LOGIT MODELLING

4.7.1 CLASSES OF STATISTICAL PROBLEMS

Traditional methods and models for spatial data analysis have typically been based on 'hard', cardinally-measured information (ie. interval or ratio data). Indeed, approaches such as optimization models, regional growth models, entropy models, and the like all reflect the past tendency to cast complex spatial integration patterns into frameworks of cardinally measured systems. More recently, however, significant progress has been made in the analysis of soft, qualitative or categorically-measured data. (Wrigley, Leitner and Nijkamp, 1985). Indeed, a wide range of techniques now exist in the fields of parametric and non-parametric statistics; techniques which are capable of dealing with the previously unmeasurable qualitative variable. Such endeavours underscore a revolution which has swept through an area of statistical analysis often referred to as 'soft econometrics'.

Although the past trend to cast patterns of spatial interaction within the framework of cardinal measurements has served a useful purpose, researchers in the areas of regional and urban economics, human geography, planning, and transportation have become increasingly aware of the necessity to incorporate categorical data in their statistical procedures:

> Classifications are a familiar part of everyday life. Individuals are classified by sex, marital status, nationality, occupation, etc. Places are classified by country, region, locality, etc. Some of these classifications define just two exhaustive and mutually exclusive categories. Others used singly, or simultaneously in the form of a cross-classification, define multiple categories. (Wrigley, 1984, p.4)

The implication, alluded to above, is that categorical data is more than just a possibility in statistical analysis; it is an ever-present and unavoidable reality permeating all sectors of social science. The procedures required to calibrate the product life cycle stand as a case in point.

In formal terms, categorical data represent all those forms of data which consist of counts of the number of observations in particular categories. If the categories are recognized as standing in some kind of relationship to each other then a ranking or ordering of the categories is possible. This data is said to be measured at the ordinal scale. If the categories cannot be ranked, however, the data is said to be measurable at the nominal scale. In total, categorical data are those forms of data measured at low level, nominal or ordinal scales. Terms commonly used to describe such data include qualitative, soft, or discrete; all of which distinguish between the low-level qualitative measurements characteristic of the social sciences and the high-level quantitative measurements characteristic of the physical sciences. (Wrigley, 1984, p.15)

Perhaps one of the most effective means of conceptualizing the classification of statistical problems is found in the application of Wrigley's matrix of statistical problems by data type. Table 4.2 provides all of the details of this simple breakdown. Notice, first, that the rows consist of response variables while the columns consist of explanatory variables. The former is analogous to the dependent variable while the latter is representative of the independent variable. Notice, also, that continuous variables are those measured at high-order, interval or ratio scales. Categorical variables, on the other hand, are those measured at low-level, nominal or ordinal scales. Such categorical variables may be

TABLE 4.2

Classes of Statistical Problems

		Explanatory Variables		
		Continuous	Mixed	Categorical
Response	Continuous	(a)	(b)	(c)
Variables	Categorical	(d)	(e)	(f)

SOURCE: Wrigley (1985).

further disaggregated into three sub-classes: dichotomous (ie. male / female), ordered polytomous (ie. young / middle-age / old), and un-ordered polytomous (ie. car / bus / cycle).

Table 4.2 is organized in such a way that as one moves from cell (a) towards cell (f), one moves towards the more pervasive problems associated with categorical data. That is to say, the techniques employed in existing statistics manuals are confined largely to handling the problems in the top row. The integrated approach to categorical analysis, however, provides methods for handling the problems which very often surface throughout cells (d) to (f). Given this paramount difference in statistical logic, it now becomes important to identify a means of overcoming the gap between traditional statistical analysis and the reality of categorical data sources. The vehicle chosen here (and it will be emphasized that there are others), is the logit model.

4.7.2 THE LOGIT MODEL IN THEORY[2]

The Logistic Function:

In terms of the scheme presented in Table 4.2, the logit model may be likened to the regression model, barring one major exception. Whereas linear regression analysis relies predominantly on continuous data responses, the logit model employs low-order discrete data responses. More specifically, the binary logit model is applicable to those cases which involve a categorical dependent variable with only two categories. Similarly, the multinomial logit model applies to those cases which are characterized by dependent variables containing three or more categories. In total, the modelling of categorical data (ie. the dependent variable is categorical) cannot be achieved through conventional *linear* regression. One type of line that is effective in the modelling of such data is referred to as the *logistics curve*. (Stynes and Peterson, 1984)

Since the logit model is based upon the logistic function, it is important to consider the nature of the logistic curve. Figure 4.1 presents a plotting of a specific form of the logistic function. The algebraic equivalent to this graph is stated as follows:

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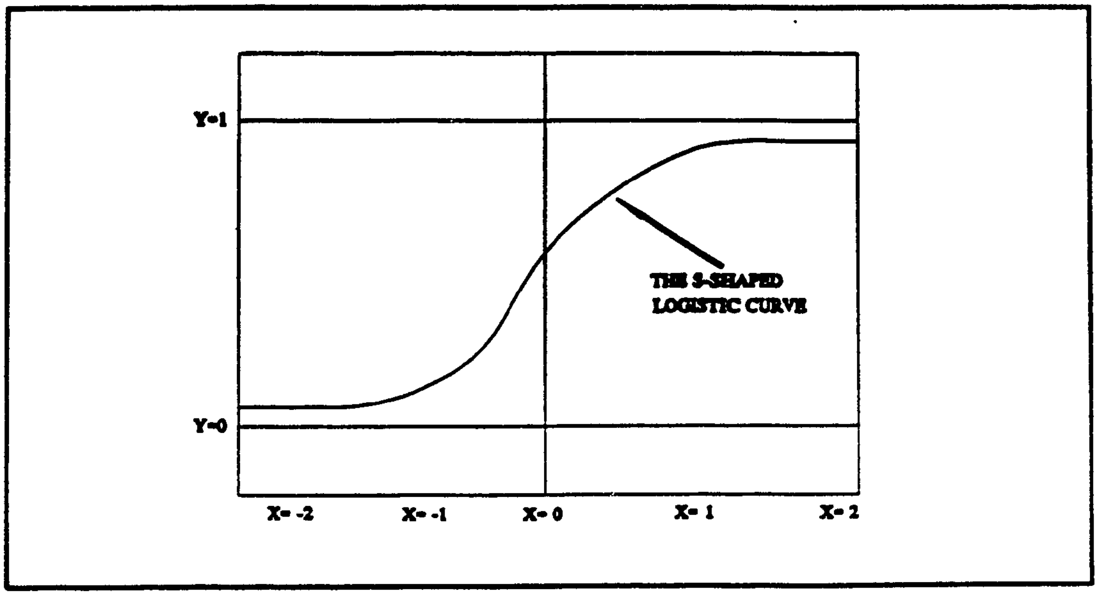
[2] The ensuing section is largely the product of discussions forwarded in Wrigley(1985) and Stynes and Peterson(1984).

FIGURE 4.1

A Graphic Illustration of the Logistic Curve



$$Y = \frac{1}{(1 + e^{-(a+bx)})} = \frac{e^{a+bx}}{1 + e^{a+bx}} \qquad (4.1)$$

where a and b are unknown parameters. Notice that the logistic function is bounded and doubly asymptotic, approaching y=0 and y=1 as x approaches - and + infinity, respectively. This specific form of the logistic function is well suited to processes which have start-up impediments and saturation effects; the curve grows slowly at first, reaches a maximum rate of growth, and then proceeds to increase at a decreasing rate, approaching the saturation point as a limit. In light of this, the primary difference between the linear and logistic function (as defined above) is that the linear function is unbounded and has a constant slope, while the logistic function is restricted to the interval (0,1) and has a changing slope. The latter is particularly well suited to the modelling of data containing a categorical dependent variable. (Wrigley, 1984, p.32-34)

The Binomial Logit:

It will be emphasized here, that the logistic function and its transformation into a linear form (the logit transformation) offer an effective means of overcoming the problems associated with statistical modelling when categorical variables are involved. The equation illustrated below (equation 4.2), represents the initial application of logistic rationale in terms of a two-category dependent variable environment. The categories could represent anything from migrating to not migrating to selecting industrial location 'A' over industrial location 'B'.

$$P_1 = \frac{e^{\beta_0 + \beta_1 X_1 + \ldots + \beta_i X_i}}{1 + e^{\beta_0 + \beta_1 X_1 + \ldots + \beta_i X_i}} \qquad (4.2)$$

where P_1 represents the probability of observing an *occurrence* in category one, β_i represents a parameter to be estimated that corresponds to the ith independent variable X_i, and β_0 is the alternative specific constant. As illustrated below, the restructuring of equation 4.2 (see steps one to three) results in a functional relationship which relates the odds of selecting one category over another equation given the constraints of the logistic function and its parameters.

$$P_1 (1 + e^{\beta_0 + \beta_1 X_1 + \dots + \beta_k X_k}) = e^{\beta_0 + \beta_1 X_1 + \dots + \beta_k X_k} \qquad \text{(step 1)}$$

$$P_1 + P_1 e^{\beta_0 + \beta_1 X_1 + \dots + \beta_k X_k} = e^{\beta_0 + \beta_1 X_1 + \dots + \beta_k X_k} \qquad \text{(step 2)}$$

$$P_1 = (1 - P_1) e^{\beta_0 + \beta_1 X_1 + \dots + \beta_k X_k} \qquad \text{(step 3)}$$

$$\frac{P_1}{1 - P_1} = e^{\beta_0 + \beta_1 X_1 + \dots + \beta_k X_k}, \text{ where } 1 - P_1 = P_2 \qquad (4.3)$$

$$\frac{P_1}{P_2} = e^{\beta_0 + \beta_1 X_1 + \dots + \beta_k X_k} \qquad (4.4)$$

Equations 4.3 and 4.4 represent the predicted odds of selecting category one over category two. Similarly, both equations relate a series of k independent variables to a logistic function.

Finally, by taking the natural logarithms of both sides of the predicted odds equation, a linear equation is yielded for the logits (L).

$$L = Log_e \frac{P_1}{P_2} = \beta_0 + \beta_1 x_1 + \dots + \beta_k x_k \qquad (4.5)$$

In formal terms, these logits ($Log_e P_1/P_2$) represent the log odds of selecting/observing one alternative/category over another. Moreover, the logits are unbounded and are linearly related to the independent variables (X_i's), while the probabilities (P_1 and P_2) are restricted to a range of 0-1 and are related to the independent variables by a logistic function.

The Multinomial Logit:

The multinomial logit model is a generalization of discrete choices involving more than two alternatives. The family of equations associated with the polytomous dependent variable of three categories is illustrated below:

$$L_1 = \log_e \frac{P_1}{P_3} = \beta_{10} + \beta_{11}x_{11} + \beta_{12}x_{12} + \ldots + \beta_{1k}x_{1k} \qquad (4.6)$$

$$L_2 = \log_e \frac{P_2}{P_3} = \beta_{20} + \beta_{21}x_{21} + \beta_{22}x_{22} + \ldots + \beta_{2k}x_{2k} \qquad (4.7)$$

In this case, β_{ji} (where j=1,2 and i=1,2,...k) are parameters to be estimated with j indicating the category of the dependent variable and i the independent variable X_{ji} to which this parameter corresponds to.

The multinomial logit model is clearly more complex than its binary counterpart and introduces a number of assumptions that may not be readily apparent. Both the major strength and weakness of the model is the independence from irrelevant alternatives (IIA) assumption. The IIA property, which dates back to Arrow (1952), implies that the ratios of the probabilities for any two alternatives is independent of any other alternatives. The implications concerning the IIA assumption are effectively discussed by Wrigley (1985) under the sections of model tractability and IIA assumptions.

Parameter Estimation and Logit Model Testing:

Maximum likelihood is typically the method utilized to estimate the parameters of a logit model. As such, this procedure is essentially analogous to least squares estimation in regression analysis. The key difference between the two estimation procedures is that maximum likelihood requires the choice of parameters that are most likely to produce the observed sample of response category choices in the data set. (Wrigley, 1985, p.36) Least squares estimation, on the other hand, requires that the selection of parameters minimize the total sum of squares. So, unlike least squares estimation, maximum likelihood requires numerical methods for the estimation of its parameters. The most widely used technique is the Newton-Raphson method, a method which proceeds in iterations, maximizes the log likelihood function associated with a specified multinomial logit model, and is considered to be one of the most effective estimation methods. (Wrigley, 1985, p.190)

Just as the effectiveness of a regression model may be tested in terms of its Goodness-of-fit and in terms of the significance of its independent variables, so too can the logit model be tested in a similar fashion. In the case of regression analysis, goodness-of-fit is indicated by the coefficient of determination, a ratio involving the total sum of squares. In logit modelling, the same measure is determined by using a ratio of maximized log likelihood values. The measure is called the Rho-square and is illustrated on the following page:

$$\rho^2 = 1 - \frac{\log_e \Lambda(\beta)}{\log_e \Lambda(c)} \quad (4.8)$$

where Log_e Λ represents the log likelihood, β hat represents a vector of the estimated parameters (β_{10}, $\beta_{11}, \ldots \beta_{1k}$), and C represents the constant terms β_{10} and β_{20}. Notice that the ratio of fitted to constant-only maximized log likelihoods terms is subtracted from one. Thus, the smaller the ratio the larger the rho-square value. It should also be noted that the rho-square value tends to be considerably lower than its regression model counterpart. As a result the standards for a very good model fit are set within a value range of .2 to .4 (Wrigley, 1985, p.49)

Along similar lines, the separate T-Test Statistic employed within regression analysis is inadequate for use in logit modelling. Consequently, a Quasi T-Test is determined by calculating the ratio of parameter estimates to their asymptotic standard errors. The quasi T-stat is given below:

$$-cv \leq \frac{\beta_k}{\sqrt{var(\beta_k)}} \leq +cv \quad (4.9)$$

where cv represents the critical value for hypothesis testing, β_k hat represents the parameter estimate for the parameter β_k, and the square root of var(β_k hat) represents the estimated standard error of the parameter estimate. It should be observed that the quasi T-test is not a true T-test in the conventional sense since the t-ratio's are asymptotically distributed as the standard normal distribution (note here, that this is also a property of the t-distribution). Nevertheless, the quasi measure is interpreted by using the conventional levels of significance - ie. ± 1.65 critical values (cv) for the 10% significance level.

The preceding discussion is in no way intended to cover all of the statistics involved in the logit modelling procedure. Indeed, the objective of this section has been to create a presentation of the logit model in a concise and easy-to-understand form. From here the principles involved in the specification and estimation of the logit model according to product cycle rationale will be more easily understood.

4.8 SPECIFICATION OF THE LOGIT MODEL ACCORDING TO THE PRODUCT AND INNOVATION LIFE CYCLES

Independent/Explanatory Variables:

Perhaps the most effective starting point in the specification procedure lies in the determination and measurement of the independent variables. Referring back to Table 4.1 on page 69, the independent variables listed refer to the traditional characteristics of the product life cycle. These variables (and their abbreviated forms in parentheses) represent those characteristics which have been associated with technological development in the past. It will be noted that the measurement of these variables is arranged on a binary basis. For example, for each alternative and for each explanatory variable, only one characteristic will be observed (the characteristic observed will be valued at 1 for the given variable while all other characteristics of that same variable will be valued at 0).

In addition to the traditional independent variables of the product life cycle (ie. the nature of the product line, the nature of production processes, the form of organizational control, etc.), several others will be introduced into the model. These variables include: form of ownership (Canadian and independent, Canadian subsidiary, and foreign owned subsidiary), location (ie. Mississauga and the CTT), industry group (ie. aircraft and parts, drugs and medicine, scientific and professional equipment, telecommunications and electronics, and so on), firm size, and firm age. In addition to contributing to the overall effectiveness of the model, the impact of these variables within the product cycle will be contrasted to the hypotheses that they have generated outside of this theory.

In most cases, a good mix of theoretical and empirical criteria should be used in the selection of a functional form. The independent variables to be considered within this specified framework have been selected on such grounds and are expected to effectively contribute to our understanding of industrial development processes in Mississauga and the CTT.

The Dependent/Response Variable:

Without a doubt, the specification of the response variable served as the most difficult procedure in this analysis. Consider, first, that the dependent variable of the product cycle is represented as the stage of technological development of a firm. Next, consider the complexity, ambiguity, and lack of standardization that is involved in defining the notion of technological development and its associated antecedents. In a nutshell, the concept of technology is "evasive and exceedingly difficult to pin down in practice" (Begg and Cameron, 1988, p.361). This problem is compounded by the fact that technology has no universally accepted form of measurement. Such a reality has left this author with the unenviable task of devising a system of measuring high technology.

Despite the problems elucidated above, the task of effectively defining different intensities of technology and technological development is not an impossibility. The procedure used in this analysis is based on both theoretical standards and empirical findings. Since this analysis is geared towards the calibration of the product and innovation cycles, two separate indices will be used to define technological development. We start with the stage parameters of the product life cycle.

It will be recalled that the product life cycle traces the development of industrial entities through three distinct stages. It will also be recalled that the measurable difference between each stage is realized as the difference in the rates of product innovation (ie. early stages of the product cycle are characterized by the highest rates of product innovation). Similarly, but based on empirical standards, the intensity of innovation can be measured as a ratio of R&D to total sales. (USDOC, 1983) This R&D criterion serves as an effective 'catch-all' parameter in the search to define technological development (despite the fact that information on R&D by type of innovation is virtually non-existent). By coordinating these two parameters, the following stage definitions[3] can be suggested:

STAGE 1: The number of product innovations is greater than or equal to 1. R&D expenditure is greater than or equal to 5% of total sales.

STAGE 2: The number of product innovations is greater than or equal 1. R&D expenditure is less than 5% of total sales.

STAGE 3: The number of product innovations is 0.

The parameters that were established to define the stages of the innovation life cycle were somewhat less arbitrary since this modified version of the product cycle centres around the dynamics of the product and process cycle. That is to say, the stages of innovation are largely the function of the combined relationship between product and process innovation. The stages were defined in the following manner:

STAGE 1: The ratio of one plus the number of product innovations over one plus the number of process innovations is greater than one.

---

[3] The R&D to sales ratio parameters are based on guidelines provided within USDOC (1983). The parameters for rates of product and process innovation are based on theoretical discussions forwarded by Utterback and Abernathy (1975) and Utterback (1982).

STAGE 2: The ratio of one plus the number of product innovations over one plus the number of process innovations is less than or equal to one. R&D expenditure is greater than 1% of total sales.

STAGE 3: The ratio of one plus the number of product innovations over one plus the number of process innovations is less than or equal to one. R&D expenditure is less than or equal to 1% of total sales.

By way of conclusion, it will be reiterated that the ill defined notion of technology has resulted in the need to draw lines that may be open to debate. What should be stressed, however, is the fact that the parameters provided above are the product of established theory and empirical observation. As such, and assuming that the standards are maintained across the analysis, the categorization of the stages of development on such grounds should provide a reasonably valid and consistent environment for analysis.

Complete Specification of the Product and Innovation Cycles:

An example of the complete and strictly specified logit model is provided in the final table of Appendix B (page 171). The first observation to note concerns the presence of the two alternative specific constants β_{10} and β_{20}. These alternative specific constants represent the difference in the likelihood that one alternative will be selected/observed over another, all other factors being held equal to zero. The remaining independent variables are referred to as alternative specific variables. These variables are interpreted in much the same way that the alternative specific variable is interpreted, however the parameter estimates of the alternative specific variable reflect the nature of the given variable. The algebraic equivalent to the table illustrated on page 171 of Appendix B is given below:

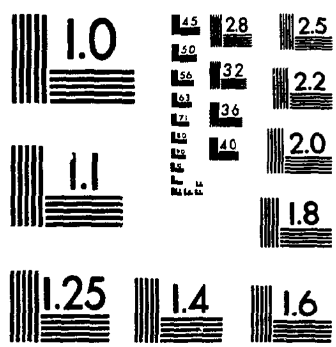
$$Log_e \frac{P_{stage1}}{P_{stage3}} = \beta_{10} + \beta_{11}.prd_{11} + \beta_{12}.prc_{12} + \ldots + \beta_{1\,20}.mar_{1\,20}$$

$$Log_e \frac{P_{stage2}}{P_{stage3}} = \beta_{20} + \beta_{21}.prd_{21} + \beta_{22}.prc_{22} + \ldots + \beta_{2\,20}.mar_{2\,20}$$

where *stage* represents the stage of technological development, β_{10} and β_{20} represent the alternative specific constants for categories one and two respectively, and β_{ji} (j=1,2 and i=1,2,...20) are parameters to be estimated with j indicating the category of the dependent variable and i the independent variable X_{ji} to which the parameter estimate corresponds to.

The analysis of the logit model as depicted above (the full linear logit model) will provide the backbone for a complete analysis of industrial development in Mississauga and the CTT. Indeed, it is expected that the examination of these log of odds equations will identify important information concerning the nature of industrial development in Mississauga and the CTT.

2



MICROCOPY RESOLUTION TEST CHART
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STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No 2)

CHAPTER 5 PRELIMINARY FINDINGS OF INDUSTRIAL DEVELOPMENT IN MISSISSAUGA AND THE CTT

5.0 INTRODUCTION

Chapter five is, for the most part, based on data obtained from the firms sampled in the study area. Furthermore, the chapter has been structured around the parameters set forth in chapter four. The analysis of results commences with an introduction to the study area, progresses towards a discussion of the sample firms, and culminates with an interpretation of industrial and technological development as it is occurring within the study area. Conclusions drawn by the calibration of the product and innovation life cycle models will be verified by considering alternative theoretical and empirical frameworks.

5.1 A GENERAL DESCRIPTION OF THE STUDY AREA

The ensuing analysis of industrial and technological development in Mississauga and the CTT is based upon survey data drawn from Mississauga and the CTT (Kitchener, Waterloo, Cambridge and Guelph). Each of these centres lies within the heart of what has come to be known as the Quebec-Windsor Axis (Yeates and Garner, 1980); in fact, each of the urban centres described above lies well within the sphere of Toronto's daily urban system.

5.1.1 RECENT INDUSTRIAL DEVELOPMENT IN MISSISSAUGA

The 1980's has seen Mississauga become home to a wide variety of large corporations: Northern Telecom, NEI Ferranti Packard Electronics, Dupont Canada, Hawker Siddeley Canada and MacDonnell Douglas to mention a few. Today, Mississauga is regarded as a highly dynamic urban centre both by academics in Canada (Britton, 1985a) and by city officials (City of Mississauga, 1990). Moreover, Canada's largest airport, Pearson International, is situated within Mississauga. Thus, in spite of the presence of Toronto, Mississauga has developed its own unique economic community - it no longer can be called "the city without a heart" (Riendeau, 1985).

5.1.2 RECENT INDUSTRIAL DEVELOPMENT IN CANADA'S TECHNOLOGY TRIANGLE

Just as Mississauga experienced bursts of industrial expansion throughout the 1900's (particularly during the war years), so too did the cities within the CTT. In fact, the latter half of the twentieth century saw the rise of 18 industrial parks, 3 major universities (Waterloo, Guelph,and Wilfrid Laurier), and the integration of the Tri-City highway network with the MacDonald Cartier Freeway. By the early 1980's, the CTT had become the home for such big name industries as NCR, Raytheon, Allen Bradley, Budd, Electrohome, Toyota, Hammond and Ciba Geigy. The recent economic development of the four composite centres has resulted in a joint industrial endeavour aimed at integrating and diversifying the economic base (and reputation) of the Upper Grand Valley. The label selected to describe this project is known as Canada's Technology Triangle. (Bathelt and Hecht, 1990)

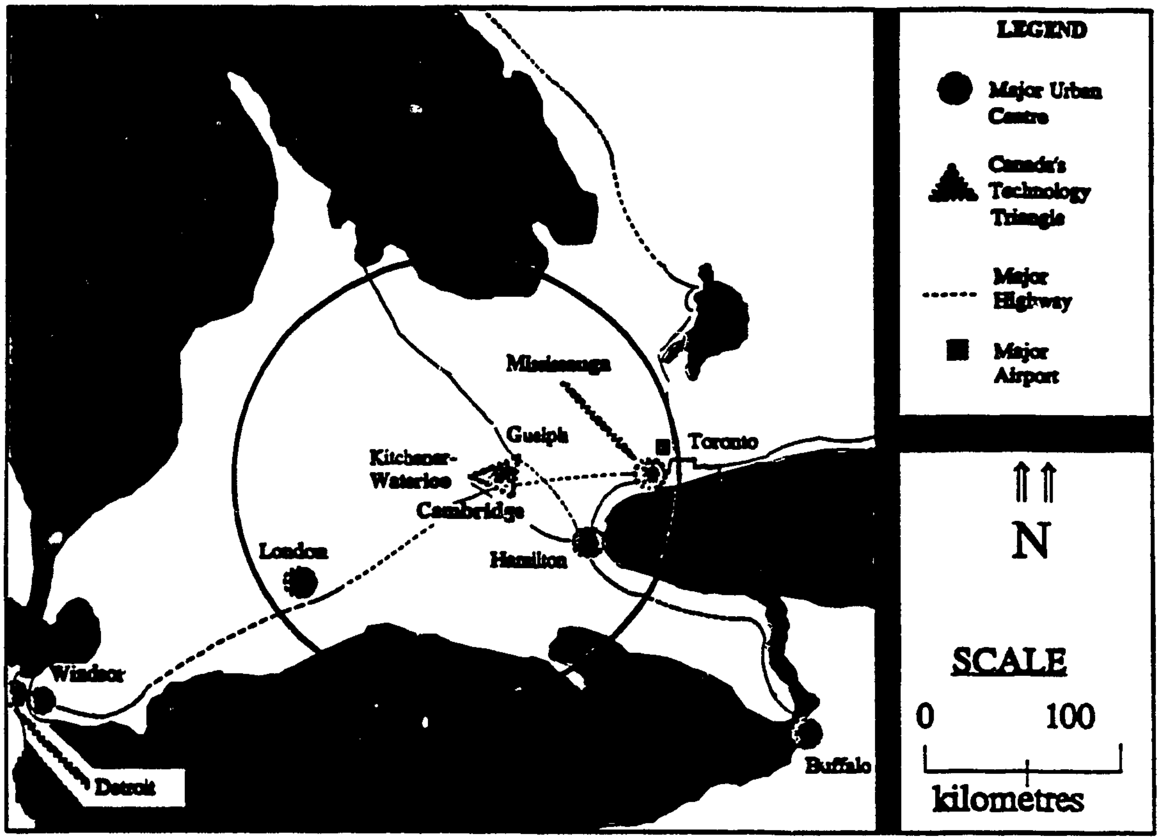
5.1.3 THE STUDY AREA AND PRESENT ECONOMIC DEVELOPMENT

The geographic location of Mississauga and the CTT is shown in Figure 5.1. Notice that Mississauga is located immediately west of Toronto while the CTT is situated approximately half way between Toronto and London. Both urban settlements are connected via the four lane MacDonald Cartier Freeway. It will also be noted that the highway network offers ready access to the United States (see: Buffalo and Detroit), to Toronto, and to other important urban centres throughout the Quebec-Windsor Axis. The relevance of this transport network is fully appreciated when one considers that 120 million people are within a one day drive of Mississauga and the CTT. (Cities of Kitchener, Waterloo, Cambridge and Guelph, 1990) A final note concerns the location of the Lester B. Pearson International Airport. This facility is of considerable importance to CTT based industries (Bathelt and Hecht, 1990, p. 229) since the airport is only 45 minutes driving time from the CTT.

General economic indicators for Mississauga and the CTT suggest the two urban settings are quite similar in terms of total business activity. In 1989, for example, Mississauga employed 260,000 total persons and operated 8,600 businesses while the urban centres comprising the CTT employed roughly 205,000 total persons

FIGURE 5.1

MAP OF SOUTHERN ONTARIO



SOURCE: Bunting (1984)

and operated just over 8,000 businesses. (Cities of Mississauga, Kitchener, Waterloo, Cambridge and Guelph, 1990) These similarities continue at the manufacturing level where Mississauga and the CTT employed about 43,317 and 59,058 manufacturing related workers respectively. (Statistics Canada C , 1985) Table 5.1 is offered as a summary of manufacturing activity in the study area. It will be noticed that the share of manufacturing activity

TABLE 5.1

GENERAL INDICATORS OF MANUFACTURING ACTIVITY IN MISSISSAUGA AND CANADA'S TECHNOLOGY TRIANGLE

CITY AND REGION	NUMBER OF ESTABLISHMENTS	EMPLOYMENT	VALUE ADDED ('000)
KITCHENER	269	23 25	1156875
WATERLOO	170	8658	457742
GUELPH	185	10842	815073
CAMBRIDGE	257	15333	834121
CTT	881	59058	3263811
MISSISSAUGA	1080	43317	2282326

SOURCE: Statistics Canada C (1985), MANUFACTURING INDUSTRIES OF CANADA: SUBPROVINCIAL AREAS, Cat. No. 31-209 (Ottawa: Supply and Services)

(according to employment, establishments, and value added) is roughly equi-proportional between the CTT and Mississauga.

5.2 AN INTRODUCTION TO THE SURVEY DATA

The data presented in Table 5.2 represents both the potential sample population of high technology firms found in the Made In Ontario Industrial Directory and the number of high technology firms that were successfully sampled within the study area. The parameters employed in the definition of high technology were based on four digit SIC codes and a full description of these firms is offered in Appendix C. It will be observed that 164 of the 245

TABLE 5.2

KEY TECHNOLOGY FIRMS IN THE STUDY AREA:
SAMPLE FIRMS BY URBAN CENTRE BY INDUSTRY TYPE †

INDUSTRY TYPE	URBAN CENTRE OR REGION						TOTAL
	WATERLOO	KITCHENER	CAMBRIDGE	GUELPH	CTT	MISSISSAUGA	
BUSINESS MACHINES	13 (9)	1 (1)	2 (2)	2 (1)	18 (13)	14 (11)	32 (24)
AIRCRAFT & PARTS	2 (1)	4 (3)	3 (2)	2 (1)	11 (7)	7 (5)	18 (12)
COMMUNICATION & ELECTRONICS	9 (7)	6 (3)	4 (2)	2 (2)	21 (14)	29 (22)	50 (36)
PLASTICS & SYNTHETICS	0 (0)	4 (0)	4 (4)	9 (8)	16 (12)	12 (8)	28 (20)
DRUGS & MEDICINE	2 (0)	2 (2)	1 (0)	2 (2)	7 (4)	20 (13)	27 (17)
SCIENTIFIC INSTRUMENTS	9 (7)	8 (7)	3 (3)	5 (2)	25 (19)	20 (12)	45 (31)
OTHER MACHINERY	6 (3)	4 (2)	4 (3)	4 (1)	18 (9)	27 (15)	45 (24)
TOTAL	44 (27)	29 (18)	21 (16)	26 (17)	116 (78)	129 (86)	245 (164)

† Bracketed values represent the absolute number of firms sampled for a given cell.

SOURCE: Abstracted from the Made In Ontario Industrial Directory (1989) according to four digit SIC classification codes.

firms (for a total return rate of 67%) were surveyed. It is important to note that every firm listed in the Made In Ontario Directory (and meeting the appropriate high technology SIC classification) was invited to participate in this survey. The firms not sampled included only those firms who refused to take part in the survey. Of the total number of sampled firms, 46 were interviewed in person while the remaining 118 were surveyed via mail. The forty firms that were surveyed in person were done so at the request of the contact person.

The return rates within Mississauga and the CTT were relatively even. Sample variation by industry was the result of substantial differences in the actual number of firms per industry rather than a reflection of sampling biases (ie. communications and electronics production is simply far more prevalent than aircraft and aircraft parts manufacture). Similarly, there did not appear to be any patterns in variation amongst those firms that did not agree to an interview. In total, it would appear that the sample taken is representative of the population.

A convenient overview of the sample firms and their general characteristics is provided for in Table 5.3. The first section of the table illustrates the absolute frequency distribution of high tech firms according to three arbitrarily selected employment size classes. Without a doubt the largest proportion of firms (about 75% of the sample) fall within the "under 100" employee category. Ironically, the average size of the sample firms was about 140 employees, however, it should be noted that this average dropped to 90 employees when the 10 largest firms were not considered. Similarly, the 14 firms allocated to the cell with more than 500 employees (roughly 8% of the sample) accounted for close to 60% of all employment in the sample.

TABLE 5.3

GENERAL CHARACTERISTICS OF THE STUDY AREA SAMPLE FIRMS†

LOCATION	SIZE DISTRIBUTION		
	0-99 EMPLOYEES	100-499 EMPLOYEES	500+ EMPLOYEES
CTT	60	10	8
MISSISSAUGA	61	19	6
TOTAL	121	29	14

LOCATION	TYPE OF OWNERSHIP		
	INDEPENDENT	CANADIAN BRANCH	FOREIGN BRANCH
CTT	46	13	19
MISSISSAUGA	38	22	26
TOTAL	84	35	45

	R&D INTENSITY (R&D EXPENDITURES AS A PERCENT OF TOTAL SALES)		
LOCATION	0%	1-10%	11+%
CTT	10	55	13
MISSISSAUGA	9	59	18
TOTAL	19	114	31

† Cell values are recorded as absolute frequency counts.

SOURCE: Based On Survey Data.

The middle portion of Table 5.3 presents information pertaining to the nature of ownership amongst sample firms. Perhaps the most significant observation concerns the high level of foreign ownership. Indeed, the already significant level of 45 foreign owned sample firms (or 27% of the sample) is magnified in importance when it is realized that they accounted for the employment of approximately 12,250 (or 51%) of all employees. Simply stated, the presence of foreign ownership amongst sample firms is significant and, assuming that the theory of truncation amongst foreign firms is an accurate one, there would seem to be room for considerable concern.

The final matrix of Table 5.3 illustrates the distribution of sample firms according to R&D intensity (as measured by the ratio of total R&D expenditures to the total level of sales). The classification scheme indicates that a mere 31 sample firms (or 18% of the sample) attained a level of R&D intensity that exceeded the 10% margin. It will be recalled, at this point, that the United States Department of Commerce defined high technology activity to include only those activities which experienced R&D expenditures in excess of 10% of total sales. (USDOC, 1983) On the flip side, Table 5.2 also shows that 19 sample firms (or about 12% of the sample) performed absolutely no R&D. Yet, evidence of intense high technology activity was found within the sample data. In short summary format, the following was the case for the 164 firms surveyed:

- 133 firms (or 88% of the sample) pursued at least some degree of R&D.
- 85 firms (or 52% of the sample) had either adopted or produced at least one product innovation.
- average rates of R&D intensity were relatively high in the business machines industry (8.4%), the communications and electronics industry (7.7%), and the scientific and professional instruments industry (6.3%).
- the average rate of R&D intensity was very high amongst

independently owned plants (11.1%).

Thus, the element of high technology exists within the study area; its presence, however, seems to be clouded by factors including size, ownership and industry type.

5.3 KEY LOCATIONAL FACTORS IN MISSISSAUGA AND THE CTT

An important consideration in any analysis of regional industrial development concerns the role that various site factors play within a given industrial community. In chapter four, the locational factors deemed to be most closely associated with high technology were discussed. The availability and presence of skilled labour, universities, effective transportation, an attractive business environment, and natural amenities were all thought to be quite important. In the survey drawn here, each firm was asked to rank various site factors as being either "very important", "important" or "not important". The results of this endeavour have been summarized in Tables 5.4 and 5.5.

From Table 5.4 it can be seen that the "very important" and "important" location factors include the founder's familiarity of the region, the quality and variety of transportation, the availability of skilled labour, the presence of an attractive business environment and the presence of a university - in each case the proportion of respondents was in excess of 45% of the

TABLE 5.4

"IMPORTANT" AND "VERY IMPORTANT" LOCATION FACTORS IN THE STUDY AREA BY OWNERSHIP†

IMPORTANT LOCATIONAL FACTORS	PROPORTION OF RESPONDING FIRMS BY OWNERSHIP:		
	FOREIGN OWNED	ALL OTHERS	TOTAL
FOUNDERS FAMILIARITY OF REGION	65.2	86.5	81.4
TRANSPORTATION	87.0	64.9	70.1
SKILLED LABOUR	56.5	67.6	64.9
BUSINESS CLIMATE	52.2	51.4	51.5
UNIVERSITIES	43.5	45.9	45.4
LAND COSTS	87.0	27.0	41.2
OTHER HIGH TECHNOLOGY FIRMS	39.1	37.8	38.1
AVAILABILITY OF LAND	87.0	21.6	37.1
AMENITIES	56.5	28.3	35.1
PROXIMITY TO MARKETS	87.0	12.2	29.9

† Site factor analysis was based on those survey firms which had located within the study area during the 1980's.

SOURCE: Based On Survey Data.

sample. As might be expected, the importance of locational factors varies by ownership type. Consider, for example, the prevailing site factors within the "foreign owned" sector of the sample firms. Notice that the factors deemed either "important" or "very important" (quality of transportation, cost of land, availability of land,and proximity to market) vary quite significantly from the set of site factors that are deemed most significant by "all other" high tech industry. Nevertheless, the attractiveness of the study area is shed in a different light when independent and Canadian owned branch plants are considered. The location factors preferred/demanded by these sample firms indicate a need for those factors most closely associated with high technology activity (ie. availability of various modes of transportation, availability of skilled labour, presence of universities, presence of amenities, and the founder's familiarity of the region).

An extension to the data presented in Table 5.4 is represented in the contents of Table 5.5. Here, the location factors deemed "not important" are illustrated, once again as a proportion of responding sample firms. Regardless of the type of ownership, the presence of government influence is unquestionably the most unimportant site factor among sample firms. The remaining "not important" factors, though, highlighted dynamics of preference which varied according to the type of ownership. The availability of cheap labour and the proximity to the market, for example, were viewed by independent plants and Canadian subsidiaries (the "all other" category) as "not important" relative to the responding foreign owned firms. Conversely, the presence of other non-high-technology firms was considered more "not important" by foreign owned plants than "all other" establishments. All of this would seem to suggest that foreign owned firms have a heavy reliance on unskilled labour and market proximity while their need to interact with local business would appear negligible at best. The opposite

TABLE 5.5

"NOT IMPORTANT" LOCATION FACTORS IN THE STUDY AREA BY OWNERSHIP

UNIMPORTANT LOCATIONAL FACTORS	PROPORTION OF RESPONDING FIRMS BY OWNERSHIP: FOREIGN	ALL OTHER	TOTAL
PRESENCE OF GOVERNMENT	78.3	67.6	70.1
AVAILABILITY OF LABOUR	43.5	54.1	51.5
PROXIMITY TO MARKET	26.1	55.4	48.5
PRESENCE OF OTHER HIGH-TECHNOLOGY FIRMS	78.3	35.1	45.4
LOCAL TAX POLICIES	43.5	44.6	44.3

SOURCE: Based On Survey Data.

would seem to be true for the "all other" sector of high technology sample firms.

5.4 LINKAGE DEVELOPMENT IN MISSISSAUGA AND THE CTT

The patterns of technical / professional linkages which characterize a region can go very far in determining the well being of an industrial region. The following section is based on the network of technical inputs that were found to characterize the sample firms of Mississauga and the CTT. Specifically, each firm was asked to indicate whether or not they obtained a given technical input from abroad and, if so, to identify the locational origin (ie. obtained "locally", "within Canada but not locally", "outside Canada"). Table 5.6 summarizes the results of this survey by listing the proportion of responding firms for each technical input cell.

Quite clearly, the strongest local linkages were found to exist in the accounting and legal services area. Here, approximately 50% of all responding firms acknowledged some form of local linkage with the business service sector. This heavy emphasis on professional business services conforms well with the findings of other Mississauga and the CTT based studies (MacPherson, 1988) and suggests a rather strong connection between high tech sample firms and local professional business services. Other mentionables at the local level include the technical inputs of university ties (the 35% responding rate is expected in light of the three universities contained within the study area), computer service firms (25% of respondents), private testing labs (24% of respondents) and other firm's technical departments (23% of respondents). Contacts with government facilities, on the other hand, were classified as lower tier local linkages - a conclusion which conforms to our site factor findings.

At the interprovincial and national level, the patterns of linkage development change quite dramatically. Indeed, the proportion of responding firms to professional business services falls dramatically while the significance of university ties, computer service firms, other firm's technical departments, and private testing labs maintain and in some cases increase their response proportions. This observation comes as little surprise since business services are much more common at the local level

TABLE 5.6

TECHNICAL/PROFESSIONAL INPUT LINKAGES IN THE STUDY AREA BY LOCATION

TYPE OF TECHNICAL INPUT	SOURCE OF TECHNICAL/PROFESSIONAL INPUT (PROPORTION OF RESPONDING FIRMS)		
	LOCAL	WITHIN CANADA	OUTSIDE CANADA
ACCOUNTING BUSINESS SERVICES	50.0	12.0	1.8
LEGAL BUSINESS SERVICES	48.8	18.9	3.0
UNIVERSITY TIES	35.4	26.2	11.6
COMPUTER SERVICE FIRMS	25.0	20.1	3.0
PRIVATE TESTING LABS	23.8	25.6	9.1
TECHNICAL DEPARTMENTS OF OTHER FIRMS	23.2	30.5	26.2
MARKETING BUSINESS SERVICES	14.0	9.1	4.9
HOSPITAL RESEARCH UNITS	6.7	19.5	3.0
GOVERNMENT TECHNOLOGY CENTRE	6.7	12.8	2.4
PRIVATE R&D LABORATORIES	6.1	7.9	3.7
GOVERNMENT RESEARCH ORGANIZATIONS	1.2	18.3	1.2

SOURCE: Based On Survey Data.

than are the other technical inputs previously noted (see: MacPherson, 1988; Perry, 1990) Interestingly, the role of government facilities as technical input sources increases at the national scale.

At the International level, the input concerning the technical departments of other firms was, by far, the most significant. In fact, over 25% of the responding firms drew upon the resources of other firm's technical departments. This observation is significant in the sense that it underscores a considerable reliance by Canadian based firms to draw upon the facilities and technical know-how of foreign based firms. The suggestion is that the heavy concentration of foreign owned firms among the survey sample may very well contribute substantially to this phenomenon.

In short, it would appear that technical / professional linkage development in the study area is quite significant (based on the proportion of responding firms to technical input requirements). At the local level, the strong linkage network appears promising in the sense that it invokes images of a healthy and vibrant industrial and business community. At the same time, this generalization may not be safely applied to all of the firms in the sample. In fact, the dynamics of the foreign owned linkage network suggests a pattern of interaction that benefits outlying regions more so than the region in which it lies - a conclusion based on the tendency for foreign owned sample firms to establish a greater average number of non-local technical / professional linkages (ie. the average number of non-local technical / professional contacts was 1.66 per foreign owned sample firm as opposed to .55 for all other firms). In this sense, it is sometimes suggested that foreign ownership may very well sponsor direct economic growth without contributing to economic development. (Rothwell and Zegveld, 1988) In the end, the analysis of linkages must be pursued from many different perspectives (ie. locational and ownership tendencies) if it is to be accurate in its portrayal of industrial development.

5.5 IMPLICATIONS OF SIZE, FOREIGN OWNERSHIP AND R&D INTENSITY

The relationship between a firm's size, its ownership, and its level of R&D performance is a source of contention. (Toretto, 1990) Throughout this analysis, the implications of foreign ownership have been correlated (perhaps prematurely) to lesser levels of innovativeness as indicated by the measure of R&D expenditures to total sales. Nonetheless, several theorists have hypothesized that the lack of R&D effort from within the large foreign owned firm is as much a result of its size as it is from the fact that their controlling interests lie outside of the domestic 'turf'. (Angel, 1990)

Table 5.7 illustrates a simple example of the relationship between size, ownership, and R&D intensity. Notice that, true to form, the average R&D intensity for all foreign owned firms is significantly less than the same measure taken for all other sample firms. This first measure, however, does not take into consideration the impact of size. The final column of Table 5.7, by restricting the analysis to only those sample firms with fewer than 100 employees, captures the essence of the dilemma concerning foreign owned firms and their propensity to pursue R&D. Indeed, the figures of this column reveal that the difference in R&D levels between foreign owned and 'all other' sample firms

TABLE 5.7

THE RELATIONSHIP BETWEEN FIRM SIZE, OWNERSHIP AND R&D INTENSITY†

TYPE OF OWNERSHIP	AVERAGE SIZE (EMPLOYEES)	AVERAGE R&D INTENSITY PER FIRM	AVERAGE R&D INTENSITY PER FIRM (0-99 EMPLOYEES)
INDEPENDENT PLANTS AND CANADIAN SUBSIDIARIES	95.6 N=119	7.8 N=119	8.7 N=101
FOREIGN OWNED SUBSIDIARIES	272.1 N=45	2.8 N=45	2.3 N=19

† Average R&D Intensity is measured as the ratio of average R&D expenditure to average total sales.

‡ "N" is the number of sample firms represented within each cell.

SOURCE: Based On Survey Data.

worsened as a result of considering the smaller firm cohort. In short, the relationship between foreign ownership and low R&D activity seems true even when the effects of size are being considered.

5.6 PATTERNS OF NEW FIRM FORMATION IN THE STUDY AREA

The analysis of new firm formation can take many forms and can be used to illustrate many different phenomena in regional industrial development. Perhaps one of the more widely used methods of interpreting new firm formation is the practice of determining the number of New Technology Based Firms (NTBF's) that have been generated by a pool or concentration of industries.

Although this serves as an effective tool in determining the rate of new firm formation, survey firms are not always willing or capable of revealing the specifics involved in such spin-off processes. That is to say, the information requested in such an examination very often involves classified or personal information of another firm. The following examination circumvented this problem by performing the survey from the incubator's perspective. Thus, rather than asking the sample firm to disclose information concerning the firms it had generated, the sample firm was asked to reveal information concerning its own locational and organizational origins by asking the question: "Was this firm created out of an idea developed at a university, another firm, government facility, or 'other' and if so, where was this establishment located?".

In Table 5.8 information is summarized according to the origins of the sample firms that were generated within the study area. Only firms that had been established between 1983 and 1989 were tabulated. Notice that, of the 46 new firms, 25 (or 54% of the sample) were generated by other firms, 16 (or 35% of the sample) were generated through "other" means such as corporate merger and acquisition, 5 (or 11% of the sample) were the result of university based endeavours, and no firm had a government facility as its source of origin. In terms of locational sources, 25 firms (or 54% of the sample) were initiated by establishments located within the local region, 5 firms (or 11% of the sample) were the result of non-local establishments located within Canada, and 13 firms (or 35% of the sample) were the result of initiatives

TABLE 5.8

SOURCE OF ORIGIN OF FIRMS IN THE STUDY AREA, 1983-1989: ORGANIZATIONAL AND LOCATIONAL SOURCES OF NTBF GENERATION

LOCATIONAL SOURCE OF PARENT FIRM:	ORGANIZATIONAL SOURCE: UNIV.	OTHER FIRM	GOV'T	'OTHER'	TOTAL	AVERAGE R&D INTENSITY PER NTBF
LOCALLY GENERATED	5	17	0	3	25	11.2
GENERATED WITHIN CANADA BUT NON-LOCALLY	0	3	0	5	8	2.8
GENERATED ABROAD	0	5	0	8	13	2.8
TOTAL	5	25	0	16	46	7.3
AVERAGE R&D INTENSITY PER NTBF	25.6	7.5	0	1.3	7.3	

SOURCE: Based on Survey Data.

triggered by establishments located outside of Canada.

There are some interesting observations regarding the number of newly formed firms (described above) and their rates of R&D intensity. From a locational perspective, notice that the average rate of R&D expenditure per firm is significantly greater for locally generated NTBF's (11.2% of total sales) than it is for those NTBF's generated elsewhere (2.8% of total sales). This fact is likely to be related to the supposition that locally generated firms tend to be small and independent and are not typically the result of corporate branch expansion. (Angel, 1990) From the organizational perspective, the spin-offs that were generated from universities[4] experienced superior average rates of R&D expenditure (25% of total sales) while those generated from other firms experienced a modestly impressive average rate of R&D expenditure (7.5% of total sales). Not surprisingly, the rates of R&D expenditure associated with "other" spin-off activity (ie. possibly merger or acquisition related) were negligible at best (1.3% of total sales).

5.7 THE SAMPLE FIRMS IN A UNIVARIATE PRODUCT AND INNOVATION LIFE CYCLE ENVIRONMENT

Before attempting to tackle all of the intricacies that are involved with product and innovation cycle analysis in a multivariate environment, it is a fruitful exercise to analyze the survey data within a simple bivariate environment. This is true in spite of the fact that the traditional form of the product and innovation cycle is geared towards the simultaneous examination of several descriptive characteristics of industrial behaviour. In any case, the following bivariate analysis is an attempt to lay the ground work for more sophisticated multivariate analyses to be pursued later on.

It will be recalled that two principle forms of the life cycle have been drawn upon in order to interpret the state and nature of

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[4] An illustration of the vitality of university based spin-off activity is provided in Appendix D. The list is representative of spin-off activity generated out of the University of Waterloo up to November of 1989.

industrial and technological development. These are the product life cycle and innovation life cycle. In the former case, the stages of development have been defined as a simple function of the rate of product innovation as constrained by varying degrees of R&D intensity (stage 1 being defined by those firms with at least 1 product innovation and a rate of R&D expenditure in excess of 5% of total sales, stage 2 with at least 1 product innovation and a rate of R&D expenditure between 1 and 5% of total sales, and stage 3 with no product innovations) . The innovation life cycle stages, however, are defined as a function of the relationship between product and process innovation together (stage 1 being defined by those firms with more product innovations than process innovations, and stages 2 and 3 with more process innovations than product innovations - stage 3 being differentiated by a rate of R&D expenditure that is less than or equal to 1% of total sales).

Both models are based on a series of industrial behaviour characteristics which are said to explain observed patterns of stage level development. Yet an attempt to analyze these behavioral characteristics at a univariate level would prove most frustrating (and perhaps futile) in practice. On the other hand, hypotheses concerning size, age, ownership and so on can be effectively and efficiently analyzed within the parameters set fourth by the stage level definitions. Tables 5.9 and 5.10 categorize five separate dimensions of industrial development (size, age, ownership type, locational tendency, and industry type) according to, both, the stages of the product life cycle and innovation life cycle.

Age, Size and Foreign Ownership Characteristics

Table 5.9 illustrates, most dramatically, the relationship between firm size, age, and type of ownership. The table shows quite clearly that stage 1 sample firms tend to be small (18.6 employees per firm in the product cycle model and 28.5 employees per firm in the innovation cycle model), young (6.5 average years for the product cycle model and 6.8 average years for the innovation cycle model), and independently owned (49 out of 55 firms in the product cycle model and 57 out of 59 in the innovation cycle model). On the flip side of this relationship, stage 3 sample firms tend to be large (214.9 employees per firm in the product cycle model and 273.5 employees per firm in the innovation cycle model), old (14.6 average years for the product cycle model and 16.4 average years for the innovation cycle model), and largely foreign owned (35 out of 78 firms in the product cycle model and 27 out of 52 firms in the innovation cycle model).

Once again, the interrelatedness between these variables warrants closer scrutiny. At this point it is not safe to say that the foreign owned firm is analogous to the stage 3 firm. The analysis of this relationship, however, will be facilitated within the framework of a multivariate environment. For now we may say that foreign ownership is associated with stage 3 level development.

TABLE 5.9

SAMPLE FIRM CHARACTERISTICS BY PRODUCT AND INNOVATION CYCLE STAGES: SIZE, AGE, OWNERSHIP AND LOCATION†

STAGE	AVERAGE FIRMS SIZE:		AVERAGE FIRM AGE:	
	PRODUCT LIFE CYCLE	INNOVATION LIFE CYCLE	PRODUCT LIFE CYCLE	INNOVATION LIFE CYCLE
1	28.5	18.6	6.5	6.8
2	180.3	162.0	15.3	13.5
3	214.9	273.5	14.6	16.4

STAGE	PRODUCT LIFE CYCLE AND TYPE OF OWNERSHIP (NO. OF FIRMS)			INNOVATION LIFE CYCLE AND TYPE OF OWNERSHIP (NO. OF FIRMS)		
	INDEP.	CANADIAN BRANCH	FOREIGN BRANCH	INDEP.	CANADIAN BRANCH	FOREIGN BRANCH
1	49	5	1	57	2	0
2	17	5	9	18	17	18
3	18	25	35	9	16	27

STAGE	PRODUCT LIFE CYCLE AND LOCATION (NO. OF FIRMS)		INNOVATION LIFE CYCLE AND LOCATION (NO. OF FIRMS)	
	CANADIAN TECH. TRIANGLE	MISSISSAUGA	CANADIAN TECH. TRIANGLE	MISSISSAUGA
1	21	34	29	30
2	23	8	24	29
3	34	44	25	27

† The values for the product and innovation cycle columns each correspond to the stage definition as defined within the giver theory - ie. the definition of stage 1 of the product cycle is based solely on the rate of product innovations while the definition of stage 1 of the innovation cycle is based on the ratio of product innovations to process innovations.

SOURCE: Based On Survey Data.

Locational Considerations within the Study Area

The study area analyzed here, can be divided into two broad agglomerative regions: Mississauga and the CTT. Up to this point, it has been concluded that both regions are, for the most part relatively homogeneous in terms of their population, work force, manufacturing base and high technology base. What remains to be tested is the nature of prevailing high tech industry within both regions.

Table 5.9 presents the stage level distribution of high technology activity according to the parameters of the product and innovation life cycles. The only notable difference between the two agglomerations appears within the product cycle classification, where Mississauga displays a strong bipolar distribution of sample firms between stage 1 and stage 3. Although the sources of this difference are difficult to interpret within the univariate environment, its presence warrants the need for further investigation at the multivariate level. As such, the impact of location within the study area will be analyzed within the multivariate network provided by the product and innovation life cycles. It is expected that the difference of location within the study area will not hold a significant bearing on the overall results.

The Implications of Industry Type within the High-Tech Sector

The distribution of industry type by stage of development displays an interesting pattern among the sample of survey firms. Specifically, Table 5.10 illustrates the tendency for 'Communication & Electronics', 'Business Machinery', and 'Scientific & Professional Equipment' industries to occupy the initial stages of the life cycle. This might be expected when it is considered that each of the above stated industries carries relatively low levels of foreign ownership (by Canadian standards) - combined, the three industries have a 15% foreign ownership rate. Industries occupying stage three levels, on the other hand, include the 'Plastics & Synthetics' industry, 'Aircraft & Parts' industry, 'Medical & Pharmaceutical' industry, and 'Other Machinery' industry. The average rate of foreign ownership among these industries was a considerable 42%.

From a univariate perspective it seems as though the industries comprising the study area may be differentiated by their typical stage of development. Moreover, the association between foreign ownership and latter stage development seems to be at the heart of the matter. These patterns of disproportionate industry distribution by life cycle stage appear to be a significant factor in the development processes of the study area. As such, the phenomenon will be followed up by the more rigorous testing of the multivariate environment.

TABLE 5.10

INDUSTRY TYPE BY PRODUCT AND INNOVATION LIFE CYCLE STAGES

STAGE	PRODUCT LIFE CYCLE AND TYPE OF HIGH TECHNOLOGY INDUSTRY						
	OTHER	DRUGS	COMM.	SYNTH.	AIRCRAFT	BUSINESS	SCIENTIFIC
1	7(29)	3(18)	16(46)	1(5)	2(17)	9(37)	17(53)
2	5(21)	6(35)	5(14)	4(20)	2(17)	4(17)	5(16)
3	12(50)	8(47)	14(40)	15(75)	8(66)	11(46)	10(31)

STAGE	INNOVATION LIFE CYCLE AND TYPE OF HIGH TECHNOLOGY INDUSTRY						
	OTHER	DRUGS	COMM.	SYNTH.	AIRCRAFT	BUSINESS	SCIENTIFIC
1	8(33)	5(30)	15(43)	1(5)	2(17)	9(38)	19(59)
2	9(38)	6(35)	13(37)	7(35)	4(33)	7(33)	7(22)
3	7(29)	6(35)	7(20)	12(60)	6(50)	8(50)	6(19)

† Relative industry frequencies are given in the brackets.

‡ Industry type abbreviations include: Other (Other Machinery and Equipment), Drugs (Medical and Pharmaceutical), Comm. (communications and Electronics Equipment), Synth. (Synthetics and Plastics), Aircraft (Aircraft and Aircraft Parts), Business (Business Equipment), and Scientific (Scientific and Professional Equipment).

SOURCE: Based On Survey Data.

CHAPTER 6 RESULTS OF LIFE CYCLE CALIBRATION BY LOGIT MODELLING

6.0 CALIBRATION OF THE PRODUCT AND INNOVATION LIFE CYCLES: UNDERSTANDING THE GENERAL FORMAT OF THE FULL LINEAR LOGIT

This chapter concerns the procedures involved in the calibration of the product and innovation life cycles. More specifically, the fitting of the product and innovation cycle models to sampled data will be pursued within a multivariate environment by employing logit modelling techniques. As a result, all variables within the life cycle model frameworks may be analyzed and interpreted simultaneously. Furthermore, alternative theoretical and empirical considerations may be readily incorporated within the existing life cycle frameworks. From this multivariate perspective it can be suggested that the observations to be outlined in this chapter will be of a form that is quite unique from traditional methods of evaluation and examination of regional industrial development.

The full linear logit format represents the culmination of the logit modelling procedure. In cases where the dependent variable has three possible outcomes, the logit model produces two algebraic expressions (known as the log of odds) each containing a set of estimated parameters that are most likely to produce the observed sample of response categories in the data set. The third equation is dropped from the system of logit equations since "it can be demonstrated that one of the three equations is redundant; the right hand sides of the first two log of odds equations show that it is only the difference of the estimated parameters from those of an arbitrary or base group which matter" (Wrigley, 1986, p.63-64).

Figure 6.1 provides the general form of the full linear logit format (as applied from the theoretical set of equations 4.6 and 4.7 on page 78). This format is particularly attractive in the sense that the most critical information generated from the fitted multinomial logit model is available at a glance. The left hand side of the equation represents the log odds of selecting or observing one category over some other base category. In the calibration of the product and innovation life cycles, the first equation represents the log odds of observing stage one classification as opposed to stage three classification. Similarly, the second equation will indicate the log odds of observing stage two classification relative to stage three classification. The alternative specific constants (asc's) in each of the two log of odds equations reflect the log odds that a given firm will be classified within one of the three stages when all alternative specific variable (asv) factors are constrained to values of zero. In the first equation (ie. the predicted odds that a given firm will be classified as stage one rather than stage three), a positive value for the alternative specific constant (asc) would indicate a greater likelihood for sample firms to be classified as experiencing stage one levels of development rather than stage three when all asv factors are valued at zero. Conversely, a negative value for the asc would indicate a greater likelihood for sample firms to be classified as experiencing stage three levels of development rather than stage one levels when all asv factors

FIGURE 6.1

THE GENERAL FORM OF THE FULL LINEAR LOGIT FORMAT

$$\log_e \frac{P_{stage1}}{P_{stage3}} = +0.00 + 0.0prd_1 + 0.0prc_1 + 0.0org_1 + 0.0com_1 + 0.0emp_1 + 0.0ino_1 + 0.0mar_1$$

$$(0.000) \quad (0.000) \quad (0.000) \quad (0.000) \quad (0.000) \quad (0.000) \quad (0.000) \quad (0.000)$$

$$\log_e \frac{P_{stage2}}{P_{stage3}} = +0.00 + 0.0prd_2 + 0.0prc_2 + 0.0org_2 + 0.0com_2 + 0.0emp_2 + 0.0ino_2 + 0.0mar_2$$

$$(0.000) \quad (0.000) \quad (0.000) \quad (0.000) \quad (0.000) \quad (0.000) \quad (0.000) \quad (0.000)$$

ρ^2 = .0000 Adjusted ρ^2 = .0000 N=164

are valued at zero. The same can be said for the second log of odds function, however in this case the predicted odds measure the log likelihood of stage two classification relative to stage three classification when all asv factors are valued at zero.

The remaining parameters in the linear logit system are referred to as the alternative specific variables (asv's). The positive or negative sign attached to the estimated coefficients of these variables indicates the likelihood that a given explanatory variable will be associated with one of the three stages when all other asv factors are valued at zero. Thus, in equation one, a positively estimated coefficient of the prd_1 variable would indicate that the presence of a custom designed product line will increase the odds that a sample firm will be classified as stage one rather than stage three when all other asv factors are valued at zero. If prd_1 was measured at a continuous level, a positive coefficient would indicate that an increase in the variable's intensity would increase the likelihood of a firm being classified as stage one rather than stage three, all else being held constant. In the product and innovation life cycles, the explanatory variables are evaluated on a binary basis; thus, the alternative specific characteristics of a given firm either exist or they do not.

Although a good deal of information can be obtained by analyzing the sign of the parameter estimate, the significance of the conclusions drawn require verification. The full linear logit format provides the information needed to draw such conclusions by listing the ratio of parameter estimates to their asymptotic standard deviations. This quasi T-test works in much the same way as the conventional T-test in multiple regression. Namely, the quasi T-test value for a given parameter is tested against the critical values for a desired level of significance (ie. ± 1.65 for a 10% level of significance and ± 1.96 for a 5% level of significance). As a rule of thumb, a quasi T-test value of ± 2 is representative of a significant parameter estimate.

The final piece of information illustrated in the full linear logit format is the Rho-square (or ρ^2). This measure, taken to be 1 minus the ratio of the maximized log likelihood values of the fitted and constant only term models (Wrigley, 1985, p.49), represents the overall goodness-of-fit of the fitted multinomial logit model to the sample data. It will be emphasized, here , that ρ^2 values of between 0.2 and 0.4 are representative of a very good fit. (Wrigley, 1985, p.50) The accompanying Adjusted ρ^2 differs from the simple ρ^2 by taking into consideration the effects of the degrees of freedom.

6.1 CALIBRATION OF THE PRODUCT AND INNOVATION LIFE CYCLES: SPECIFIC DEFINITIONS OF THE FULL LINEAR LOGIT

The calibration procedure used in this analysis of industrial and technological development in Mississauga and the CTT can be seen as a logical progression of steps. To start, the product and innovation life cycles will be expressed in their most strict theoretical form. This model fitting will be useful as a starting point since it involves only those alternative specific variables that are deemed to be most significant to the understanding of each stage of development. The signs and levels of significance for each of the parameter coefficients will be examined in the fashion outlined earlier. Furthermore, the overall goodness-of-fit will be considered in light of the ρ^2 values.

The next version of the full linear logit system incorporates all independent variables available to the model system. At the point where the full linear logit model has incorporated all possible variables, it becomes important to break down the model system into a format which includes only those variables which are most significant. This procedure is referred to as 'parsimonious logit model fitting' and it involves an analysis of T-test scores in conjunction with the matrix of first order parameter correlation coefficients. Simply stated, this procedure requires the singular elimination of asv's based on the presence of a combination of high (multi)collinearity and low levels of significance. The resulting model system will include only those variables with significant T-scores (at least a 10% level of significance) and, as such, the model system will indicate, with considerable accuracy, the product and innovation life cycle characteristics most representative of industrial development in the study area.

The availability of a parsimonious full linear logit model will create an opportunity to examine explanatory variables that are suggested by outside theory and empirical observation. Such exogenous considerations will include the effects of size, age, ownership, location, and industry types within the high technology sector of the study area. Moreover, hypothesized relationships may be tested within the parsimonious framework. Of particular importance, here, will be the investigation of first order parameter correlation coefficient matrices as they pertain to the relationship between foreign ownership, size, and quality of industrial and technological development.

The final form of the full linear logit model will integrate the most significant factors of the life cycle paradigm with the most significant exogenous factors represented outside of the theory of life cycles. It is expected that the integration of these widely ranging factors in industrial development will increase the overall quality of the traditional life cycle paradigms (as indicated by ρ^2 goodness-of-fit tests).

6.2 INTERPRETATION OF THE CALIBRATED PRODUCT AND INNOVATION LIFE CYCLES

Before proceeding with the analysis of the calibrated life cycle frameworks, it is should be stressed that the boundaries used to define the stages of technological development for the product and innovation life cycles are based on different criterion. It will be recalled that the product cycle stage of development is a function of the rate of product innovation as constrained by the level of R&D expenditures. The stages of development in the innovation cycle, however, are defined in terms of the ratio between the rate of product and process innovation as constrained by the level of R&D expenditures. The formal definition of each stage of development (according to the type of life cycle) is offered in Table 6.1. Notice that the standards used to define each stage of the product life cycle are different from the standards used to define each stage of the innovation life cycle. These definitional variations will clearly have an impact on the final format of the respective linear logit systems (ie. the pattern of observed sample response category choices will vary according to the criterion used to define each stage of development). For this reason, the log of odds equations have been carefully annotated (ie. the log odds of the first product cycle stage will be identified as $\log_e [P_{Pstage1}/P_{Pstage3}]$ while the first innovation cycle stage will be identified as $\log_e [P_{Istage1}/P_{Istage3}]$).

TABLE 6.1

STAGE LEVEL DEFINITIONS FOR THE PRODUCT AND INNOVATION CYCLES

	DEFINITION OF THE STAGE OF DEVELOPMENT STAGE ONE	STAGE TWO	STAGE THREE
PRODUCT LIFE CYCLE	The # of product innovations is ≥ 1. R&D to sales ratio is ≥ 5%.	The # of product innovations is ≥ 1. R&D to sales ratio is < 5%.	The # of product innovations is 0.
INNOVATION LIFE CYCLE	The ratio of one plus the # of product innovations to one plus the # process innovations is > 1.	The ratio of one plus the # of product innovations to one plus the # process innovations is ≤ one. The R&D to sales ratio is > 1%.	The ratio of one plus the # of product innovations to one plus the # process innovations is ≤ one. The R&D to sales ratio is ≤ 1%.

SOURCE: Abstracted from Utterback and Abernathy (1975), Utterback (1982), and USDOC (1983).

6.2.1 STRICT THEORETICAL CALIBRATION OF THE PRODUCT AND INNOVATION LIFE CYCLES

The fully fitted linear logit model obtained from the formal calibration of the product and innovation life cycles is illustrated in Figure 6.2. Notice, first of all, the general form of the full linear logit model system. For both the product life cycle and the innovation life cycle there exist two log of odds equations. Listed immediately below each parameter estimate, in parentheses, is the associated value for the T-score. Lastly, notice that the logit models are anchored by summarizing ρ^2

FIGURE 6.2

MULTIVARIATE LOG OF ODDS FUNCTIONS FOR THE LIFE CYCLES: STRICT THEORETICAL SPECIFICATION *

The Formal Product Cycle within the Study Area

$$\log_e \frac{P_{Pstage1}}{P_{Pstage3}} = \underset{(-5.199)}{-2.35} + \underset{(0.486)}{.23prd_1} + \underset{(1.366)}{.65prc_1} + \underset{(1.001)}{.44org_1} + \underset{(0.750)}{.34com_1} + \underset{(3.566)}{1.57emp_1} + \underset{(1.783)}{.81ino_1} + \underset{(1.291)}{.63mar_1}$$

$$\log_e \frac{P_{Pstage2}}{P_{Pstage3}} = \underset{(-1.165)}{-0.50} - \underset{(-0.016)}{.74prd_2} - \underset{(-0.306)}{.13prc_2} + \underset{(0.449)}{.21org_2} - \underset{(-1.553)}{.70com_2} - \underset{(-0.543)}{.24emp_2} - \underset{(-1.081)}{.51ino_2} + \underset{(0.619)}{.27mar_2}$$

ρ^2 = .2168 Adjusted ρ^2 = .1766 N=164

The Formal Innovation Cycle within the Study Area

$$\log_e \frac{P_{Istage1}}{P_{Istage3}} = \underset{(-4.828)}{-2.94} + \underset{(1.141)}{.57prd_1} + \underset{(2.729)}{1.40prc_1} + \underset{(1.794)}{.89org_1} + \underset{(0.384)}{.19com_1} + \underset{(2.560)}{1.26emp_1} + \underset{(2.801)}{1.43ino_1} + \underset{(1.504)}{.84mar_1}$$

$$\log_e \frac{P_{Istage2}}{P_{Istage3}} = \underset{(-0.288)}{-0.12} - \underset{(-0.286)}{.12prd_2} - \underset{(-1.688)}{.68prc_2} + \underset{(1.492)}{.64org_2} + \underset{(0.400)}{.16com_2} + \underset{(0.607)}{.24emp_2} - \underset{(-0.416)}{.17ino_2} + \underset{(0.942)}{.37mar_2}$$

ρ^2 = .2422 Adjusted ρ^2 = .2034 N=164

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* For a definition of the independent variables please consult Table 4.1 on page 69.

† Recall from Table 6.1 that the product cycle stages are defined as a function of the rate of product innovations (ie. the number of product innovations either generated or adopted within the firm within a 1 year period). The innovation cycle stages are defined as 1 plus the number of product innovations over 1 plus the number of process innovations.

¥ 'N' represents the number of observations.

‡ Bracketed figures represent the quasi T-tests for the estimated parameters.

goodness-of-fit measures, one of which has been adjusted for the degrees of freedom.

Starting at a broad level, it can be seen that the ρ^2 measures lie within the range that is considered to represent a good fit (ie. between 0.2 and 0.4). Specifically, the product life cycle specification carries a ρ^2 value of .2168 while the innovation life cycle was evaluated at a considerably more significant .2422. This pattern continues at the level of the adjusted ρ^2 where the values obtained were .1766 and .2034 for the product and innovation life cycle, respectively. In total, it would appear that the life cycle models, as calibrated here, display a reasonably good fit to the sample data.

By concentrating on the fully formatted linear logit model of the product life cycle, it can be seen that only 3 parameter coefficient estimates are rated significant beyond the 10% level of significance. Namely, asc_1, emp_1, and ino_1 each carry a T-score of -5.199, 3.566, and 1.783 respectively. The significant negative coefficient of the first category suggests that there is a greater likelihood for sample firms to be classified within stage three rather than stage one when all other asv factors are valued at zero. Similarly, the significant positive values attached to emp_1 and ino_1 suggest that a firm which has to respond to the needs of the market and has a highly skilled work force will increase the odds of being classified within stage one rather than stage three when all other asv factors are valued at zero. Although the significance levels are not overly impressive within this calibrated version of the product life cycle, it is interesting to note that the parameter signs follow very closely to expectations (at least in the first log likelihood equation). In the first log of odds equation, for example, all asv signs are positive. This indicates that the first dimension of the product life cycle characteristics correspond more closely to the first stage of industrial and technological development rather than the third stage level of development. The pattern of the parameter signs in the second log of odds equation is not totally unexpected considering the similarities that exist between stage two level development and stage three level development (ie. the similarities between stage two and stage three are far greater than the similarities between stage one and stage three).

Moving on to the calibrated version of the innovation life cycle, we can see a generally widespread improvement in terms of the number of significant parameter estimates and their signs. More specifically, six parameter estimates were determined to be significant beyond the 10% level. These parameters included asc_1, prc_1, org_1, emp_1, ino_1, and prc_2 and each carried a T-score of -4.828, 2.729, 1.794, 2.560, 2.801, and -1.688 respectively. Once again the negative value of the alternative specific constant indicates a greater odds for sample firms to be classified as stage three rather than stage one when all asv factors are valued at zero. It can also be concluded with at least a 10% level of significance that a sample firm exhibiting the presence of a flexible production system, an informally organized establishment, a highly skilled labour force, and an ill-defined market will increase the likelihood that a sample firm will be classified as experiencing stage one development rather than stage three development. The analysis of the parameter signs suggests that the expected innovation life cycle parameters are adhered to quite closely, even when considering the second log of odds equation. This is an important consideration since it suggests that the full linear logit specification of the innovation life cycle catches several parameter dynamics not caught within the product life cycle framework.

In total, it would appear that the product and innovation life cycles offer an effective means of conceptualizing the pattern of observed sample response categories. Indeed, the performance of the calibrated innovation life cycle scored quite highly both in terms of its overall goodness-of-fit and its ability to generate significant parameter estimates. The next step in the calibration procedure will be directed at the need to fit a full linear logit model that most closely represents the nature of technological and industrial development in Mississauga and the CTT.

6.2.2 PARSIMONIOUS CALIBRATION OF THE PRODUCT AND INNOVATION LIFE CYCLES

The specification of a parsimonious linear logit model system requires considerable deliberation. It will be emphasized that alternative specific variables were removed from the model system in only those cases where low levels of significance were matched with highly collinear first order parameter coefficients. The end result of such a procedure tends to be a robust linear logit format that can not be significantly influenced by the addition of alternative specific variables already abstracted from the model system.

The final results of the parsimonious breakdown are presented in Figure 6.3. As illustrated, the remaining parameters for both the product and innovation life cycle frameworks are all significant beyond the 10% level. The ρ^2 goodness-of-fit measures are a considerable .2408 and .2597 for the product cycle and innovation cycle, respectively. The alternative specific variables indicate the same patterns of classification found in earlier calibrated models. Moreover, the tendency for the calibrated innovation life cycle to generate a more reliable system of parameter coefficients was maintained throughout the procedure of parsimonious model fitting - this is reflected by its larger number of significant parameter coefficients.

The first log of odds equations (ie. the first category representing each of the two types of life cycles) identifies several significant alternative specific variables. The first dimension of the employment factor (emp_1 or a highly skilled labour force) was significant (T-scores of 4.141 and 2.121) and positive for both the product and innovation life cycle models. Therefore, the presence of a highly skilled labour force within a sample firm would increase the odds of being classified within stage one rather than stage three when all other asv factors are valued at

FIGURE 6.3

PARSIMONIOUS SPECIFICATION OF THE LIFE CYCLES: DYNAMICS OF INDUSTRIAL BEHAVIOUR IN THE STUDY AREA

Parsimonious Product Life Cycle Specification

$$\log_e \frac{P_{Pstage1}}{P_{Pstage3}} = -1.68 + .76prd_1 + 1.76emp_1 + .79ino_1 - 2.48com_3$$
$$(-4.154) \quad (1.673) \quad (4.141) \quad (1.796) \quad (-2.298)$$

$$\log_e \frac{P_{Pstage2}}{P_{Pstage3}} = -.18 - .77prd_2 - 1.56prd_3$$
$$(-0.522) \quad (-1.813) \quad (-1.889)$$

$\rho^2 = .2408$ Adjusted $\rho^2 = .2193$ N=164

Parsimonious Innovation Life Cycle Specification

$$\log_e \frac{P_{Istage1}}{P_{Istage3}} = -.88 + 1.74prc_1 + 1.22org_1 + 1.01emp_1 - 2.40ino_3 - 2.04mar_3$$
$$(-1.788) \quad (3.422) \quad (2.643) \quad (2.121) \quad (-2.206) \quad (-3.390)$$

$$\log_e \frac{P_{Istage2}}{P_{Istage3}} = .33 - .81prc_2 + .91mar_2 - .77prd_3$$
$$(0.891) \quad (-1.962) \quad (2.345) \quad (-1.850)$$

$\rho^2 = .2597$ Adjusted $\rho^2 = .2364$ N=164

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zero. In tha parsimonious product cycle model, the first dimension of the product line factor (prd_1 or custom designed products) was found to be significant (T-score of 1.673) and positive. Thus, the presence of a predominately custom designed product line within a sample firm increases the odds of being classified as stage one rather than stage three when all other asv factors are valued at zero. Also found in the first log of odds equation of the product cycle model was a significant (T-score of 1.796) and positive parameter estimate for the first dimension of the variable representing the source of R&D efforts (ino_1 or R&D stimulated by the needs of the market). Again, the need for a firm to pursue R&D due to the demands of the market will increase the odds of being classified within stage one rather than stage three when all other factors are valued at zero.

The log of odds function for the first alternative within the calibrated innovation life cycle model emphasizes the importance of the first dimension of the production processes and organizational control factors (prc_1 or labour intensive production and org_1 or informal organizational control, respectively) in a significant (T-scores were 3.422 and 2.643 respectively) and positive manner. Therefore, the presence of either of these characteristics within a sample firm implies a greater likelihood of being classified within stage one rather than stage three when all other asv factors are valued at zero.

The second log of odds equations for the product and innovation cycle models identified three significant parameter coefficients, two of which countered theoretical expectations. In the product cycle model, the second dimension of the product line (prd_2 or increasingly standardized products) exhibited a significant (T-score of -1.813) but negative sign on the parameter coefficient. Similarly, in the innovation cycle model, the second dimension of the production process (prc_2 or pockets of automated sub-processes) displayed a significant (T-score of -1.962) but negative sign on the estimated parameter coefficient. This suggests that sample firms exhibiting these characteristics are more likely to be associated with stage three rather than stage two when all other asv factors are valued at zero. As stated previously, the presence of such 'unexpected' results is not so surprising when it is realized the parameter estimates of this alternative are being compared to those of a closely related base or anchor group category.

Several alternative specific variables were included into the parsimonious system of log of odds equations as a result of the original model specification (ie. inclusion of all available independent variables). Within the first log of odds function of the product life cycle model, the third dimension of the competitive emphasis factor (com_3 or competitive emphasis based on cost reduction) showed up as significant (T-score of -2.298) and negative. This suggests that a sample firm exhibiting this characteristic would most likely be classified as a stage three level firm as opposed to a stage one level firm when all other asv factors are valued at zero. In the second log of odds function of the product life cycle model and the innovation life cycle model, the third dimension of the product line factor (prd_3 or a highly standardized product line) showed up as being significant (T-scores of -1.889 and -1.850 respectively) and negative. Thus, the presence of a highly standardized product line within a sample firm can be related to stage three levels of development more so than stage two levels when all other asv factors are valued at zero. Lastly, the first log of odds equation for the innovation life cycle contains two significant and negatively signed parameters from the third dimension - R&D stimulated by the need to reduce production costs (inc_3 had a T-score of -2.206) and markets with minimal market uncertainty (mar_3 had a T-score of -3.390). Again, it must be suggested that the exhibition of these characteristics by a sample firm will increase the odds of being classified within stage three rather than stage one when all other factors are valued at zero.

In aggregate, the parsimonious product and innovation life cycle models have proven quite effective in targeting those characteristics of industrial behaviour that can be associated with industrial development in Mississauga and the CTT. In addition to this, the parameter coefficient signs follow a general pattern that can be explained within the theory of life cycles; these patterns have been shown to be reliable at the 10% level of significance.

6.3 THE PARSIMONIOUS FRAMEWORK AND OTHER THEORETICAL AND EMPIRICAL CONSIDERATIONS

Based on the fact that there is a considerable number of 'true' high technology firms within the study area (consider the findings of the bivariate analysis forwarded in Chapter 5), it becomes quite apparent that some other factors may need to be consulted in order to improve on the calibration of the product and innovation life cycles. In this section of our calibration procedure, several considerations from outside the theory of product and innovation life cycles (as summarized in Table 4.1 on page 69) will be introduced to the linear logit model. These factors include the effects of size, age, ownership, location and industry type.

6.3.1 SIZE AND AGE CONSIDERATIONS

The introduction of the size and age factors to the parsimonious innovation life cycle model is illustrated in Figure 6.4a. The results of adding the **SIZE** factor (measured as the total number of employees) have far reaching implications to say the least. In the first case, the introduction of the size factor added a considerable boost to the overall quality of the model - the ρ^2 leaped to a significant .3382, a figure that is representative of a very good fit to the sample data. Even more interesting than this is the fact that size had a considerable impact on the overall quality of the model without seriously influencing the parameter estimates of the existing asv's. A second critical observation relates to the positive conversion of the previously negative

FIGURE 6.4a

IMPACTS OF SIZE AND AGE ON THE PARSIMONIOUS INNOVATION CYCLE MODEL

The Innovation Life Cycle and Size Considerations

$$\log_e \frac{P_{Istage1}}{P_{Istage3}} = 1.11 + 1.27prc_1 + .50org_1 + 1.04emp_1 - 2.39ino_3 - 2.25mar_3 - 2.92SIZE$$

(1.623) (2.212) (0.911) (1.946) (-2.136) (-3.446) (-2.922)

$$\log_e \frac{P_{Istage2}}{P_{Istage3}} = .54 - .82prc_2 + .90mar_2 - .77prd_3 - .009SIZE$$

(1.350) (-1.953) (2.231) (-1.831) (-1.306)

$\rho^2 = .3382$ Adjusted $\rho^2 = .3131$ N=164

The Innovation Life Cycle and Age Considerations

$$\log_e \frac{P_{Istage1}}{P_{Istage3}} = .14 + 1.60prc_1 + 1.12org_1 + .77emp_1 - 2.49ino_3 - 2.10mar_3 - .07AGE$$

(0.221) (3.049) (2.364) (1.510) (-2.274) (-3.409) (-2.263)

$$\log_e \frac{P_{Istage2}}{P_{Istage3}} = .50 - .82prc_2 + .96mar_2 - .83prd_3 - .01AGE$$

(1.195) (-1.978) (2.426) (-2.004) (-0.709)

$\rho^2 = .2813$ Adjusted $\rho^2 = .2480$ N=164

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asc's - this is all the more important when one considers that the asc for the first log of odds equation just barely missed the 10% level of significance. At a minimum, the introduction of the size factor helped to break the negative asc trend - a trend which suggests a tendency towards stage three development rather than stage one development. The third point that bears emphasis is related to the negative sign and the level of significance associated with the size factor (T-scores were -2.922 and -1.306 in the first and second log likelihood equations respectively). The negative sign attached to the size parameter indicates that an increase in the size (number of employees) of a sample firm will increase the likelihood that a firm will be associated with stage three development rather than stage one.

Although the impact of age (measured as the total number of years that the plant has been in operation) on the parsimonious innovation model can be viewed as quite significant, caution must be taken before concluding that both size and age factors are equally significant. This is true in spite of the fact that the AGE factor displays the expected sign and is significant within the first log of odds equation. Indeed, the impact of size and age on the linear logit system was so similar, a running of the parsimonious innovation cycle model with both factors became absolutely necessary. Not surprisingly, the first order parameter correlation coefficients were highly collinear - the SIZE and AGE correlation coefficient for the first category stood at .2692 while the correlation coefficient for the second category stood at .5767. As for the estimated parameter coefficients associated with each factor, it comes as little surprise that the only significant alternative specific variable was the size factor within the first log of odds equation.

The introduction of size and age factors to the calibrated product life cycle model are illustrated in Figure 6.4b. As was the case with the innovation life cycle model, size plays a rather important role within the model system. Consider, for example, the

FIGURE 6.4b

IMPACTS OF SIZE AND AGE ON THE PARSIMONIOUS PRODUCT CYCLE MODEL

The Product Life Cycle and Size Considerations

$$\log_e \frac{P_{pstage1}}{P_{pstage3}} = .85 + .70prd_1 + 1.59emp_1 + .38ino_1 - .83mar_1 - 1.2com_3 - .009SIZE$$

(1.768) (1.487) (3.610) (0.795) (-1.697) (-1.770) (-2.198)

$$\log_e \frac{P_{pstage2}}{P_{pstage3}} = -.19 - .73prd_2 - 1.60prd_3 + .0008SIZE$$

(-0.533) (-1.441) (-2.782) (0.115)

ρ^2 = .2720 Adjusted ρ^2 = .2467 N=164

The Product Life Cycle and Age Considerations

$$\log_e \frac{P_{pstage1}}{P_{pstage3}} = .79 + .76prd_1 + 1.21emp_1 + .86ino_1 + 1.08mar_1 - 2.18com_3 - .09AGE$$

(1.565) (1.652) (2.580) (1.938) (1.990) (-1.999) (-2.530)

$$\log_e \frac{P_{pstage2}}{P_{pstage3}} = -.25 - .74prd_2 - 1.59prd_3 + .005AGE$$

(-0.616) (-1.452) (-2.816) (0.329)

ρ^2 = .2698 Adjusted ρ^2 = .2445 N=164

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increase in the ρ^2 (.2720) and the significance of the estimated parameters for SIZE (T-scores were 2.198 and 0.115 in the first and second log of odds equations respectively). Moreover, the signs of the parameter estimates are negative as would be expected. In a similar fashion, the introduction of the age factor adds to the strength of the model system (ie. the ρ^2 increases to .2698 and the parameter estimate for AGE in the first log of odds function carries a T-score of -2.530). Also, the signs attached to the parameter estimates of the AGE variable are negative as would be expected. In terms of the impact of AGE and SIZE on the asc's of the product cycle model system, it should be noted that the signs of the asc parameter estimates became positive while the asc parameter estimates of the second log of odds equations remained negative. Therefore, according to the product cycle paradigm, sample firms are more likely to be classified as experiencing stage one level development rather than stage three level development, all other factors being held constant. On the other hand, and according to the second log of odds equation, sample firms are more likely to be classified as experiencing stage three level development rather than stage two level development.

In total, the inclusion of the size and age factors appear to contribute a great deal to the parsimonious model. Even more significant than this is the realization that the significantly negative estimates of the size and age parameters suggest that the stage one level of development is definitely a small firm (ie. in terms of the number of employees) and, likely, a young firm activity. The conclusions drawn, here, correspond to the findings of Angel (1990), Scott(1987), Evans(1987), and Haug(1985).

6.3.2 TYPE OF OWNERSHIP

Figure 6.5a illustrates the fully fitted linear logit models for the innovation life cycle inclusive of three types of ownership. The first system of equations introduces the factor of

FIGURE 6.5a

THE IMPACT OF OWNERSHIP ON THE PARSIMONIOUS INNOVATION CYCLE MODEL

The Innovation Life Cycle and Independently Owned Plants

$$\log_e \frac{P_{Istage1}}{P_{Istage3}} = -3.21 + 1.19prc_1 - .04org_1 + .77emp_1 - 2.01ino_3 - 1.29mar_3 + 4.39INDEP$$
$$(-2.969) \quad (2.003) \quad (-0.070) \quad (1.380) \quad (-1.745) \quad (-1.781) \quad (3.825)$$

$$\log_e \frac{P_{Istage2}}{P_{Istage3}} = .28 - .68prc_2 + .75mar_2 - .81prd_3 + .28INDEP$$
$$(0.696) \quad (-1.652) \quad (1.885) \quad (-1.864) \quad (0.560)$$

$\rho^2 = .3509$ Adjusted $\rho^2 = .3263$ N=164

The Innovation Life Cycle and Canadian Owned Subsidiaries

$$\log_e \frac{P_{Istage1}}{P_{Istage3}} = -.29 + 1.75prc_1 + .94org_1 + .83emp_1 - .21ino_3 - 2.27mar_3 - 2.97CSUB$$
$$(-0.544) \quad (3.289) \quad (1.897) \quad (1.603) \quad (-1.880) \quad (-3.662) \quad (-2.645)$$

$$\log_e \frac{P_{Istage2}}{P_{Istage3}} = .34 - .81prc_2 + .83mar_2 - .76prd_3 + .04CSUB$$
$$(0.893) \quad (-1.956) \quad (2.078) \quad (-1.807) \quad (0.086)$$

$\rho^2 = .2991$ Adjusted $\rho^2 = .2725$ N=164

The Innovation Life Cycle and Foreign Owned Subsidiaries

$$\log_e \frac{P_{Istage1}}{P_{Istage3}} = -.37 + 1.45prc_1 + .95org_1 + 1.03emp_1 - 2.41ino_3 - 1.44mar_3 - .001FSUB$$
$$(-0.712) \quad (2.676) \quad (1.976) \quad (2.077) \quad (-2.153) \quad (-2.209) \quad (-0.161)$$

$$\log_e \frac{P_{Istage2}}{P_{Istage3}} = .45 - .75prc_2 + .83mar_2 - .78prd_3 - .23FSUB$$
$$(1.029) \quad (-1.793) \quad (2.043) \quad (-1.786) \quad (-0.485)$$

$\rho^2 = .2918$ Adjusted $\rho^2 = .2649$ N=164

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independent plant ownership (INDEP is assigned a value of one if observed and zero otherwise) to the parsimonious framework. The results are quite significant. The ρ^2 of .3509 is very significant with respect to the general rule of thumb for rho-square goodness-of-fit tests. Moreover, the positive and significant value of the estimated parameter coefficients (T-scores were 3.825 and 0.560 in the first and second log of odds equations respectively) in the first log of odds equation suggests that a strong positive relationship exists between the earliest stage of development and independent plant ownership. In more formal terms, the conformation that a plant is independently owned increases its likelihood to be associated with the first stage of development rather than the third stage when all other asv factors are valued at zero.

Although the impact of the independent ownership variable is substantial, to say the least, it would be incorrect to suggest that this variable is on an equal par with the size factor, let alone the other existing alternative specific variables. This point is made in strong terms because its introduction can be associated with high levels of multicollinearity, most notably with the alternative specific constant of the first category (.5526). As a consequence, independent ownership, which should be independent of the category that it has been specified to (consider the independence from irrelevant assumption - Wrigley, 1985, p.324-330), is actually very highly correlated to the first category. In summary, the suggestion that independent ownership can be associated with the first stage of the innovation life cycle goes without saying. Its introduction into the model system, however, poses problems for the other parameters included in the model system.

The role of the Canadian owned subsidiary (CSUB is assigned a value of one if observed and zero otherwise) is illustrated in the second fully fitted linear logit model of Figure 6.5a. This variable, while not as overpowering to the system equations, certainly does offer some interesting, if not disturbing, information. Specifically, the parameter estimate for the first log of odds equation is negative and it is significant (T-score of -2.645). In formal terms, the significant negative value of the estimated parameter indicates that a sample firm exhibiting the characteristic of Canadian branch plant ownership will display a greater likelihood of being associated with the third stage of development relative to the first stage of development when all other asv factors are valued at zero. It will also be noted that the inclusion of this variable cannot be associated with any other existing alternative specific variables (ie. in terms of collinearity). For this reason, the factor of Canadian subsidiary ownership will be considered a potentially significant factor within the parsimonious model system.

The final form of ownership to be considered is that of the foreign owned subsidiary (FSUB is assigned a value of one if observed and zero otherwise). The full linear logit model for this factor is provided for at the bottom of Figure 6.5a. The problems that were associated with the Canadian ownership factor can be paralleled here, except in an inverse fashion. Analysis of the model system in Figure 6.5a reveals that the introduction of the foreign ownership factor has very little impact on the ρ^2, and therefore the goodness-of-fit. In addition to this, the significance levels of the parameter estimates are microscopic for both the first and second log of odds functions. At first, it might be assumed that the presence of the foreign ownership factor in the first log of odds equation would be expected to produce a significantly negative parameter estimate. After all, Chapter 5 portrayed the foreign owned branch plant as being large and established and pursuing only negligible levels of R&D. Why, then, is there a lack of (negative) association between the foreign owned plant and stage one level of development? The answer may relate to the simple fact that not one foreign owned sample firm met the classification of stage one level development as prescribed by the innovation life cycle. Thus, as in the case of independent ownership, the influence of foreign ownership is just too closely related to the third category to be considered within the model system.

The influence of ownership type within the calibrated product life cycle framework is illustrated in Figure 6.5b. For the most part, the implications of each type of ownership are similar to the effects that were observed within the innovation life cycle model. For example, the introduction of the INDEP, CSUB, and FSUB ownership factors resulted in increased ρ^2 values (.3110, .2585, and .2741 respectively) and each of the parameter estimates carried

FIGURE 6.5b

THE IMPACT OF OWNERSHIP ON THE PARSIMONIOUS PRODUCT CYCLE MODEL

The Product Life Cycle and Independently Owned Plants

$$\log_e \frac{P_{Pstage1}}{P_{Pstage3}} = -2.58 + .29 prd_1 + 1.46 emp_1 + .08 ino_1 + .46 mar_1 - 2.00 com_1 + 2.73 INDEP$$

(-4.770) (0.556) (3.208) (0.158) (0.894) (-1.781) (4.371)

$$\log_e \frac{P_{Pstage2}}{P_{Pstage3}} = -.95 - .43 prd_2 - 1.03 prd_3 + 1.27 INDEP$$

(-1.971) (-0.808) (-1.672) (2.563)

ρ^2 = .3110 Adjusted ρ^2 = .2871 N=164

The Product Life Cycle and Canadian Owned Subsidiaries

$$\log_e \frac{P_{Pstage1}}{P_{Pstage3}} = -1.23 + .71 prd_1 + 1.72 emp_1 + .57 ino_1 - .69 mar_1 - 2.54 com_1 - 1.28 CSUB$$

(-2.727) (1.511) (4.019) (1.266) (-1.389) (-2.360) (-1.999)

$$\log_e \frac{P_{Pstage2}}{P_{Pstage3}} = .03 - .69 prd_2 - 1.57 prd_3 - .98 CSUB$$

(0.080) (-1.341) (-2.754) (-1.744)

ρ^2 = .2585 Adjusted ρ^2 = .2328 N=164

The Product Life Cycle and Foreign Owned Subsidiaries

$$\log_e \frac{P_{Pstage1}}{P_{Pstage3}} = -1.16 + .55 prd_1 + 1.56 emp_1 + .71 ino_1 + .77 mar_1 - 2.05 com_1 - 2.69 FSUB$$

(-2.691) (1.160) (3.531) (1.596) (1.483) (-1.823) (-2.543)

$$\log_e \frac{P_{Pstage2}}{P_{Pstage3}} = -.12 - .68 prd_2 - 1.42 prd_3 - .38 FSUB$$

(-0.327) (-1.335) (-2.334) (-0.726)

ρ^2 = .2741 Adjusted ρ^2 = .2490 N=164

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with them the expected sign values. Moreover, the problem concerning multicollinearity and the form of ownership (as witnessed within the innovation life cycle framework) was quite pronounced within the product life cycle model system. This was particularly true with respect to the INDEP ownership factor, where the parameter first-order correlation coefficients indicated high levels of collinearity with the first and second asc's (.5177 and .6492 respectively) as well as several other alternative specific variables. Similar observations were confirmed with respect to the CSUB ownership factor and the FSUB ownership factor, where high levels of multicollinearity resulted in drastic reductions in the significance levels of most other alternative specific variables. In short, it would appear that the stage level definitions for both the product and innovation life cycle models are so closely related to the ownership type factors (ie. the close association between independent ownership and stage one development and the close association between foreign ownership and stage three development) that the inclusion of such factors must be discouraged within the life cycle framework as presented here.

6.3.3 SAMPLE FIRM LOCATION WITHIN THE CTT

In order to test for the industrial homogeneity of the study area, those firms that represented the CTT high technology industrial sector were tested within the parsimonious versions of the product and innovation life cycle models. The results are illustrated in Figure 6.6. The contents of Figure 6.6 reveal the

FIGURE 6.6

THE PARSIMONIOUS FRAMEWORKS AND LOCATION WITHIN THE CTT

The Product Life Cycle and Location Within the CTT

$$\log_e \frac{P_{Pstage1}}{P_{Pstage3}} = -1.32 + .84prd_2 + 1.27emp_1 + 1.13ino_1 + 1.38mar_1 - 2.50com_3 - 1.18CTT$$

(-3.170) (1.752) (2.754) (2.409) (2.395) (-2.341) (-2.254)

$$\log_e \frac{P_{Pstage2}}{P_{Pstage3}} = -1.00 - .45prd_2 - 1.14prd_3 + .98CTT$$

(-1.790) (-0.834) (-1.896) (1.935)

$\rho^2 = .2776$ Adjusted $\rho^2 = .2526$ N=164

The Innovation Life Cycle and Location Within the CTT

$$\log_e \frac{P_{Istage1}}{P_{Istage3}} = -1.02 + 1.79prc_1 + 1.19org_1 + 1.08emp_1 - 2.48ino_3 - 2.04mar_3 + .18CTT$$

(-1.652) (3.439) (2.551) (2.213) (-2.240) (-3.354) (0.339)

$$\log_e \frac{P_{Istage2}}{P_{Istage3}} = .45 - .75prc_2 + .86mar_2 - .83prd_3 - .20CTT$$

(1.009) (-1.779) (2.171) (-1.899) (-0.457)

$\rho^2 = .2613$ Adjusted $\rho^2 = .2333$ N=164

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first considerable divergence in terms of the calibrated application of the product and innovation life cycle models to the sample data.

Originally, it had been hypothesized that firm location within the study area would bear very little, if any, influence on the system of log of odds equations. That is to say, it had been suggested that the differential locations of sample firms within the study area (ie. sample firms within Canada's Technology

Triangle as opposed to Mississauga) would not be significantly related to the various stages of development. While the parameter estimates for the CTT factor within the innovation life cycle paradigm certainly lend support for such a conclusion (note the insignificant T-test values for the CTT parameter estimates), the same cannot be said for the results of this factor's inclusion into the product life cycle framework. Indeed, for the first time in this investigation, the ρ^2 of the product cycle model system (.2776) surpassed that of the innovation cycle model system (.2613). Furthermore, the CTT parameter estimates were significant for both the first and second log of odds equations (T-test scores were 2.254 and 1.935 respectively) of the calibrated product life cycle model. This latter observation is an especially important consideration since the CTT parameter estimate of the first log of odds equation carried with it a negative sign. This suggests that any association between a sample firm and the Canadian Technology Triangle will increase the likelihood of that firm being classified as stage three rather than stage one when all other asv factors have been valued at zero.

Therefore, according to the calibrated product life cycle, it would appear that CTT based firms may be associated with latter stages of technological development. This conclusion has far reaching implications since the notion of the Canadian Technology Triangle is based upon the assumption that high technology development within this region is representative of a core of small but rapidly growing technology intensive firms (a description that is symbolic of the early stages of technological development). Of course, a conclusion that the CTT accolade is mis-assigned based upon these grounds must be weighed against the findings revealed within the calibration of the innovation life cycle.

6.3.4 GROUPING OF THE POORLY PERFORMING HIGH TECH INDUSTRIES

The full linear logit system illustrated in Figure 6.7 is the result of calibrating the parsimonious product and innovation life cycle models inclusive of the group of sample high technology industries displaying the poorest R&D track record and highest foreign ownership levels (see Chapter 5). This group of industries includes: Other Machinery, Plastics and Synthetics, Drugs and Medicine, and Aircraft and Parts. Although the parameter estimates were not rated as significant according to the T-scores (-1.507 and 0.765 for the estimated PIND coefficients of the product life cycle and -1.426 and -0.204 for the PIND coefficients of the innovation life cycle), it will be noted that the parameter estimates for this 'lower tier' of high technology manufacturing are predominantly negative. The negative sign indicates that an increase in the categorization of sample firms according this less dynamic group of high technology activities will increase the odds of classification at the stage three level of development rather than the stage one level of development when all other asv factors are valued at zero. This should be expected since the PIND industrial group tends to be indicative of large standardized firms (see chapter five).

FIGURE 6.7

THE PARSIMONIOUS FRAMEWORKS AND INDUSTRY TYPE CONSIDERATIONS

The Product Life Cycle and Industry Type Considerations

$$\log_e \frac{P_{Pstage1}}{P_{Pstage3}} = -1.29 + .64prd_1 + 1.64emp_1 + .69ino_1 + .86mar_1 - 2.57com_3 - .70PIND$$

(-2.768) (1.386) (3.795) (1.597) (1.702) (-2.353) (-1.507)

$$\log_e \frac{P_{Pstage2}}{P_{Pstage3}} = -.33 - .80prd_2 - 1.68prd_3 + .35PIND$$

(-0.815) (-1.558) (-2.872) (0.765)

ρ^2 = .2522 Adjusted ρ^2 = .2262 N=164

The Innovation Life Cycle and Industry Type Considerations

$$\log_e \frac{P_{Istage1}}{P_{Istage3}} = -.60 + 1.78prc_1 + 1.25org_1 + .87emp_1 - 2.42ino_3 - 1.93mar_3 - .76PIND$$

(-1.125) (3.443) (2.676) (1.795) (-2.239) (-3.124) (-1.426)

$$\log_e \frac{P_{Istage2}}{P_{Istage3}} = .38 - .81prc_2 + .92mar_2 - .78prd_3 - .09PIND$$

(0.883) (-1.965) (2.332) (-1.825) (-0.204)

ρ^2 = .2661 Adjusted ρ^2 = .2328 N=164

†PIND represents the following group of industries: Other Machinery, Plastics and Synthetic Resins, Drugs and Medicine, and Aircraft and Aircraft Parts (ie. a value of one was assigned to each sample firm which fell into one of these four industrial groups; otherwise, a value of zero was assigned).

6.3.5 THE COMPLETE PARSIMONIOUS MODEL: LIFE CYCLE CHARACTERISTICS IN COMBINATION WITH OTHER CONSIDERATIONS

The *complete parsimonious* model system in Figure 6.8 was obtained in much the same way that the original *parsimonious* life cycle models (Figure 6.3 on page 127) had been obtained. This time

FIGURE 6.8

THE COMPLETE PARSIMONIOUS MODELS: ALL FACTORS CONSIDERED

The Product Life Cycle

$$\log_e \frac{P_{Pstage1}}{P_{Pstage3}} = .53 + .56prd_1 + 1.50emp_1 + .46ino_1 - 1.96com_3 - 1.94PNS - .009SIZE$$

(1.118) (1.761) (3.407) (1.950) (-1.791) (-1.779) (-2.131)

$$\log_e \frac{P_{Pstage2}}{P_{Pstage3}} = -1.35 - .91prd_3 + 1.23CTT$$

(-3.161) (-1.738) (2.632)

ρ^2 = .2940 Adjusted ρ^2 = .2718 N=164

The Innovation Life Cycle

$$\log_e \frac{P_{Istage1}}{P_{Istage3}} = 1.07 + 1.20prc_1 + .67org_1 + .96emp_1 - 2.53ino_3 - 2.08mar_3 - 2.02PNS - .03SIZE$$

(1.590) (2.055) (1.710) (1.760) (-2.264) (-3.109) (-1.739) (-2.809)

$$\log_e \frac{P_{Istage2}}{P_{Istage3}} = .38 - .81prc_2 + .92mar_2 - .87prd_3$$

(1.006) (-1.937) (2.294) (-2.071)

ρ^2 = .3443 Adjusted ρ^2 = .3195 N=164

---

however, the original parsimonious models were flooded with all available independent variables representing other considerations (size, age, ownership, location, and industry type). The extraction of any alternative specific variable was based on the systematic and simultaneous examination of quasi T-tests and first order parameter correlation coefficient matrices.

The inclusion of the considerations found outside of the innovation life cycle resulted in the introduction of only two new alternative specific variables, both being specified within the first log of odds function. The first of these new additions was the size factor, and as witnessed before, the associated parameter coefficient was valued significantly negative as expected (T-score of -2.809). The only other explanatory variable that was introduced into the linear logit model was the alternative specific variable representing the plastics and synthetics industry (PNS). The significantly negative (T-score of -1.739) parameter estimate for the plastic and synthetics industry indicates that a sample firm displaying an association with this area of high technology production will demonstrate a greater likelihood to be classified within the third stage of development rather than the first stage. This is not a surprising result since the plastics and synthetic resins industry is inundated with a vast number of large and foreign owned firms.

At this point, it might prove helpful to step back and look at the complete parsimonious innovation life cycle model. In terms of the overall goodness-of-fit, the ρ^2 of this model system is valued at an impressive .3443 and when adjusted for by the degrees of freedom the fit remains significant at .3195. Furthermore, the system of log of odds functions represented within the full linear logit model incorporates a thorough sample of the characteristics which make up the innovation life cycle (six of a possible seven innovation life cycle characteristics are utilized in the complete model system). Moreover, the dimensions of these parameter estimates closely adhere to the expectations drawn by innovation life cycle theory and several other outside considerations. Indeed, of the alternative specific variables listed in the logit systems model in Figure 6.8, only one parameter estimate displays a sign that may be construed as counter-intuitive. Specifically, the negative coefficient attached to the prc_2 variable in the second log of odds equation, suggests that a sample firm exhibiting pockets of automated subprocesses is more likely to be classified within the third stage rather than the second stage. In theory, this dimension of the production process is said to relate to those firms that have been classified as experiencing stage two level development.

Perhaps one of the most exciting results of the calibrated innovation life cycle model concerns the positive value assigned to the asc parameter estimate. The values for both asc's were positive and the T-score in the first log of odds equation was just shy of the 10% level of significance. These positive asc parameter estimates are an important consideration since a positive value indicates that the odds of a sample firm to be classified within the first stage of development are greater than the odds of a sample firm to be assigned to the third stage of development. The sample data, then, seems to point to a stage of development that lies somewhere along the early portions of the portions of the product and process life cycle curves (although such a conclusion has not been deemed significant at the 10% level of significance).

As a final note, the effectiveness of the innovation life cycle has been verified by the ability of its explanatory characteristics to withstand the incorporation of other considerations found outside of the theory of product life cycles. In fact, with the exception of the size factor, most other considerations added either invalid levels of explanation to the model (ie. the INDEP and FSUB factors) or negligible levels of explanation (ie. the PIND and CTT factors). The AGE factor, while significant on its own, added very little to the model system when SIZE was present. In aggregate, the stages of innovation life cycle development appear to be most clearly understood within the context of the explanatory variables offered within the traditional frameworks of the theory of life cycles.

The results of the *complete parsimonious* model system for the product life cycle framework are also illustrated in Figure 6.8. On the whole, the final logit systems model for the product life cycle appears to be less notable than that of its counterpart. For example, the ρ^2 is a modest .2940 and the number of significant alternative specific variables is considerably smaller than the number found in the innovation life cycle framework. Nevertheless, the estimated parameter coefficients for each of the variables included within this final parsimonious form carry, with them, the signs that would be expected from theory and empirical observation.

Notice that prd_1, emp_1, and ino_1 each carry the expected positive signs and that each is significant (T-scores were 1.761, 3.407, and 1.950 respectively). Therefore, the presence of either one of these characteristics will increase the odds of being associated with stage one level development rather than stage three level development, other factors being held equal. Also in the first log of odds equation, it can be seen that the parameter estimates for the PMS and SIZE factors carried negative signs, as would be expected. In this case, the presence of either of these characteristics will increase the odds of being associated with stage three level development as opposed to stage one level development.

The second log of odds equation of the calibrated product life cycle displays a negative sign on the estimated parameter coefficient of the prd_3 asv and a positive sign on the estimated parameter coefficient of the CTT locational factor. The former case suggests that standardized product lines are more likely to be associated with stage three level development rather than stage two level development. The latter case suggests that sample firm association with the CTT (ie. a firm that is located within the CTT) will increase the odds of being classified within stage two rather than stage three. Critical to note, here, is the fact that the negative estimated parameter coefficient for the CTT factor within the first log of odds equation was extracted in this final parsimonious model. This alternative specific variable lost a considerable amount of significance when all other considerations were included into the model system.

Perhaps the most significant difference between the results of the two calibrated life cycles is found in the estimated parameter coefficients of the asc's. In the final parsimonious innovation life cycle model, both asc coefficients were not significant yet both were positive. This is most desirable since it suggests an affiliation with the early stages of the innovation life cycle rather than the third stage of development. In the calibrated product life cycle however, the coefficient of the asc in the second log of odds equation was negative and significant (T-score was -3.161). This suggests that the likelihood of being assigned to the third stage of development is greater than the likelihood of being assigned to the second stage of development. Such late stage classification may very well warrant concern by those who advocate the importance of the small technology intensive firm within an economy.

6.4 CONCLUSION

It can safely be said that the calibration of descriptive industrial location models (such as the product life cycle and the innovation life cycle) is not an unrealistic objective. The preceding chapter has attempted to present, in a raw form, the first formal attempt aimed at calibrating the product and innovation life cycles. Of the criticisms directed at the product life cycle and its antecedents, few have been more detrimental to its continued maturation than the criticism claiming that the model is of limited use because of its non-quantifiable descriptive configuration. This chapter has also illustrated the ability of the life cycle approaches to capture the essence of industrial behavioral characteristics within a quantified environment. Furthermore, the procedure was augmented by specifying the product and innovation life cycle models in their most parsimonious form. By doing so, the characteristics deemed most significant in the industrial development of Mississauga and the CTT became observable (consider the asv estimated parameters, their signs, and their level of significance as indicated by the quasi T-test). In the end, the calibration of descriptive models will add a much needed dimension to the science of regional and industrial development. Specifically, descriptive models such as the product/process/innovation cycles are high powered (Markusen et al., 1986); this power can be unleashed by way of calibration through logit modelling and other related forms of discrete choice analysis.

CHAPTER 7 SUMMARY AND AFTERTHOUGHTS

7.0 A REVIEW OF THE OBJECTIVES

The primary objective of this thesis has concerned the calibration of the product and innovation life cycle frameworks. Although the application of life cycle rationale has been practised in several disciplines (Markusen et al., 1986), it is quite interesting to note that there has been no real attempt directed at the formal calibration of the product life cycle or any of its antecedents. This dissertation has attempted to bridge this gap by presenting a quantitative application of life cycle rationale to regional industrial development.

The backdrop to this original attempt at life cycle calibration came in the form of the high technology firms that occupy Mississauga and Canada's Technology Triangle (in general, the study area may be said to represent the region of Mississauga and the CTT). In combination, the examination of all sample firms according to the product and innovation life cycle paradigm afforded the opportunity to develop some sense of the size and nature of regional industrial development in Mississauga and the CTT.

Note, here, that the size and nature of high technology industrial development in Mississauga and the CTT was measured both in terms of a regional life cycle perspective and in terms of several aspects of alternative regional science frameworks (ie. site factor analysis, the theory of linkages, the theory of truncation, and so on).

7.1 SUMMARIZED RESULTS OF LIFE CYCLE CALIBRATION

The results of the calibration procedure may be broken down into two broad categories. First of all, the overall effectiveness of the product and innovation life cycle was evaluated in terms of its ability to capture the essence of high technology development in Mississauga and the CTT. Effectiveness, here, was assessed both in terms of goodness-of-fit measures (ρ^2) and in terms of the number of significant alternative specific variables (T-scores).

The Rho-square values for both life cycle frameworks varied between the range of 0.2 to 0.4 (a range which is considered to represent a good fit). More specifically, the parsimonious innovation life cycle framework carried a Rho-square value of .2597 while the parsimonious product life cycle framework carried a more modest value of .2408. In terms of the number of significant variables, the parsimonious innovation life cycle model included eight significant alternative specific variables (at the ten percent level of significance). Again, the effectiveness of the parsimonious product life cycle model was rated at a more modest level since a smaller number of significant alternative specific variables (6) was recognized.

A final note on the effectiveness of the calibrated life cycle frameworks may be made in reference to the dynamics of parameter estimates and their signs. Specifically, for each parameter estimate there exists a sign which relates the given alternative specific variable to an arbitrary base group. As such, the expected dynamics of the life cycle characteristics (the explanatory variables) can be examined in relation to the actual dynamics (as indicated by the signs of the estimated parameters). It was concluded that both life cycle models scored quite well in these terms. In fact, in the strictly specified versions of the life cycle (see Figure 6.2 on page 122) all parameter estimates carried the expected signs in the first log of odds equation while more than half of the parameter estimates carried the expected signs in the second log of odds equation.

The second broad area of calibration results (that merit further reiteration) concerns the state and nature of industrial development amongst the high technology industries of the study area. In terms of the traditional characteristics of the product and innovation life cycle, several life cycle characteristics were recognized to be significant (see Figure 6.8 on page 146). For example, within the first log of odds equation of the innovation life cycle positive and significant parameter estimates were found for the following alterative specific variables: flexible production with almost no automation (prc_1), informal and entrepreneurial organizational control (org_1), and highly skilled labour (emp_1). Stated as given, it can be concluded that the presence of these alternative specific variables increase the likelihood of being associated with stage one levels of development rather than stage three levels. On the flip side, the alternative specific variables that were recognized as being negatively associated with stage one level development included R&D stimulation due to market needs (ino_3) and limited entry into well established markets (mar_3).

Within the second log of odds equation of the innovation life cycle framework, the presence of an accessible but established market (mar_2) was recognized as being positively associated with stage two levels of development. Highly standardized product lines (prd_3), on the other hand, were associated with the third stage of development more so than the second stage. Perhaps the most important conclusion to be drawn from the above observations concerns the harmony that was found to exist between the estimated parameters and the theoretical expectations. Indeed, of the parameter estimates included in the log of odds equations of Figure 6.8 on page 146, only one (prc_2) had an estimated parameter that countered theoretical expectations.

From a more general perspective, the stage of industrial development amongst high technology firms in Mississauga and the CTT can be determined by analyzing the alternative specific constants (asc's) for each log of odds equation. The innovation life cycle framework estimated asc parameters that were positive but insignificant (T-scores were 1.590 and 1.006 for the first and second log of odds equations respectively). These results suggest that, while the asc parameter estimates are not significant beyond the 10 % level of significance, there is a greater likelihood to be associated with stage one and stage two levels of development rather than stage three levels of development. The same can be said of the product life cycle, with one exception. The asc parameter estimate in the second log of odds equation is negative and significant (T-score of -3.161). This observation suggests that there is a greater likelihood for sample firms to be associated with stage three level development rather than stage two level development. In total, it would appear that the high technology firms examined within the study area are roughly positioned along the more intermediate sections of the product and innovation life cycle curves (ie. latter portions of stage one and stage two).

The results of the complete parsimonious life cycle models (Figure 6.8 on page 146) also reflect the importance of several considerations found outside of the theory of product and innovation life cycles. As illustrated in the first log of odds equation, the parameter estimates for the size factor (SIZE) and the plastics and synthetic resins industry (PNS) were recognised as significantly negative for both the product and innovation life cycle models. T-scores for the size parameter estimates were -2.131 and -2.809 for the product and innovation life cycle models respectively. Thus, an increase in the size of a sample firm will increase the odds of being associated with stage three rather than stage one when all other asv factors are valued at zero. Along similar lines, the significantly negative parameter estimates (T-scores of -1.779 and -1.739 for the product and innovation models respectively) for the PNS factor implies that classification within the plastics and synthetic resins industry may be associated with stage three level development rather than stage one level development. The only other outside consideration included in the complete parsimonious product life cycle model was the CTT alternative specific variable (1 if located within Canada's Technology Triangle; 0 otherwise). The significant (T-test score of 2.632) and positive value of this estimated parameter suggests that location in the CTT is associated with stage two level development rather than stage three level development.

The contents of Chapter 5 conform to the results of life cycle calibration described above. According to the site factor analysis, the top five "important" locational factors included the founder's familiarity with the region, availability of transportation, availability of skilled labour, presence of a strong business climate, and the presence of universities (see Table 5.4 on page 97). These site factors tend to be associated with relatively high levels of R&D intensity. (Markusen et al., 1986; Rees and Stafford, 1986) In terms of the technical / professional linkages analysis, it appears that there is a modest network of local linkage development (see Table 5.6 on page 101). The strong presence of technical/professional linkages to accounting business services, legal business services, universities, computer service firms, and private testing laboratories lends support to the hypothesis that high technology development in Mississauga and the CTT rests somewhere amidst the intermediate stages of technological development. Further evidence of a relatively young and vibrant high technology sector was provided by Table 5.8 on page 106. From this table it was illustrated that 46 sample firms (or 28% of the sample) had been generated between 1983 and 1989 and that 25 of these 46 firms (or 54% of the firms formed between 1983 and 1989) had been generated by incubator firms located locally.

Although the preceding discussion suggests a generally "healthy" high technology climate in the study area, there is reason to believe that considerable disparity in technology intensity exists among sample firms. This is particularly true if one considers disaggregation of the sample population by type of ownership. Table 5.9 on page 110 highlights the effects of differentiating the sample by type of ownership (independently owned plant, Canadian owned subsidiary, and foreign owned subsidiary) by stage of development. The predominance of the independently owned plant within stage one of both life cycles and the predominance of the foreign owned branch plant within stage three of both life cycles underscores the importance of recognizing undercurrents in the overall industrial regional development process. Even so, there are those who insist that the behavioral characteristics of a given firm are more a factor of size than they are a factor of ownership type. Regardless of the semantics involved in this debate, there is little question that foreign ownership has a strong association with the latter stages of development while independent ownership has a strong association with the earlier stages of development. From a regional planning perspective, it would appear that the targeting of such industrial subgroups for closer scrutiny may serve a useful purpose.

7.2 AFTERTHOUGHTS

The successful evolution of any science requires the opening of new avenues for continued research. This thesis has been written with this objective in mind. Specifically, the contents of this paper represent an innovative attempt aimed at illustrating the possibilities of the product and innovation life cycle models when applied in a quantitative fashion. Of course, the opening of such "avenues" does not come easily and may leave the adventurous researcher open to criticism. Standard definitions are rare, appropriate data is virtually nonexistent, and confirmation of results is a hard to come by. In any case, this dissertation offers the first formal groundwork directed at the calibration of the product life cycle. It is hoped that the contents of this paper may serve as a starting point towards more refined quantitative applications of life cycle rationale.

APPENDIX 'A'

THE QUESTIONNAIRE

(1) What was your level of total sales in 1989?

$ ______

(2) In what year was your firm established? ☐

(3) What was your total number of employees in 1989? ☐

(4) Is your operation (check please):

☐ an independent operation

☐ a Canadian owned subsidiary

☐ a Foreign owned subsidiary

(5) What is your level of research and development (R & D) spending as a % of your total sales? (check one please)

0%	1%	2%	3%	4%	5%	other (please specify)
☐	☐	☐	☐	☐	☐	☐

(6) Did your R & D efforts contribute to the development of any new products during the year 1989 (ie."new" in terms of technical changes to the product used)?

yes	no	If yes how many?
☐	☐	☐

What was the total number of innovations (ie. technical changes made) to both products <u>and</u> processes? ______

(7) Was this firm created out of an idea developed at (Please Check):

University	Another Firm	Government Facility	Other
☐	☐	☐	☐

Where is/was this establishment located? ______

(8) Please indicate the sources of outside technical/professional inputs that are used by your firm. Could you also indicate where the inputs are obtained. (check any that apply)

Input	Obtained: Within Locally	Canada	Abroad
Universities/Colleges	☐	☐	☐
Government Research Organizations	☐	☐	☐
Government Technology Centres	☐	☐	☐
Computer Service Firms	☐	☐	☐
Hospital Research Units	☐	☐	☐
Technical Departments of Other Firms	☐	☐	☐
Private Testing Laboratories	☐	☐	☐
Private R & D Firms	☐	☐	☐
Marketing Business Services	☐	☐	☐
Legal Business Services	☐	☐	☐
Accounting Business Services	☐	☐	☐
Other	☐	☐	☐

(9) Which of the following factors were considered in the location of your firm (check any that apply) and at what level of importance?

	Very Important	Important	Not Important
Land Value	☐	☐	☐
Land Availability	☐	☐	☐
Tax Reason (eg. low property taxes)	☐	☐	☐
Market Potential	☐	☐	☐
Access to large pools of inexpensive labour	☐	☐	☐
Transportation (ie. easy access to several modes of transportation)	☐	☐	☐
Location matched the criterion set forth by the parent corporations mandate	☐	☐	☐
Access to highly educated labour pools	☐	☐	☐
Presence of Universities	☐	☐	☐
Presence of other high-tech firms	☐	☐	☐
Presence of non-high-tech firms	☐	☐	☐
Presence of government facilities (eg. ORF)	☐	☐	☐
Local Reputation (eg. business climate	☐	☐	☐
Amenity Reasons (eg. 'suburban' environment	☐	☐	☐
Founder's Familiarity of the area	☐	☐	☐
Other	☐	☐	☐

* For the remaining questions could you please check the box that most closely matches the situation of your firm. (please check only one box per question).

(10) Would you consider your production process:

☐ Highly labour intensive production.

☐ Production processes are characterized by a relatively balanced level of mechanization and labour intensity.

☐ Highly standardized in the sense that production is almost completely mechanized and focused on a small number of products.

(11) Which group most closely represents your product line?

☐ The products are highly unique and require custom design.

☐ The range of products in the product line is narrowed. The emphasis on custom designed products is reduced due to increased mechanization.

☐ All products are standardized in production.

(12) Which group most closely describes the nature of your organizational control?

☐ Informal and Entrepreneurial. Allows for efficient and rapid response to internal/external changes.

☐ Through liaison relationships, project and task groups.

☐ Through emphasis on corporate structure, goals and rules.

(13) Which group most closely defines your competitive emphasis?

☐ Emphasis falls primarily on product performance and product differentiation from competing firms.

☐ Emphasis is on an even balance between product performance and cost reduction.

☐ Emphasis is mainly concerned with cost-reduction.

(14) Which group most closely describes your firm's employment structure?

☐ The largest proportion of your employment structure consists of engineers, technicians, computer programmers, systems analysts, and scientists engaged in research.

☐ There is a relatively even split between technical employees (ie. engineers, computer programmers, systems analysts, and scientists) and non-technical employees (ie. management and administration).

☐ The largest proportion of your employment structure consists of management, administration and other non-technical employees.

(15) Innovation in your firm is stimulated by:

☐ Information concerning market needs.

☐ Opportunities created by expanding internal capabilities (ie. the need to improve the efficiency of production.)

☐ Pressures to minimize the costs of production (ie. to maintain competitive prices).

(16) Would you consider your market:

☐ Ill-defined with the potential for vigorous sales volume expansion.

☐ Market uncertainty is minimal (ie. consumers are well aware of the product and the supplier is well aware of the location of consumer demand). Market entry is still quite profitable.

☐ There is virtually no market uncertainty. A small number of very large firms hold a large share of the market. Entry into the market is quite difficult.

A P P E N D I X 'B'

T H E P R O D U C T C Y C L E:

A MULTIVARIATE SPECIFICATION

THE STAGE SPECIFIC CHARACTERISTICS OF THE PRODUCT LIFE CYCLE

INNOVATION LIFE CYCLE ATTRIBUTE	STAGE OF TECHNOLOGICAL DEVELOPMENT: FLUID PATTERN	TRANSITIONAL PATTERN	SPECIFIC PATTERN
Product Line: (prd)	diverse, often including custom design.	includes at least one product that is standardized in production.	products are differentiated and highly standardized.
Mfg. Process: (prc)	flexible with almost no automation.	becoming more rigid with "pockets" of automated subprocesses.	efficient, capital intensive, and very rigid.
Aim in competition: (com)	functional product performance.	product variation.	pressure to reduce cost and improve quality.
Form of Control within the Firm: (org)	informal and entrepreneurial.	through liaison relationships, project and task groups.	through emphasis on structure, goals and rules.
R&D inspired by: (ino)	the needs of the market.	the need to increase the scale of production.	the need to reduce cost.
Nature of Labour Force: (emp)	highly skilled and well educated.	a balance between technical and non-technical labourers.	predominantly administrative and non-technical.
State of Market: (mar)	ill defined with the potential for vigorous market expansion.	minimal market uncertainty; entry remains profitable.	no market uncertainty; entry is very difficult.

SOURCE: Interpreted from Abernathy and Utterback (1982) and Rothwell and Zegveld (1985).

A GENERAL DESCRIPTION OF LOGIT MODEL SPECIFICATION:

BASIC EQUATION -----> stage = f(prd,prc,mar,com,org,ino,emp)

WHERE---> stage is the stage of technological development (ie. these alternatives represent the dependent variable of the innovation life cycle in a multivariate environment).

WHERE---> prd is the nature of the product line, prc is the nature of production, mar is the state of market development, com is the competitive emphasis in production, org is the form of organizational control, ino is the source of innovative stimulation, and emp is the basic structure of the labour force (ie. these characteristics represent the independent variables of the innovation life cycle).

THE DISCRETE ENVIRONMENT

The equation illustrated atop the page is a useful conceptualization of the multivariate environment when data sources are of a continuous nature (as is often the case in traditional regression analysis). As illustrated on the previous page, however, we are dealing with discrete and qualitative variables that cannot be measured on the cardinal scale. As such, the above equation does not do justice to the type of relationship(s) that we are faced with. The following page displays the *categorization* (ie. specification) of the innovation life cycle model in terms of the model's three discrete stages (ie. alternatives). Each of these stages will be referred to as a separate *dimension* for each explanatory variable.

THE PRODUCT LIFE CYCLE

A CATEGORIZATION OF THE RESPONSE/EXPLANATORY VARIABLE RELATIONSHIP

STAGE OF TECHNOLOGICAL DEVELOPMENT	STAGE LEVEL CHARACTERISTICS		
ALTERNATIVE	EXPLANATORY VARIABLE (INDEPENDENT VARIABLES)		
(DEPENDENT VARIABLE)	Product Line (prd)	Production Process (prc)	... ...
Stage 1 •# of product innovations is ≥ 1. •R&D ≥ 5% of total sales.	prd1=1 if product line is largely custom designed prd1=0 otherwise	prc1=1 if production process is flexible with no automation prc1=0 otherwise	... ...
Stage 2 •# of product innovations is ≥ 1. •R&D ≥ 1% and < 5% of total sales.	prd2=1 if product line is at least partially standardized prd2=0 otherwise	prc2=1 if some sub-processes have been automated prc2=0 otherwise	... ...
Stage 3 •# of product innovations is = 0.	prd3=1 if product line is totally standardized prd3=0 otherwise	prc3=1 if production processes are completely automate prc3=0 otherwise	... ...

† Stated as given, the table above illustrates the categorization of the *basic equation* shown atop the previous page. For each alternative (ie. stage of development) there exists one dimension of a given explanatory variable (ie. characteristic) that is theorized to best describe the dependent variable outcome. For example, stage 1 is expected to be positively related to the first dimension of explanatory variables (ie. prd_1, prc_1, org_1, com_1, and so on). From this line of rationale, it may be seen that each alternative (ie. stage) will be most effectively explained by the string of explanatory variables associated with that same dimension.

‡ Note that the possible outcomes for every type of variable is based on a binary selection (ie. a value of 1 is assigned to the explanatory variable prd_1 if the firm sampled displays a diverse product line requiring custom design; otherwise, a value of 0 is assigned to this explanatory variable).

FORMAL LOGIT MODEL SPECIFICATION OF THE LIFE CYCLE FRAMEWORKS:

PARAMETER NAME	ALTERNATIVE STAGE 1	SPECIFIC STAGE 2	VALUES STAGE 3
β_{10}	1	0	0
β_{20}	0	1	0
β_{11}	1 if product line is diversified and includes custom design; 0 otherwise.	0	0
β_{21}	0	1 if product line is diversified and includes custom design; 0 otherwise.	0
β_{12}	1 if there is at least one product that is standardized in production; 0 otherwise.	0	0
β_{22}	0	1 if there is at least one product that is standardized in production; 0 otherwise.	0
β_{14}	1 if production is flexible with almost no automation; 0 otherwise.	0	0

β_{24}	0	1 if production is flexible with almost no automation; 0 otherwise.	0
β_{15}	1 if production has pockets of automated subprocesses; 0 otherwise.	0	0
β_{25}	0	i if production has pockets of automated subprocesses; 0 otherwise.	0
β_{17}	1 if competitive emphasis is based on functional product performance; 0 otherwise.	0	0
β_{27}	0	1 if competitive emphasis is based on functional product performance; 0 otherwise.	0
β_{18}	1 if competitive emphasis is based on product variation; 0 otherwise.	0	0

β_{28}	0	1 if competitive emphasis is based on product variation; 0 otherwise.	0
β_{110}	1 if organizational control is informal; 0 otherwise.	0	0
β_{210}	0	1 if organizational control is informal; 0 otherwise.	0
β_{111}	1 if organizational control is sought through liaison relationships, project and task groups; 0 otherwise.	0	0
β_{211}	0	1 if organizational control is sought through liaison relationships, project and task groups; 0 otherwise.	0
β_{113}	1 if R&D is inspired by the needs of the market; 0 otherwise.	0	0
β_{213}	0	1 if R&D is inspired by the needs of the market; 0 otherwise.	0

$\beta_{1\,14}$	1 if R&D is inspired by the needs to increase the scale of production; 0 otherwise.	0	0
$\beta_{2\,14}$	0	1 if R&D is inspired by the needs to increase the scale of production; 0 otherwise.	0
$\beta_{1\,16}$	1 if the labour force is highly skilled and well educated; 0 otherwise.	0	0
$\beta_{2\,16}$	0	1 if the labour force is highly skilled and well educated; 0 otherwise.	0
$\beta_{1\,17}$	1 if there is a an equal balance between technical and non-technical employees; 0 otherwise.	0	0
$\beta_{2\,17}$	0	1 if there is an equal balance between technical and non-technical employees; 0 otherwise.	0

$\beta_{1\,19}$	1 if the market is ill defined with the potential for vigorous expansion; 0 otherwise.	0	0
$\beta_{2\,19}$	0	1 if the market is ill defined with the potential for vigorous expansion; 0 otherwise.	0
$\beta_{1\,20}$	1 if market uncertainty is minimal and entry remains profitable; 0 otherwise.	0	0
$\beta_{2\,20}$	0	1 if market uncertainty is minimal and entry remains profitable; 0 otherwise.	0

A P P E N D I X 'C'

INDUSTRIAL COMPOSITION AND SIC CLASSIFICATION OF HIGH TECHNOLOGY

INDUSTRIAL COMPOSITION OF THE HIGH TECHNOLOGY SECTOR

SIC CODE **INDUSTRY AND PRODUCT LINE CONSTITUENTS**

(A) Aircraft and Aircraft Parts Industry

3211 **Aircraft & Aircraft Parts Industry**
- aircraft assemblies, aircraft engines and parts, airframes, guided missile and space vehicle parts, Aircraft pontoons, aircraft propellers, aircraft turbines.

(B) Communication & Other Electronic Equipment Industry

3351 **Telecommunication Equipment Industry**
- carrier current equipment, switching equipment, intercommunicating telephone sets, microwave transmitting equipment, multiplex equipment, telegraph equipment, telephone equipment.

3352 **Electronic Parts and Components Industry**
- audio frequency amplifiers, electric capacitors, electric connectors, electric chips & bubbles, integrated circuits, non-rotating power supply converter units, electric resistors, satellite parts & components, electrical transformers.

3359 **Other Communication & Electronic Equipment Industry**
- signed systems, aviation radio communication equipment, closed circuit TV equipment, electric process control equipment, robotics equipment, micro-wave transmitting equipment, radar equipment, sonar equipment, image arrays, image scanners, alarm systems.

(C) Office, Store and Business Machine Industry

3361 **Electronic Computing and Peripheral Equipment**
- analog electric computing and processing equipment, central processing units, computers, digital electronic control units, disc drives, drum drives, key-punch drives, digital electric memory modules, digital electric peripheral processing units, tape drives, digital electric input/output on-line devices, digital electric computer connectors, monitoring systems, computerized control systems.

(D) Plastic and Synthetic Resin Industry

3731 Plastic and Synthetic Resin Industry
- acrylic resins, amino-aldehyde resins, cellulose nitrate, epoxy resins, ion exchange resins, phenol-formaldehyde resins, polymerizing/condensing plastics and synthetic resins, polyamide resins, silicone resins, styrene resins, polypropylene resins, polyurethane resins.

(E) Pharmaceutical & Medical Industry

3741 Pharmaceutical & Medical Industry
- antacids, anaesthetics, antibiotics, antiseptics, antitoxins, cathartics, digestants, diuretics, haematological agents, micro/macro premixes, ophthalmic agents, purgatives, serums, vaccines, vitamins, vasodilators, vasoconstrictors.

(F) Scientific and Professional Equipment Industry

3911 Indicating, Recording and Controlling Instruments
- Control panels, control valves and regulators, flow regulators, galvanometers, mechanical motion/rotation/timing/cycle instruments, pressure regulators, thermostats.

3912 Other Instruments and Related Products Industry
- aeronautical instruments, scientific balances, engineering/geophysical instruments, navigational instrument, ophthalmic examining/diagnostic equipment, photographic equipment, photographic film, pyrometers, scientific scales, surgical instruments, thermometers, X-Ray equipment, lasers, solar conversion kits, erosion control systems, thermocouples, pyrotechnic devices, telescopic towers, bombs.

SIC CODE	INDUSTRY AND PRODUCT LINE CONSTITUENTS
	(G) Other Machinery & Equipment
3341	Record Player, Radio, TV Receiver Industry - audio/video recording/duplication equipment, record player & tape recorder parts, stereo amplifiers, TV converters, loud speakers, CD systems.
3371	Electrical Transformer Industry - ballasts and transformers, constant current transformers, control/signalling transformers, distribution transformers, ignition transformers, power transformers, transformer parts.
3372	Electrical Switchgear - transmission/distribution/power connectors, fuses and fuse links, low voltage switch boards, oil circuit reclosers and sectionalizers, power capacitors, power circuit breakers, switchgear relays, switchgear assembly.
3381	Communication & Energy Wire Industry - electric wire, fibre optic cable, heating cable, magnet wire/cable, power cables, annunciator wire/cable, radio/telephone hot wire.
3391	Battery Industry - alkaline batteries, dry cells, battery separators, lead acid batteries, storage cells, storage batteries.

A P P E N D I X 'D'

THE UNIVERSITY OF WATERLOO:

SPIN-OFF ACTIVITY UP TO 1990

UNIVERSITY OF WATERLOO:
SPIN-OFF COMPANIES AND PRODUCTS (AS OF NOVEMBER, 1989)

Advanced Greenhouses Ltd., Waterloo; faculty (Brundrett) (energy efficient greenhouses)

Advanced Scientific Computing Ltd., Waterloo; faculty (Raithby) (heat transfer/fluid flow modelling)

Alan Hale & Associates, Waterloo; faculty (patent consultants)

Astron Specialty Metals Ltd., Waterloo; faculty (Raithby) (maple syrup evaporators)

Aquasave Ltd., ex-staff member (Phripp) (water conservation device)

Beyond Words Desktop Publishers, Waterloo; staff Shirley Fenton, computing and communications, and others (publishing services, mailing lists)

Calnek, Price & Associates Ltd., Waterloo; ex-students (computer programming)

Camp Catchacoma; staff (Totzke) (Kawartha summer camp)

Canadian Centre for Creative Technology, Waterloo; faculty (Lane-Smith) (creative summer camp)

Canadian Posture & Seating Centre, Kitchener; alumnus (Mundy) (devices for the handicapped)

Canviro Consultants, Waterloo; co-founder, alumnus (Richard Rush) (environmental engineering and consulting)

Computer Performance Instrumentation Inc.

Computer Systems Design, Inc.

Conestoga Medical Electronics Ltd., Waterloo; faculty (Cadell) (medical electronic devices)

Control Dynamics Inc. (telecommunications equipment and software)

Corma Inc., Concord; alumni (plastic pipe-making equipment)

Corman Technologies Inc., Waterloo; alumnus (circuit boards, etc.)

CRAC Software Inc., Waterloo; alumna (Harris) (computer software)

Creative Organizational Design, Waterloo (management consultants)

Crop Technologies, Inc.; alumnus (microcomputer applications)

Dalsa Inc., Watarloo; faculty (Chamberlain) (microchip design)

Dantec Electronics, Waterloo; (based on UW research) (grain drying technology)

Datem Inc., Ottawa; alumni (Thomas Dale, William Thomas) (production control software)

Mark L. Dorfman Planner Inc., Waterloo; alumnus (planning consultant)

EMJ Data Systems Ltd., Guelph; alumnus distributors of computer equipment with offices in Guelph, Vancouver, Calgary, Winnipeg, Montreal, Halifax; yearly sales $20 million (1989). president: Jim Estill, systems design grad.

Eastman Computing Inc. (computer software)

Ecologistics Ltd., Waterloo; faculty, alumni (environmental consulting)

Ecoplans Ltd., Waterloo; (environmental consulting)

Elmira Independent, Elmira; alumnus (weekly newspaper)

E M Enterprises, Waterloo; alumnus (laser instruments)

Enersource Inc., St. Catharines; faculty (Redekop) (solar heating equipment)

Energetex Engineering, Waterloo; faculty, alumnus (consulting services -- environmental clean-up)

Experience the Travel Game Inc., Ottawa; alumni, (Lennox brothers) (games)

Federal Technical Surveys, Cambridge; faculty, alumni (pavement management consultants)

Guymark Palmer Design Group, Guelph; ex-staff, Don Palmer (interior design)

Harriett Hardman and Associates Ltd., Kitchener; alumna (computer software, instruction)

Hendershot Media Services, Conestogo; former teaching staff, Richard Hendershot (communications and marketing consultants)

Hypercube Inc., Cambridge; ex-faculty (Neil Ostlund) (software for parallel computing -- supercomputers -- modelling of organic molecules)

Image Corp.

Independent Newsmagazine, The, Listowel; alumnus (Slykhuis) (publishing)

Isotope Analysis, Inc., Waterloo; staff (hydrology consulting)

Jankins Computers, Kingston; alumnus (Kim Leung) (microcomputer merchandisers)

Jonet Publishing, Kitchener; faculty (Dr. John Orlando) (book publishing)

Keynote Computer Products Inc., Waterloo; alumnus (computer software)

Linton Technology Group Ltd., Waterloo; alumnus

Looking Glass Software Ltd., Waterloo; alumnus (Brad Templeton) (computer software)

Mortice Kern Systems, Waterloo; alumni (Ruth Songhurst, Trevor Thompson, Alex White, Randall Howard); computer software, consulting

Nardac Systems Ltd.

NFAM Games Ltd., Waterloo; faculty (table games)

Northern Digital, Waterloo; alumnus (computer hardware)

Northern Software Ltd., Waterloo; (computer software)

Octant Computers Inc.

Pace Computing Solutions Inc., Waterloo; WATCOM subsidiary (fourth generation systems)

Pasdeloup Press, Stratford; faculty (Burnett) (publishing)

Pavement Management Systems, Cambridge; faculty, alumni (highway assessments)

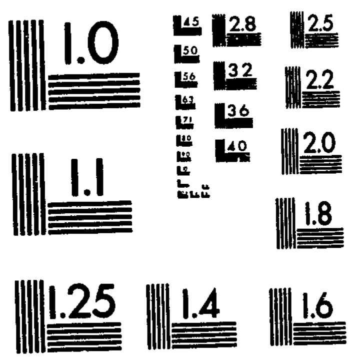
Platinum High Technology Inc. (computer software)

ProSync, Waterloo, Division of IntraSyst Inc.; alumnus (Hogg) (CAD/CAM training and consulting services)

Quantum Software Systems Ltd., Ottawa; (computer networks)

Radiation Environmental Management Inc., Waterloo; faculty (consultants on hazards)

3 of/de 3



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No. 2)

Research in Motion, Waterloo; alumni (customized display technologies)

ShawWare Inc., 3365 Harvester Rd., Hamilton; alumnus (Bill Shaw); software (maintenance and materials management); about 100 employees

Solar Computers (Cambridge) Ltd.

Spectrix Microsystems Inc., Markham (microcomputers)

Spicer Corp., Waterloo (hardware peripherals and software)

Structured Computing Systems Ltd.

Symantec Corp. (California-based computer software dealer); set up first Canadian branch specifically to be near University of Waterloo. Paul Singer, operations manager.

Taiwan Connection, Etobicoke and Taipei; students, alumni cross representation of Canadian and Taiwanese industrial clients (often high tech). David Allan, Dennis Mumford, Patrick Jabal, Mike Volker, David Jones. 27 Taber Rd., Etobicoke; M9W 3A7; 740-8953.

Technicom Consultants (satellite imagery analysis)

Telepresence Research Inc., 655 West 75th Ave., Vancouver, V5Z 1B6; alumnus (Tom Mitchell) (remote sensing, remote vision, robots, medical/space/industrial/ocean applications)

Turbotak, Inc., Waterloo; faculty (Spink, Dullien) (scrubbers)

Vivid Effects Inc., Toronto alumni (Vincent John Vincent, Frank MacDougall) Mandala management-developing video game

Volker-Craig Ltd., Waterloo; alumni (computer terminals)

Waitronics, 1-251 King St., N., Waterloo alumnus (Phil Wai) (high speed 386 and 286 - based computers)

WATCOM Group Inc., Waterloo; alumni (computer software)

Waterloo Computing Systems

Waterloo Distance Education, Inc., Waterloo; faculty (Dixon, Leslie) (correspondence courses)

Waterloo Dynamic Systems, Inc., Waterloo (consultants)

Waterloo Engineering Software, Waterloo; faculty (specialized software)

Waterloo Management Education Centre, Waterloo; ex-staff (management education seminars)

Waterloo Microsystems, Inc., Waterloo; ex-faculty (Malcolm) (portability software)

Waterloo Scientific Inc., Waterloo; faculty (Dixon) (microscopes)

Waterloo Systems Specialists, Ltd., Waterloo (systems engineering)

Waterloo Technologies Inc., Waterloo

Tomek's Dill Pickles, Etobicoke (Tomek Wolski, alumnus) (dill pickles)

Wordswork Associates, Waterloo; alumnae (writing, editing services, instruction)

Zykor Technologies Inc., Mississauga; alumnus (high-speed computing "motherboards" and systems)

SOURCE: University of Waterloo, Archives.

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